Farm Machinery and Equipment II

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Farm Machinery and Equipment II

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Index

MODULE 1. PRINCIPLES AND TYPES OF CUTTING MECHANISM

LESSON 1.HARVESTING AND THRESHING TERMINOLOGY

Harvesting and threshing is an important operation in the farming. This can be done either manually or with the help of power operated machinery. Harvesting of field crops continues to be one of the most labour intensive operations in agricultural production system. Manual harvesting with different hand tools continues to be dominant, which takes 170-200 man-hours to harvest one hectare of paddy crop. Due to high labour demand at the time of harvesting, the operation continues for weeks together, resulting in over drying of crops in the field causes grain losses to the extent of 5 to 15 percent and even results in loss of crop due to untimely rain during harvesting. Higher shattering losses occur while harvesting crops like wheat, barley and gram in over dried conditions. Harvesting of crops like maize, sorghum and arhar is done at relatively low moisture content. The crop stacks are thick and woody and the hand sickle is adequate tool used for harvesting. For other conditions, a hand chopper is sometimes also employed. Now mechanized harvesting devices such as reapers, combine harvesters etc. are being used for harvesting these crops.

Harvesting and threshing terminology

1. **Combine:** a machine designed for harvesting, threshing, separating, cleaning and collecting grain while moving through the standing crop. Bagging arrangement may be provided with a pick-up attachment. It may be used for handling crop that has been swathed. It may be self-propelled type or tractor operated type.

2. **Self-propelled combine:** a combine on which an engine of suitable power rating is mounted to serve as source of power, this may be wheeled type or track-laying type.

3. **Wheeled Combine:** A combine in which the pneumatic wheels are used.

4. **Track-laying combine:** A combine fitted with full or half tracks instead of pneumatic wheels.

5. **Tractor operated combine:** A combine which requires a tractor of suitable power rating to serve as a source of power for its working. It may be trailed type or side mounted type.

6. **Header:** The portion of the combine comprising the mechanisms for gathering the crop.

7. **Gathering width:** The distance between the centerlines of the outermost divider points expressed in millimeters. Where adjustable dividers are used the maximum and minimum dimensions shall be stated.

8. **Grain header width:** The distance between the side sheets of the header measured immediately above the forward tips of the sickle sections. Width shall be expressed in millimeters.

9. **Corn Header width:** The average distance between the centre lines of adjacent picking units multiplied by the number of units. Where the header width is

adjustable, maximum and minimum di8mensions shall be stated. Width shall be stated in millimeters and the number of picking units shall be stated.

10. **Knife or Sickle:** The reciprocating component of the header fpr cutting the crop.

11. **Knife or Sickle Frequency:** The number of cycles which the sickle makes in a given period of time. One cycle is the full movement of the sickle in one direction and its return to the starting point. Frequency shall be expressed in whole cycles/minute.

12. **Sickle Stroke:** The distance that a point on the sickle travels with respect to the centre line of a guard n one half cycles. Stroke shall be expressed in millimeters.

13. **Knife Registration:** The alignment of centre line of knife section with the centre line of guard.

14. **Pick up:** A device for gathering a crop from a window.

15. **Peg Drum:** A cylinder having rows of spikes or pegs.

16. **Rasp Drum:** A cylinder having bar with serrations.

17. **Cylinder Diameter:** The diameter of the circle generated by the outermost point of the cylinder threshing elements, expressed in millimeters.

18. **Cylinder Width:** The length of the cylinder bar measured parallel to the cylinder axis, expressed in millimeters.

19. **Concave Arc:** A means of defining the width of a concave in degrees. This shall be measured from the front to the first bar to the rear of the last bar and in relation to the centre of the cylinder

20. **Cylinder and Concave Clearance:** The gap between the tip of the cylinder to the inner surface of the concave expressed in millimeters. The minimum and maximum clearance in a particular setting and adjustment range for both the front and the rear side of the concave shall be stated.

21. **Concave Width:** The minimum distance between the two panels of the combine in which the concave is mounted, expressed in millimeters.

22. **Concave Length:** The distance from the front of the first bar to rear of the last bar, measured around the contour formed by the inner surfaces of the concave bars, expressed in millimeters.

23. **Concave Area:** The product of the concave width and concave length expressed in square millimeters.

24. **Concave grate area:** That portion of the concave area which is permeable for separation. The area shall be calculated using the outside dimensions of the permeable surface and be expressed in square millimeter.

25. **Concave grate extension:** A permeable element approximately concentric with the cylinder and generally forming an extension of the concave contour.

26. **Concave grate extension area:** The product of concave ratio extension length and concave width expressed in square millimeters.

27. **Transition grate:** A permeable element to provide transition from the concave or concave grate extension to the straw walkers or rack.

28. **Transition grate length:** The contour length of the upper surface of the transition grate, ex[pressed in millimeters.

29. **Transition grate area:** The product of the transition grate length and the concave width, expressed in square millimeters.

30. **Straw walker or straw rack area:** The product of thee straight length and the inside width of the separator side structure immediately adjacent to the straw walkers or rack, expressed in square millimeters. Where walker extensions are used in the standard specifications of the machine.

31. **Straw raddle area:** The product of the raddle length and the exposed width of the raddle, expressed in square millimeters.

32. **Shoe:** The oscillating structure which supports the cleaning sieve of sieves and which may also support the chaffer sieve and chaffer sieve extension.

33. **Sieve cleaning areas of the shoe:** The chaffer sieve, intermediate sieve, cleaning sieve and extensions to them. The area of each shall be calculated using the outside dimensions of the permeable surface, and shall be expressed in square millimeters.

34. **Pneumatic cleaning areas:** Where chaff is removed by aerodynamic means alone. These areas shall be calculated as the product of the width and depth of the air stream at the point of contact of the air with the crop material. The depth shall be measured perpendicular to the direction of the air flow. The area shall be expressed in square millimeters.

35. **Other cleaning areas:** Dirt screens, re-cleaners and other auxiliary cleaning devices. These areas shall be specified.

36. **Cleaning area total:** The sum of the area of each chaffer, chaffer extension, cleaning sieve (s) and sieve extension (s), if any, obtained by using the outside dimensions of the sievable surface expressed in square millimeters.

37. **Component areas:** For purposes of combine specification, the areas defined in 28, 29, 31, 34, 35, 36, 38, 39, and 40 shall be listed individually and should not be used singly or in combination as a measure of machine performance or capacity.

38. **Header loss:** The loss of grains and ear heads being shed and left over on the ground as a result of operation of cutter bar and header unit.

39. **Non-collectable loss:** The loss of grains and ear heads being shed and left over on the ground as a result of operation of cutter bar and header unit.

40. **Pre-harvest loss:** The loss of grain or ear heads from the standing crop prior to the operation of harvesting machine in the field.

41. **Cylinder loss:** The loss of unthreshed heads and damaged grains passing out of threshing cylinder.

42. **Rack loss:** The threshed grains passing out in the straw.

43. **Shoe loss:** The threshed grains blown or carried out with the chaff.

44. **Engine displacement:** Engine displacement shall be expressed in cubic centimeters to the nearest whole number.

45. **Turning radius:** The distance from the turning center to the center of tire contact of the wheel describing the largest circle while the vehicle is executing its shortest turn without turning brakes in operation. The wheel base and guide wheel tread width shall be stated. Turning radius shall be expressed in whole centimeters.

46. **Clearance radius:** The distance from the turning centre to the outermost point of the combine executing its shortest turn without brakes in operation. If equipment options on attachment affect this dimension, such equipment shall be specified. The wheel base and guide wheel tread width shall be same as in turning radius. Clearance radius shall be expressed in whole centimeters.

47. **Combine weight:** The weight of the complete machine equipped for field operation. The weight shall be determined under the conditions specified in cutter bar height no. 16 and the fuel tanks shall be full. If other equipment options or attachments affect the weight, such equipped shall be specified. Combine weight shall be expressed in quintals.

48. **Combine length:** The overall dimension from the foremost point to rear-most point of the combine equipped for field operation measured parallel to the longitudinal centre line of a combine. The header installed shall be stated, and if other equipment options or attachments affect the length, such equipment shall be specified. Combine length shall be expressed in whole centimeters.

49. **Combine height:** The vertical distance from plane on which the combine is standing to the highest point on the combine. The height shall be measured under the conditions expressed in cutter bar height no. 16. The height with all components in position for field operation shall be specified. Combine height shall be expressed in whole centimeters.

50. **Combine width:** The overall width measured horizontally covering outer extremities of combine expressed in millimeters.

51. **Ground clearance:** The height of the lowest point of the combine from a level supporting surface when the combine is fitted with all its usual accessories, fuel, radiator, hydraulic, lubrication and grain tank full and tyres inflated to recommended pressure for field work.

52. **Ground contact area (Track):** Product of track chain length and width on ground multiplied by two, expressed in square millimeters.

53. **Length of track-chain on ground:** Length at base of track shoes disregarding the grouser, as measured between first and last track roller centers, on from front idler

wheels centre line if they are so designed as to hold the track chain level with the track rollers expressed in millimeters.

54. **Medium plain of wheels or tracks:** It is equidistant from the two planes containing the periphery of the rim or tracks at their outer edges.

55. **Specific ground pressure:** The quotient of front axle mass and ground contact area, giving a rating comparable to tyre pressure in case of wheeled combine.

56. **Wheel base:** The horizontal distance between front and rear wheels on a wheeled combine measured at the centre of ground contact.

57. **Wheel-base:** The horizontal distance between front and rear wheels on a wheeled combine measured at the centre of ground contact.

58. **Wheel track:** The distance between the median planes of wheels or tracks on the same axle measured at the point of ground contact.

59. **Width of track-chain on ground:** Width of track shoes including rounded ends if any expressed in millimeters.

60. **Discharge height of unloader:** The vertical distance from the plane on which the combine is standing to the lowest point of the discharge opening with the unloader in operating position. The height shall be measured under conditions specified in cutter bar height 16; discharge height shall be expressed in whole centimeters.

61. **Clearance height of unloader:** The vertical distance from the plane on which the combine is standing to a point on the underside of the unloader located at a horizontal of 914 mm from the lowest point of the discharge opening.

62. **Reach of unloader:** The horizontal distance measured perpendicular to the longitudinal centre line of the combine from the lowest point of the unloader discharge opening to the outermost point of the header on the unloader side. The reach shall be measured under conditions specified in discharge height of unloader and expressed in whole centimeters.

63. **Grain tank capacity:** The number of the volumetric units of wheat that are unloaded by its own unloading system expressed in cubic meters.

64. **Grain tank unloading time:** It is the minimum time in seconds required to unload the grain tank capacity.

65. **Reaper:** A machine to cut grain crops.

66. **Side delivery reaper:** A machine which harvests crops and delivers them on the side having the space for the next run clear.

67. **Windrower:** A machine to cut crops and deliver them in a uniform manner in a row.

68. **Binder:** A machine for cutting standing crops and tying them into neat and uniform sheaves.

69. **Cutter loader:** A machine to cut crops and to deliver them to vehicle.

70. **Ejection:** Throwing of the tied bundles over the conveyor of a reaper binder.

71. **Knotting:** The operation of automatic tying of bundles in a reaper binder.

LESSON 2. PRINCIPALS AND TYPE OF CUTTING MECHANISM

The operation of cutting plant is carried out by four different actions:

- Slicing action with a sharp smooth edge.
- Tearing action with a rough serrated edge.
- High velocities single element impact with a sharp or dull edge.
- A two-element scissors type action or shearing type cutting.

Generally manual harvesting involves slicing and tearing actions those results in plant structure failure due to compression, tension or shear. The serrated sickle combines a slicing and sawing action. It does not require repeated sharpening as in the case of smooth edge sickle. A single element impact cutting may be either moving or stationary type. An impact cutter has a single high speed cutting element and cuts mainly due to inertia. This cutting method is an economical method widely used in rotary lawn mowers, forage choppers and in some tractor mounted cutter bar. Usually a single element, sharp edged blade requires a velocity of about 10 m/s for impact cutting. A dull edged single element blade requires a velocity of about 45 m/s. In the rotary cutter the knives rotate in a horizontal plane as in the rotary mowers, whereas, in flail shredder the knives rotate in a vertical plane parallel to the direction of travel. In shearing type cutting, cutting takes place due to shear. A system of forces acts upon the material in such a manner as to cause it to fail in shear. Shear failure is invariably accompanied by some deformation in bending and compression, which increases the energy required for cutting. A common way of applying the cutting force is by means of two opposite shearing elements, which meet and pass each other with little or no clearance between them. Both or one of the elements may be moving with a linear uniform, reciprocating or rotary motion. This type of cutting mechanism is most widely used for harvesting agricultural crops. The reciprocating cutter bars that are commonly used for harvesting wheat or paddy crops use this principle. The inclined angle between the cutting edge is about 30 degrees. The serrated blades cannot easily slip between the two cutting edges. Reciprocating cutter bars do an excellent job of harvesting but are characterized by high-energy losses, short dynamic imbalance and limited operating speeds.

Balancing of Reciprocating Masses

The cutter bar of a reaper is one such component and is major cause for vibrations of the reaper and a limiting factor for the speed of reaper. Mostly slider crank mechanism is employed for converting rotary motion in translating motion. Such components are seldom balanced in the farm machinery and are one of the major factors in the frequent breakdown of such machinery. The inertial force 'F' transmitted to the frame and the rotating un-balanced mass 'm_{rot}' are the main causes of vibrations. The periodic vertical reactions F_g may cause early fatigue failure of the knife back if the knife guides are loose. The rotary unbalanced mass can be balanced by providing a counter balancing mass on the flywheel but in opposite direction of crank pin so that

$R_b \times m_b = R \times m_{rot}$

Where, m_b = the counter balancing mass

R_b = distance of counter balancing mass from centre of fly wheel

R = distance of un-balancing mass from centre of fly wheel

The full dynamic balancing of reciprocating parts can be obtained by the addition of a second driven reciprocating mass that moves in direct opposition to first mass (cutter bar) and is as closely in line with it as feasible. So the balancing mass induces equal inertial forces but in the opposite direction that of the cutter bar. If the reciprocating counter weight is offset from the line of motion of the knife it will induce a cyclic couple.

The rotating counter weight commonly provided on the flywheel on a pitman type drive does not give complete balancing because its centrifugal force is constant where as the inertia force of the reciprocating parts is a function of the crank angle q. The usual practice is to provide sufficient mass opposite the crank pin to counter balance m_b and half of the reciprocating unbalanced mass m_{rot}. The vertical vibration component introduced by the counter-weight is then equal to the reduced maximum horizontal component.

Full dynamic balancing minimizes vibration at a given crank speed. It also permits the use of higher crank speeds and, hence, greater forward speeds. Counter balancing is not imperative if the weight of the machine or component supporting the cutter bar is large in comparison with the reciprocating force, as on a self-propelled windrower or combine. But counter balancing is needed much on a field mower because its frame is relatively light.

Balancing Machine Elements with Rotary & Translatory Motion

The balancing of members that do not move with plane rotation is much more difficult. A typical four-bar mechanism is the most common of all mechanisms (representing rocking mechanism or mechanism for transferring rotary motion to oscillating motion, oscillating sieves or oscillating blade). Crank 2 rotates with a constant angular velocity, rocker 4 oscillates, and coupler 3 moves with a combination of rotation and translation. The system can be balanced by introducing mechanisms that produce the opposite effects. A mechanism that is the mirror image of the original but moves in the opposite sense can be introduced to balance the vertical shaking forces and moments due to angular accelerations of links 3 and 4. The motion of the combination of linkages would give unbalanced horizontal shaking forces, which can be balanced by a mechanism that is a mirror image of this combination but moves in the opposite sense. This method of balancing is usually impractical.

Partial balance of the four-bar mechanism can easily be obtained. First, it is necessary to consider equivalent links. Two members are dynamically equivalent if they have the same total weight, the same center of gravity, and the same moment of inertia. The equivalent coupler replaces the original coupler. Link 2 and weight W_1 can be balanced by W_3 to bring the centre of gravity to centre of rotation. Similarly, link 4 and W_2 can be balanced by W_4. This will eliminate all vertical and horizontal shaking forces, but there will remain the unbalanced and variable torque on the frame owing to the angular acceleration of links 2.3 and 4.

The sieves of thresher sieve rocking mechanism and oscillating blades of oscillating implements can be partially balanced by this technique.

Shearing - type cutting mechanism

The cutting mechanism depending entirely on shearing utilizes the principle of scissor action which causes cutting by bringing two edges to bear on one plane across the material to be cut. As such there is negligible bending or crushing and only resistance to be overcome is the shearing strength of the material. The well-known mechanism in this category is the pitman and reciprocating knife-bar type mechanism. The invention of this mechanism can truly be regarded as a "mechanical break-through" for harvesting. The cutter bar has triangular knife sections riveted to a bar which reciprocates in slots of the stationary guards to cut the crop against the ledger plates of the guards. This type of cutting mechanism is used in the mowers, reapers, binders, forage harvesters and combines. The greatest efficiency in this mechanism is affected when there is minimum of crushing and bending of the material and when there is no bunching of material at the rear of the knife sections. Generally, a 3" (75 mm) stroke is used. However, double knife bars with 6" (150 mm) stroke with opposite motions are also used now. The reciprocating motion is imparted with the help of a crank wheel and a pitman.

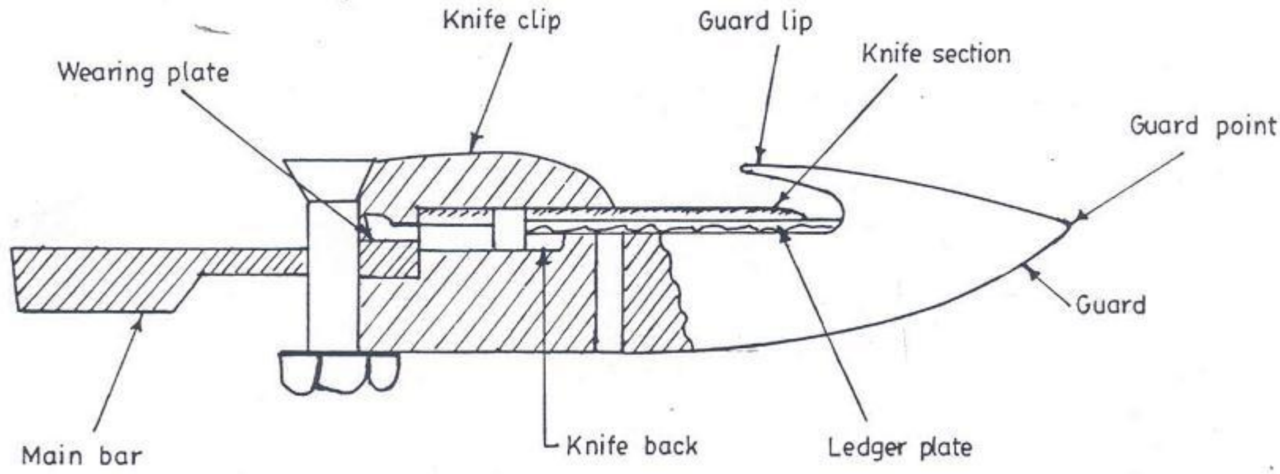
Cutting Speeds required for reapers:

The speed requirement of the reciprocating knife-bar at peak cutting velocity seldom exceeds 100 m/min for the reapers, binders and combines. But when such a mechanism is used in a grass mower/forage harvester, the speed ranges from 120 to 170 m/min. The speed of the knives is essentially dictated by the "feed rate" of the material to be cut and its shearing resistance. The shearing resistance of the grain crop depends upon the moisture content of the stalks. As such the stage of maturity at the time of harvesting is an important parameter in determining the power requirements for cutting. For the grasses and fodder crops, the feed rate is usually higher than the grain crops. As such the shearing resistance is also considerably higher, depending upon the succulence and fiber-content of the stems and leaves. The reciprocating speed of the knife bar should be 20 to 25 higher than the forward speed of travel for efficient shearing of grain crops but about 40 to 45 higher than the forward speed for grass mowers to overcome the problem of bunching and over-feeding. In the reapers, binders and combines, it is not essential to use knife-clips to minimize clearance at shear and ensure maximum bearing of the shearing edges. In fact, in many grain harvesting machines now a days, there are not separate ledger plates, instead the case-hardened guard edges only serve as stationary shear plates. Even in such machines, the impact has little to do with cutting, since the cutter bar speed is too low. It is unwise to attempt to gain affect of impact-shear in cutter bar-type mechanism because 800 to 1600 strokes per minute with a back and forth stroke of 75 mm is far too short of the 4000 strokes which is the minimum requirement to effect the shear by impact alone. It is not possible to use higher speeds in the pitman and reciprocating cutter-bar type mechanisms since it is difficult to balance the unbalanced forces. A part of the unbalance is caused by uneven load and a part is the function of the constantly changing crank angle. If higher cutting bar speeds are to be used in reapers, binders and combines, it would lead to rapid wear and even mechanical failure of components.

MODULE 2. CONSTRUCTION AND ADJUSTMENT OF SHEAR AND IMPACT TYPE CUTTING MECHANISMS

LESSON 3. SHEAR TYPE CUTTING MECHANISMS, ADJUSTMENTS, REGISTRATION AND ALIGNMENT

It has knife that moves against stationary fingers. Horizontal reciprocating type mower has knifes that rotate at high speed in horizontal plane (Fig. 1). Due to reciprocating action of knife, grasses are cut uniformly. The mower/reaper consists of following parts:



Cutter Bar: Cutter bar is designed to cut 25-50 mm above the ground level up to 100 mm or more. It must be able to cut a wide variety of crop materials from grasses to tough stocks without clogging. A number of attempts have been made to replace the reciprocating knife with continuous moving cutting units such as chain or band knives in helical roller cutters but none have performed so well that commercially feasible. It is steel flat made with high-grade steel. All other sub component included in the cutting mechanism is connected directly or indirectly to it.

Cutter Bar Assembly: It is heart of the mower. The knife is metal bar on which blades are mounted that are triangular shaped sections. The cutting edges of these sections are mostly smooth edges. The knife sections move back and forth and cut plants in both directions. The section of the knife should always stop at the center of the guard on each stroke. The length of the stroke is 7.5 cm. Guards are provided with ledger plates on which the knife sections move. Knife clips hold the sections down against ledger plates but allow it to move freely. Knife clips are placed together with the wearing plates to absorb the rearward thrust of the crop to the knife. A badly worn wearing plate or a loose knife clip may allow the knife to bend. This is a common cause of the knife head, breaking at the point where it is attached to the bar. There is a grass board on the outer end of the mower, which causes the cut plants to fall towards the cut material. The angle of the board can be changed for different crops. A shoe on each end of the cutter bar is always provided to regulate the height of the cut above the ground. The inner shoe has a larger area of contact with the ground than the outer one. This results in smooth and easy sliding of the cutter bar on the ground.

Guards: These are provided to hold the forage while it is being cut. These also serve to secure the cutting units and provide a place for the ledger plates. The guards are made with malleable casting or pressed steel, pointed at one end for parting and guiding the grass to the knife sections.

Ledger Plate: The ledger plates are fixed over to the guards. They form one half of the cutting unit, the knife section acts as the other half. The edges of ledger plates are serrated to prevent stems of grass from slipping off the points of the shears.

Knife Section: Triangular shaped knife sections are fixed over to the cutter bar. The rear part of knife section is kept square shaped for its easy fixing. These are perfectly smooth and work well in most of the grass and legume crops. Some sections are top serrated which work well in dry grass or straw.

Wearing Plates: Wearing plates supports the knife from rear side. They provide vertical support to the rear of the knife sections and also absorb the forward thrust of the knife.

Knife-clips: These are provided to hold the knife section down close against the holder plates. They are made of malleable iron or steel. Knife clips are generally spaced three or four guards apart.

Inside Shoe: The inner end of the cutter bar during the operation is supported with a shoe like runner. A replaceable sole is placed underneath the shoe, which is adjustable to regulate the height of cut.

Outside Shoe: The outside shoe supports the outer end of cutter bar. It also has an adjustable sole to regulate the height of cut. The pointed front part of the other shoe acts as a divider. It separates the cut grass from standing uncut grass.

Power Transmission Unit: The knife of cutter bar is powered through a long pitman attached to the knife head. The power transmission consists of main axle, gears, crankshaft, crank wheel and pitman. The main axle receives power from one of the transport wheels. A spur gear mounted on the main axle drives the spur pinion on one end of the counter shaft in the gearbox. The bevel gear, which is provided to the other end of the counter shaft, engages with the bevel pinion on the crankshaft. The crank wheel and pitman are fixed on the outer end of crankshaft and the reciprocating motion is transmitted to the pitman, which in turn operates the knife in the cutter bar. The knife is connected to the pitman with a ball and socket joint. Crank speeds on most of the mowers are 850-1000 rpm for conventional pitman drives and 1000-1200 rpm for dynamically balanced systems. The knife makes about 1600 cutting strokes per minute. The tractor-drawn mowers are operated by PTO shaft. Most tractor-drawn mowers have a V-belt in the drive which provides overload protection and check high frequency peak torque and shock loads, sometimes dog clutch or a slip clutch is provided.

Wheels: A pair of wheel made of cast iron with sufficient widths and number of lugs to develop better traction are provided in the mowers. Now, pneumatic wheels are also in use. The transport wheels transmit power to the knife. It is so arranged that when the wheel move forward the ratchet and pawl mechanism comes into play to drive the main axle. When the wheel is turned backward the pawl slips giving a clicking noise.

Frame: The main frame of the mower is made with heavy casting that supports other parts and provides openings for main axle, counter shaft and crank shaft. It provides space for gearbox, clutch and bearing. A triangular shaped welded frame is common in semi-mounted mowers over which power transmission unit is installed.

Pitman: The pitman is the connecting rod between the crank wheel and the knife. Pitman may be made of well-seasoned wood or of steel which supports weight and absorbs vibrations.

Grass Board and Stick: The grass board is provided to clear the cut material from narrow strip next to the standing crop and hence provide a place for the inner shoe for operation on the next turn. A stick is also provided to keep the forage falling correctly. It can be set high for tall grass and low for short material. The grass board is spring loaded and free to move to some extent when it meets an obstruction.

Adjustments: A system of force acts upon the material to cut it in such a manner as to cause it to fail in shear. A common way to apply the cutting force is by means of two opposed shearing elements, one or both may be moving. The motion may be linear with uniform velocity, reciprocating or rotary. Impact cutting principle is applied in rotary cutters and flail shredders. A continuous reciprocating knife type of cutter bar is commonly used to cut a wide variety of crop materials. Cutting in this case utilizes both impact and shear. There are two adjustments, which are very important for proper functioning of a mower. They are registration and alignment.

Registration: A knife is in proper registration when midpoint of the knife section stops in the center of guard on each stroke (Fig. 2). It is very essential for an even job of cutting and unclogging of the cutter bar. If it is not properly registered then it can be adjusted by moving the entire cutter bar in or out with respect to the pitman crankshaft. The results of failing to register are an uneven cutting and an uneven loading of the entire mower. It also results in more draft and clogging of knife. There is provision to change the pitman length, which is provided in some of the mowers.

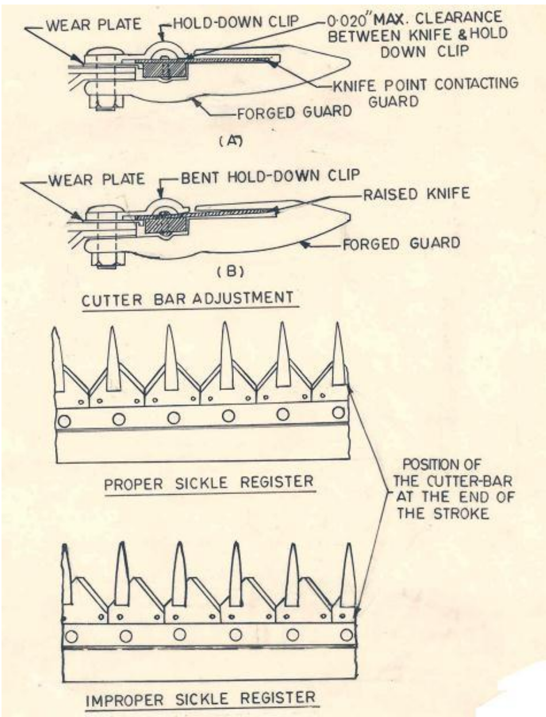


Fig. 2: Adjustment in the cutter bar unit.

Alignment: The outer end of the cutter bar is fitted a little ahead of the inner end so that the outer end may align with the inner end, when the mower is pulled through crops. This is called lead and gives better cutting when the cutter bar is properly aligned i.e. the knife and the pitman run in a straight line. To allow for rear word deflection of the outer end of cutter bar during operation, it is customary to adjust the mower so that when not in operation, the outer end of cutter bar has a lead of about 2-cm per meter of cutter bar. To measure the lead of a mower, stretch a stirring parallel to the vertical plane of the pitman and determine the difference in the horizontal fore-and-aft distances from the string to the knife back at the inner and outer ends. Adjustment, if needed be done by rotating an eccentric bushing on one of the hinged pins. Fig. 3 shows a typical arrangement of a pitman drive and inertia-force relations for the reciprocating knife, pitman and crankpin. Pitman mass is assumed to be divided into two components, W_1 being subjected to rotary motion and W_2 having reciprocating motion. If W_s is the mass of knife and W_c is the mass of crankpin, uniform angular velocity of the crank can be assumed if $R/(L^2 - S^2)^{1/2}$ is less than 0.25. The inertia force of the reciprocating parts can be represented by the equation

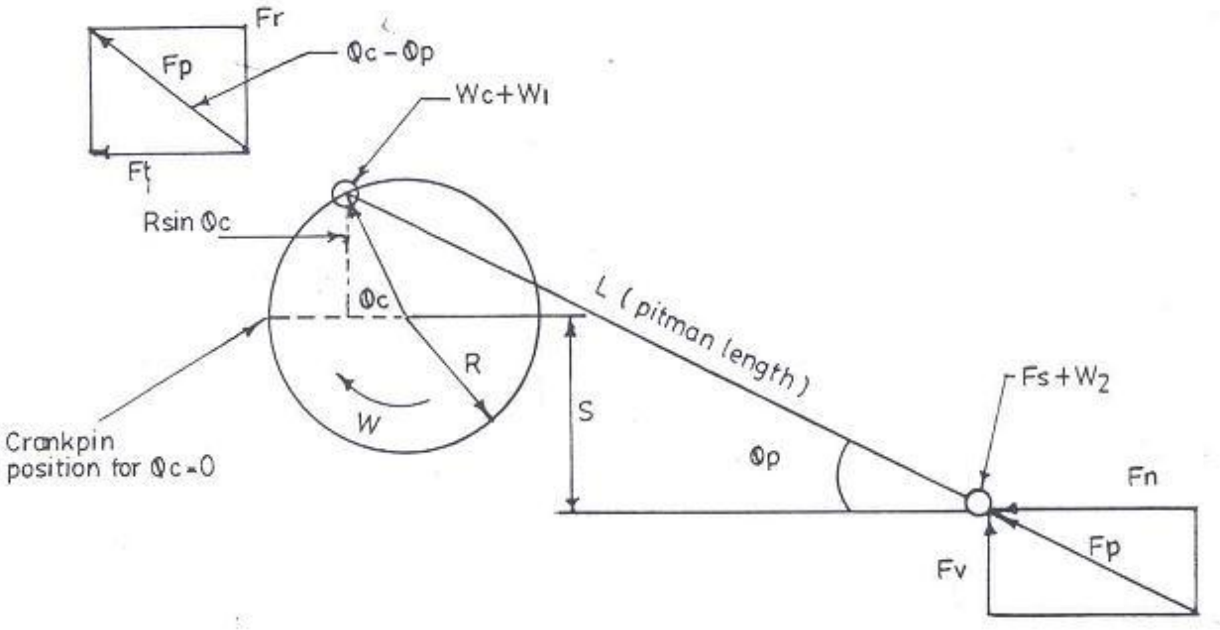


Fig. 3: Forces due to inertia of reciprocating parts in a mower pitman drive.

(Kepner et al. 1987)

$$F_h = (W_s + W_2)\, R\, w^2 \left(\cos j_c + \frac{K\,S}{R} \sin j_c - K \cos 2j_c\right) \qquad \text{------- (1)}$$

Where,

F_h = inertia force of the knife

W_2 = portion of pitman mass during reciprocating motion

w = angular velocity of crank, radians/s

L = length of pitman

j_c = angle of crank rotation

R = radius of rotation of crank pin

S = height of crank shaft center line above the plane of pivot connection

Between knife and pitman

K = $R/(L^2 - S^2)^{1/2}$

Because of angle between pitman and knife, a periodic vertical reaction F_v, alternating upward and downward, is introduced at the knife head. If the knife head guides are loose may cause early fatigue of knife back. Cutting energy and power requirements of a 2.13 m tractor-mounted mower is given in Table 1. Height of cut of crop can be adjusted by varying the adjustable shoes at the inner and outer ends of the cutter bar.

Table 1: Cutting energy and power requirements of a 2.13-m tractor-mounted mower.

	Average Equivalent Knife Load (kN)	Average PTO Power (kW)	Average Peak PTO Power (kW)
Inertia & friction load (no cutting)	1.82	1.27	4.61
Mowing at 7.9 km/h	2.54	1.90	5.22
Increase due to cutting	0.72	0.63	0.61

Source: Kepner et al. 1987

LESSON 4. IMPACT TYPE CUTTING MECHANISMS

The impact/ cutting mechanisms are of a rather recent development. They depend upon the effective shear of the material to be cut by a sharp impact of blade(s) travelling at 1300 to 2700 m/min. The more rigid the stalks and therefore resistant to bending, the more easily they gives way through shear failure/ under impact. The impact cutting mechanisms are being used in the rotary mowers (also called flail type) and forge harvesters with great advantage. Greatest efficiency is derived from the use of sharp edged, long rotating blades to have higher peripheral speed and higher inertial momentum of the heavy blades to sustain their speed when cutting dense-growth. To utilize the impact-shear principle effectively, it is essential to employ a mechanical prime mower. The manually-carried Japanese power reaper with a circular blade employs the impact cutting principle. The advantages of impact-cutting mechanism are the minimum initial cost, simplicity of repair and maintenance as well as high efficiency. The impact-type mechanisms are particularly well-suited to rough land and rough pasture. The impact-type cutting mechanisms are, however, not suited to harvesting grain crops due to higher shattering of the grain as well as the spreading of the stalks upon being cut.

The flail type forage harvesting is simple in design and construction. It can be used for cutting any type of forage crops and grasses including lodged crops. Overload encountered by the machine during operation is absorbed by freely hanging flails and thus machine components are protected from field damage. This makes it a unique machine to be used in stony, stumpy and uneven land. Forage crops cut by flail mower do not require any additional chopping by chaff cutter. This is done in the process of harvesting in the field itself by repeated beating action of the flails on the plants. Tractor rear mounted hydraulically controlled PTO operated flail type forage harvesting machine is versatile for numerous field operations such as fodder maize cutting, grass topping and mowing, green manure topping, cutting shrubs on river banks and drainage channels etc.

A flail-type mower comprises of a horizontal rotor with two blades each of about 60 cm. The blade rotates at peripheral speeds of 2000-3000 rpm (Fig. 1). These mowers are extremely sturdy and as such can work under varying field conditions. When used for grasses, it causes excessive field loss as short pieces are hardly recovered in raking or during picking from the windrows. Losses can be reduced using lower peripheral speeds. A flail mower has a full width adjustable gauge roller located behind the rotor to provide accurate control of cutting height and prevent scalping of high spots. Cutting widths are usually 1.8 to 3.0 meters. Pull type flail mowers are generally attached at the back of tractor and kept offset so that the tractor wheel runs on the cut hay rather than on the standing crop. Some of these units are provided with augurs to convey the cut material into trailers. It uses free-swinging chains and knives to sever the plants by beating or cutting action (Fig. 2). The flails or knives travel in the same direction the machine moves. It does not have chopping knives on the blower fan to chop the material into desired length for silage. The beating by flails more or less conditions the hay.

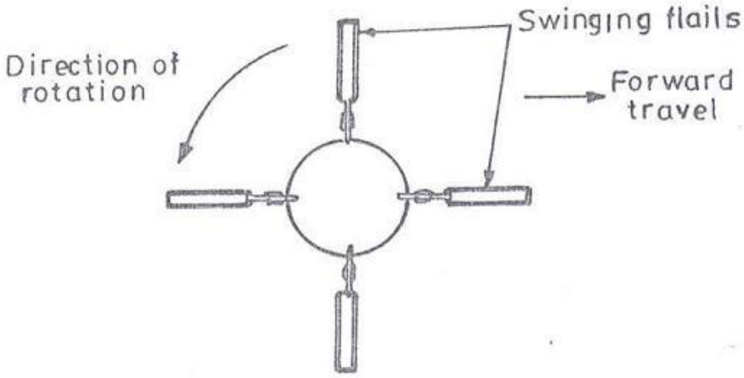


Fig. 1: Flail action during work.

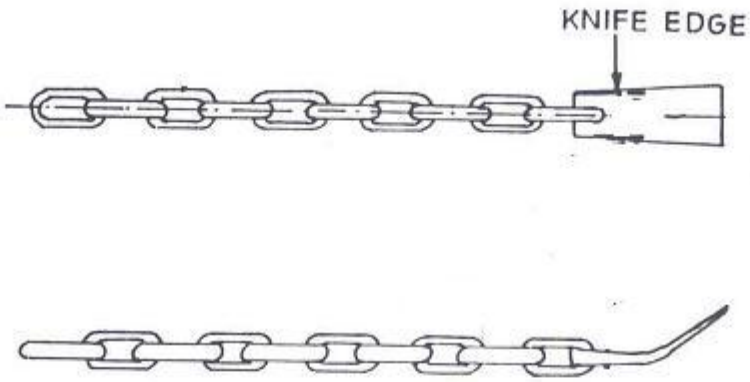


Fig. 2: Details of free swing chains.

Problem 1: Determine horizontal inertia force at each end of stroke and magnitude and direction of vertical reaction at each end of stroke for reciprocating cutter bar knife in a mower. Given:

Crank speed = 1000 rpm; pitman length = 1.06 m; crank pin radius = 38 mm; mass of knife = 4.4 kg; mass of pitman = 3.5 kg; mass of crank pin = 0.35 kg; centre of gravity of pitman = 0.48 m from knife end and height of crank shaft centre line above pivot connection between knife and pitman = 240 mm.

Solution: Refer to Fig. 3 and equation 1 in lesion 3

Weight of pitman ($W_1 + W_2$) = 3.5 kg

Since centre of gravity of pitman is 0.48 m from knife end,

$$W_2 = \frac{0.48 \times 3.5}{1.06} = 1.58 \text{ kg}$$

$$W_1 = \frac{(1.06 - 0.48) \times 3.5}{1.06} = 1.92 \text{ kg}$$

$$K = R/(L^2 - S^2)^{1/2} = 0.038/(1.06^2 - 0.24^2)^{1/2} = 0.0356$$

$$w = 2\pi N/60 = 2\pi \times 1000/60 = 104.7 \text{ rad/s}$$

Inertia force at each end of stroke can be calculated by putting $j_c = 0^0$ and $j_c = 180^0$

For $\varphi_c = 0^0$

$$F_h = (4.4 + 1.58) \times 0.038 \times (104.7)^2 \left(\cos 0 + \frac{0.0356 \times 0.24}{0.038} \sin 0 - 0.0356 \cos 0\right)$$

$$= 245.1 \text{ kg}$$

For $\varphi_c = 180^0$

$$F_h = -263.2 \text{ kg}$$

Since, the pitman and cutter bar are not in the same plane, an intermittent vertical force will be introduced at knife head at each end of the stroke.

$$F_p = \frac{F_h}{\cos \varphi_p}$$

and $$F_v = F_p \sin \varphi_p = F_h \tan \varphi_p$$

$$S + R \sin \varphi_c = L \sin \varphi_p$$

$$\sin \varphi_p = \frac{S + R \sin \varphi_c}{L}$$

$$\varphi_p = \sin^{-1} \frac{S + R \sin \varphi_c}{L}$$

For $\varphi_c = 0°$

$$\varphi_p = \sin^{-1} \frac{0.24 + 0.038 \sin 0}{1.06} = 13.1°$$

$$F_v = 245.1 \tan 13.1 = 56.97 \text{ kg acting upward}$$

For $\varphi_c = 180°$

$$\varphi_p = \sin^{-1} \frac{0.24 + 0.038 \sin 180}{1.06} = 13.1°$$

$$F_v = -263.2 \tan 13.1 = -61.25 \text{ kg acting downward}$$

Problem 2: A 1.2 m mower is working at a speed of 3.5 km/h and experiences a load of 75 kgf/m length of cutter head. What will be the horse power requirement if mechanical efficiency of mower is 70%.

Solution:

Total load on the cutter head= 1.2 x 75 = 90 kgf

Total power $= \dfrac{90 \times 3.5 \times 1000}{60 \times 4500} = 1.17$ hp

BHP required to pull the mower = 1.17/0.7 = 1.67 hp

Problem 3: A trailed type mower has drive wheel of 65-cm diameter. The crank of mower makes 850 rpm when it is hitched to a tractor moving at a constant speed of 3 km/h. If the speed ratio between the crank wheel and land wheel is changed to 30:1, calculate the increase in speed of mower to maintain same speed of crank.

Solution: rpm of crank = 850

rpm of drive wheel = 850/30 = 28.33

Linear speed of mower = p D R = 3.14 x 0.65 x 60 x 28.33/1000

= 3.47 km/h

Increase in speed of mower = 3.47 - 3.0 = 0.47 km/h

Where, D = diameter of drive wheel

R = rpm of drive wheel

MODULE 3. CROP HARVESTING MACHINERY

LESSON 5. MOWERS AND WINDROWERS

Forage harvesting is more complex as compared to grain crops. Forage crop is of great bulk and mass, containing 70-80% water when first harvested. For storage it must be dried, either naturally or artificially, to a safe moisture content of about 20 to 25%. Due to low product value it limits the economic feasibility of mechanization of harvesting operation of forage crops. The mowers are used to cut the crop and windrow in the field, which is manually collected for further chopping.

The forage harvester consists of a combination of plant-cutting unit and a chopping unit and is called field forage harvester. The field forage harvester performs the functions of both row binder and silage cutter, as it severs the standing stalks from the ground and chops them into silage in one continuous operation in the field. It can be grouped into two according to the mechanism used to cut the crop viz. field choppers and flail harvesters.

Mower

The mower is a machine mainly used for harvesting grasses and forage crops. It cuts the stems of standing vegetation to make hay out of them. The mower cutter bar is capable of cutting the stems at 3-10 cm above the ground. There are different types of mowers used for cutting grass and forage crop such as cylinder, reciprocating, horizontal rotary and flail type mowers. According to the source of power, mowers can be classified as manually operated, animal-drawn, tractor-drawn and self-propelled. According to the mode of hitching, mowers can be classified as trailed type, semi-mounted and integral mounted type. Semi-mounted and integral-mounted mowers can be further classified as rear, mid and front-mounted. According to drive used, mowers can be classified as ground-driven, engine-driven and PTO driven. The conventional animal-drawn mower has the following main parts:

- A cutter bar to cut the crop and separate it from uncut portion.
- Power transmission unit to receive and transmit motion force.
- Frame to support moving parts.
- Wheels to transport and for operating the cutting mechanism, and
- Auxiliary parts to lift and drop the cutter bar.

Classification of Mowers

The mowers on the basis of their cutting mechanism are classified as:

a) Finger-type cutter bar mower

Here the plant is pressed by the active knife against the fixed ledger-plate of the finger guard and sheared.

b) Under-knife mower

Double knife cutter bar with one knife fixed falls under this category. With this system one knife acts as ledger plate of the guard and the other performs the function of a normal reciprocating knife. These mowers are simple in construction and minimize the chances of blockage by dense crop and by small soil obstructions. However they are not suitable in stony fields.

c) Double cutter-bar mower

It is provided with two cutter-bars which operate in opposite directions. The plants are sheared by the two active blades instead against the ledger plate of guard. Such mowers have advantages of minimum power requirement clean cut, higher speed of operation, cutting close to the ground etc. The cutter-bar mowers are further classified on the basis of their finger spacing.

(i) Normal cutter-bar: In these mowers the spacing of guard fingers and knife sections is kept equal to 76.2 mm. These mowers are most suitable for thick stemmed crops like jowar, maize, bajra etc.

(ii) Medium fine cutter-bar: In this type of cutter-bar the finger spacing is reduced from 76.2 mm to 50.00 mm and the knife spacing is kept constant to 76.2 mm. This mechanism helps better cutting in dense crops.

(iii) Fine cutter-bar: Here the finger spicing are kept 38.1 mm and the knife spacing remains 76.2 mm. This mechanism is especially suitable for the grasslands to harvest fine stemmed plants on broken terrain.

(d) Mower-cum-crusher

To perform cutting and condition operation the reciprocating mower is provided with a conditioning attachment. Such mowers are called mower-cum-crushers.

(e) Disc mowers

In these machines the plants are cut by the revolving blade in horizontal plane fitted on round discs. On the basis of their construction these mowers are further classified as:

(i) Drum Disc Mower: These mowers are provided with drum type discs, i.e. a drum is fitted over the disc to enable the cut material to push back to place it in the swath.

(ii) Rafter-disc Mower: These mowers are similar to the drum disc mowers except that (a) the power to the disc is transmitted through the system located below the disc and (b) the cut material is pushed back by the revolving discs and not by the drums as in the previous case. The discs are provided with throw-away pieces which help pushing back the cut material.

Rotary Mower

It consists of a single high speed cutting element in horizontal plane (60-70 m/s) and relies primarily upon the inertia of the material being cut to furnish the opposing force required for shear. The ground also acts as one of the shearing elements. It works on the principle of free-cutting. When a revolving blade hits, the plant, it is sheared and carried with the blade. The normal component of the force cuts the stalk and the tangential component helps imparting kinetic energy to the plant so as to carry it along with the blade up-to certain distance. The forward velocity component also helps adding to the magnitude of both the four components.

The rotary mowers are also of two types: (i) Disc-type mower and (ii) The Rotary stalk-cutter and shredder. The disc type mower has 2-3 swinging blades of approximately 75 mm x 40 mm x 3 mm size fitted to the disc. The diameter of the disc and number of the discs depends upon the swath width. Owing to the rotary speed of the disc and forward speed of the tractor, the blade travels in a cycloid-path. The tangential component of the force is much higher in magnitude than the radial component; as such the material is cut but not carried away from the cut area. The throw-away pieces are provided on the cylinder and/or on the discs to throw the cut material rearwards. The rotary cutter and shredder consist of two swinging knives rotating in a horizontal plane and housing. The rotating knives cut the material by impact and shear force. The material is carried to the discharge end by virtue of the kinetic energy imparted by the cutting blade.

Flail Mower

The flail mower cuts the plants, chops for them into small feed lengths and blows the cut and chopped material into the accompanying trailer. These machines are used for harvesting the crop for daily consumption or for silage making. The chopped lengths of the stalks can be varied from fine-medium to course by increasing or decreasing the clearance between the shear-bar and the flail-tip. The above machine can also be used for forge conditioning required to increase the drying rate during hay making process.

Cylinder Type Mower: It is generally used for lawn mowing. It includes lawn mowers and gang mowers. It could be hand-propelled and self-propelled lawn mowers and tractor-drawn and tractor-mounted gang mowers. It has rotating helical blades arranged in horizontal plane (Figs. 1 & 2). There are three gangs in this mower having 3-4 helical blades each supported over vertical discs. The rotors of this type of mowers are supported on ball bearings at each end. With the rotation of blades, forage or grasses are cut for example lawn mower. It can cover about 1.5-2.0 ha/h at a speed of 8-10 km/h.

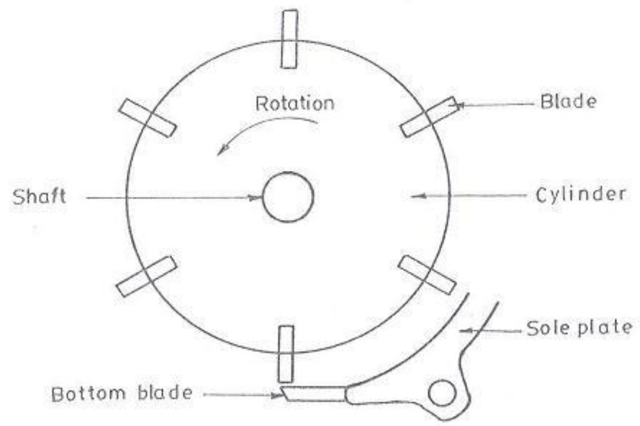


Fig. 1: Side view of a cylinder mower.

Rotating Disc-type Mowers: There are two types of disc mowers. In one type, there are discs on the periphery of which free-swinging knives (2-4 in numbers) are attached. Sometimes the rotating knives are mounted on bearings on a cutter bar similar to one used for a conventional reciprocating mower. Cutting in this type of mower takes place due to impact and as such energy requirements are comparatively low. In drum-type mowers, usually there are two large-diameter moving drums. These are driven by belt and pullet system. Three to four steel blades are attached to each disc, which revolve at a speed of about 2000-rpm. The diameter of disc ranges from 60 to 80 cm. In this one also, cutting takes place due to impact. These types of mowers make fairly good swaths and the harvested material is dried speedily. Due to absence of gear or chain drive, the action is usually quite smooth and power consumption low.

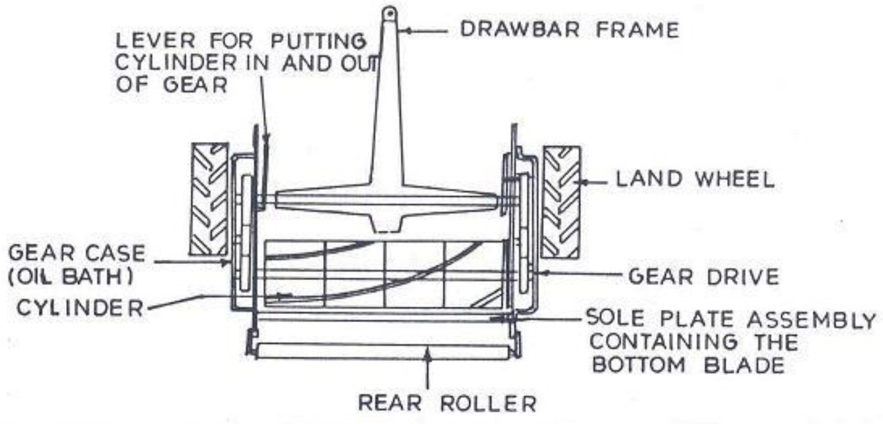


Fig. 2: A view of gang mower.

Adjustments of mower reaper

Sr. No.	Part	Problem	Adjustment
1.	Reel	i) Does not rotate ii)Improper gathering of crop	i) Check tension of reel belt. Reel by hand to ensure that the drive pulley key and belt are secured. ii) Adjust height according to height of crop
2.	Cutter bar	Unsatisfactory cutting	i) Reduce forward speed ii) Correct the registration iii) Sharpen the knife sections or replace if worn out. iv) Check drive belt tension. If loose, tighten

Windrowers

In some areas, farmers find that cutting and windrowing the top portion of the plants with the grain attached permit earlier harvesting and protect the grain under the following conditions.

(i) When the grain is unevenly ripened.

(ii) When fields are weedy.

(iii) When the straw is green but the crop is ripe.

(iv) When the grain is high in moisture.

(v) When crop conditions are such that legume crops tend to shatter if left until ripe, and

(vi) When weather conditions delay direct combining. The windrowing machine consists of a power-takeoff-driven knife, platform canvas, and reel.

The heads of grain are clipped off and fall upon the travelling platform canvas, which delivers the grain over one end onto the stubble. Most windrowing machines deliver the grain over the end farthest away from the standing grain. Center-delivery machines are available.

Self-Propelled Windrowers

Self-propelled windrowers consist of two types of headers. The augur cross feed is the most common type on hay machines but is too aggressive for grain. The draper type is employed on windrowers intended for both grain and hay. The maximum width that should be cut with a hay windrower is limited primarily by the maximum size of windrow that will cure in an acceptable time. Windrowers with cutting widths of 3.65 m and 4.25 m are popular in irrigated areas where hay yields per cutting are usually 2.2 to 3.4 Mg of dry matter per ha. Knife speeds are about the same as on mower-conditioners but strokes are often 6 to 10 mm greater than the 76.2 mm guard spacing. Chrome-plated knife sections are used almost universally. Conditioning attachments are usually 0.9 to 1.4 m wide, but the direct-feed, full-width-conditioner system of pull-type mower-conditioners has also been applied to some 2.75 m self-propelled machines.

LESSON 6. REAPER AND REAPER BINDERS

Harvesting equipment may be manually operated, animal-drawn or power operated. Sickle is the most widely used harvesting tool for various crops (Fig. 1). Sickle used may be plain or serrated edged and both types are found effective in cutting plants. Animal drawn reapers have been tried and proved successful on wheat crops. Power operated machines can be reaper, mower, rotary power scythes, forage harvester, binder and conventional combines. A manually operated rotary power scythe (push-cutter) uses a high-speed engine for rotating the cutter blade. A rotary circular disc with plain or serrated edge accomplishes the cutting by impact force. The unit is mounted on the back of the operator, who also activates the cutting rod. The crop is cut and laid in windrows. The output varies between 0.2 to 0.4 ha/day. Tractor front mounted reapers and mowers are also being used for harvesting various crops. It can be powered with power tiller or tractor. Combine harvesters are now becoming increasingly popular in northern India and also in other parts of country. Combines are being used mostly for harvesting crops like wheat, paddy, soybean, sunflower and other crops. Both types of combines viz. self-propelled and tractor operated are common for these crops.

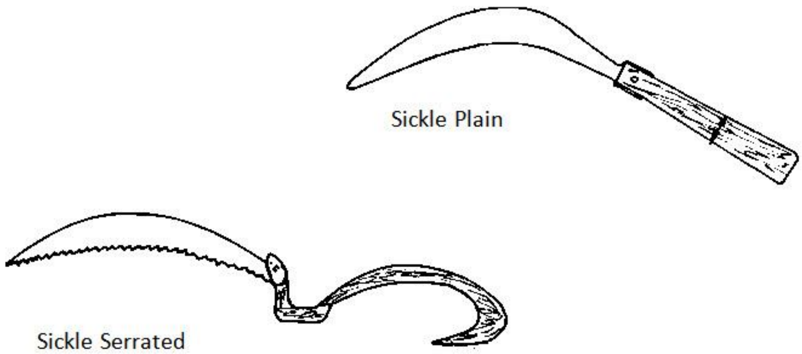


Fig. 1: Sickles used in harvesting of crops.

Reaper

Harvesting of cereal crops especially wheat and rice is a serious problem. There is a tremendous crop loss when untimely rain is experienced. Delayed harvesting causes grain shattering due to over maturity. The standing crop in the field can be harvested with the use of reapers. A reaper may be classified as animal-drawn reaper, animal-drawn engine operated reaper, tractor rear mounted PTO operated reaper, power tiller operated or tractor front mounted vertical conveyer type reapers and tractor mounted reaper binder.

Animal-drawn reaper: It consists of a cutter bar of 1.05 m length (Fig. 2). The power to drive the knife bar is given from the ground wheel by means of gear box, crank and connecting rod mechanism. As the machine is pull forward by a pair of bullocks, a reciprocating motion is imparted to the knife bar with a peak cutting velocity of about 100 m/min. The crop is cut and laid in windrows. The effective field capacity of machine varies between 0.2-0.3 ha/h.

Fig. 2: Animal-drawn reaper.

Animal-drawn engine operated reaper: It has a cutter bar of 1.35 m length. A 2 hp 4-stroke petrol engine operates the cutter bar. The drive to the cutter bar from engine is given through V belt and gearbox. It can cover 0.2-0.4 ha/h with field efficiency of about 80%.

Power tiller/Tractor front mounted vertical conveyer reaper windrower: A machine called vertical conveyor reaper–cum-windrower can cut the crop and lay it in the form of windrow for easy picking. It consists of a conventional cutter bar assembly, crop row dividers with star wheels, covers, pressure springs and vertical conveyor belts (Fig. 3). Cutter bar is given reciprocating motion by crank wheel. Crop row dividers with star wheels enter the standing crop, help in lifting, gathering and guiding the crop towards the cutter bar. After the crop is cut, held in a vertical position during its passage by means of pressure springs and star wheels. Vertically held crop is then delivered towards right side of the machine in a windrow perpendicular to the direction of movement of machine with the help of lugged conveyor belt. The gearbox and windrower is coupled to the drive shaft of the prime mower. The output shaft transmits power to the shaft driving the lugged flat conveyor belts and a crank is attached at the lower end of the output shaft to operate the cutter bar through connecting rod. The serrated blade cutter bar with standard knife guards is fitted. The top lugged conveyor belt drives the star wheels on the crop row dividers. Pressure springs are fitted below the star wheels between the conveying platforms to keep the cut crop in upright position while it is being conveyed out of the machine. The power in case of power tiller units is transmitted through an intermediate shaft to the gearbox on windrower either by belt or by shaft drive. In tractor mounted models, the power to the gearbox is transmitted from PTO shaft through gearbox by a long shaft running beneath the tractor body to the front and with the help of universal joint and telescopic shaft which is connected to the gearbox. Lowering and raising of reaper is carried out with the help of hydraulic system of a tractor. In case of power tiller the machine pivots on the power tiller wheels. By pushing the handle, the cutter bar can be raised.

A front mounted vertical conveyor reaper is the most common reaper, to harvest wheat and paddy crops. It can also be used for harvesting of soybean and other similar crops. Engine operated reaper (Fig. 4) can be operated with a 5-6 hp engine, whereas, tractor operated reapers (Fig. 5) can be operated with 25-35 hp tractor. Width of cut is about 1.6 m in power tiller reaper, and about 2.05 m in tractor operated reapers. Stroke per min of cutter bar is 1225 and 1550 in case of power tiller and tractor operated reapers, respectively. Power tiller and tractor-front mounted vertical conveyer reaper windrower can cover about 0.2 ha/h and 0.4 ha/h, respectively.

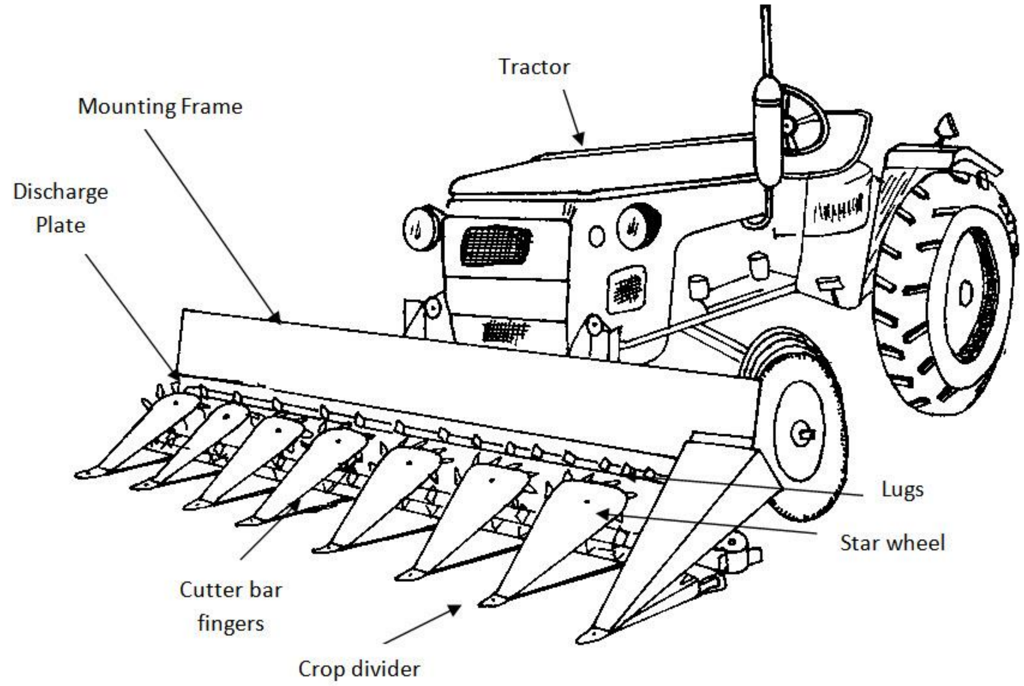


Fig. 3: Tractor front mounted vertical conveyer reaper windrower.

Fig. 4: Self-propelled vertical conveyor reaper-cum-windrower.

Fig. 5: Tractor front mounted vertical conveyor reaper-cum-windrower.

Tractor rear mounted PTO operated self-raking reaper: The machine carries a cutter bar of 1.5m length, the drive to which is given from PTO of a tractor. It is a side delivery machine in which crop is collected over a platform and is delivered on one side in the form of bound bunches of desired size (Fig. 6). The raking and sweeping of harvested crop is done mechanically. A profile cam controls raking motion. An index lever regulates the movement of cam rollers in such a way that either of first, second, third or fourth rake sweeps out the cut crop laid on the platform. The crop is tied into bundles of desired size manually. It can cover about 3 ha/day with field efficiency of 85%. The grain loss varies between 0.2-3.1percent.

Tractor-rear mounted reaper binder: The machine consists of a cutting, gathering knotting mechanism mounted on a high pressure pipe frame with a 3-point linkage arrangement for hitching at the rear of a tractor. It has a 1.36m long cutter bar and power to various components is given from PTO through v-belts and pulleys. The machine can cover 1.5-2.0 ha/day at a forward speed of 2 km/h. Machine can be used for harvesting wheat and paddy both. Grain losses are 2.2-8.0% for wheat and 1.0-5.0% for paddy.

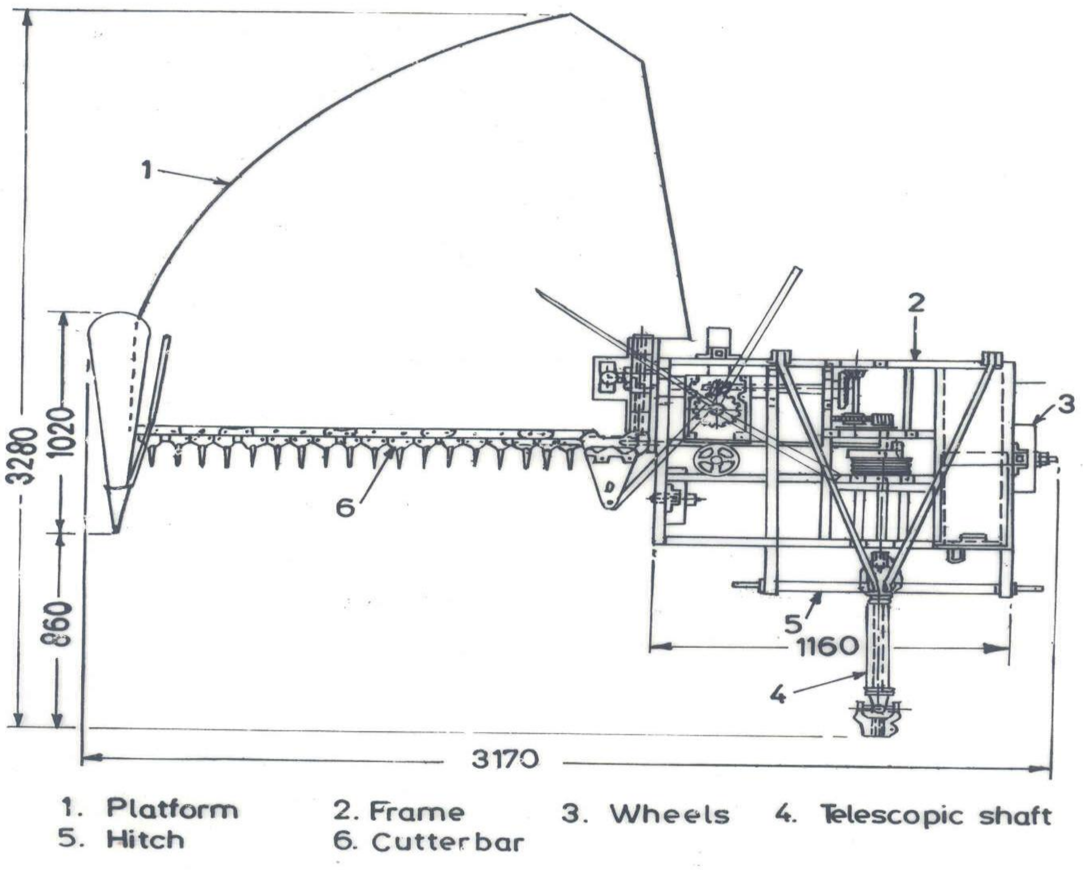


Fig. 6: Schematic view of tractor-rear mounted PTO operated self-raking reaper.

Self-propelled reaper binder

It is suitable for harvesting and making bundle of wheat, paddy and other oilseeds and pulse crops. It is operated by 9 kW diesel engines (Fig. 7). The riding type self–propelled vertical conveyor reaper windrower is powered by a 9 kW, single cylinder, water cooled diesel engine having rated engine speed of 3000 rpm. It is provided with four pneumatic wheels; two driving wheels in the front having agricultural tread pattern tyres and two steering wheels at the rear having automotive tyres. Other systems include clutch, brakes, steering, hydraulics, and power transmission and an operator's seat is available to make the machine riding type. The harvesting system include crop row dividers, star wheels, standard cutter bar having 76.2 mm pitch of knife section, vertical conveyor belts and wire springs. The effective cutter bar width is 1.2 m. The crop row dividers enter the standing crop and the star wheels guide the crop towards the cutter bar and help in slightly lifting the crop after it is cut, and in turning it at right angle, prior to its conveying by the lugged conveyor belt. The two lugged flat belts convey the cut crop towards the centre of the machine and moves back on a platform where it makes a bundle of about 5 kg each. At the end, the crop is discharged on the ground in the rear. Working capacity of reaper binder is 0.3-0.4 ha/h. Weight of the machine is about 450 kg.

Fig. 7: Self-propelled reaper binder

Reaper problems and adjustments

For proper field efficiency and minimum grain loss, correct field layout and preparation of the field are the most important factors. A swath of about 1.5 m width is required to be first cut all around the field to make passage for the tractor to travel. Alternately, the farmer may want to sow some other crop which could be harvested earlier than the main crop to save the trouble of the hand-harvesting of the initial swath. There are two different modes of turning at the corners as shown in the "Guidelines for proper working of the Reapers." In round turning, the corners are cut in an area to permit the turning of the reaper without pressing or trampling of the stalks by the outer shoe and swath divider. This, however, is not necessary in the poop method of turning. Machine adjustments like the height of the cut and the adjustment of the rakes are made next before starting the operation. As the cutter bar is provided on the right hand side the reaper should be worked in a clockwise direction in the field. The reaper should be run for some distance and the size of the crop-bunches be examined. To make bigger or smaller bunches, the frequency of the sweeping rake needs to be adjusted accordingly. Care should be taken to keep the delivery end of the platform about 15 cm above the ground to facilitate easy dropping of the bunches. The forward speed of the tractor should be carefully selected in accordance with the crop and field conditions. Under Indian field and crop conditions the forward speed is limited to 3 km/h or so. Since the bunches are laid on one side, the passage for the subsequent run of the tractor is cleared automatically. The harvested crop is later tied into bundles of required size manually. The following table gives the common problems in the operation of the reaper-binder which can be remedied through necessary adjustments:

Sr. No.	Part	Problem	Adjustment
1.	Reel	i) Does not rotate ii)Improper gathering of crop	i) Check tension of reel belt. Reel by hand to ensure that the drive pulley key and belt are secured. ii) Adjust height according to height of crop
2.	Cutter bar	Unsatisfactory cutting	i) Reduce forward speed ii) Correct the registration iii) Sharpen the knife sections or replace if worn out. iv) Check drive belt tension. If loose, tighten
3.	Binding & tying mechani sm	i) Broken or torn twine ii) Loose or untied knot iii) Frequent untied bundles iv) Improper cutting of twine	i) Remove twine and clean needle eyelet and pliers. Reduce tension on twine under the tension plate through fly-nut ii) Tighten the twine disc with the help of spring loaded screw-bolt provided for the purpose iii) Adjust spring tension and smooth face of pliers by emmary paper. Use twine of uniform thiclmen
4.	Conveyo r	i) Bundles keep collecting on conveyor ii) Conveyor slackened & bundles not conveyed at regular internal	i) Check the tension or the v-belt over the conveyor roller pulley. ii) Tighten the convas conveyor with help of the sum buckles provided
5.	Bundle size		Increase or decrease the size of bundles by increasing or decreasing the tension of trigger. For this the trigger spring is hooked on to different holes provided

Reaper problems and numerical

Problem 1: The cutter bar of a mower to the P.T.O of a tractor makes 2000 strokes per minute. The mower has following specifications:

Length of pitman, L = 85 cm

Radius of rotation of crank pin, = 5 cm

Height of the crank shaft centre above the plain of the joint between the cutter and pitman, S = 21 cm

Weight of cutter bar, $W_k = 5.3$ kg

Weight of crankpin, $W_c = 0.5$ kg

If the pitman weighing 40 kg has its centre of gravity at a distance of 45 cm from the knife end, calculate

a) The inertia force at each end of the stroke

b) Resulting unbalance forces at each end of the stroke

c) Centrifugal force developed on the crank pin at each end of the stroke

Solution :

a. Revolution of the crank per min, N = 1000

Let the weight of the pitman coming on the knife = W_1

And weight of the pitman coming on the crank = W_2

So, $W_1 + W_1$ = weight of pitman

Since the centre of gravity of pitman is 45 cm from the knife end,

$W_2 =$ = 2.12 kg and $W_1 =$ _= 1.88 kg

Fig. no. shows the forces acting on the crankpin and on the knife at any crank angle, ϴ.

Fig. Forces acting on a reciprocating cutter bar

The inertia force, F_h for the knife and for W_1 portion of the pitman weight according to the equation, $F_h =$ rw^2…(1)

Where, $K = r/L^2 - S^2$

= $5/85^2 - 21^2 = 0.06065$ and w = = = 104.67 radians/sec$^{\theta}$

Equation (1) can be used to calculate the inertia, force $F_{h1}$and F_{h2} at the end of stroke by substituting ϴ = 0° and ϴ = 180° respectively.

For ϴ = 0°, $F_{h1} = 5 \times 104.67^2$ 359 kg

For ϴ = 180°, $F_{h2} = 5 \times 104.67^2$ -0.05 kg

b. Because the pitman and cutter bar are not in the same plane an intermittent vertical force F_v will be introduced at the knife head as shown in Fig. from this figure the resulting unbalanced force at any crank angle can be given by the relationship,

$$F_p = \frac{Fh}{Cos\ \Theta p} \quad \ldots\ldots\ldots\ldots \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (2)$$

Θ_p = is related to Θ as L Sin Θ_p = r Sin Θ

$\ni_p = Sin^{-1}(S/L) = Sin^{-1}(21/85) = 14°.3$

From eq. (2), for $\Theta = 0$, $F_{p1} = \frac{Fh1}{Cos\ 14°.3} = \frac{359}{0.969} = 370$ kg

And for $\Theta = 180°$ $F_{p2} = \frac{Fh2}{Cos\ 14°.3} = -\frac{405}{0.969} = -417$ kg

c. At the crank pin, as shown in Fig. the total unbalanced force F_p can be resolved into two components; F_r in the radial direction and tangential component F_t in the tangential direction. In addition to F_r the crank pin will have additional centrifugal force say, F_{rt} due to rotation of the crankpin plus the component of pitman weight.

Weight of crankpin = W_c = 0.5 kg

Component of pitman weight, W_2 = 2.12 kg

So, $W_c + W_2$ = 2.62 kg

Hence $F_t = \frac{Wc + W2}{g} w^2 r = \frac{2.62}{981} \times 104.67^2 \times 5 = 145$ kg

From Fig.

$F_r = F_p\ Cos\ (\Theta - \Theta_p)$, at $\Theta = 0°$, $F_{rt} = F_{pl}\ Cos\ (\Theta_p) = 30 \times Cos\ 14°.3 = 358.5$ kg

At, $\Theta = 180°$ $F_{r2} = F_{t2}\ Cos\ (180° - 14°.3) = 405$ kg

Thus total centrifugal force,

= 145 + 358.5 = 503.5 kg when $\Theta = 0°$ and

= 145 + 405 = 550 kg when $\Theta = 180°$

Problem 2: A trailed mower has drive wheels of 60 cm diameter. The crank of the mower makes 600 rpm. When it is hitched to a tractor moving at a constant speed of 2.1 km/hr. if the speed ratio between the crank wheel and land wheel is changed to 27:1, calculate the increase in speed of the mower to maintain same speed of crank.

Solution:

The rpm of the crank = 600
The rpm of the drive wheel = 600/27 = 22.2
Linear speed of the mower

$$= \frac{600}{27} \times \pi \times \frac{600}{100} \times 60 \text{ m/hr} = 2.51 \text{ km/hr}$$

The increase in speed of mower = 2.51 – 2.10 = 0.41 km/hr

Problem 3: A universal joint is used to transmit power from the power take-off of a tractor to a mower. The two shafts are inclined at 20° and the power take-off shaft rotates at a speed of 540 rpm. Find the extreme angular velocities of the mower shaft and its maximum acceleration.

Solution:

The angular velocity of the driving shaft, $w = \frac{2\pi \times 540}{60} = 56.65$ radians/sec

The maximum velocity of the mower shaft, $w_1 = \frac{w}{\cos 20°} = 60.2$ radian/sec

The minimum velocity of the mower shaft, $w_2 = w \cos 20° = 53$ radians/sec

The acceleration of the driven shaft at any angle Θ is given by,

$$\frac{dw1}{dt} = \frac{-\cos\alpha \; X \; \sin^2\alpha \; X \; \sin 2\theta \; X \; w^2}{(1-\cos^2\theta \; X \; \sin^2\alpha)^2} \qquad \dots\dots (1)$$

Where, α is the angle between two shafts = 20°

The value of Θ for which the acceleration is maximum may be found by differentiating with respect to Θ and equating to zero. The resulting expression is, however, very cumbersome. The following approximate equation gives fairly accurate results

$$\cos 2\theta = \frac{2\sin^2\alpha}{2-\sin^2\alpha} \qquad \dots\dots (2)$$

$$= \frac{2\sin^2 20°}{2-\sin^2 20°} = 0.1242 \text{ or } \Theta = 41°26'$$

Substituting for w_1, α and Θ in equation no. (1), the maximum angular acceleration of the driven shaft is given by:

$$= \frac{(56.65)^2\{0.9397 \times (0.3420)^2 \times 0.9923}{(1-0.7497^2 X \; 0.3420^2)^2} = 755 \text{ radians/sec}^2$$

The acceleration is in the opposite direction to the velocity i.e. the mower shaft has maximum retardation, when Θ = 41°26´ or 180° + 41°26; and it is in the same direction as the velocity when Θ = 138° 34´ or 180° + 138° 34´.

MODULE 4. FORAGE HARVESTING, CHOPPING AND HANLING EQUIPMENT

LESSON 7. FORAGE HARVESTERS, HAY CONDITIONERS

Forage harvesters

The flail type forage harvesters use free-swinging chains, hammers or knives to sever the fodder plants by beating or cutting action. At the time of plants being severed, the flails or knives travel in the same direction the machine is moving. The flail choppers do not have chopping knives to chop the material into acceptable lengths for silage. The flails are just used for severing the plants and harvested material can be blown into windrows for curing. The beating by the flails more or less conditions the hay.

A simple flail type forage harvester (Fig. 1) can be mounted behind the tractor. Offset types of flail type forage harvester are preferred as they avoid problems associated with one set of tractor wheels running through the crop before it is cut. The degree of chopping and laceration is governed mainly by the rotor speed, partly by the relationship between rotor speed and forward speed and partly by the clearance between the flail tips and an adjustable shear bar. Rotor speed has much more effect than forward speed. Fitting two shear bars can reduce the length of chop. The machine can pick up crops fairly cleanly from a windrow.

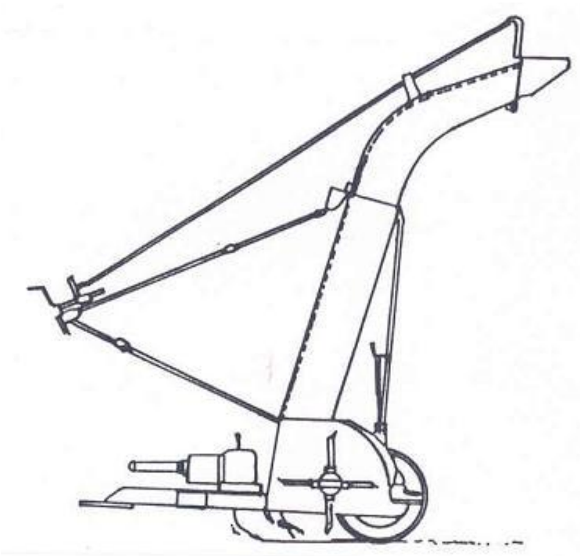


Fig. 1: Flail type forage harvester fitted with adjustable twin-chop shear-plate.

A number of forage harvesters have large diameter cylinder with multiple knives, designed to avoid serious damage of cylinder by foreign materials, by allowing individual knife to either bend or forced inward to create wide clearance between knife and shear-plate. The damaged knife can be easily replaced. The machine has simplified feed and delivery systems. One such design uses a very wide contra-rotating cylinder in conjunction with a pair of feed rollers (Fig. 2). The machine ejects the foreign matters such as small rocks and uses little energy in propulsion of the crop. Some new designs have achieved high throughput in relation to power input, partly as a result of less chopping. Electro-hydraulic systems are used on high-output forage harvesters for effective and rapid adjustment of discharge chute angle and the flaps.

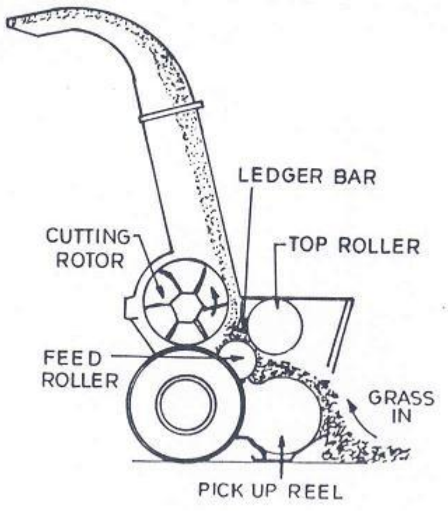


Fig. 2: Forage harvester with pick-up, pair of feed roller and wide contra-rotating cylinder.

Tractor operated Flail type forage harvester cum chopper

This machine in a single operation can harvest chop and load the chopped fodder in the tractor-trailer attached to the machine. It is operated by a 26.1 kW tractor (Fig. 3). This machine in a single operation can harvest, chop and load the chopped fodder like maize, *bajra*, and oats in the trailer attached to the machine. It consisted of a rotary shaft on which flails are mounted to harvest the crop, auger for conveying the cut crop, cutters for chopping & conveying chopped fodder through outlet into the trailer. After the blades cut the crop, it comes in auger, which conveys it to the chopping mechanism. The chopping mechanism cuts the crop into pieces and chopped material is thrown out with a high speed and is filled into the trailer hitched to the machine. Working capacity of forage harvester is 0.2 ha/h. Weight of the machine is about 670.0 kg.

a) A view of forage harvester in field

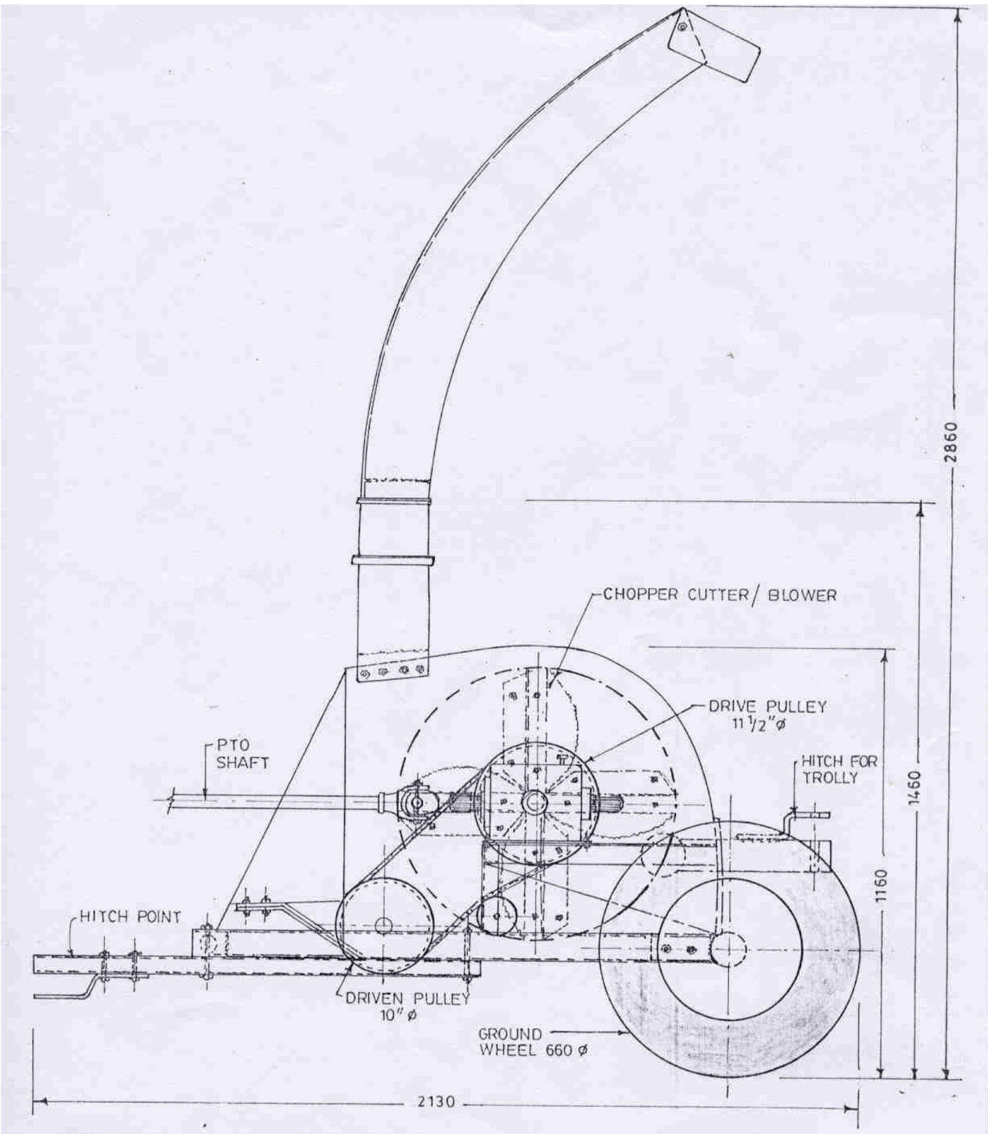


FIG.82 SIDE VIEW OF TRACTOR OPERATED FLAIL TYPE FORAGE HARVESTER

b) Details of forage harvester in field

Fig. 3: Tractor operated Flail type forage harvester cum chopper.

Tractor operated cutter bar type forage harvester and loader

The system consisted of a two separate units. First one consisted of a mower and the second one was a chaff cutter cum loader. Both the machines are tractor operated. The mower has a working width of 196 cm and so designed that it can be folded easily during transportation. The machine cuts the fodder crops and lays in the field which is manually collected and then fed into the loader where it is chopped in to small pieces and directly loaded into the trailer. It is operated by a 26.1 kW tractor (Fig. 4). The system consisted of a two separate units. First one consisted of a mower and the second one was a chaff cutter cum loader. Both the machines are tractor operated. The mower has a working width of 196 cm and so designed that it can be folded easily during transportation. The chaffer cum loader has a cross section area 28 x13.5 cm^2. It has two powered feed roller and one compressing roller. It had two chaffing blades for chaffing of fodder and six thrower attachments are being mounted on the periphery of the cutter. A reversing mechanism has also provided for safety. The fodder cut with mover and is collected in the field manually. The chaffer-cum-loader chaps the fodder at site and the throwers mounted on the periphery of the cutter throws the fodder directly into the trailer. Working capacity 0.2 ha/h for cutter and 12-18 t/h for Chaffer-cum-loader.

Weight of the machine (cutter and chaffer-cum-loader) is 150 + 690 kg. Overall dimensions are:

Fig. 4: Tractor operated cutter bar type forage harvester and loader.

Self-propelled fodder harvester (cutter bar type)

The self-propelled fodder harvester consists of 1450 mm cutter bar (Fig. 5). It is mounted in the centre of the power transmission with the help of two side linkages made of high-pressure circular pipes to dampen the vibration of cutter bar. The unit is also provided with crop gathering drum-having flappers rotating inwards near the cutter bar. The vertical side covers around the transmission system are provided to avoid blockage of the fodder and extended vertical guides are provided for proper windrowing. The ground clearance of the machine has been increased to 480 mm to facilitate easy passage of fodder. Power to wheel is provided through extension with the help of chains and sprockets with the chassis suitably strengthened. The track width is also widened to 1040 mm and a caster wheel is provided at the rear to improve stability and maneuverability. The effective field capacity of machine is 0.1 ha/h at a forward speed of 1.5-2.0 km/h.

Fig. 5: Self-propelled fodder harvester (cutter bar type) in operation.

Self-propelled Lucerne harvester

Lucerne is perennial leguminous plant growing to a height of 60 to 90 cm. It is a forage crop generally grown in basins of size 1.20 x 6 m having a very high yielding potential under appropriate fertilizer and irrigation management. Harvesting of crop is one of the important agricultural operations, which demands considerable amount of labour because it is done manually by sickles. The cutting and laying in the windrows consume 65-75% of labour and gathering, bundle making and transport in the field involve the rest of the labour requirement. The scarcity and high cost of labour and drudgery during harvesting are the serious problem faced by the farmers. It is, therefore, essential to adopt the mechanical methods so that the timeliness in harvesting operation could be ensured and field losses are minimized to increase the productivity and production on the farm. The self-propelled Lucerne harvester consists of a gearbox and cutter bar (Fig. 6). Type of cutter bar is bi-directional reciprocating type made from high carbon steel. Length of stroke for cutter bar is 25 mm and effective width of cutter bar is 860 mm. A man can walk behind the machine with an average speed of 2 km/h. The recommended speed ratio of the average cutter bar speed to the forward speed of machine is 1.3: 1.4. Two wheels are used for transportation purpose. The ground wheels drive the reel of the harvester. Ground drive provides the desirable feature of maintaining a constant speed ratio between peripheral speed and forward speed. The reel is made up from Ø 6 mm MS bar of diameter 70 cm and length 74 cm. The speed ratio of the ground wheel to reel is 1:1. The preliminary field trials were conducted at different locations. The effective field capacity was found to be 0.113 ha/h and field efficiency was 70-75%. Thus, there is net saving of 52% in cost of cultivation and net time saving of 90%.

Fig. 6: A self-propelled lucerne harvester in operation.

Self-propelled cutter bar type harvester for fodder crops

The machine consisted of a 10.2 hp, 4 stroke, single cylinder, air-cooled diesel engine (Fig. 7). The machine has cutter bar width of 130 cm. The power from engine has been provided to the traction wheels with the help of gear trains. The machine has four forward speeds and one reverse. The track width of machine is 1.23 m and the ground clearance of machine 41 cm. The steering of machine is done with the help of foot-operated pedal provided below the operator seat, which guides the wheel. The crop after harvesting falls behind the cutter bar and was guided with wooden sticks provided behind the cutter bar for small height/hard stem crops. But in case of tall and weak stem crops, binding attachment without twine is required to avoid wrapping of crop to cutter bar. The average field capacity of the machine for harvesting barseem and oat crop was 0.42 and 0.28 ha/h respectively, whereas the corresponding throughput of material was 6.0 t/h and 11.0 t/h. The field efficiency of machine was 66.57 % and 40.55 % for barseem and oat crop. The height of cut from the ground for barseem and oat crop was 7.0 cm and 12.5 cm but it was more near the bunds. The saving in cost of operation and labour for harvesting barseem and oat crop with machine as compared to manual harvesting was 42-44 and 55% respectively.

Barseem fodder Bajra fodder
Fig. 7: Self-propelled cutter bar type harvester in operation for harvesting barseem And bajra fodder.

Hay Conditioners

The conditioning of hay by means of crushing, crimping or flailing is becoming increasingly popular with many hay-makers. It has many advantages viz. speeds up field curing and reduces drying time by 30%, reduces weather damage and field losses and conserves colour and feed value through shorter exposure and less shattering. There are three types of hay conditioners: smooth roll, corrugated roll or crisper and flail type forage harvester. The smooth rolls give continuous crushing action to hay, leaving no part uncrushed. It has two rolls of a combination of one rubber roll and another steel roll. Most rubber rolls have spiral grooves to aid in picking up the hay and feeding between the rolls. The corrugated-roll type hay conditioner is also equipped with two malleable iron rolls with tapered flutes that mesh together. Some conditioners use a fluted bar roll that presses against a smooth rubber roll. As the hay passes between the rolls, it is bent, crimped, cracked at intervals and in some cases crushed. The flail-type conditioner is a hay harvester, but it is used as a hay conditioner also. In this the shear bar is removed to reduce the cutting action. The hay is partially chopped by the swinging hammers or knives.

Separate conditioners: Separate conditioners usually pickup mowed hay from the swath, but windrowers can be put through them. The bottom roll acts as the pickup. Mower – conditioners with not over 2.75 m cuts have conditioner rolls with lengths approximately equal to the width of cut, and the hay is fed directly to the rolls from the cutter bar. Originally, conditioning ease often a separate operation, performed with a second tractor following the mower. Subsequently, mowers were made available with hitches and PTO extensions to permit pulling a conditioner behind the mower. The conditioner than picks up the swath adjacent to the one being cut.

Mower conditioners: Pull-type mower conditioner consists of a cutter bar, a reel, a pair of full-width conditioning rolls, and a deflector. The most common cutting width is 2.75 m, but widths range from 2.13 to 3.65 m. The 3.6 model have rolls 2.13 to 2.75 m long with short, auger-type cross conveyors at the outer ends of the header. The conditioned hay can be left evenly spread in a swath a little narrower that the cut or side deflectors behind the rolls can be adjusted to obtain various windrows widths and positions. Windrows cure more slowly that hay in the swath but can be straddled with the tractor and sometimes eliminate the raking operation. The cutter bar is similar to that of a conventional mower except that the guards are more pointed and slender to improve performance in tangled or lodged crops and are made in pairs to provide greater support in mounting

LESSON 8. FORAGE CHOPPING AND HANDLING EQUIPMENT; RAKES AND BALERS

Field Choppers

The machines are available both as a tractor-drawn and self-propelled type. PTO of tractor drives some tractor-drawn field choppers while an auxiliary engine mounted on the machine drives others. The offset hitch permits the chopper to trail to the right of tractor so that tractor does not run over the crop. The cutter bar consists of a regular mower like cutter bar and a reel to throw the crop back onto an apron which conveys the material to auger, which takes into the chopping unit. In this machine, there are two types of cutter heads: flywheel-type and cylinder-type. In the flywheel-type cutter head, knives for cutting and impeller paddles for throwing and blowing are mounted on the wheel separately. The cylinder-type cutter head has knives designed both to cut and blow but in some cases separate impeller blower is provided. The cylinder-type cutter head has built-in sharpeners, but knives are removed from the flywheel for sharpening. The capacity of a field chopper is affected by area of throat opening, speed and rate of feeding and density of material, which in turn is affected by yield of the crop.

The capacity of field chopper can be calculated by:

$$C = 60\, h\, D\, L\, W\, H\, n\, N \qquad \text{------------ (1)}$$

Where,

C = capacity of field chopper, kg/h

h = field efficiency

D = bulk density, kg/m^3

L = length of cut, m

W = width of throat, m

H = height of throat, m

n = number of knives

N = rpm of flywheel

Chaff Cutters

Green fodder crops are essential food requirement for on-farm animals. These fodder crops are harvested from the field daily either by sickles or reapers. Then crop is collected from the field and carried to the farmhouse where it is cut into small pieces. This is done to save storage, to aid in curing and to make it more palatable. The cutting of fodder into small pieces is done either manually using 'Gandasa' or by using manually or power operated chaff cutters. Depending on the type of cutting head, chaff cutters may be classified as cylinder cutting head machine and flywheel type cutting head machine. According to power used chaff cutters are classified as hand chaff cutters, animal operated chaff cutters and power chaff cutters or silage cutters.

Cylinder type cutting head chaff cutter: It is commonly used on power chaff cutters. This type of cutting heads is sometimes used on field forage harvesters that cut the fodder crop from the field, chop and blow into wagon. The machine consists of four spiral-shaped knives on a revolving cylinder, which looks like the rotary lawnmower (Fig. 1). The knives can be sharpened without being removed from the cylinder. The size of chaff can be adjusted by changing the speed of feed rollers provided adjacent to the shear plate. The chopped material fall into housing from where it is stored at a proper place. This type of machine is not commonly used in India and is more costly as compared to flywheel type machine.

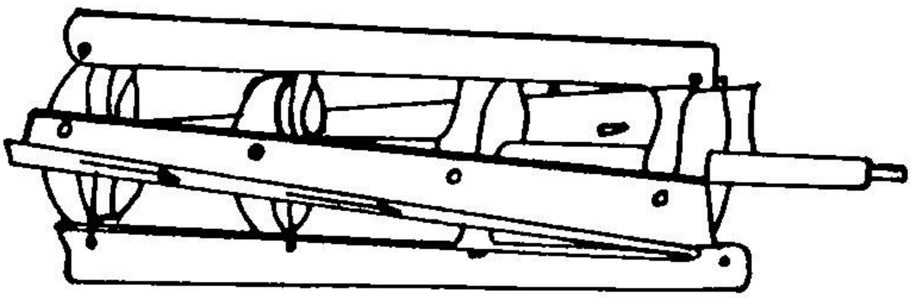


Fig. 1: Cylinder type cutting head.

Flywheel type chaff cutter: It consists of a cast iron flywheel and radial mounted knives (Fig. 2). Straight knives are used on power chaff cutters and curved knives on hand chaff cutters. The number of knives varies from two to six depending upon the type of chaff cutters and size of chaff desired. Hand operated chaff cutters are provided with two knives only. Some power chaff cutters of large size have blower used for silo filling. The average working speed of hand chaff cutter is 50 rpm with one knife and 35 rpm with two knives. The power operated chaff cutters are operated at working speed of 600-1000 rpm. For proper cutting of silage, knife should operate close to the shear plate without striking. Clearance between the shear plate and knife can be adjusted by a set of screws provided for the purpose. The knife is fastened on the flywheel by means of two or three counter sunk bolts.

The size of chaff or length of cut can be changed by changing the speed of feed rollers. Hand operated chaff cutters are provided with a two speed worm for adjusting the length of cut where as two or three speed gearbox has been provided on power operated chaff cutters. Reducing or increasing the number of knives on the flywheel can also changes the length of cut of silage. This can be done easily on the hand operated chaff cutters. On power operated chaff cutters, length of cut of silage can be adjusted by increasing the speed of cutter head. The length of cut of silage varies from 20-40 mm and for green fodder 25-50 mm or sometimes more.

The feeding mechanism of a power operated chaff cutter consists of an apron and two feed rollers. Aprons are generally provided with metal or wooden slates to give a positive feed. The length of the table on which the apron moves is about 2 m so as to accommodate tall grasses or fodder crops. Spring-loaded feed rollers are provided to compress and feed the uncut material to the cutting head. Generally, corrugated or toothed rolls are preferred. Hand operated machines are not provided with aprons. A feed-table or merely a feed box is considered to be enough for this machine and the feeding is done by hand. Feed rollers of the hand-operated machine have variable spacing and the worm mounted on the flywheel shaft operates them. The bullock operated chaff cutters is similar to hand operated one but it is provided with a smaller diameter flywheel on which two or three knives are mounted. By means of a set of gears and universal joints, the slow speed of bullocks is utilized to operate the machine at about 250 rpm and thus its capacity becomes 4 to 6 times more than that of the hand operated machine. The capacity of the chaff cutters can be calculated by:

$$C = 60 \times 10^{-3} D\ L\ W\ H\ n\ N \quad \text{------------------- (2)}$$

Where,

C = capacity of machine, t/h

W = width of throat, m

H = height of throat, m

L = length of cut, m

N = number of knives on the flywheel

n = speed, rpm

D = bulk density, kg/m^3

Length of cut of chaff can be determined by

$$L = 2\ p\ R\ \tan a\ /N$$

Where,

R = radial distance between centre of rotation of flywheel and inner edge of throat

a = clearance angle between the knife and plane of rotation

The power requirement of chaff cutter can be grouped into three parts:

- Power loss in friction in bearing, rubbing of knife on shear bars and in compression of fodder between feed rollers,
- Power required for cutting the fodder, and
- Power required in conveying the material to be cut and cut material.

Power required in cutting the fodder depends on the shear strength of material, throat area of machine, number of stems cut at one time and diameter of each stem. It can be represented by

$$F = A\ N_s\ s$$

Where,

F = force required in cutting the fodder

A = cross-sectional area of individual stem

N_s = number of stems at a time in the throat

s = shear strength of material

The variation in the power requirement depends upon the rate of cutting the fodder. In order to get smooth operation of chaff cutter without many fluctuations in power requirements, the length of knife in contact with fodder must be uniform and continuous throughout the cutting action. To keep the length of knife in action uniform the outer contour of knife should follow a longitudinal spiral as represented by the equation:

$$r = a\,e^{bq}$$

Where,

r = radial distance of the outer contour of blade from centre of flywheel shaft at any angle q

q = angle, radians

a & b = characteristics constants

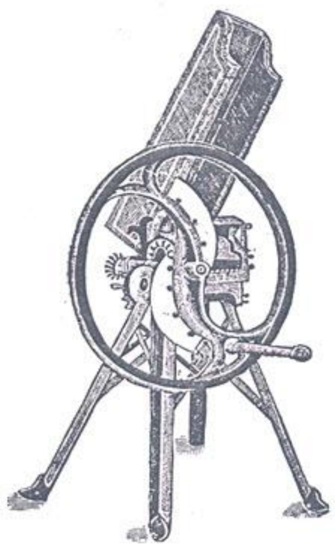


Fig. 2: Hand chaff cutter.

Hand operated chaff cutter

The chaff cutter consists of a feeding tray, curved blade fixed on to a spring loaded lever, anvil which also acts as cutting blade and a suitable frame work (Fig. 3). The cutting action is similar to the shearing machine used in the workshop. The blades are made from medium carbon steel or low alloy steel, hardened and tempered to about 45 HRC. For operation, fodder is fed in the tray pushed by one hand, and the other hand and a leg actuates the curved cutting blade. A thin layer of fodder is spread on the anvil blade and the curved blade progressively shears the fodder into small pieces. It is used to cut chaff, grass, green and dry fodder crops and paddy straw into bits for feeding to animals.

Fig. 3: Hand operated chaff cutter.

Care and adjustments of hand chaff cutter: Since the hand operated chaff cutter is a simple and useful machine, it is very popular among Indian farmers. In order to get the most efficient operation for a long time; it must be properly installed on a rigid foundation preferably under shed. Many farmers have converted hand chaff cutters into power chaff cutters by using 1 hp electric motor or small engine. The following general procedure of maintenance and lubrication should be followed:

1. Before the machine is put into operation, its gears and bearings should be lubricated.
2. The knives should be sharpened by hand filing. If the cutting edge has become too blunt, it should be sharpened on a grinder to the proper bevel only on one side.
3. The clearance between the knives and the shear plate should be adjusted for the effective cutting.
4. Loose nuts, bolts, and screws should be tightened to avoid accidents.
5. After the day's work is over, dirt from the gears and bearing parts and moisture from the knives should be wiped off.
6. While the machine is idle, its flywheel should be kept locked so that the children do not operate it.
7. Most of the cast iron parts and particularly the flywheel of the machine are quite susceptible to breakage by hammering, which should always be avoided.
8. The moving parts should be properly lubricated.

Problem 1: Find the capacity of a field chopper with throat size of 25 x 5 cm operating at 50 rpm. The number of knives on cutter head is two and bulk density of material is 500 kg/m^3. Length of cut is 2 cm and field efficiency of chopper 70%.

Solution: Using equation 1

C = 60 x 0.7 x 500 x 0.02 x 0.25 x 0.05 x 2 x 50

= 525 kg/h

Problem 2: A small knife chaff cutter fitted with two knifes cuts dry hay at 40 rpm giving 400 kg of cut hay per hour. The throat size of chaff cutter is 20 x 5 cm. The effective distance of centre of throat from flywheel is 20 cm. The blade makes a clearance angle of 10 degrees between the knife support and plane of rotation. Distance of inner edge of throat from flywheel centre is 10 cm. Calculate:

a) Length of cut of chaff

b) Effective density of dry hay, and

Solution:

a) Length of cut of chaff is given by

L = 2 p R tana /N

= 2 p x 10 tan10/2 = 5.5 cm

a) Effective density of dry hay is given by

C = 60 x 10^{-3} D L W H n N

0.4 = 60 x 10^{-3} D x 0.055 x 0.2 x 0.05 x 40 x 2

D = 151.5 kg/m^3

Conventional Balers

Conventional balers are automatic tying machines with reciprocating plungers those produce bales of rectangular cross-sections. The number of wires or twines placed around each bale classifies them. The three-wire balers commonly used in areas where high percentage of hay is sold and transported commercially. Most field balers are pull-type operated by a tractor, but self-propelled balers are also available commercially. Pull-type balers are available with either a PTO drive or mounted engine type. PTO driven pull-type balers are very common now days (Fig. 4).

Plunger-type field balers have following functional components:

a) A unit to pick-up hay from windrow and elevate it.

b) A conveyor to move the hay to the bale chamber entry.

c) A packer to place the hay in the chamber while plunger is on its retracted stroke.

d) A reciprocating plunger to compress the hay and move it through the bale chamber.

e) Means of applying forces to resist the movement of hay through the bale chamber and thus control the degree of hay compression and the resultant bale density.

f) An automatic metering device for controlling bale length.

g) means of separating consecutive bales and placing the wires or strings around each bale.

h) Automatic tying devices that operate when the bale reaches the pre-selected length.

Field balers employ cylinder-type-picking units with spring teeth on cam-controlled tooth bars. The counterbalance springs supports the pick-up mass. The peripheral speed is generally kept higher than the forward speed. Floating cross-conveyor auger and packer fingers push hay into the chamber when the plunger is on its retracting stroke. As the plunger moves on its compression stroke, each new hay charge is compressed until plunger force becomes large enough to move the completed bales along the chamber. On the return stroke of the plunger, fixed wedges and spring-loaded dogs hold compressed hay. The density of bale is affected by the type of material, moisture content and the total resistance that the plunger must overcome in moving the material through bale chamber. One of the problems encountered in baling hay is the change of bale density as the moisture content varies from one part of the field to another or it changes with time. The density of compressed bales can be adjusted by density setting screws provided at exit of baling chamber. The wire is placed across the periphery along the length of bale at two locations. The machine has, therefore, two wire twisters, wire cutting discs and needles. The binding mechanism is put into operation by a clutch actuated by clutch lever, which in turn pressed by a cam mounted on a notched metering wheel. The straw baler can also be used as hay baler.

Baler is also called packing machine which picks up loose hay or straw, Compress it into bales of even size & weight then ties them with twines or wires and finally the completed bale is discharged from the back of the baler to ground. Fig. 4 shows the baler in field operation. Fig. 5 and Fig. 6 shows the schematic view of straw baler and mechanism for varying bale length respectively.

Fig. 4: Tractor-drawn PTO operated straw baler.

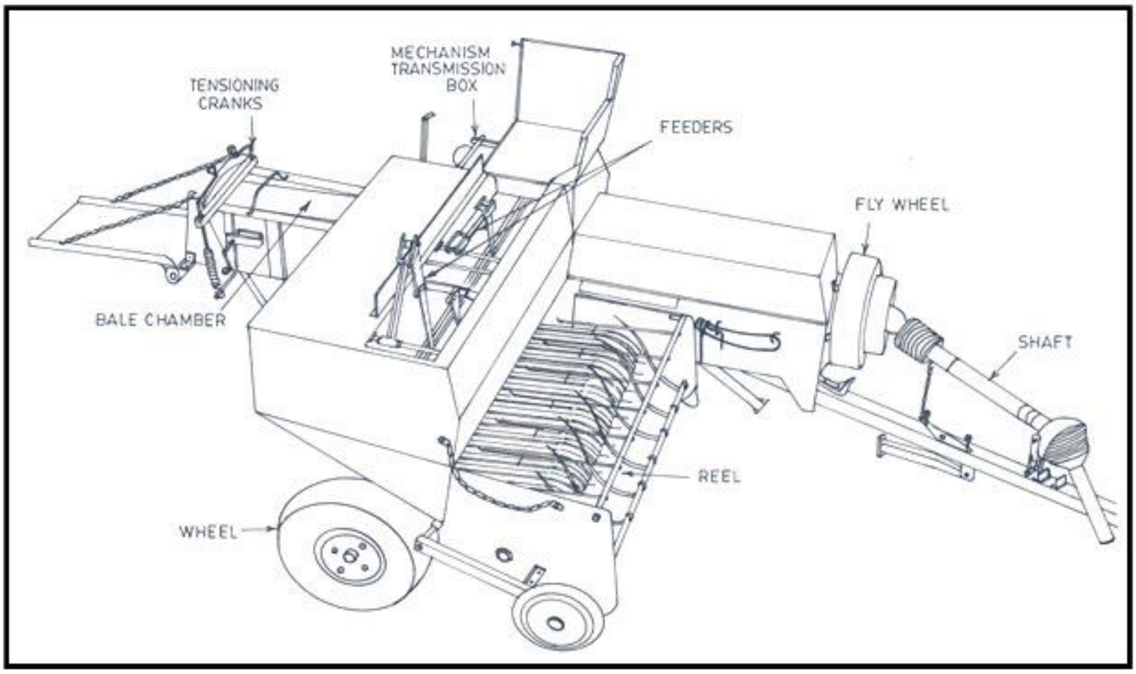


Fig. 5: Schematic view of straw baler.

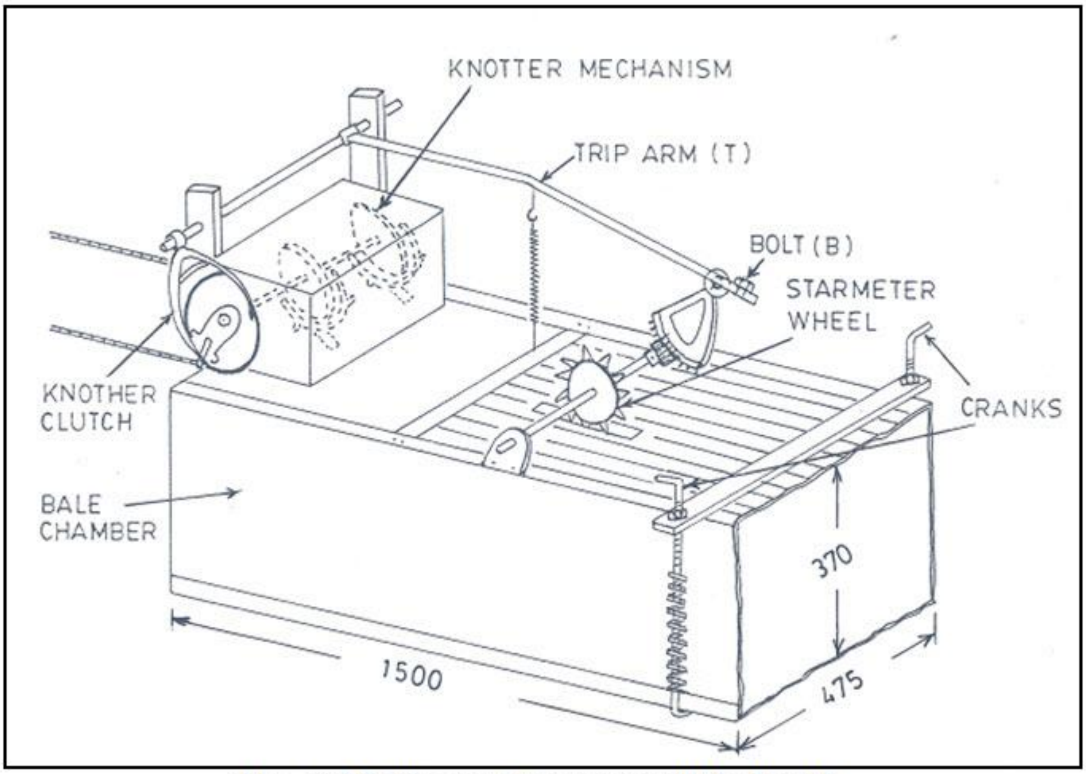


Fig. 6: Mechanism for varying bale length.

Classification: Baler can either be classified on the basis of power source or on the basis of types of bales.

1. **On the basis of power source**

- PTO operated

- Auxiliary engine
- Self-propelled baler

2. On the basis of types of bales

- Rectangular Bales
- Round Bales

Functional Components: Baler mainly consist of following units:-

1. Pick Up Unit
2. Feeding Unit
3. Compressing Unit
4. Knotting Unit
5. Conveying Unit

Description of functional components: Most of the field balers employee cylinder type pickup units with spring teeth on cam control tooth bars, loading cross conveyor auger and packer. Windrow pickup, conveying and feeding device is shown in the Fig. 7.

Fig. 7: Windrow pickup, conveying and feeding device.

Compressing unit: In the compressing unit firstly feeder teeth pull the hay into bale chamber, plunger compresses the hay into bale chamber and when plunger is at rear position knotting device makes the knot.

Compressing hay and controlling bale density: The plunger, fixed wedges, spring loaded dogs are used to compress hay. Method of controlling bale density is done by squeezing together two sides or all the four sides of the bale chamber at the discharge end. There are two types of the bale tension control devices used which are (i) Automatically controlled hydraulic type; and (ii) Spring type.

Automatic wire tying devices: There are two types of automatic wire tying devices which are: (i) Loop twist type, and (ii) Straight twist type. Each type has a clamping device that holds the end of wire. When the needle has moved to its extreme penetration position, the clamping device is moved to release wire end that had been held during bale formation then, shear the wire that has been brought by needle and finally clamp the wire from needle which will become held end for next bale. Fig. 8 and Fig. 9 shows the two types of automatic wire tying devices respectively.

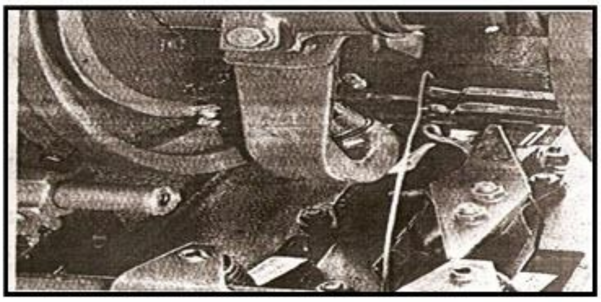


Fig. 8: Loop twist type

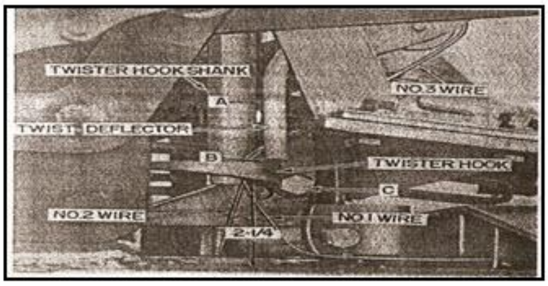


Fig. 9:Straight twist type

Rectangular bales: The hay lying in the field gets collected by the revolving pick up drum. The pickup tynes rotates in opposite direction to the land wheel. The cross auger rotates continually and delivers the crop to the packer arms or feeder teeth which pull the hay into the bale chamber. Then it`s feed to the high pressure press. The piston of the high pressure press works 69 to 80 stokes per min. and press the hay in compact form. The Ram is fitted with knife blade on straw entrance side which cut the straw when the Ram is in the onward stroke. When the bales take up the shape the tying unit operates automatically and bind the bales at low places. After binding the bales, the binding unit of the baler, throw that on ground. Rectangular bales generally vary from 14" x18" to 16"x18" and 32" to 42" in length. The weight of each bale 15 to 40kg. The Schematic view of baler giving rectangular bales is shown in Fig. 10.

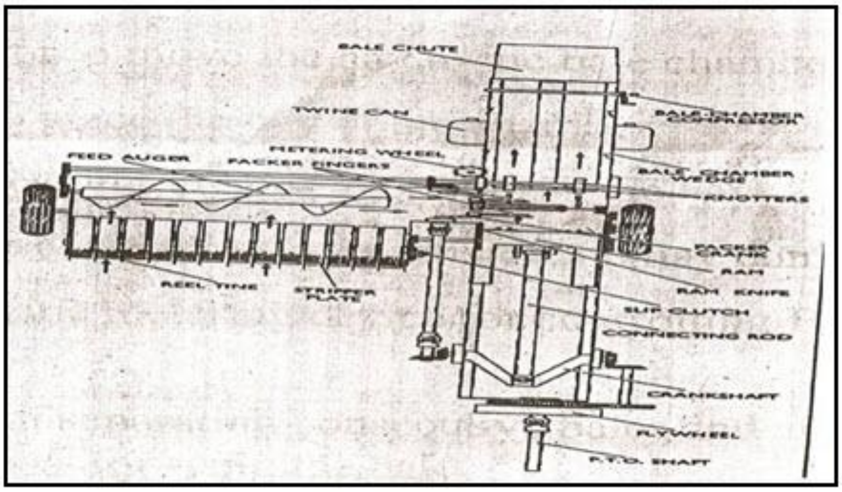


Fig. 10: Schematic View of rectangular bales

Baler giving round bales: In case of round bales, the pickup lifts the hay from the windrow and carries it between steel compression rollers. Six bands or belts pass over the lower drive roll and also over a trip roll and a tension roll. The upper part of the mechanism consists of six more bands, which passes through a small drive roll, a tension roll and a trip roll. As the bale is rolled, the upper belt arms extend the tension spring and tension increases in the upper belts to squeeze the ball. When the belts have completely extended a relative value, the hydraulic rear gate cylinder opens and triggers the gate bottom to move to the rear until the maximum bale diameter is reached. When the full bale diameter is reached, twine is feed into the bale chamber with the hay. When the bale is twine wrapped, the twine is cut off. Finally the hydraulic controlled gate is raised and the bale is discharged. Most of the round bales are of 1.5 to 2.1 m in diameter and 1.2 to 2.1 m in length. The Schematic view of baler giving round bales is shown in Fig. 11.

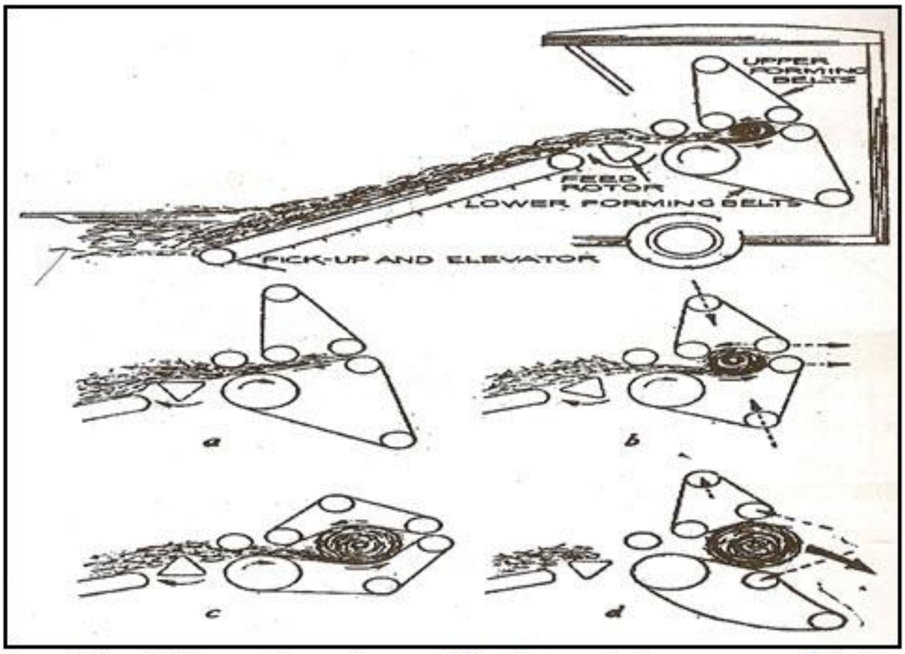


Fig. 11: Schematic view of baler giving round bales

Power Transmission: The PTO drive is transmitted through a heavy flywheel to a gearbox. Here a pair of bevel gears put the drive through a 90 degree. A crankshaft on the gearbox output shaft gives the plunger it's back and fro motion. Drive to pick up, auger, packers and tying unit is also taken from the main gearbox. Most of the drive is by chain and sprockets.

Baler capacities: Baler capacities are affected by:

1. Size of the bales
2. no. of the plunger stokes per min
3. the amount of power available
4. the durability and reliability of the machine

Expected break down in balers:

1. Overloading due to picking up of foreign objects or slogs of hay and careless operation
2. choking due to the excessive clogging of the straw
3. Failure of the machine parts like plunger, fly wheel and bolts

Straw balers can be used either in combine-harvested paddy field or in the combine-harvested rice field where stubble shaver has been used for cutting of standing straw. The forward speed of baler generally varies between 2 km/h to 3.0 km/h. The fuel consumption is in the range of 10-11 l/ha. The field capacity is 0.25 ha/h to 0.35 ha/h. The size of rectangular bales can be varied from 80 x 45 x 45 cm to 150 x 45 x 45 cm and bale weight can be varied from 15 to 45 kg. The number of bales formed may vary from 80 in combine-harvested field and 170 in stubble-shaved field. The bales so formed by the baler may be transported (Fig. 12) to the paper mills or to the location where it can be used for electricity generation.

Fig. 12: Straw bales being transported.

Hay Stackers

Sometimes hay is stacked in the field rather than stored in the barn. Many types of stackers are built both commercially and locally. For medium-sized stacks, sweep-rake stackers attached to tractor are used (Fig. 13). A new system of stacking hay consists of a windrow pick-up and a compression chamber. The hay is picked up and blown into the chamber in stages where it is compressed with a power packer until the chamber is full. When the compression chamber is full, the stack is transported to storage site and unloaded. Special stack mowers are also available.

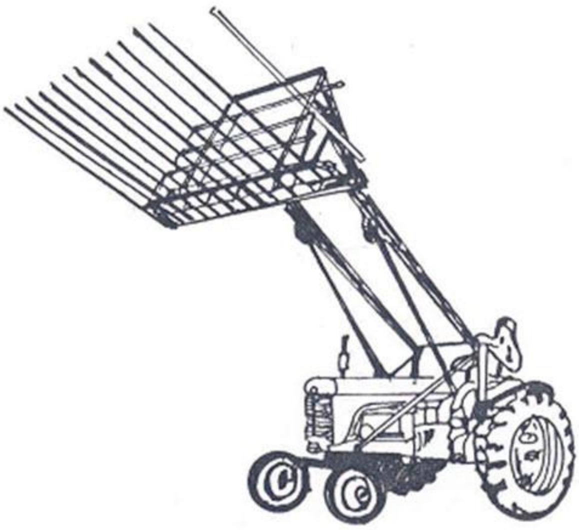


Fig. 13: Tractor mounted sweep rakes cum stackers.

Hay Rakes

The use of hay loaders and pickup balers created a demand for a hay rake that makes a loose, fluffy and continuous windrow. Hay rakes can be classified as side-delivery and sweep. Side-delivery rakes are further classified according to the types of reel construction such as cylindrical-reel, parallel bar or side stroke and finger wheel. The reel bars are attached to three spiders and the rake teeth are curved forward near the end to aid in picking up the hay. Most teeth are made of spring steel and have a coiled section next to the reel bar. While in contact with hay, the teeth are held at an angle with the points leading. This gives a pushing with a slight lifting action to the hay. Cylinder-reel side delivery hay rakes are generally available in four types; ground-driven trailing, semi-mounted ground-driven, tractor mounted PTO driven and hydraulic drive.

The parallel-bar or side stroke hay rake may have four to six reel bars attached to two parallel plates or spiders at each end of the reel. The plates are set at right angle to the direction of travel. As the reel revolves, each bar rotates within the bearing mounts to keep the teeth in a vertical position at all times. When a bar approaches its lowest position, teeth come in contact with hay and rakes for a short distance. The next bar follows it. Sweep rake is sometimes called a buck or bull rake. It collects hay from the windrow and transports for short distance to a stationary baler or stack.

A hay rake is an agricultural rake used to collect cut hay or straw into windrows for later collection. It is also designed to fluff up the hay and turn it over so that it may dry. It is also used in the evening to protect the hay of the dew. The next day a tedder is used to spread it again, so that the hay dries more quickly. A hay rake may be mechanized, drawn by a tractor or draft animals, or it may be a hand tool. The earliest hay rakes were nothing more than tree branches, but wooden hand rakes with wooden teeth, similar in design to a garden rake but larger, were prevalent in the 19th and early 20th centuries, and still are used in some locations around the world.

Mechanical rake known as the side delivery rake usually had a gear-driven or chain-driven reel mounted roughly at a 45-degree angle to the windrow, so the hay was gathered and pushed to one side of the rake as it moved across the field (Fig. 14). A side delivery rake could be pulled longitudinally along the windrow by horses or a tractor, eliminating the laborious and inefficient process of raising, lowering, and back-and-forth raking required by a dump rake. This allowed for the continuous spiralling windrows of a farm hayfield. Later versions of the side delivery rake used a more severe transverse angle and a higher frame system, but the basic principles of operation were the same. Later, a variety of wheel rakes or star wheel rakes were developed, with 5, 6, 7 or more spring-tooth encircled wheels mounted on a frame and ground driven by free-wheeling contact as the implement was pulled forward.

Desirable characteristics of hay rakes: The following are the some of the desirable characteristics of hay rakes:

a) The amount of leaf loss due to shattering.

b) The amount of hay missed.

c) The amount of trash, dirt etc. put into windrows.

d) Uniformity and continuity of windrow.

e) Amount of leafy portion in centre of windrow and stems toward the outside.

The amount of leaf loss is affected by the distance the hay is moved from swath into windrow, average hay velocity, type of hay moving action i.e. rolling, lifting or dragging and periodic impact of rake teeth upon the hay. Average hay velocity is affected by forward speed and high forward speed increases the leaf shattering.

The type of side delivery rakes are Reel-type units and Finger-wheel units. All reel type rakes were of the cylindrical-reel type. The tooth rotated in parallel positions in planes perpendicular to the reel axis, similar the pickup reel. The reel heads are set at a horizontally acute angle from the reel axis but in parallel planes. The tooth bar ends are shaped so the axes of the tooth-bar bearings are perpendicular to the planes of the reel heads. This arrangement automatically maintains the teeth in parallel positions as the reel rotates. The horizontal path of any tooth is in a plane parallel to the reel-head planes. Thus the horizontal movement of the teeth with respect to the rake can be 85° to 90 ° from the direction of forward motion.

Finger-wheel units: As finger rake has a series of individually floating, ground-driven wheels set at an angle to the direction of motion and overlapping each other. Each wheel is partially counterbalanced with a tension spring and has spring teeth around the periphery that operate in light contact with the ground. The floating feature allows the rake to adjust itself to the contour of surface irregularities such as irrigation levees or terrace channels. Wheel tooth-tip diameters are usually about 1.5 m.

Fig. 14: A view of rakes used to collect cut hay or straw into windrows.

MODULE 5. THRESHING MECHANICS, TYPES OF THRESHES, GRAIN COMBINES AND STRAW COMBINES

LESSON 9. PRINCIPLES AND TYPES OF THRESHERS; CONSTRUCTIONAL DETAILS, FEATURES AND ADJUSTMENTS

The operation of detaching the grains from the ear head, cob or pod is called threshing. It is basically the removal of grains from the plant by striking, treading or rupturing. The traditional method of threshing using manual labours requires 150-230 man-h/ha. Threshing is normally done after the grain moisture content is reduced to 15 to 17%. In various parts of world, threshing is accomplished by treading the grains under the feet of animals or under the tractor tyres, striking the grains with sticks, pegs or loops and removing the grains by rubbing between stone or wooden rollers on a threshing floor or between the rasp bar and a concave of combine. The threshing can be achieved by three methods: Rubbing action, Impact and Stripping.

Threshers are the most important component of farm mechanization. If threshing is not done timely, all efforts made by farmers and inputs given to crop goes wasted. Traditional method of threshing by animal is very slow. It gives low output. Due to low output, the cost of operation is high and there is a huge loss of grains because of rodents, birds, insects, wind, and untimely rain and fire hazards. Wheat threshers overcome these difficulties to a great extent. Wheat threshers are of two type viz. animal-drawn and power threshers. In animal-drawn threshers, olpad thresher is a common machine used in different parts of the country. Power wheat thresher is a machine, which thresh the wheat crop and performs several other functions such as:

- Feed the harvest crop to the threshing cylinder,
- Thresh the grain out of the ear head,
- Separate the grain from the straw,
- Clean the grain, and
- Make 'bhusa' suitable of animal feeding.

During the last two decades in the country, power threshers have become quite popular. The famous Ludhiana thresher was first introduced in India during 1956-57. The thresher was tractor operated type and used mainly for wheat. It was a very good machine, which threshed, cleared and bagged the grain, at the same time it made the quality straw (bhusa). Further development work took place during the period from 1965 onwards for low horsepower threshers. The most widely used design, spike tooth cylinder thresher was commercially marketed in the country around 1970. This simple design has been able to maintain the cost of machine low as the total weight of machine was greatly reduced. The output capacity also improved. These threshers are available in various sizes operated by 3-40 hp power sources. The grain output is 20-25 kg/hp-h. Beater type threshers take comparatively more power than spike tooth threshers.

Spike tooth/peg tooth type thresher has cylindrical drum having five to six rows of spikes or pegs mounted on periphery of drum. Threaded mild steel bolts or spikes of same material are used. Thresher with spike is better than bolts as former takes less energy as compared to later. Threshing is accomplished due to impact and rubbing action. The separation is affected through aspiration of material falling through concave. Cleaning is done on a set of oscillating sieves provided in the machine. The fan and cylinder are mounted on the same shaft that makes construction simpler as compared to beater type threshers. The drive to the oscillating sieves is provided from main shaft with the help of crossed belt.

Types of Power Threshers

1. According to crops being threshed

- Single Crop
- Multi-crop

2. According to functional components

- Drummy
- Regular (Through-put)
- Axial flow

3. According to types of threshing cylinder

- Syndicator
- Hammer Mill or Beater type
- Spike tooth type
- Rasp bar type

Main Components of Thresher

(i) Drive pulley

(ii) Fan/blower

(iii) Feeding chute

(iv) Spikes

(v) Cylinder

(vi) Concave

(vii) Flywheel

(viii) Frame

(ix) Towing hook

(x) Upper sieve

(xi) Lower sieve

(xii) Transport wheel

(xiii) Suspension lever

(xiv) Can pulley

(xv) Shutter plate

Principles of threshing: The threshing mechanism, which separates the grain from the stalks, consists mainly of a revolving cylinder and the concaves. A feeder beater is usually located in front of the cylinder and at the upper end of the elevator-feeder to assist the elevator-feeder in feeding the grain to the threshing mechanism. Most threshers are provided with the rasp-bar type cylinder and concaves. The grain is rubbed from the stems without materially cutting the straw. Tooth-type cylinder and concaves are available on some combines. Adjustments are provided for varying the speed of the cylinder to suit the kind of crop being harvested. V belt variable-speed drives are used on most combines. The straw is thrown back onto the separating mechanism, while the grain falls through the concaves onto a grain pan or grain carrier and is conveyed to the cleaning mechanism.

Axial Flow Thresher: The crop in this thresher is fed into the cylinder through a feeding chute located at one end of the threshing drum. In a multi-crop thresher, threshed wheat crop passing through concave is cleaned by a set of sieves and a blower or aspirator. Axial flow of paddy crop is facilitated by the use of louvers provided on the upper concave. The straw is thrown out of the threshing unit by paddles. The cleaning and separation of grain is accomplished by a set of sieves and a blower or aspirator.

Functional components of threshing unit: A power thresher essentially consists of feeding unit, threshing unit, cleaning unit, power transmission unit, main frame and transport unit (Fig. 1). The operation of conveying the cut crop into threshing unit is known has feeding. Normally, one of the two types of feeding units 'throw-in-type' or 'hold-on-type' is used in power threshers (Fig. 2). In 'throw-in-type' feeding unit, the cut crop is pushed into threshing cylinder, where as in 'hold-on-type' the heads is only pushed into the cylinder and straw is manually or mechanically held. Throw-in-type feeding device is quite common in the threshers, which may be a feeding hopper or feeding chute.

Feeding Hopper: In this type of feeding device there is a hopper, placed on the top of the threshing cylinder. Generally hopper type of feeding units have a rotating star wheel mechanism between the hopper and threshing drum to facilitate the uniform feeding of crop to the drum. The initial cost of this system is high, hence is mostly used on a large thresher e.g. axial flow thresher of large capacity.

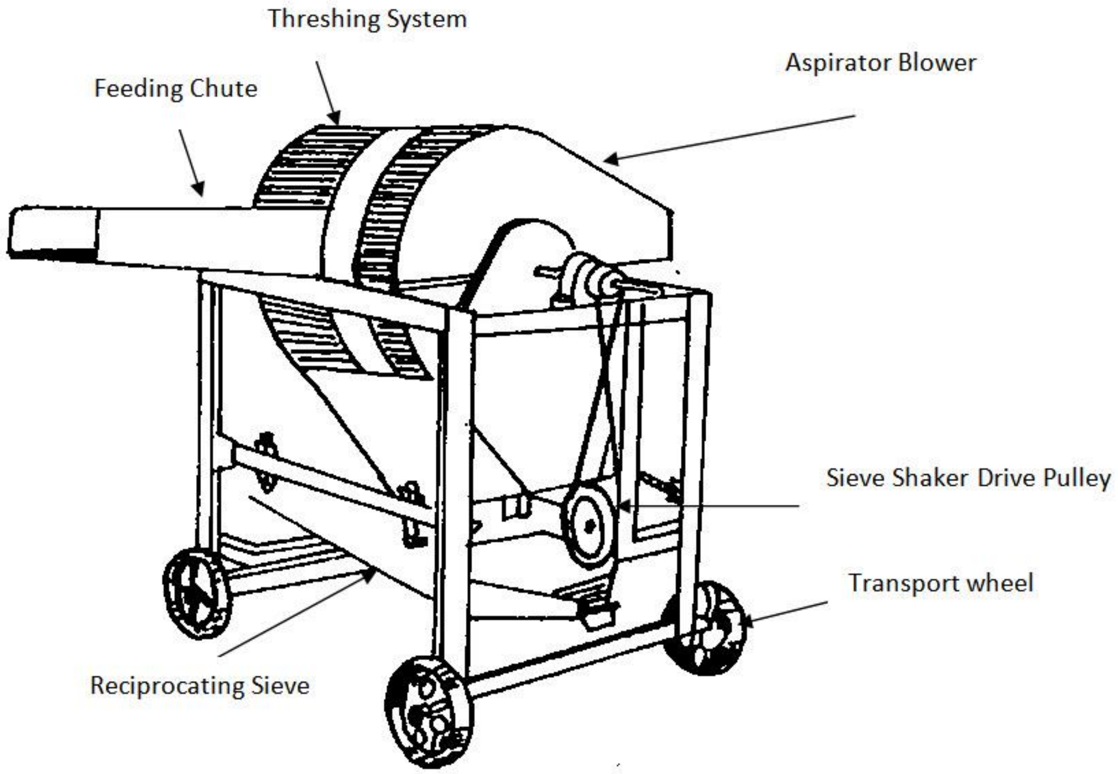


Fig. 1: Details of wheat thresher.

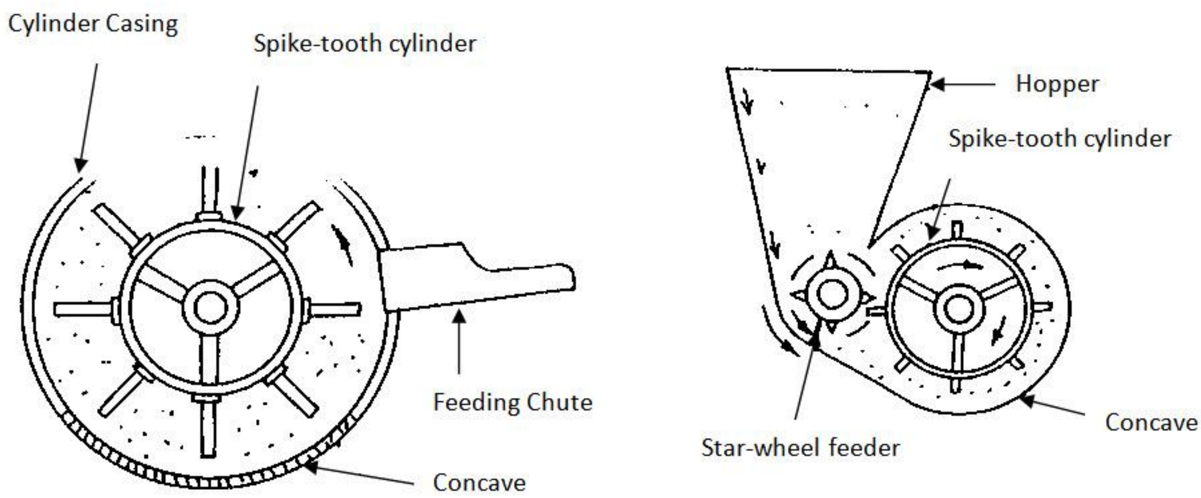


Fig. 2: Different types of crop feeding systems.

Threshing Unit: The threshing is accomplished by the impact of the rotating pegs mounted on the cylinder, over to the ear heads, which force out the grain from the sheath holding it. In the threshing of wheat crop, the straw is also bruised and broken up by the impact, thus converting it into 'bhusa' (straw). Threshing unit is mainly consists of a cylinder and concave. There are different types of threshing cylinders (Fig. 3) such as:

- Spike tooth/peg type cylinder
- Rasp bar type cylinder
- Angled bar type cylinder
- Wire loop type cylinder
- Cutter blade or syndicator type cylinder

- Hammer mill type cylinder

Spike tooth type cylinder: In this type of threshing drum, there is a hollow cylinder, made out of MS flat. Over to its entire periphery, a number of spikes/pegs of square /round bars or flat iron pieces are welded or bolted. Now days, in most of threshers, round peg with adjustable length are used. These spikes are staggered on the periphery of the drum for uniform threshing. The crop is fed along with the direction of motion of the rotating drum. The spike tooth cylinders are available in various sizes. A spike tooth cylinder with spikes of flat front and streamlined back has lower energy consumption.

Rasp bar type cylinder: In this type of cylinder, there are slotted plates, which are fitted over to the cylinder rings, in such a way that the direction of slot of one plate is opposite to another plate. This type of cylinder is commonly used in threshers. It gives better quality of bhusa and it can be used for a wide variety of crops viz.-wheat, paddy, maize, soybean etc.

Wire loop type cylinder: In this type of threshing drum, there is hallow cylinder, over which a number of wooden or MS plates are fitted. On these plates, number of wire loops is fixed for threshing purposes. This type of cylinder is common in the manually operated paddy threshers. Holding the bundle against the loops of revolving cylinder does threshing of paddy crop.

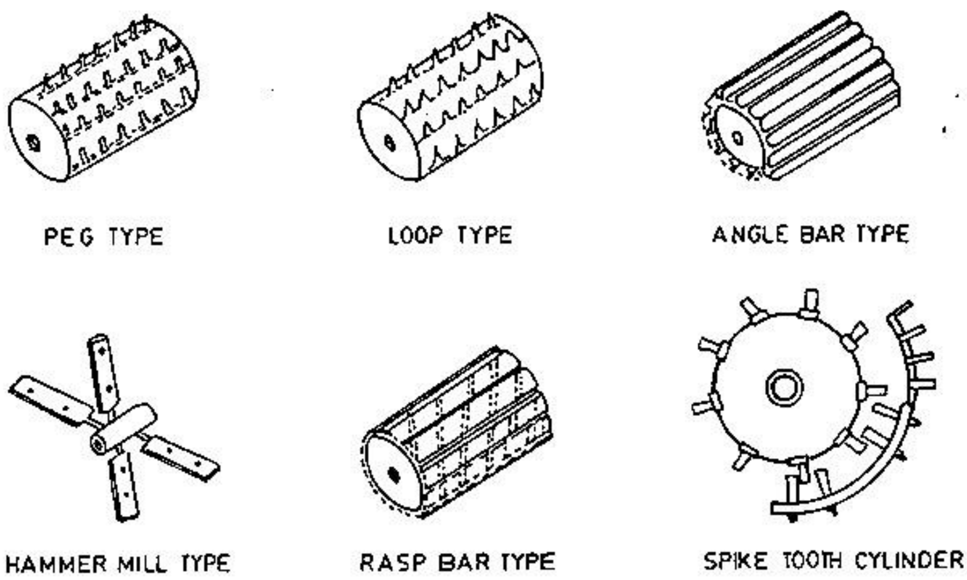


Fig. 3: Different types of threshing cylinders.

Chaff cutter/Syndicator type thresher: This is essentially an adoption of chaff cutter for threshing (Fig. 4). The crop is fed as is done in case of chaff cutters. After passing through a set of rollers, crop is cut into pieces. Varying the set of gears can vary the size. Three to four serrated blades are fastened on the radial arm of the flywheel. Threshing is done mainly due to cutting helped by rubbing and impact. The main advantage of syndicator thresher is that it can handle crop with higher moisture content. However, chopping knives need to be sharpened every 3-5 hours of operation. The machine is more prone to accidents due to positive feed rollers.

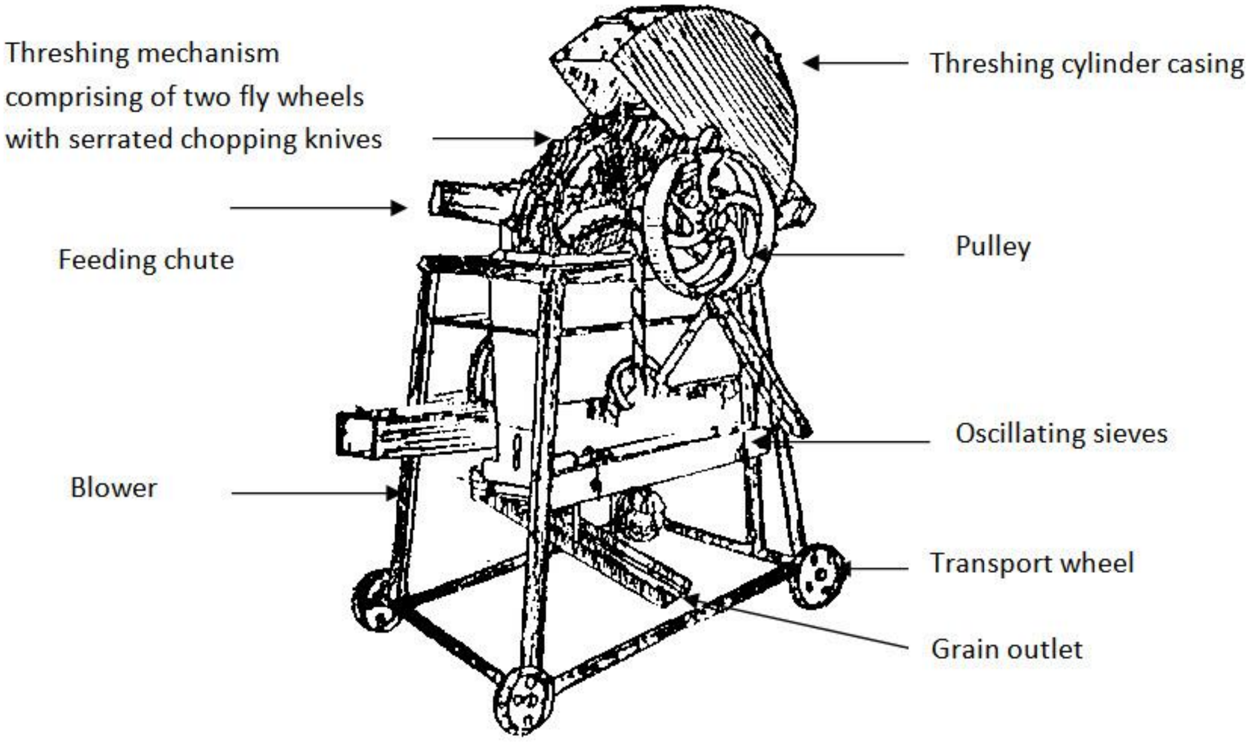


Fig. 4: Detail components of chaff cutter type thresher.

Hammer mill type cylinder: it uses beaters to do the required job of threshing. The shape of this type of cylinder is different from the above-discussed cylinder. The beaters are made of flat iron pieces and are fixed radically on the rotor shaft. Generally feeding chutes are used with hammer mill type threshing cylinder. The cut crop is fed perpendicular to the direction of motion of rotating beaters. This type of thresher requires more power as compared to spike tooth type of thresher.

Concave: Cylinder and concave together makes the threshing unit. It separates the grain from the crop and removes grain from the straw. Concave is provided in the thresher to hold the fed crop inside the threshing chamber and allows only grain and small amount of chaff to pass through it. The threshing takes place only in this space. It is a curved unit, made of iron steel or iron bar, fitted near the threshing cylinder. The clearance between cylinder and concave is adjustable, depending upon the size and type of grain. The concave clearance for wheat is 5 to 13 mm and for paddy is 5 to 10 mm. As the concave clearance is reduced, the threshing efficiency increases but losses increase and vice versa. The concave clearance at the inlet is less as compared to outlet. There are different types of concave, which are used in thresher.

Screen type concave: It is made of MS rod. It is semicircular in shape and sometimes made with wire also. The screen allows the material after threshing to pass through its perforation.

Perforated concave: In this, perforations are made in a mild steel sheet. The concave is closed from both the ends by iron sheet. The size of perforation is made as per the size of grain of a crop.

Cleaning unit: This unit is provided to separate the grain from chaff. It further uses sub units, like aspirators or blowers, sieves and sieve shaking mechanisms to separate out grains from chaff. The thresher that is provided with aspirator unit is usually called aspirator type thresher. Those threshers fitted with blower which blows air in horizontal direction is called drummy threshers.

Blower or Aspirator: After threshing unit carries out threshing, the cleaning and separation of straw from grain is required. The fan is generally installed on the main shaft over which cylinders, flywheel and driven pulley are mounted. Fan lifts/sucks the lighter material chaff and other plant portion and throw away from the out let. Rest of the separation-cum-cleaning is done by screen with its oscillating motion.

Screens: Most of the power threshers are equipped with two screens. Top screen is provided so as to pass the grain to second screen and chaff etc is taken out from it. Other screen sieves out the smaller grain or weeds seeds and delivers the cleaned grain towards outlet. The size of screen hole is selected on the basis of grain size. These screens are effective when kept under oscillation.

Shaking mechanism: The screens are oscillated or shaken with a crank attached to the screen. This crank is powered from main axle either by belt or by rod. The circular motion of the main shaft is converted into oscillating motion of screen, which shakes it and separates the grain from other foreign material and chaff. The separating effectiveness depends on the frequency of strokes of crank, which is adjustable.

Power transmission unit: Threshers are usually powered with tractors and sometimes with electric motors or diesel engine also. After installing the thresher into the threshing floor in the field, tractor PTO shaft is coupled with a flat pulley. A corresponding matching pulley of appropriate size is provided over to the thresher main shaft. These pulleys are connected with a proper rating of flat belt and thresher is operated. Blower fan is provided into the main shaft of the thresher, which rotates and does the required job. The screens are oscillated with the help of a v-belt and a crank wheel, powered with main shaft of thresher. A heavy flywheel is also provided on the main axle of the thresher. It is very important part of any thresher. It is provided to store the energy to supply continuously and equally to the entire threshing cylinder. It is made up of cost iron, and fitted on one end of the main shaft of thresher.

Main frame: A very strong frame is provided in the thresher on which all the functional parts are attached. The frame is made usually of heavy angle iron sections. It should be strong enough to sustain vibrations of machine, during its operation in the field.

Transport wheels: Thresher is provided with wheels at its legs, so that transportation can be done easily. These wheels are made mostly with cost iron but new and large capacity threshers are equipped with pneumatic wheels for better performance during transportation.

Thresher ddjustments: The following adjustments can be done on a stationary power thresher:

Cylinder and concave clearance: In order to get cleaned grains and proper threshing, it is very important to set the proper clearance between tip of cylinder and concave. On an average, concave clearance is kept about 25 mm at the mouth, 10 mm at the middle and 15 mm at the rear end. Start operating the thresher, by keeping proper recommended speed, and check if any grain is left in the ears. If it is so, reduce the concave clearance gradually, until drum is threshing cleanly. Too close concave setting is likely to crack some of the grains.

Cylinder speed: The drum of the thresher should be rotated at proper speed for better threshing and cleaning efficiency. Normally, manufacturers specify the cylinder speed for different crops. The cylinder speed can be checked using tachometer. Operator should check the speed occasionally under load for proper functioning of thresher. The cylinder peripheral speed for wheat is kept between 1520 to 1830 m/min and for paddy between 370 to 920 m/min.

Fan adjustment: Fan(s) fitted on thresher must provide the proper amount of blast. The shutter(s) at each end of fan should be adjusted properly so that it could provide blast sufficient enough to remove chaff and light materials without grain. Watching the sample and adjusting the blast can help in getting the desired results.

Drummy Thresher: These threshers were very popular in the beginning when threshers were introduced because of its simplicity and low cost. The radially arranged arms known as beaters are mounted on the shaft (Fig. 5). These are made of mild steel square section with mild steel flat welded or bolted at the top. The beaters revolve inside an enclosed casing. Ribs are provided inside of upper half of the cover in order to have better threshing. The lower half (known as concave) has rectangular openings made out from square bars. The crop is fed through feeding chute. Crop receives impacts from the rotating beaters till size is reduced to pass through concave. The clearance between beater and concave is kept about 18-20 mm. The crop should be well dried before feeding in the thresher. A wet crop raps around the beater shaft and machine becomes overloaded. These threshers do not have provision for separation and cleaning of grains. The threshed material is later separated and cleaned by small pedal type blower.

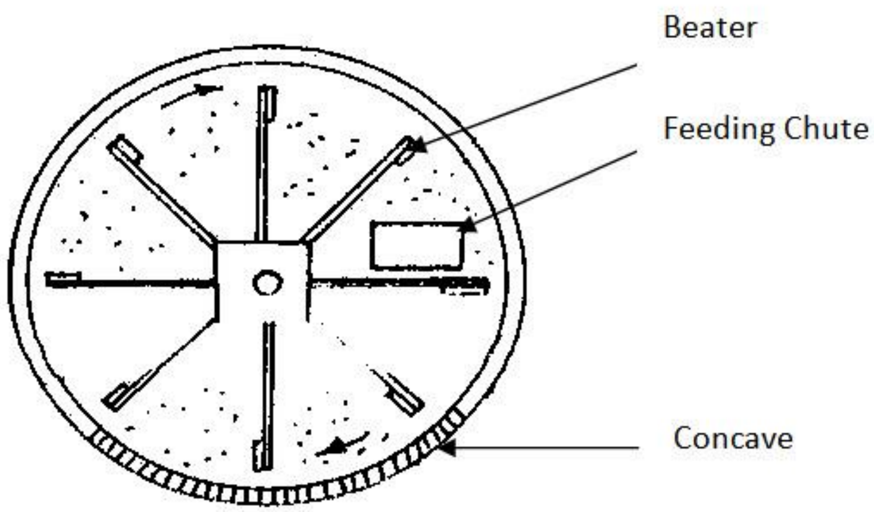


Fig. 5: Beater type drummy thresher.

Olpad thresher: 'Olpad' threshers (Fig. 6) are also used for threshing wheat crop. A pair of bullocks pulls it around over the dried crop spread in a circular form on the threshing ground. Threshing is continued till the entire material becomes a homogeneous mixture of grain and 'bhusa' (chaff). It consists of about 20 circular grooved discs each of 45-cm diameter and 3-mm thickness placed 15 cm apart in three rows. An operator's seat is provided on the frame to control the movement of animals. All discs are mounted staggered to give more effective cutting of the straw. It has 3 or 4 wheels to facilitate its movement from one place to other. Threshing by this thresher is fairly efficient and cheap but is quite slow with low output capacity. This machine can be used for threshing wheat, barley, gram etc.

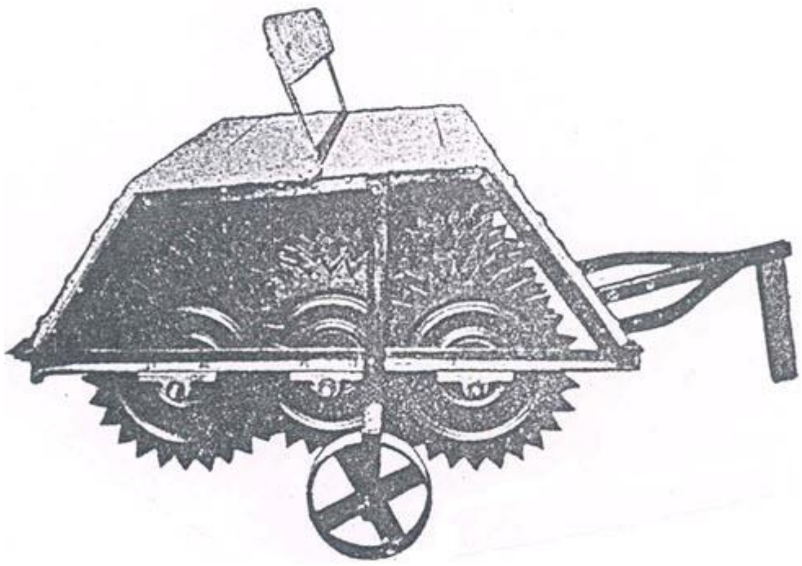


Fig. 6: Olpad thresher

Paddy Threshers: Paddy thresher of pedal operated type (Fig. 7) consists of mainly a well-balanced cylinder with a series of wire loops fixed on wooden slates. It has got gear drive mechanism to transmit power. While cylinder is kept in rotary motion at high speed, the paddy bundles of suitable sizes are applied to the teeth. The grains are separated by combining as well as by hammering action of threshing teeth. Paddy is threshed due to impact and rubbing action between threshing drawn loops and concave screen. The grains are cleaned with the help of a fan and cleaned grain goes down through the grain outlet at the bottom of the thresher. They are available in different horse power range.

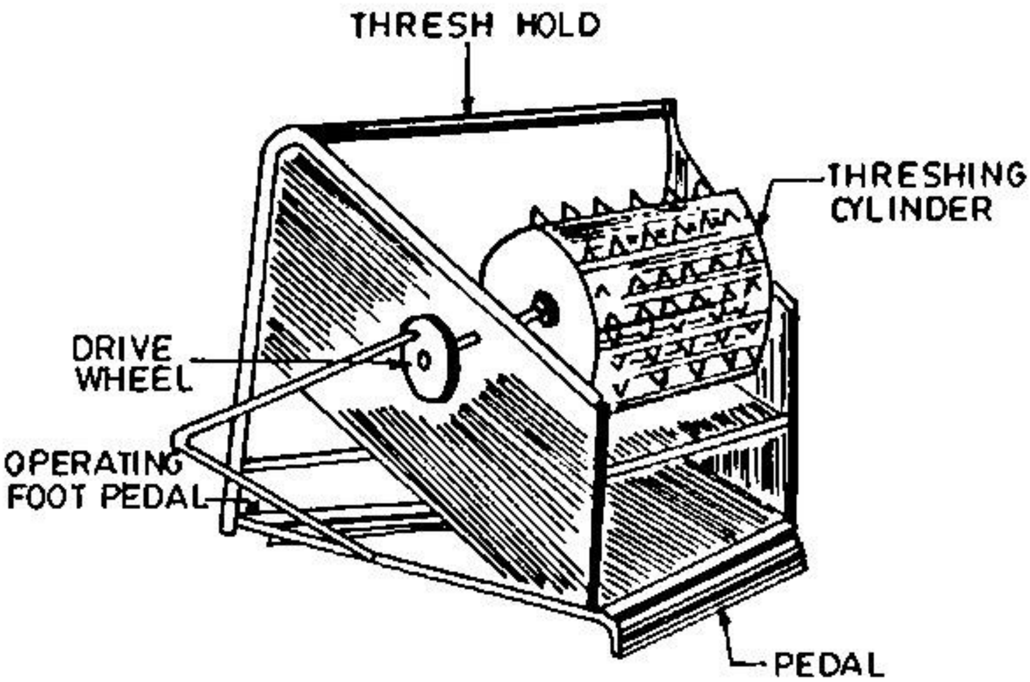


Fig. 7: Pedal operated paddy thresher.

Multi-crop Threshers: Since, the Indian farmers raise variety of crops as per the suitability of particular region, climate and soil conditions, there was need to thresh all these crops for timelines of operation. Developing a multi crop thresher has solved this problem. It can thresh crops like wheat, moong, paddy, grain, soybean etc. For these crop requirements are different, as in the case of wheat bruised straw (bhusa) is the main requirement. For paddy, farmers need long straw. For pulses, seed damage should be minimal; as damaged seeds lower the quality and causes spoilage in storage. The crop factors such as moisture content, grain size, grain-straw ratio, condition of straw etc influence the design consideration of main components of threshers. The farmer is primarily interested in end product, low cost, durable and reliable machine. The suitable multi crop threshers for cereals and pulses are commercially available in the country.

A multi-crop thresher (Fig. 8) attains the axial movement of the crop while handling paddy and all crop material is made to move through the concave in case of wheat. The main components of multi-crop threshers are: feeding chute, threshing cylinder, aspirator blower, paddy chaff outlet, wheat straw outlet, hopper, and cam for oscillating sieves, oscillating sieves, transport wheel, frame, main pulley and louvers. The axial flow of material can be accomplished by providing seven louvers with spacing of 150 mm in the hexagonal casing. The clearance between louvers and tip of cylinder spikes is 20 mm. For wheat threshing, the first three louvers are placed with ribbed casing and side plates are fixed with top casing and concave to prevent material flow in the second portion. The direction of rotation of threshing cylinder is opposite for wheat than paddy. That is why; straw outlet of aspirator blower is repositioned. The top sieve has holes of 9-mm diameter for wheat and 5 mm for paddy grains. The lower sieve has holes of 1.5-mm diameter common for both the crops. The upper sieve can be changed easily depending upon crop to be threshed. The cylinder-concave clearance in the first section of threshing system (i.e. facing the feeding chute) has to be more while handling paddy than wheat. The machine output is 500 kg/h for wheat and 700 kg/h for paddy.

Fig. 8: Axial flow paddy thresher.

High capacity (Harambha) threshers: It is a basically a chaff-cutter type thresher. It consists of a threshing cylinder, concave, two aspirator blowers, reciprocating sieves, feeding chute, feeding conveyor, feed rollers, safety lever in the feeding chute and flywheel. A platform is attached to the main frame of thresher, on which a person stands and feeds the crop into thresher. All the crop materials are fed through the conveyor of feeding chute and feed rollers move the crop into threshing cylinder. A safety lever provided in feeding chute prevents the entrapping of hands by the feed rollers. Threshing cylinder has two chaff-cutter type blades and beaters. Chaff-cutter blades cut the crop into pieces and beater helps to detach grain from crop. All the threshed materials pass through the concave where it is subjected to aspiration action of blower. Light materials like chopped straw are blown away and grain etc. fall on a set of reciprocating sieves. The clean grain is collected in trolley through auger elevator. It can be used to thresh the crop having high moisture content also. The machine is operated by PTO of a 35-hp tractor and is mounted on two pneumatic tyres for easy transportation. It can thresh 1.5-2.0 tonnes/h.

Sunflower thresher: It consists of a threshing cylinder, concave, casing fitted with louvers, cleaning system, feeding hopper and frame (Fig. 9). The cylinder concave clearance is 40 mm and is uniform throughout its length. The diameter of cylinder is 65 cm and length 150 cm. The first part of cylinder of length 133 cm has flat bars for crop threshing and the 2nd portion of length 17-cm has straw throwing blades. The cylinder casing is of hexagonal shape and is fitted with 7 louvers. The louvers help the crop to move axially and the crop is rotated three and half times for complete separation of grains. The cleaning system has a blower and two sieves. The opening of top sieve is 16 mm and of lower sieve 6 mm. Recommended cylinder and blower speeds are 300-350 rpm and 1200-1400 rpm respectively. A tractor or 7.5 hp motor can operate machine. The machine has a capacity of 600-900 kg/h of clean grain.

Fig. 9: Sunflower thresher in operation.

LESSON 10. SAFETY, ADJUSTMENTS AND PERFORMANCE OF THRESHERS

Safe Use of Threshers: Introduction of power wheat threshers has greatly reduced the time required for threshing as well as physical burden and drudgery of work for human beings. However, these machines have lead to the problem of involvement of the operators in accidents while using the thresher. The threshers are generally of spike-tooth cylinder type, chaff-cutter type and hammer mill or beater type. The crop is fed manually into these machines through a feeding chute. It has been observed that human factors such as inattentiveness, un-skilfulness, overwork, and physical incapability, wearing of loose clothes, hand-wears and use of intoxicants are mainly responsible for about 73% of accidents. The machine factors such as improper design of feeding systems, substandard material and defective design contribute to about 13% of accidents. Crop factors such as feeding of ear-heads, short crop stalks and wet crop contributed about 9% of accidents whereas inadequate light, crowded surroundings and slipping on the threshing yard contributed to about 5% of accidents. The threshing accidents can be minimized provided the farmers adopt the following measures:

- The farmer should buy only those threshers, which are fitted with safe feeding chute as per B.I.S. standards (Fig. 1). For safety, the minimum length of feeding chute should be kept 90 cm, covered upto a minimum of 45 cm and inclined to the horizontal at an angle of 5-10 degrees. The angle of covered portion with the base length of feeding chute should be kept equal to 5 degrees.
- Employ only skilled and trained workers for feeding the crop to the thresher.
- Avoid feeding ear-heads without stalks as it may lead to serious hand injuries. Similarly, feeding of wet crop should also be avoided which otherwise might lead to fire accidents.
- Avoid talking while working on the thresher. Do not work on thresher under the influence of alcohol or any other intoxicants. Do not work on thresher for more than 8 hours or when feel tired. Do not wear loose clothes, wristwatch, and bangles while working on the thresher.
- Ensure proper lighting in case the machine is to be operated at night, other poor visibility may lead to accidents.
- Keep the work place and surroundings of thresher free of all kinds of obstructions.
- Do not smoke or light a fire near the threshing yard.
- Do not cross over the flat belt or moves near it.
- Keep a first aid box handy for use in the event of need.

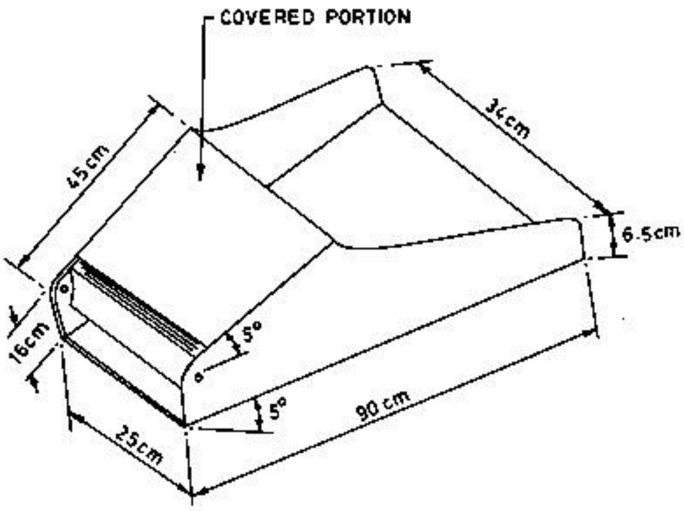


Fig. 1: Safe feeding chute.

Adjustments in threshers: Adjustments involved in the threshers are:

Cylinder speed: A thresher is operated at a recommended speed for belt performance. The speed is changed by changing diameter of pulleys using the following relationship.

$$N = \frac{N_p \times D_p}{d}$$

Where,

N = Speed of thresher pulley, rpm

d = Diameter of thresher pulley, cm

N_p = Speed of primary pulley, rpm

D_p = Diameter of primemover pulley, cm

Cylinder-concave clearance- It is adjusted by following methods:

-
  1. Raising or lowering the cylinder
  2. Adjusting height of concave assembly
  3. Adjusting length of spikes

The clearance is measured at five points and an average is taken.

Blower speed: The speed of blower or aspirator is changed by using pulleys of different diameters in accordance with above equation.

Air flow: A thresher may be provided with a sliding gate for air flow adjustment at the same speed of blower or aspirator.

Sieve slope: The slope of cleaning and grading sieves is changed with the help of I-bolts of the units.

Speed and strokes of sieves: The frequency and stroke length of reciprocating sieves which govern the cleaning efficiency can be adjusted by changing the length of connecting rod or eccentricity of crankshaft or both in accordance with the available provisions.

Factors affecting performance: Parameters that are important for threshing which effect the separating and cleaning units are percent of seed separated through concave grate (separating efficiency) and the degree of the breakup of the straw. Most of the seed damage caused occurs in the threshing unit because of impact blows received during the threshing process. Seed damage may be visible or it may be internal which is determined only by germination tests.

Effects of feeding pattern upon cylinder and concave performance: When the material enters, a cross-flow cylinder has considerable effect upon cylinder and concave performance. Based on the tests performed on wheat and barley in the laboratory it was found that cylinder losses is twice as when fed heads first with the stalks parallel and the heads on top of the layer. The percentage of the grains that failed to pass through the concave grate was also twice as high. Tangled pattern, simulating the effect of header gave about the same cylinder losses as the head first feeding. Feeding heads first with the heads on the bottom of the layer was better than with the heads on top.

Effects of cylinder and concave design factors upon performance: With the increase in concave length the separation efficiency also gets increased but at the diminishing rate. Also, increased concave length increases the straw breakup and tends to increase the seed damage, especially with low moisture contents and high cylinder speeds.

Effects of operating conditions upon cylinder loss and seed damage: Threshing effectiveness is related to:

(i) Peripheral speed of the cylinder: Increasing the cylinder speed reduces the cylinder loss and but may substantially increase damage. Seeds of dicotyledonous plants, such as beans may be damaged excessively at peripheral speeds as low as 7.6 m/s.

(ii) Cylinder concave clearance: Reducing the cylinder concave clearance tends to reduces the cylinder losses but it increases the seed damage. But the effects are generally small in comparison with the effects of increasing cylinder peed.

(iii) Number of times the material passes through concave

(iv) Number of rows of concave teeth used with a spike tooth cylinder

(v) Type of crop

(vi) Moisture content of the crop: Seed damage increases as the seed moisture content is reduced. Several investigators found that germination of wheat was reduced when threshed at seed moisture content above or below the optimum range of about 17 to 22%.

(vii) Rate of material feeding: Increasing the non-grain feed rate increases the cylinder losses. Increased feed rate tends to reduce seed damage, but the effect is very small.

Effect of operating conditions upon straw breakup and seed separation through concave grate: Harvesting of cereal grains with combines having rasp-bar cylinders and open-grate concaves, 60 to 90% of the seed is usually separated through the concave grate. Increasing the cylinder speed or decreasing the clearance causes more seed to be forced through the grate, thereby reducing the amount of seed that must be handled by the walkers. Increasing the cylinder speed makes the layer of material between the cylinder and concave less dense, and decreasing the clearance makes it thinner. Increasing feed rate makes the layer denser and reduces the amount of seed separation.

Performance of Threshing System: The performance of a threshing unit is the percent of seed detached from the non-grain parts of the plant and the percent of seed damaged. Two other important parameters are performance of cleaning and separating units. Power requirement is not a functional performance parameter. The performance of threshing system as defined by Bureau of Indian Standards in IS: 6284-1971 is given below:

Total grain input: It is the feed rate multiplied by grain content as obtained from straw-grain ratio.

$$\text{Threshing efficiency (\%)} = \frac{\text{Total grain input (kg) - unthreshed grain from all outlets (kg)}}{\text{Total grain input (kg)}} \times 100$$

$$\text{Blown grain (\%)} = \frac{\text{Quantity of threshed grain obtained at 'Bhusa' outlet (kg)}}{\text{Total grain input (kg)}} \times 100$$

$$\text{Damaged grain (\%)} = \frac{\text{Quantity of damaged grain from all outlets (kg)}}{\text{Total grain input (kg)}} \times 100$$

$$\text{Sieve loss (\%)} = \frac{\text{Healthy grain obtained at sieve overflow + sieve underflow + struck grain (kg)}}{\text{Total grain input (kg)}} \times 100$$

Cleaning efficiency: It is the percentage clean grain in the total grain obtained from the main grain outlet. It is affected by various factors such as crop mat thickness, crop mat velocity, cylinder speed, concave clearance, spike shape etc.

$$\text{Cleaning efficiency (\%)} = \frac{\text{Total grain received at main grain outlet (kg) - refraction At main grain outlets (kg)}}{\text{Total grain received at main outlets (kg)}} \times 100$$

Total Loss = Unthreshed grain + blown grain + cracked grain + sieve loss

LESSON 11. GRAIN COMBINES, TERMINOLOGY, ADJUSTMENTS, LOSSES, TROUBLE SUITING

A combine is farm machine that combines the reaper and thresher to harvest the standing crop, thresh it and clean the grain from straw in one operation. According to source of power used combines may be classified as self-propelled combines (Fig. 1) and tractor operated (Fig. 2) or trailed type combine. Self-propelled combines use a propelling power source to do various operations. In tractor operated combine, the power is being optioned through detachable tractor. Only at the time of harvesting tractors are attached and rest of the times it can be used for other farm operations.

The present day combine harvesters are being mostly used for harvesting two major crops namely wheat and paddy. Other crops can also be harvested with combines like, sunflower, maize, soybean, pulses etc, with slight changes in the combine. A combine harvester consists of header platform, reel, cutter bar, crop divider, platform auger, feeder conveyer, cylinder, concave and grate, fan, chaff sieves, straw walkers, grain sieves, grain auger, tailing auger, grain elevator, grain container and grain unloading auger (Figs. 3 and 4).

Fig. 1: Self-propelled combine in operation.

Fig. 2: A grain combine with 55-hp tractor mounted on it.

Cutter bar assembly: The cutter bar assembly comprises of finger bar, fingers, knife guides, wearing plates, outer shoes and main shoes that is non-reciprocating part of the cutting mechanism (Fig. 5). The cutting unit of a combine uses a mower type cutter bar. The knife on the combine uses serrated edge sections. The length of stroke is often longer and sometimes the section passes over two guards in one stroke. The knife section edge is serrated to help keep the straw from slipping while it is being cut. The serrated sections cannot always be sharpened and are generally replaced when they become dull. The cutting platform of combine should be adjustable to operate at a height, from 7.5-90 cm above the ground level. The platform is also provided with a reel and a canvass carrier.

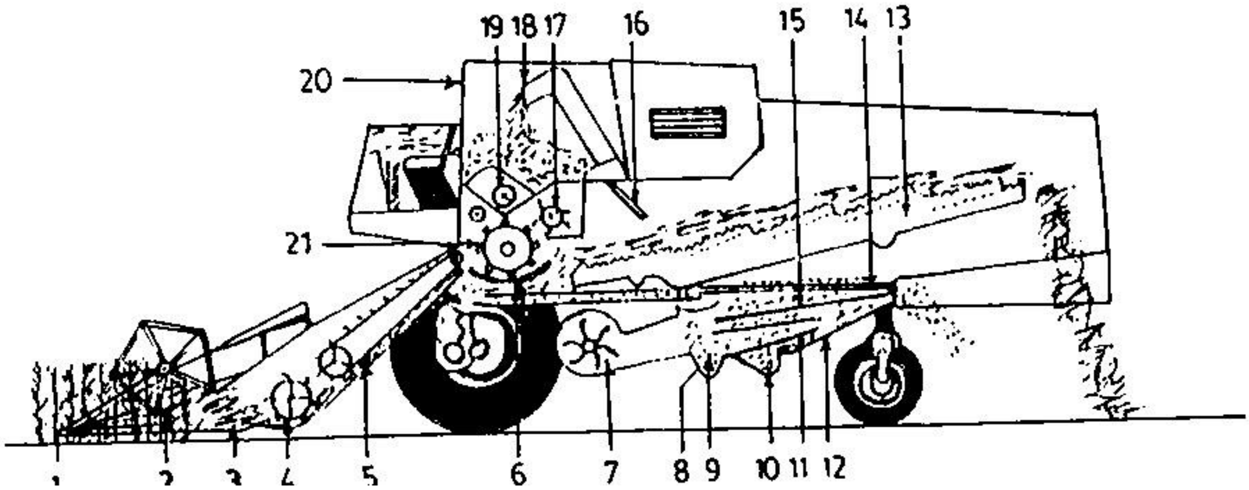


Fig. 3: Details of a self-propelled combine.

1. Crop divider	2. Reel	3. Knife	4. Auger conveyer
5. Feeding conveyer	6. Concave	7. Blower	8. Grain auger
9. Grain elevator	10. Ear auger	11. Grain collector	12. Ear collector
13. Straw walker	14. Rake	15. Sieves	16. Deflector
17. Straw guide drum	18. Tank filling auger	19. Tank auger	20. Grain tank
21. Threshing cylinder			

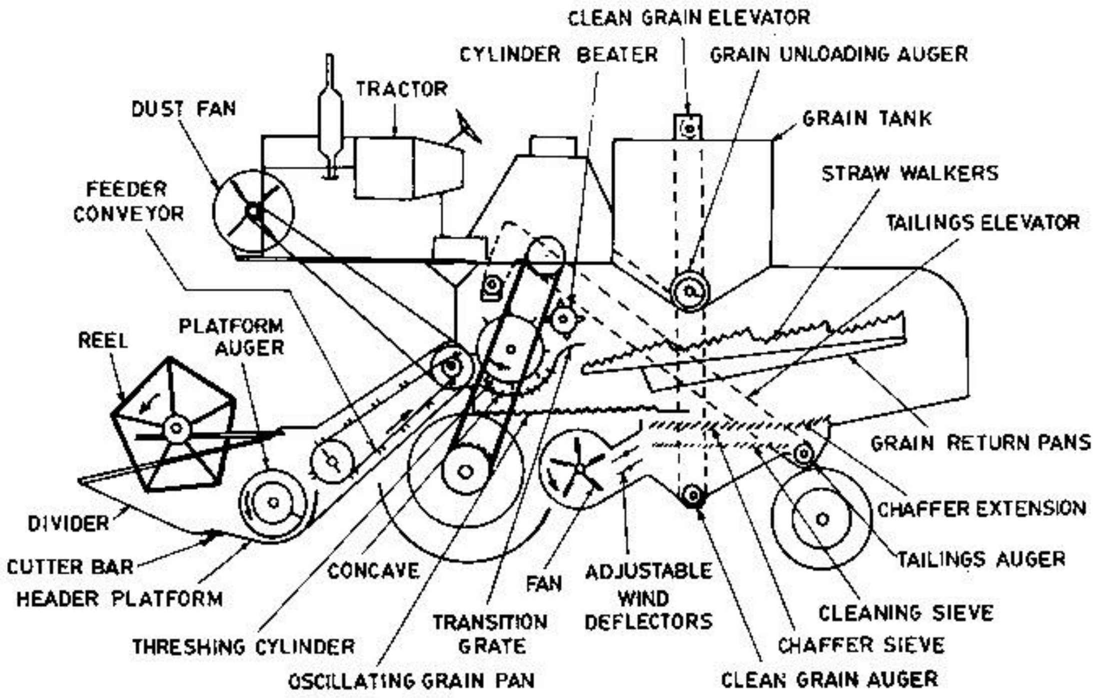


Fig. 4: Details of a tractor operated combine harvester.

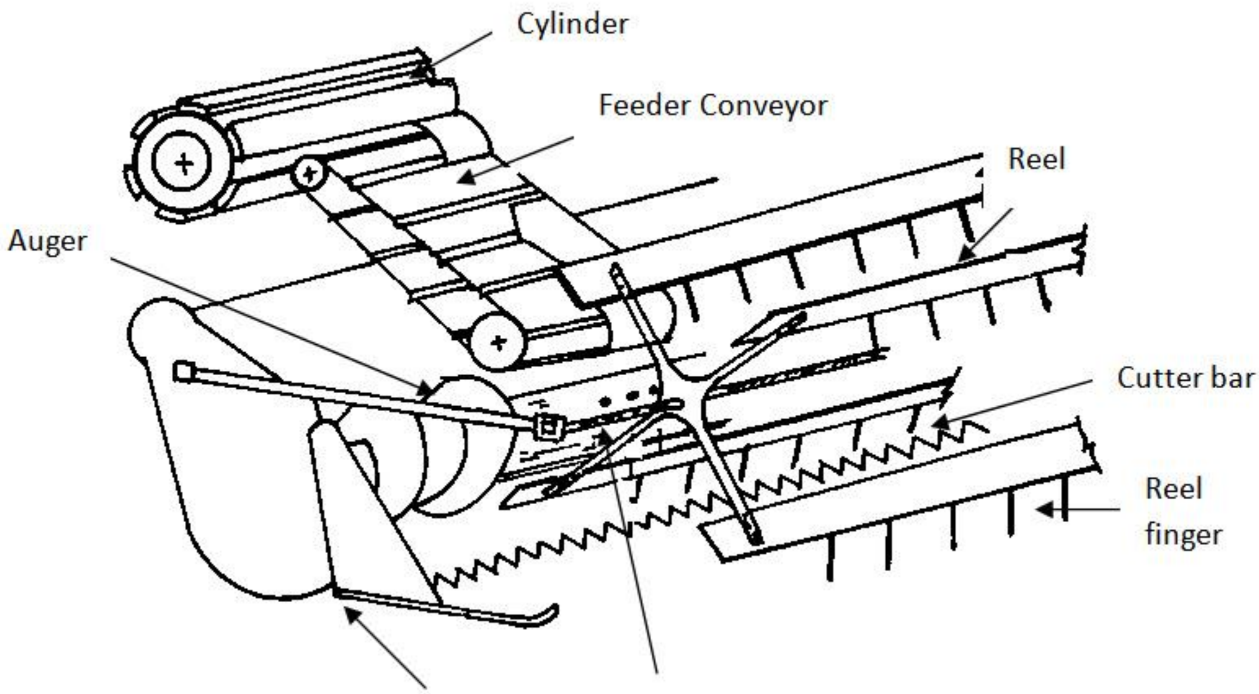


Fig. 5: Cutter bar assembly of a combine harvester.

The reel consists of a number of wide slats or arms with battens arranged parallel to the cutter bar to hold the crop being cut by the knife and to push and guide it to feeder conveyor auger. The reel may be of spring type or slat type. Its height and speed are adjustable. A clearance of about 12.5-25.0 cm between the reel and cutter bar is suitable for all purposes. The reel gets power through suitable gears and shafts. The reel revolves in front of cutter bar while working in the field. The cut crop is then fed to cylinder and threshing takes place between cylinder and concave units of machine. The basic components of threshing unit of combine are similar to that of power thresher (Fig. 6). The threshed material then moves to oscillating straw walker, which separate the grain from straw. The amount of grain not separated at any point along the walker length can be determined by

$$R_L = e^{-b\,L}$$

Where,

R_L = decimal fraction of the grain onto the walker that is not separated at distance L

L = distance along the walker from the effective point of delivery of material onto the walker

b = constant (function of feed rate, grain-straw ratio, crop variety and condition, walker design etc.)

If the walker is divided into uniform length increments, the amount of seed separated in any increment is a constant percentage of amounts of seed onto that increment. The effective delivery point on the walkers is 150-230 mm from the front end of walkers. If walker loss for a given crop condition and feed rate and seed rate onto the walker are known, the value of b can be calculated.

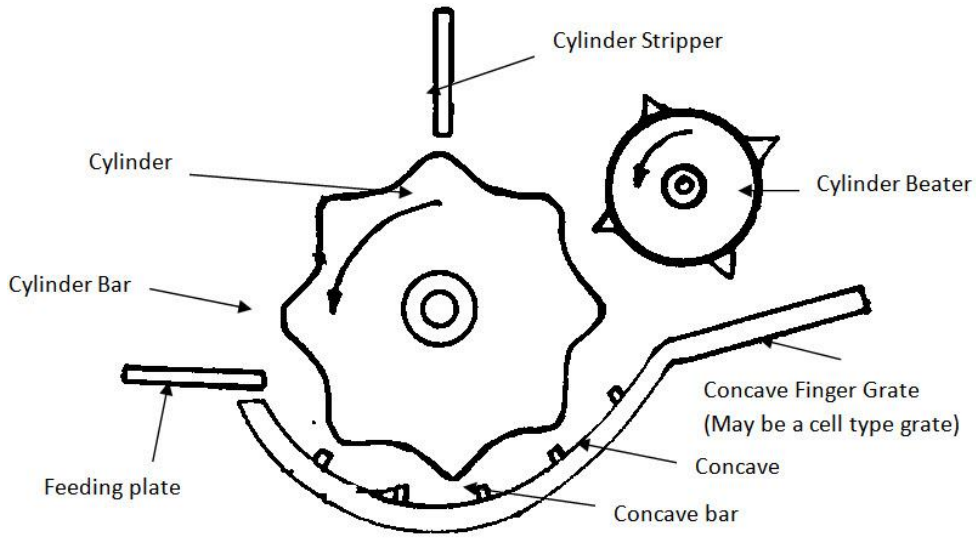


Fig. 6: Threshing unit of a combine harvester.

The cleaning unit (Fig. 7) consists of a number of sieves and fan cleans the grain. The un-threshed grains pass through tailing auger and go to cylinder for re-threshing. The grain passes through an elevator and collected in a hopper or directly unloaded to the trailer. The fan is adjusted such that the chaffs are blown off to the rear of the machine. The size of the combine is indicated by the width of cut it covers in the field. Some adjustments are always necessary on combines before being used for harvesting of crop. These adjustments are:

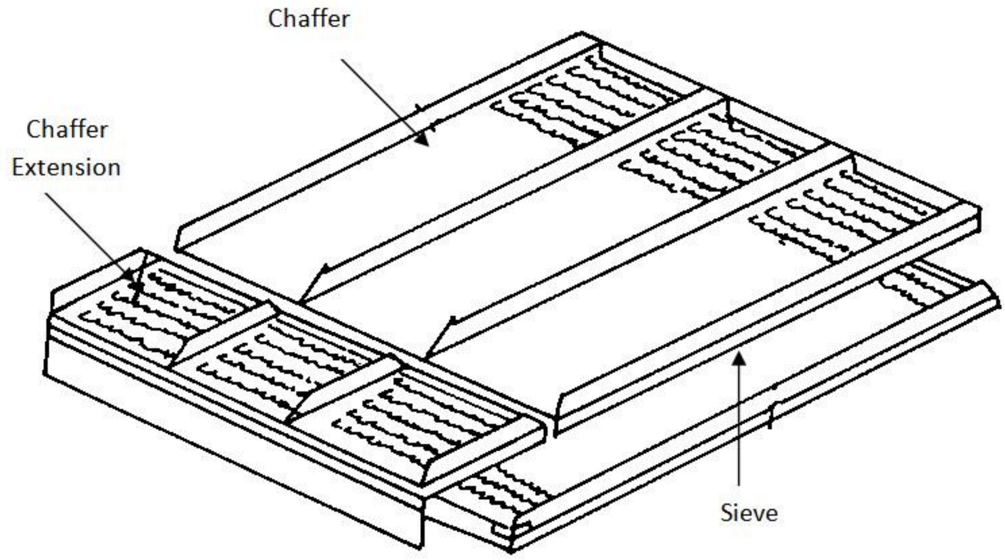


Fig. 7: Cleaning unit of a combine harvester.

Cutter bar height: The height of the forward tip of any knife section above the plane on which the combine is standing expressed in millimeters, is called cutter bar height. This height is adjustable and ranges from 75-900 mm. The crop is cut just low enough to cover nearly all the heads. If straw is to be saved cutting may be at a lower height.

Reel speed: It is essential to keep the reel speed in proper relation to the forward speed of the combine. If reel speed is more, grain shattering from heads occurs. If reel speed is lower then grain may fall on the cutter bar. Hence speed of reel should neither be more nor less. The speed of reel can be adjusted by changing the reel-driving sprocket.

Feeding: The tension of upper and lower feeder canvass is kept tight enough to prevent slippage. If they are too tight, there will be wastage of power and excessive wear will take place.

Cylinder-concave clearance: The gap between the tip of the cylinder to inner surface of the concave is called cylinder-concave clearance. The method of adjusting clearance varies with different machines. In some of the combines, raising or lowering the cylinder changes the cylinder-concave clearance, whereas, in other cases, the height of concave assembly is adjusted to change the cylinder-concave clearance. Close clearance results in more breaks up of the straw, which decreases the effectiveness of separating and cleaning unit. The spacing between concave and cylinder at front is usually adjusted from 2-30 mm and at rear 2-18 mm. With close type concave, the normal setting of concave is closer to the cylinder at the front rather than rear. With open type concave, the concave is normally closer at rear than at front.

Chaffer opening: This is upper sieve on which grass and chaff mixture falls for initial cleaning. The sieve is oscillated so that grains pass through chaffer openings and chaff and un-threshed materials thrown at rear of the machine. The chaffer opening should be provided such as to float chaff away without blowing out grain, but coarse heavy material should be retained and discharged at the rear.

Shoe sieve opening: The opening should be just large enough to permit free passage of grain. Adjustable shoe sieve with smaller lips and openings are the most common.

Tailing gate height: Tailing gate is a device provided at the rear of the cleaning unit to prevent un-threshed material from passing out of the combine. It can be adjusted by raising the tailboard at the end of the chaffer extension if necessary to prevent threshed grain from being blown out.

Platform: The platform holds the cutter bar and feeding mechanism.

Cutting platform auger moves the cut grain to the centre of the platform where the retractable fingers feed the crop into the feeder conveyer.

Feeder convener: The feed conveyor or feed rake is designed to feed the crop in a steady even flow into the threshing unit.

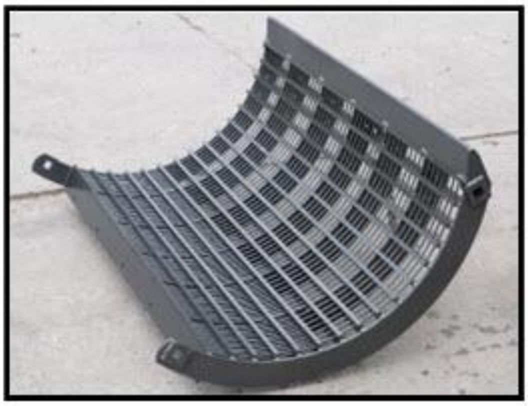
Feeder beater takes the crop from the feed conveyer and feed it uniformly to the threshing unit.

Threshing unit: The function of this section of combine is to thresh the grain from the heads. This is done by passing the grain between a rapidly revolving cylinder and a stationery surface underneath which is called the concave. The grains are separated from the pods by impact, rubbing or squeezing actions between cylinder and concave.

Threshing cylinder: The threshing cylinder may be of different types

1. Rasp bar type - having corrugated bars
2. Angle bar type - right angle bar with rubber facing
3. Spike tooth type - pegs or spikes on it.

Concave: The concave is the stationary part that the cylinder works against in the threshing action. The concave is a grate composed of rods and bars or wires. It is at the concave grate and finger grate that as much as 90% grain is separated from the crop. The separated grain falls through the grate on to the shoe pan where it is delivered to the cleaning unit. The straw and the remaining grain pass on to the separation unit.



Cylinder beater: The beater behind the cylinder slows down the material coming from the cylinder tears apart the straw and delivers the material to the straw rake or straw walker. The beater helps in cleaning the straw from the cylinder thus preventing cylinder wrapping and feedback.

Separating Unit: The separating unit agitates the straw after it comes from the threshing unit. This shakes out the loose grain remaining in the straw and delivers it to the cleaning unit. The straw is carried out of the combine by the rack.

One piece straw rack: The straw rack is a one piece unit with risers pointed toward the rear of the combine. The straw rack is mounted on cranks located at the front and rear which give it an oscillating motion. As the crank moves rearward and upward the straw is tossed up and to the rear. As the rack returns forward and downward the straw stays in mid air for a short time and then falls in to the section of the rack nearer the end of combine. In this way the straw moves step by step out of the combine.

Walker type straw rack: Some large combine may use a walker type straw rack which operates on the same principle as the rack. The straw walker has three or more narrow sections placed side by side. Each section is mounted on multiple throw cranks located at the front and rear. The crank throws for section are equally spaced around the circle of rotation thus the sections do not operate as a unit as one piece rack does.

Grain return pan: It is located under the straw rack. It catches the grain as it falls through the rack and moves forward to the grain pan.

Grain return conveyor: In place of grain return pan some combines will use a conveyor to catch the grain and move it forward.

Grain pan: The grain pan is located under the forward part of straw rake behind and below the cylinder. Its function is to catch the grain from the concave and cylinder grates and from grain return pan or conveyor for delivery to the cleaning unit.

Cleaning unit: The function of cleaning unit is to separate the clean grain and deliver it to the grain tank, return tailings to the cylinder for re-threshing, and move the remaining material out of the combine. This is accomplished by means of gravity and air blast.

Adjustable chaffer: The adjustable chaffer act as a sieve. It is made up of a series of cross pieces mounted on rods and fastened together so they can be moved at the same time to adjust the size of the openings.

Chaffer extension: This is an extension of chaffer having adjustable lips. The un-threshed portion of gain heads fall through the chaffer extension into the tailing anger.

Sieve: The sieve likes chaffer except that the lips and openings are smaller. The final job of cleaning is done here.

Cleaning fan: The fan furnishes a blast of air. The strength of air blast is controlled by wind board. The function of the air blast is to keep the material alive on the chaffer and sieve. The air blast should be strong enough to lift the chaff slightly off the chaffer and sieve, but not strong enough to blow grain out of the combine.

Tailboard: The tailboard keeps the un-threshed material from being carried out of the rear of the machine while still allowing the chaff to in blow cut. It may be raised or lowered as needed.

Material Handling: The grain auger collects the clean grain and angers it to the clean grain elevator which delivers the clean grain to the grain tank. Crop flow in combine is given in Fig. 8.

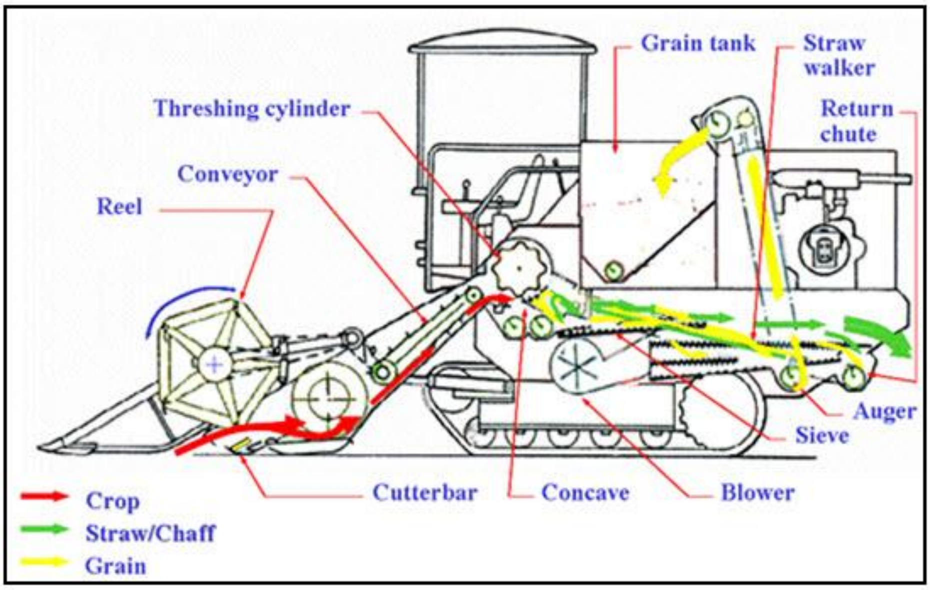


Fig. 8: Crop flow in combine

LESSON 12. GRAIN COMBINE LOSSES AND STRAW COMBINES

Grain losses before and during field operation of combine: There are different types of grain losses in the field before and during combining of crops. Moisture contents at the time of harvesting affects the grain losses. At low moisture content, grain losses are pre-harvest shattering loss, cutter bar loss and more breakage of grain. At low moisture the straw is broken finely by the cylinder and more material flows to the sieve resulting into separation problem. There is a risk of natural hazards like rain and hailstorm, which also leads to lodging of crop. Due to delay in harvesting, more weed growth takes place that causes choking of combine. At high moisture content, grains are badly damaged by the cylinder action. The threshing is poor and good cleaning is also a problem. This leads to higher cylinder loss and lower cleaning efficiency. The grains get struck to moist straw and are carried away with straw and chaff. There might be choking problem at different stages in the combine due to high moisture content. As per BIS the combine losses should be maximum 2.5% for wheat, paddy and gram and 4.0% for soybean (IS: 8122 Part II – 1981). Various combine losses (Fig. 1) are discussed below:

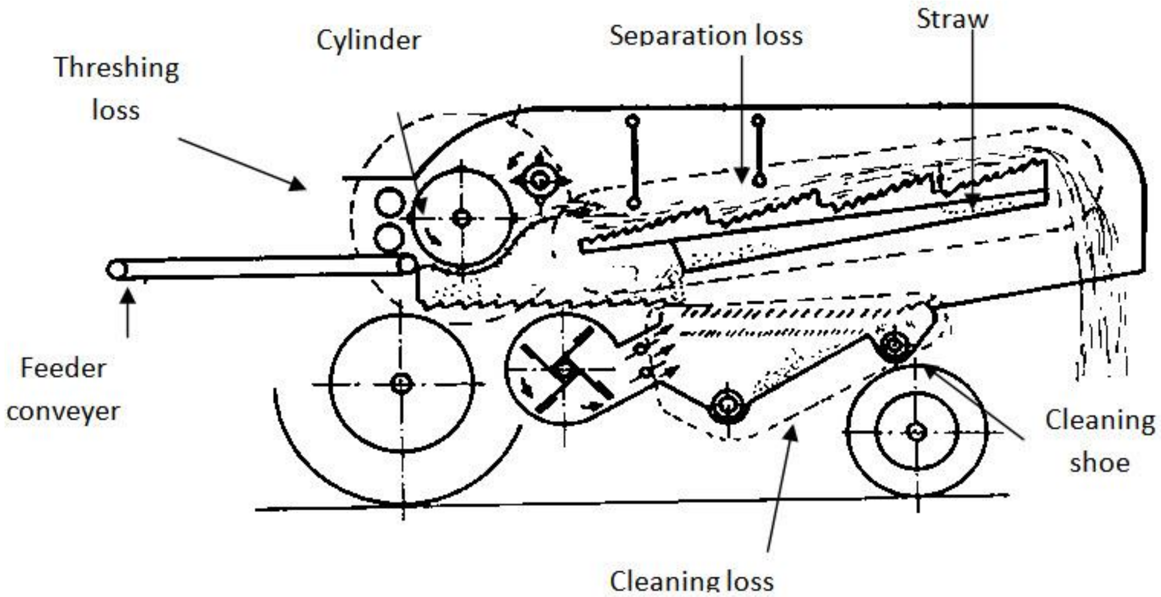


Fig. 1: Various combine loss sections on the combine harvester.

Pre-harvest loss: It is determined at minimum of three places randomly selected in the field where combine harvester is to be operated. The sample should be collected from the area having one-meter length in the direction of travel and full or half width of cutter bar of machine depending upon its size. All the loose grains, complete and incomplete ear heads fallen in the marked area have to be picked up manually without vibrating the plants before the machine is to be operated. This will give pre-harvest loss.

Header loss: It is determined on those portions of ground, which are protected from combine afflux by the use of rolls of cloth. The loose grains and complete and incomplete ear heads fallen on the marked area, where pre-harvest losses were determined, shall be collected manually. This gives the header loss. It is also called cutter bar loss.

$$\text{Header Loss (\%)} = \frac{\text{Grain collected from 1 m}^2\text{ area after harvest – grain Collected from same area before harvest}}{\text{Gross Yield}} \times 100$$

$$\textbf{Cylinder Loss (\%)} = \frac{\text{Unthreshed grain collected from straw rack \& sieve}}{\text{Gross Yield}} \times 100$$

Rack and shoe loss: For determining the rack and shoe loss, the straw and chaff afflux is collected separately. To collect these, two rolls of cloth 30 m in length and one and half times the width of straw/chaff outlet is suspended on especially attached fittings beneath the rear of machine. As the sheets of cloth unroll, one sheet retains the afflux from straw walker and other from sieve for 20 m run length. Unrolling operation starts 5 m in advance and terminates 5 m ahead of end point.

$$\text{Rack Loss (\%)} = \frac{\text{Free grain collected from straw rack sample}}{\text{Gross Yield}} \times 100$$

$$\text{Sieve Loss (\%)} = \frac{\text{Free grain collected from sieve sample}}{\text{Gross Yield}} \times 100$$

Grain crackage: It is determined from the samples taken from grain tank. Only visible damaged grains are separated and expressed in percentage of sample taken.

$$\text{Grain Crackage (\%)} = \frac{\text{Damaged grain wholly or partially collected from sample}}{\text{Gross Yield}} \times 100$$

Net Yield = Grain collected in the bag from combine test area.

Gross Yield = Net yield + header loss + cylinder loss + rack loss + sieve loss

Total combine loss = Cutter bar loss + cylinder loss + rack loss + sieve loss

$$\text{Performance efficiency, \%} = \frac{\text{Net yield}}{\text{Gross yield}} \times 100$$

$$\text{Unthreshed (\%)} = \frac{\text{Unthreshed grain in tank + cylinder loss}}{\text{Gross Yield}} \times 100$$

$$\text{Cleaning efficiency, \%} = \frac{\text{Clean grain}}{\text{Total grain collected from main outlet}} \times 100$$

$$\text{Threshing efficiency, \%} = \frac{\text{Threshed grain from all outlets}}{\text{Grain output in tank}} \times 100$$

Expected range of losses: Losses, with the best combine adjustments, will vary greatly depending upon the type's variety and the condition of the crop. Total losses in clean crop of wheat oats and barley will vary from 1% to 4% of total yield. Under good harvesting condition the total loss should not be more than 1.5%.

(i) Cutter bar loss - 0.5 to 2%

(ii) Cylinder loss - 0.5 to 1%

(iii) Rack loss - 0.2 to 0.4%

(iv) Shoe loss - 0.2 to 0.4%

The losses could be minimized by running the combine at proper adjustment. Setting and performance of different parameters are discussed below:

Cutting and conveying: The height of cut can be adjusted from 5 cm to 75 cm in most of the combines. The rate of feeding can be adjusted by manipulating height of cut and forward speed of machine. Forward speed range of 2.5 - 4.5 km/h for standing crop and 1 - 1.5 km/h for lodged crop has been recommended by ISI. The speed of cutter bar varies from 400 to 550 rpm.

Reel adjustment (ISI): The horizontal positioning should be such that real bats have a distance of 50 to 100 mm in front of the cutter bar. The optimum value of reel index should be 1.10 to 1.25.

Problem 1: A combine was tested for harvesting jowar and following observations were recorded:

Total area harvested = 78 sq. m.

Total time required = 65 seconds.

Total material left over the rack =18 kg.

Free seed over the rack =150 gms.

Unthreshed seed over the rack = 120 gms.

Free seed over the shoe = 530 gms.

Unthreshed seed over shoe = 150 gms.

Total material left over shoes = 8 kg.

Net grain collected in the tank = 34 kg.

Calculate:

1. Seed yield and total loss in kg/hectare.
2. Cylinder loss, rack loss, shoe loss and total grain loss as percent of total yield.
3. Total feed rate in kg/hour.
4. Rates of straw and chaff over the rack and over the shoe in kg/hr.
5. Percentage of straw and chaff retained by r4ack.

Solution:

1. Total area harvested = 78 m^2

Total seed harvested = 150 +120 + 530 +341 =34.95 kg

So, seed yield = 34.95/78 x 10^4 kg/hectare = 1480 kg/ha

Total seed loss = (34.95 – 34.0)/78 x 10^4 kg/ha

= 121.8 kg/ha

2. **Cylinder loss** is the un-threshed seed discharged from the rear of the machine, either in the straw or in the material from the cleaning unit.

Total un-threshed seed = (120 +150) = 0.270 g

Total cylinder loss = (0.270 x 100)/34.95 = 0.773%

Rack loss is the free threshed seed carried over the rack in the straw and discharged from the machine.

So, rack loss = (0.150 x 100)/34.95 = 0.429%

Shoe loss is the loss of free seed carried over the rack in the straw and discharged from the machine.

So, rack loss = (0.530 x 100)/34.95 = 1.518%

Total loss of seed = 150 m + 120 m + 530 m + 150 m = 950 g = 0.95 kg

3. Total material fed including seed and straw

= 18 + 8 + 34 = 60 kg

So, feed rate = (60/65) x 60 x 60 = 3320 kg/h

4. Over the rack total material is 18 kg. Out of which free seed is 150 gm and un-threshed seed is 120 gm. So, net weight of straw in rack is

= (18-0.15-0.12) kg = 17.73 kg.

Rate of straw over rack = (17.73/65) x 60 x 60 kg/h = 982 kg/h

Similarly net weight of straw over shoe = (8-0.53-0.15) kg = 7.32 kg.

So, rate of straw over shoe = (7.32/65) x 60 x 60 = 405 kg/h

5. Percentage of straw and chaff retained on rack

={ (18-0.15-0.12)/(17.73+7.32)} x 100 = 70.9%

Straw combine

Use of grain combines has helped in timely harvesting of cereal crops and saves from huge grain losses due to bad weather during harvesting period. But, it also results in loss of straw 'bhusa' which is used as cattle feed in most part of the country. After harvesting of crop by grain combine, straw and stubble left in the field are burnt by most of the farmers, which leads to loss of 'bhusa' and environmental pollution. Straw combine (Fig. 1) is a machine that cuts and collects the stubble left behind in the field after grain harvesting and converts both of them into small pieces of straw. The machine is pulled and powered by a 45-50-hp tractor. Self-propelled straw combines are also available. The 'bhusa' is collected in an enclosed trailer attached behind the machine.

The machine consists of stubble cutting unit, straw collecting unit, feeding unit, straw bruising unit and straw blowing unit (Fig. 2). Three different types of straw bruising mechanisms are used in straw combine viz. spike-tooth type, chaff cutter type and serrated saws type bruising mechanism. The major components of machine are reel, cutter bar, auger, feeder, straw bruising cylinder, concave, aspirator blower, sieves and gearbox. It has cutter bar reel, feeding auger and bruising cylinder like a traditional thresher. Straw thrown and stubble left by the grain combine is collected by straw combine and delivered to the cylinder-concave section, where it is cut into pieces and passed through the concave. A reciprocating cutter bar is used for reaping the standing stubbles and the portion of the straw left uncut by the combine harvester. Straw, which passes through the concave, is aspirated by a blower and fed into a trolley on rear side covered by a wire net. For recovering the left grains from the straw, a sieve system is provided below the concave. Working capacity of straw combine is 0.4 to 0.5 ha/h and it can make 'bhusa' between 1.5 to 2.5 t/ha. Weight of the machine is about 1700 kg. It can recover 55-65% of straw successfully as compare to the traditional method of threshing. The fuel consumption varied from 3.5-4 l/h. There is also a recovery of 75-100 kg of grain per hectare. Overall dimensions are:

Overall dimensions, cm	468 x 160 x 197
Power source	Tractor of 35 hp and above
Cutter bar width, cm	200
Threshing cylinder type	Cutter blade mounted on the cylinder
Blower size, cm	50 x 70
Concave opening, cm	1.27

Other features of machine are:

Speed of operation, km/h	4.0
Straw recovery, %	55 - 60
Grain recovery, kg/ha	30
Height of cut, cm	2.0
Quality of straw	Very good
Saving as compared to traditional method	
Labour requirement, %	60
Cost of operation, %	33

Fig. 2: A view of Straw combine in field with trolley attached.

Tractor operated straw reaper with storage box mounted above straw reaper for easy turning has also been developed (Fig. 3). It has hydraulically unloading device to unload 'bhusa' in the field or at storage place.

Fig. 3: Tractor operated straw reaper with storage box mounted above straw reaper.

MODULE 6. MAIZE HARVESTING AND SHELLING EQUIPMENT

LESSON 13. MAIZE HARVESTING EQUIPMENT, COMPONENTS, ADJUSTMENTS

Corn occupies the greatest area as a field crop and also acts as the important source of food. During 1920s mechanical corn pickers were developed with the adaptation of the tractor PTO to their operation. The first picker-Sheller was developed in middle 1930s. Then attempts were made to adapt the grain combine for harvesting the corn, which includes the feeding the entire corn plant into the machine. The early investigators concluded that corn can be shelled and cleaned with a combine but introduction of the stalks into the machine was the major problem. In 1950s rasp-bar cylinder was evaluated as the corn husker or the sheller, same problem of introduction of the stalks into the machine existed. The next step in the evolutionary process was to equip the combines with corn snapping units in order to leave the stalks in the field and introduce only the ears into the machine (Fig. 1). Following the development of acceptable corn heads, the popularity of grain combines for harvesting corn increased rapidly during 1960s. In 1970s approximately 70% of the corn produced in 5 of the principal corn-belt states in USA was harvested by combines equipped with corn heads.

The maize crop is harvested when the husk has turned yellow and the grains are hard enough having not more than 20 percent moisture. Ears are removed from the standing crop. Harvested ears are dried in the sun before shelling.

Fig. 1: Corn picker

The corn picker is a single or two-row machine equipped with snapping rolls to remove the ears from standing stalks. It replaces the slow and hard hand method of harvesting. The chains guide the stalks into throat between the downwardly revolving snapping rolls, which pinch and snap the ears from stalk. The ears then moved to elevator, which conveys them to trailer drawn either beside or behind the machine. The ears can also be snapped, husked and shelled in a continuous operation. Maize harvesters (corn picker) may be classified as:

a) Snappers

b) Picker-huskers

c) Picker-shellers

d) Grain combines equipped with corn heads

Three different types of machines are available for harvesting corn. The simplest machine snaps the ears from stalks and does not remove husk called **snapper**. **Picker-husker** is one that snaps the ears from stalks and removes the husk also. The most recent development is a machine that snaps the ears from stalks and shells in the field. This type of machine is called **picker-sheller**. Tractor-mounted and self-propelled corn harvesters are available in different sizes i.e. 2-row, 4-row and 6-row.

Snappers consist of all basic components plus an elevating conveyor to deliver the ears (mostly not husked) into a trailing wagon. The addition of a husking bed to remove the husks from the ears identifies the machine as a corn picker. A picker-sheller has a shelling unit instead of a husking unit. Sometimes these units are interchangeable. The shelled corn may be delivered to a trailing wagon or to a tank on the machine. When a grain combine is to be used for corn, a corn head is installed in place of the grain header. A corn head has the basic gathering and snapping components listed above (similar to a corn snapper) plus a conveying system to deliver the ears to the combine cylinder for shelling.

Both mounted and pull type pickers and snappers are available. Mounted units are mostly 2-row machines, whereas 1-row, 2-row, and 3-row sizes are common with pull type machines. Picker shellers are usually two row machines. Most 2-row machines have snapping-unit center distances of about 102 cm, but a narrow row models for 76 cm row spacing are available. Differences of 56 to 80 cm between the row spacing and the snapping-unit center-line distances are tolerable in 2-row harvesters.

There are many factors that affect the performance of corn pickers. They are plant characteristics such as variety, condition of stalks, height of ears, toughness of ear shanks, size of ears and thick and tight husk; mechanical factors such as type of snapping roll surface, clearance between snapping rolls, rate of travel and timing of snapping rollers. Timeliness of harvesting, weather conditions, cleanliness of field, row length and row spacing also affect the performance of machine. Field losses in snapping ears from standing corn stalks are largely attributed to lodging of stalks, date of harvest and rate of travel of machine. Losses increase when picking is delayed and rate of travel is increased but decrease as the moisture content of cob decrease. Fig. 2 gives the details of losses at various stages during the de-husking and shelling of maize crop.

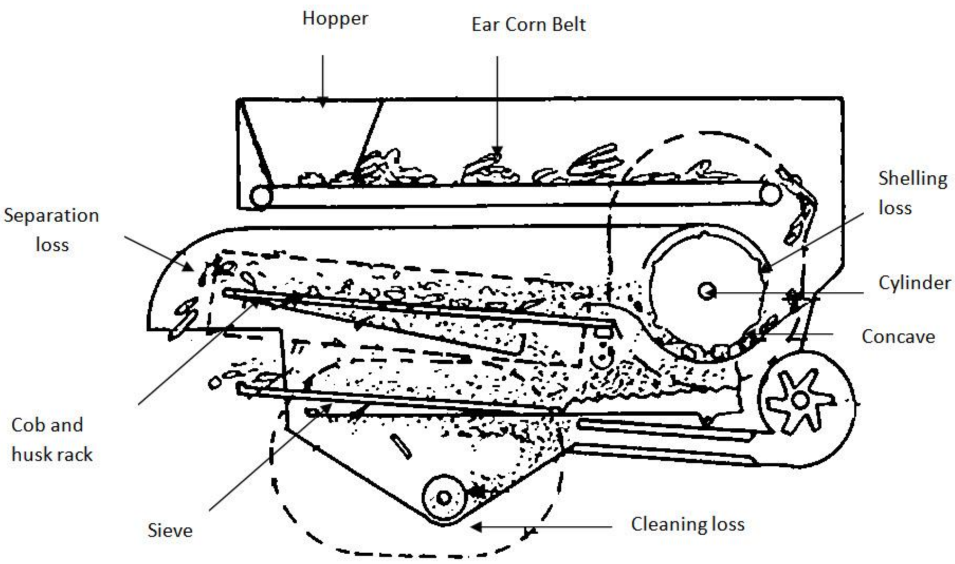


Fig. 2: Details of losses at various stages during de-husking and shelling of maize.

Shelling and cleaning in a picker-sheller

Although at least one model of picker-sheller has had a rasp-bar cylinder and concave as the shelling unit, most picker-shellers have axial-flow cage type shellers. A cage-type sheller has a rotating cylinder with lugs, spiral flutes, or paddles around the periphery. The cylinder operates within a stationary cage that is 1020 to 1420 mm long and 280 to 380 mm in diameter. The cage periphery is made of perforated metal or parallel round bars and has openings large enough to permit easy passage of shelled kernels but not the cobs. The cylinder is operated at 700 to 800 r/min and has a peripheral speed of 6.1 to 10.2 m/s.

Ears form snapping units are fed radially into an opening at one end of the cage and pass circumferentially and longitudinally along the cylinder during the shelling process. Shelling is accomplished primarily by rubbing and rolling of ears and cobs against each other and against the cage (concave) and the rotating cylinder. The length of time that the ears remain in the shelling unit can be varied, by means of an adjustable cob gate at the discharge end of the cage, to accommodate different crop conditions.

The shelled corn falls through the openings in the cage and is conveyed to the tank or wagon. Light trash is removed from the shelled corn by means of an air blast or with a suction-type fan. On some shelling units the material discharged from cage passes over a cleaning shoe for final separation of shelled corn from the cobs, husks, and other trash.

Functional components of corn harvester: The basic components for all types of maize harvester include a gathering unit to guide the stalks into the machine, snapping rolls to remove the ears from the stalks, and lugged gathering chains to assist in feeding the stalks into the rolls and moving the stalks and snapped ears rearward through the snapping zone.

Different units of maize harvester

a) Gathering units: It is relatively simple matter for gathering device control stalks and feed them into the snapping units when the stalks are standing. Unfortunately, many stalks become lodged (leaning or broken) during the season, due to adverse weather conditions, disease, and high plant populations. The gathering assembly must be able to lift lodged stalks and guide them into the snapping unit with a minimum number of ears lost during the process. This requires having pick up devices close to the ground and handling the stalks gently to avoid excessive accelerations and consequent detachment of ears.

b) Snapping units: Two general types of snapping rolls are employed. These may be described as spiral-ribbed or spiral-lugged rolls and straight-fluted rolls. Types have tapered, spiral-ribbed points to facilitate stalk entry, and both types pull the stalks downward between the two rolls. With spiral-ribbed rolls, the ears are snapped off of the stalk when the ears contact the closely spaced rolls. Straight-fluted rolls pull the stalks down between two stripper plates and the ears are snapped off when they contact the plates.

c) Trash removal: special trash rolls are often provided on corn pickers to remove trash and broken stalks not expelled by spiral-ribbed snapping rolls. Fluted sections may be incorporated on the upper ends of the snapping rolls. Transverse, fluted rolls are sometimes mounted at the discharge end of a snapper-ear conveyor. The principal function of the transverse rolls is to remove relatively long sections of stalk. Small blowers may also be used to assist in removing trash.

d) Husking units- The husking unit on a picker has pairs of rolls that grasp the husks and pull them downward between the rolls. Usually, all the husks are taken at once when one is caught. Most husking beds have either 2 or 3 pairs of rolls per corn row. The rolls may be in a separate husking bed at the discharge end of a conveyor from the snapping rolls and fed by snapping roll conveyor. With separate husking beds, there may be one per row or one per machine. Husking rolls are generally 64 to 76 mm in diameter and 760 to 1270 mm long. They operate at about 500 r/min.

LESSON 14. MAIZE SHELLER: TYPES, COMPONENTS AND WORKING PRINCIPLES

Harvesting and de-husking of corn (maize) is done manually. De-husking of maize cobs is necessary for use on shellers. Octagonal hand maize sheller (Fin type) is used for shelling of dehusked maize cobs, especially for seed purposes. It is manually operated (Fig. 1). It is a manually operated simple device to remove maize grains from the dehusked cobs. The sheller is of octagonal shape. The sheller consists of 4 mild steel fins tapered along their length, one edge of the fin is taper. In each fin, two holes are provided for riveting. Each fin is bent at two places in a manner for assembling in octagonal shape. The corners of the fins are rounded in order to avoid injury to the operator during shelling operation. The fins are joined together with rivets. The assembled sheller has thus four tapered projections inside the sheller body that accomplishes removal of the grain from the maize cob. In order to avoid corrosion, the sheller is powder coated which also increases its working life. For operation, the sheller is held in left hand and the dehusked maize cob in right hand (for right hand person). The cob is inserted in the sheller and is given forward and backward twist or given clockwise and anticlockwise strokes repeatedly. The tapered edges of the fins dig into the space between the rows of the grains in the cob and with the forward or backward stroke the grains are released from the cob. After grains are separated from one end of cob, the other end is inserted in the sheller to complete the removal of grains from cob. Due to the taper edges of the fins, which are projected inside the sheller body, one end of the sheller has larger opening and the other smaller. Therefore, for shelling the larger end of the cob it is inserted in the larger opening of the sheller and the smaller opening of the sheller is used for smaller end of the cob. Working capacity maize sheller is 15 to 20 kg/h and weight of the machine is 0.22 kg.

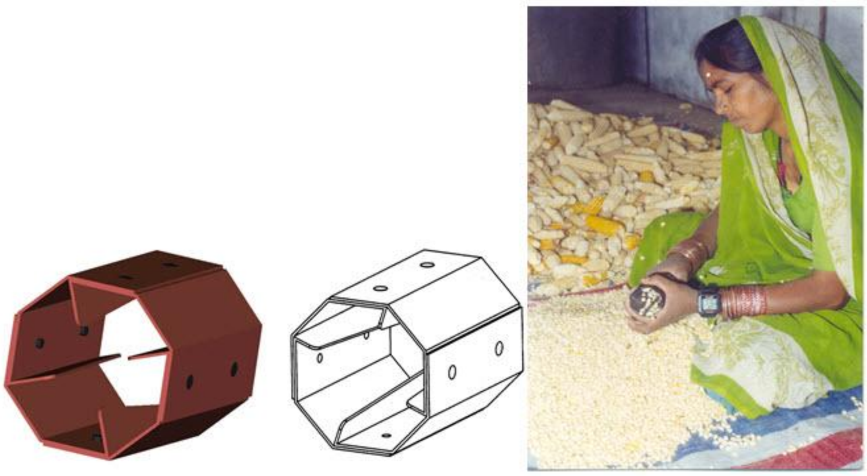


Fig. 1: Octagonal hand maize sheller (Fin type).

Maize sheller (Power operated)

Maize Sheller is used to separate grain from cobs. Before shelling, the foliage is removed manually. Maize shellers are either manually operated or power operated. A power operated maize Sheller uses 30-36 cm diameter cylinder of 80-100 cm lengths (Fig. 2). On the periphery of the cylinder, there are pegs that remove the grain from cobs using axial flow movement. The cylinder speed is maintained in between 500-600 rpm. The cob moves toward the end of sheller from feeding side and during this process grains are rubbed against drum and posses through the concave. Blower is provided to remove lighter material. Concave clearance and cylinder speed can vary and adjusted as per recommendation.

Maize shellers are used for all types of maize varieties local as well as hybrid and composites. Maize shellers are of two types' viz. spring type and cylinder type. Spring-type sheller consists a rotating fluted cylinder, a rotating disc and a spring pressure plate. The cobs are fed to rotating fluted cylinder and kernels are removed from cobs as they move in between cylinder and disc. Blower blow off the light material and clean grain is collected separately. These shellers are available in various sizes such as domestic shellers, single-hole and double-hole shellers. Domestic sheller is a hand operated and available with small farmer for shelling of small quantity of maize.

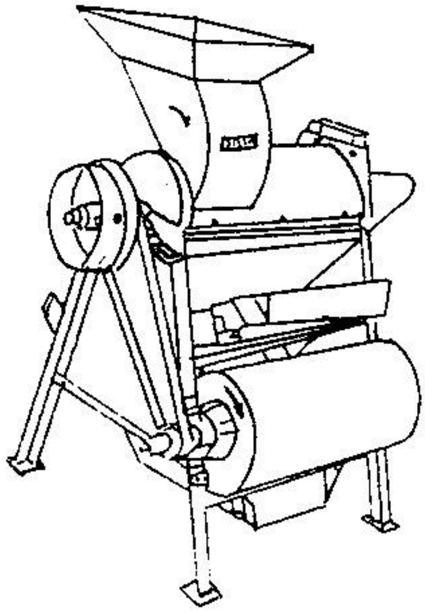
The cylinder-type sheller consists of a cylinder with lugs, concave assembly and a blower unit. Spiral ribs are provided in the cylinder for smooth movement of cobs. Cobs are fed in between cylinder and concave and kernels are removed by the action of lugs. Blower cleans the lighter materials and small pieces of cobs and clean grain is collected. The 5-10 hp electric motor or tractor can operate the machine. It can give output of 5-15 q/h depending upon the size of power sources and machine. Overall dimensions are:

Size of feeding hopper, mm	575x510
Length of drum, mm	890
Dia of drum, mm	305
Concave opening size, mm	11
Cylinder concave clearance, cm	1.6
Pulley size, mm	400

Other features of machine are:

Peripheral cylinder speed, m/s	11.2
Labour requirement to work on the machine	two
Blower speed, rpm	890
Straw grain ratio	5:1
Average feed rate, q/h	25
Average grain output, q/h	20
Grain losses, %	less than 1
Cleaning efficiency, %	more than 99
Threshing efficiency, %	more than 99
Grain crack age, %	0.5-1.0

Fig. 2: Maize sheller (Power operated).



Maize dehusker-sheller

The department of Farm Power & Machinery, PAU Ludhiana has developed two types of Maize dehusker cum threshers namely spike tooth type (modified version of wheat thresher) and axial flow type (modified version of sunflower thresher) for threshing the maize along with the husk. It is used for dehusking and shelling of maize cobs simultaneously. It is operated by a PTO of 26.1 kW tractors (Fig. 3). In the spike tooth type sheller, pegs are staggered at varying heights for better shelling efficiency. The spikes are placed in 6 rows with 6 pikes in each row. The sieves have 1.25 cm diameter opening to separate the shelled maize from husk. In axial flow type threshers, pegs are provided on the cylinder and louvers were provided on the upper periphery of the drum to convey the crop to the outlet. Working capacity of sheller is 15-20 q/h. Weight of the machine is about 600-700 kg. Shelling efficiency is about 100% in both the cases and broken grains are maximum up to 2.0%. Dehusking-cum-shelling saves lot of labour in comparison to traditional system. Performance results of the machine are given below.

S. No.	**Parameter**	**Observations**
2	Grain straw ratio	4.2
3	M.C. of grain, %	12.1-18.5
4	Cylinder speed, rpm	670-750
5	Broken grain (%)	1-3
6	Un-threshed grain (%)	0.74
7	Threshing efficiency (%)	98-99.5
8	Cleaning efficiency (%)	90-95
9	Grain output capacity, q/h	4.5-6.5
10	Blown kernal, %	1-3
11	Labour requirement, man-h/ha	5
12	Labour saving in comparison to traditional shelling, %	50-60

Fig. 3: Maize dehusker-sheller during operation.

Whole crop maize thresher

A whole crop maize thresher (Fig. 4) has been developed at MPUAT Udaipur with the objectives to do the shelling of maize cob and simultaneously stalk is converted to chaff. A tractor operated multi crop thresher was also modified with arrangement so of spikes on threshing cylinder and concave made of 8 mm square bar with 19 mm spacing. The output of grain was observed as 710 kg/h with chaff size of 16 to 63 mm. This chaff was fed to the animals and 85% material was consumed in comparison to the whole stalk. The significant saving in labour was found for detachment of cobs and transportation of crop from field to home. The threshing efficiency was 99% and cleaning efficiency 96.4%.

Fig. 4: The whole crop maize thresher during operation.

Tractor-drawn combines with suitable adjustment can be used for de-husking and shelling of maize in stationary operation. The following adjustments can be made in the combine before using for maize shelling:

(i) The drive to cutter bar should be disconnected and reel removed for easy feeding of maize ears.

(ii) Rasp bar cylinder used for wheat threshing should be used for maize threshing. The speed of the cylinder may be kept between 500-600 rpm as compared to 900 rpm for wheat.

(iii) Cylinder-concave clearance should be around 25 mm for maize threshing.

(iv) The sieve in the cleaning shoe should be replaced by large size hole (approximately 12.5 mm).

(v) If the combine does not have a grain tank, grain should be collected directly from the chaffer to avoid grain damage. However, if the grain tank is provided no such change is necessary.

(vi) There should be at least two canvas screens on the straw rack/walkers. One screen is normally provided at one-third distance in the first portion. The second screen should be provided at one-third distance from the rear. This is necessary to avoid grain losses.

The combine, if modified as above, can be used for de-husking and shelling of maize cobs satisfactorily at cylinder speed of 575 rpm and cylinder-concave clearance of 20 mm. The capacity of machine ranges between 2.0-2.5 t/h at a feed rate of 3.0-3.5 t/h. Cylinder and shoe (including rack) losses are 1.5% each and grain crackage about 2%.

MODULE 7. ROOT CROP HARVESTING EQUIPMENT

LESSON 15. ROOT CROP HARVESTERS FOR POTATO, GROUNDNUT-DESIGN CONSIDERATIONS

Classification of Root Harvesting Equipment

The root harvesting equipment can be classified in several different ways as described below:

A. According to the source of power:

i) Manual operated, viz. hand tools and digging aids such as spade, khurpa, digging and picking fork etc.

ii) Animal-drawn equipment such as potato-plough, animal drawn groundnut digger etc.

iii) Tractor operated equipment such as spinner-digger, elevator-digger, groundnut-digger-shaker-windrower, sugarbeet-harvester, carrot-harvester, radish-harvester etc.

iv) Self-propelled machine such as potato-harvester/combine, groundnut combine, sugarbeet harvester etc.

B. According to the mode of hitching:

i) Trailed type

ii) Mounted type

iii) Semi-mounted type

iv) Self-propelled type

C. According to the unit operations performed:

a) Simple digger

b) Digger-shaker

c) Digger-elevator-windrower

d) Digger-shaker-conveyor/digger-shaker-windrower.

D. According to completion of operation:

i) Direct harvesting equipment, i.e. equipment which accomplishes the complete operation of digging and separating to the soil as well as of collecting the recoverable products in one 'go'.

ii) Indirect harvesting equipment, i.e. equipment which accomplish the complete operation in more than one passes. For instance, a groundnut digger shaker windrower digs the vines and deposits them in a windrow after shaking out the soil. The vines are sun-dried for a few days and thereafter a groundnut combine with a pick-up attachment is used to pick the vines and separate the nuts.

Considerations for proper field operation of root crop harvesting equipment: Following are some of the general considerations for efficient utilization of the root harvesting equipment:

(i) Proper field layout

(ii) Proper planting method

(iii) Proper moisture content at the harvest time

(iv) Pre-harvest treatment such as haulm-cutting, vine-killing etc.

(v) Proper adjustment of the depth of the digging.

(vi) Proper hitching of the machine.

(vii) Proper adjustment of the speeds of the picking, conveying and shaking system

(viii) Selection of desired forward speed in keeping with the field and crop conditions.

(ix) Number of workers in the crew to pick and collect the material simultaneously.

(x) Matching of the transport and handling equipment to the capacity of the digger/harvester.

(xi) Proper harvesting, maintenance and repairs of the equipment.

General design considerations for root crop harvesting equipment: For designing a root crop harvesting equipment, the following points should be kept in view:

a) **Variety of the crop and its cultural practices**: In case the existing varieties and cultural practices pose some problems in mechanical harvesting, attempt should be made to make necessary modifications.

b) **Soil Type**: The soil type and moisture content at the time of harvesting are important factors influencing the machine performance. Suitable soil-amending substances may help to develop the proper soil-texture to eliminate problem of excessive blade clogging and clod-formation. The soil for root crops should be friable for easy separation.

c) **Method of Irrigation:** One must carefully consider the method of irrigation being followed. Depending upon where the crop is sown on ridges/beds/flat surface, proper method of irrigation should be selected. The availability of right moisture content at the time of harvesting is very essential for proper penetration of blade and efficient soil-fragmentation.

d) **Machine design considerations:**

(i) Type of the digging shovel, shape and size.

(ii) Conveying and separation system. It must be efficient to handle and separate the loose material with minimum injuries.

e) **The height of fall**: Avoid excessive height of fall of the roots/tubers to lesson injuries. If required use inside rubber padding at the components to minimize external/internal injuries.

f) **Proper speeds**: The speeds of the components used for the translocation and separation of the material should be such that these do not lead to excessive agitation, damage and loss of the products.

g) **Controls:** The various controls for raising and lowering of the blade, varying speeds, etc should be carefully designed. Provision should be made for adjusting the speed of the components in accordance with the field conditions.

(h) Use of Multi-speed gear box and vary-speed drives is desirable on root crop harvesting machines.

Operational design considerations: Design requirements of the root crop harvesting equipment should be as follows:

(i) The digger should cut the vines below the tuber zone, say at a depth of 7 to 10 cm, lift all vines, shake off the soil and put them in a windrow in single operation.

ii) Desired penetration of the blade should be possible at the working moisture contents of the soil.

iii) The digger should work with a seasonable overall efficiency for both erect and spreading varieties.

iv) Pod detachment losses for the existing varieties should be reasonably low.

v) It should be possible with a tractor of 30 hp or more.

vi) It should be mounted type for easy transport and better operational manoeuvrability.

Types of Blades used: Three types of blades are usually used in the diggers. Half sweep types blades are sometimes not used as the flow of material is not smooth and some undug plants are also left. The single piece curved blade is commonly used in the diggers.

Adjustments & method of working: Before working the machine, necessary adjustments should be made. The depth of penetration of the blade is adjusted with the help of the gauge wheels and by lengthening or shortening the top link of the tractor. Normally, a depth of working of 7.5 to 12.5 cm or about 4 cm below the pod zone is adequate.

The front end of the shaker conveyor should be adjusted with the help of a hand lever, so that the spikes on the cross bars do not go too deep in the soil. These should comb the top about 3 cm of the soil. Precautions should be taken not to run the teeth deeper than necessary as it increases the load on the shaker conveyor and makes separation of the soil from the vines more difficult. Forward speed of the tractor should be kept between 2.5 to 3 kmph. Speed of the shaker conveyor should be about 10% more than the forward speed of the tractor to clear the harvesting stuff quickly without accumulation. After making necessary adjustments, the machine should be operated in the field. For better efficiency and output, it is necessary that the machine should be operated along the length of the field, which should also be the direction of the rows. The size of the fields should be kept as big as possible.

LESSON 16. POTATO AND GROUNDNUT DIGGERS

Potato-Digger

Potato cultivation, especially on large size farms, has got mechanized because; it was not possible to handle the labour intensive operations like sowing and harvesting. Manually harvesting of potatoes requires about 800 man-h/ha, which is quite a labour intensive job. However, potato-digging operation has been mechanized with the introduction of potato diggers. The machine may be manually operated or power operated such as animal-drawn potato digger (Fig. 1), tractor-drawn potato digger (Fig. 2), potato digger shaker and potato digger elevator (Fig. 3). The potato digger elevator consists of a shovel, rod chain conveyor, gearbox and two gauge wheels. The machine digs one or two ridges of potatoes at a time and picks up the soil-potato mass over the rod chain conveyor. Agitating sprocket, of this conveyor oscillates the rod chain and separates the soil. The tubers with no or very little soil drop out on the ground in a row behind the machine, which are later collected manually. These machines are commercially available and are used widely in the northern states of India. Most of these machines are 2 row machines, but 1-row and 2-row both types of diggers are also available. The machine can cover 1.5-3.0 ha/day at forward speed of 2.0-3.0 km/h. Potatoes are easily bruised or skinned but are less susceptible when fully mature than when immature.

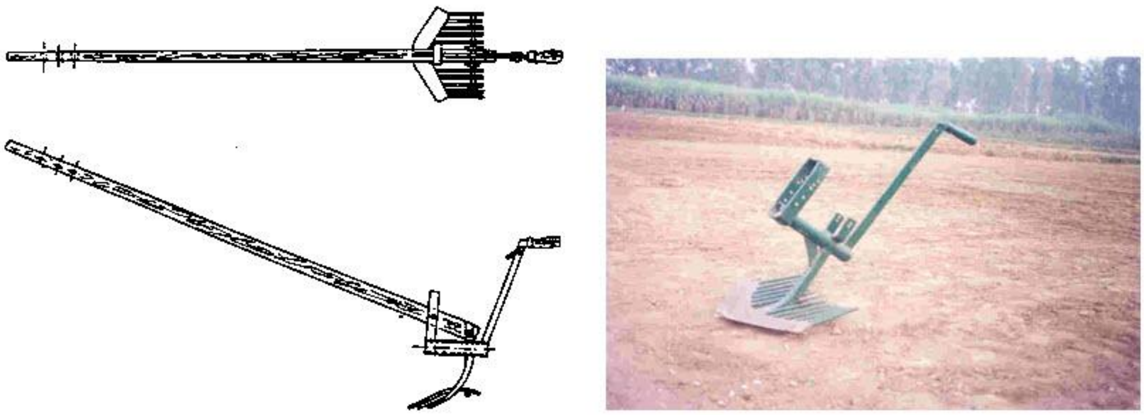


Fig. 1: Animal-drawn potato digger.

Fig. 2: Tractor-operated 2-row potato digger.

Fig. 3: Tractor-operated single row potato digger elevator.

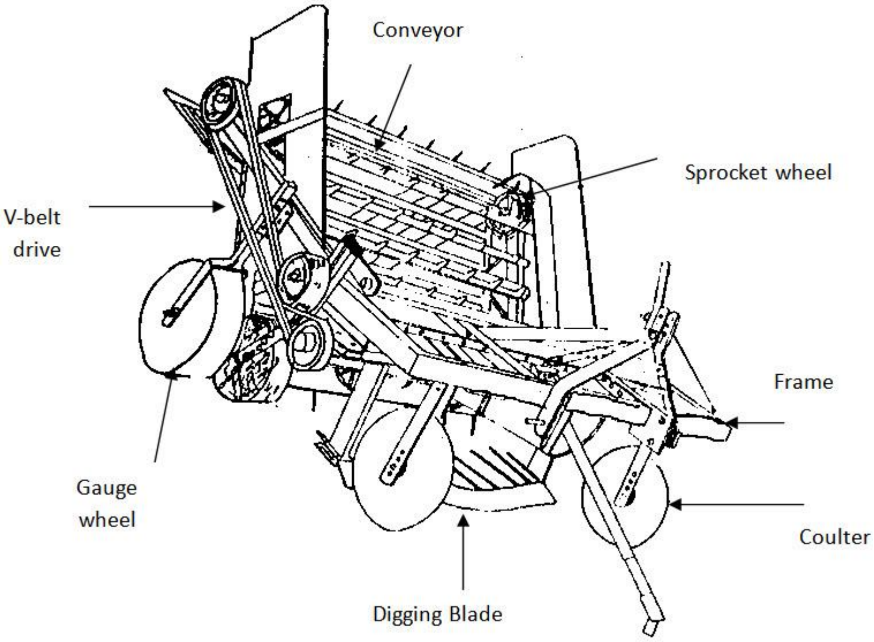
Groundnut digger shaker

The combination digger shaker comprises of single piece curved blade with extension rods welded at the rear, two disc coulters and an endless chain type pick-up elevator-cum-shaker conveyor (rattler) having spiked rakes bolted to the chains. Power transmission of the digger consists of a gear box, a cross drive shaft, V-belt & pulleys and driving sprockets mounted on a shaft supported over members of the frame. Blade, shanks, coulter forks and gear box are all clamped to a rectangular tool bar to which are also welded two inclined side members on which the sprocket drive shaft is supported. Roller chains of the shaker conveyor are supported over two idler sprockets at the front end. Gauge wheels are also provided to adjust & maintain the desired working depth. Front portion of the shaker conveyor can be adjusted up or down with the help of a hand lower chain. The width of cut is 1.22 m.

Principle of operation: The blade digs the crop from a 1.2 meter wide strip. The vines are picked up and lifted by the shaker conveyor that follows blade. The soil adhering to the roots and pods is shaken off at the conveyor and the vines are dropped at the back in the form of a fluffy windrow. The vines are laid up-side down, thus exposing the pods effectively to the sun. After one or two days sun drying the vines are gathered manually and hauled to a central place for threshing. In foreign countries, a combine is used for these operations.

Tractor PTO operated groundnut digger shaker is quite popular in northern India far harvesting groundnut. The machine consists of a blade, elevator-cum-pick up reel, power transmission system, windrower attachment and fenders, gauge wheels and coulters (Fig. 4). The front end of pick up-cum-elevator reel is adjustable in accordance with depth of working of blade. It digs out the plant along with groundnut. The material is moved over the conveyor; the soil is loosened and removed. It has been designed to suit a tractor of 30 hp or more and is being operated by PTO shaft of the tractor. The digging shovel may be either of pointed type or conveying cutting edge type. The width of digging shovel ranges from 50-60 cm. This machine has an average output of 0.27 ha/h. The forward speed of digger is kept between 2.4-3.0 km/h. In order to pick and gather the tubers dropped in a windrow behind the digger, nearly 10-12 workers are required for continuous working of the digger.

Groundnut digger blades with corrugated roller at rear (Fig. 5) are also used in medium and heavy soils where the corrugated roller helps in crushing the clods. This helps in easy picking of groundnut tubers. Another simple groundnut digger blade (Fig. 6) is also used in light soil where clod formation is not much. Loose soil falls through the extension rods behind the blade and groundnut tubers are left over the soil for easy picking and gathering.



(a) An isometric view of groundnut digger shaker.

(b) Groundnut digger shaker.

Fig. 4: Tractor-operated groundnut digger shaker

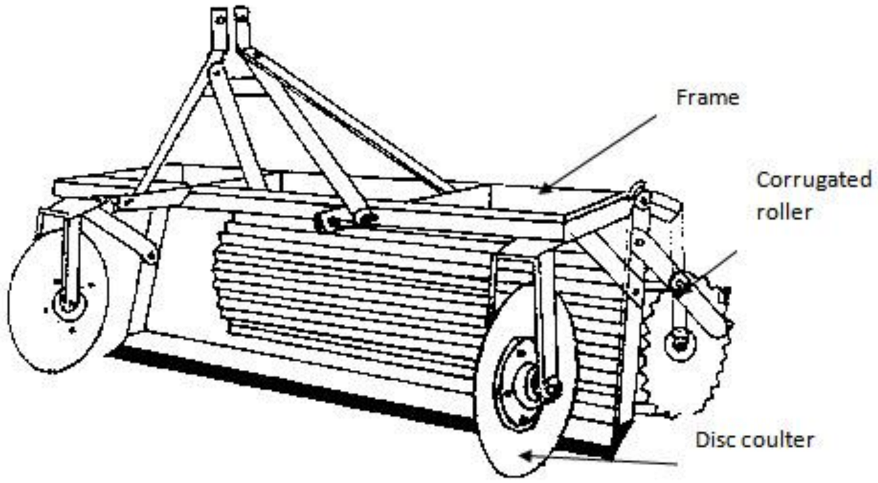


Fig. 5: Tractor operated groundnut-digging blade with corrugated roller.

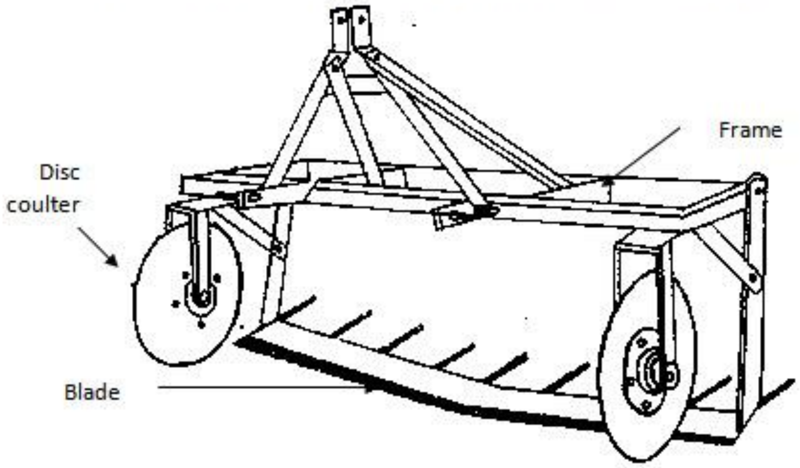


Fig. 6: Tractor operated groundnut-digging blade.

LESSON 17. GRADERS AND ROOT CROP COMBINES

Grading machinery

Grading of size and quality is an essential for the marketing of fruits and vegetables. Sizing machines may be grouped broadly into two based on diameter and based on weight. Machines, which grade by diameter, vary in design and size. It gives higher output than the machine grade by weight. Roller feed conveyor is used for quality sorting of fruits/vegetables. A good weight grader has many advantages. It can be used for any shape, easily adjustable and can be used for crops that are easily blemished. Grading by weight can be more accurate than grading by diameter.

Grading refers to quality separation of food product. The term 'quality' has different conditions for different commodities and relative importance of the component material properties. Actually, grading involves overall balanced assessment of all those properties of a material, which affects its acceptance as a food product and as working substance for the processor. Mostly, grading involves simultaneous evaluation of multiple properties which makes complexity in mechanical grading and hence manual grading is preferred. The separation may be based on size, shape, colour of the food product, which is done to make different qualities.

Grading method: In general the properties of food product which determine its quality may be shape, size, maturity, texture, flavour, and colour and contaminants. Grading may be done manually or with the help of specialized machines, which are discussed below:

Manual grading: Most of the grading of fruits, vegetables, eggs or such food product is carried out manually. The grader forms a balanced judgement of the overall quality and physically separates the food into quality categories. Apples may be graded using colour cards making various grades in terms of proportion of the surface showing characteristics of fruit colour, extent of rusting, surface imperfections etc. Cherries are compared against models made from spheres of plastic, fitted with nylon stems. Eggs are graded manually by candling. It is a non-destructive test of egg content. In this type of test, the translucent shell of the egg is spun in front of a powerful light in a darkness booth. The presentation of each egg is automatic and candling operator can separate several thousand eggs in one hour into 3-4 grades.

There are some disadvantages of manual grading. It is a labour intensive job, which requires a lot of labour to grade fruit and vegetables. But still most of the grading of fruits like, mango, orange, kinnow and vegetables are done manually in India.

Machine grading: Grading machines are available for cereals and fruits and vegetables separately. Machine grading for cereals is of two types viz. rotary screen grain cleaner and grader and spiral separator.

Grading machines for fruits and vegetables: There are four types of grading machines for fruits and vegetables. They are screens, roller grader, and diverging belt grader and weight grader.

Screens: There is variety of fruits and vegetables which are graded with the help of vibrating screens made of copper, stainless steel or plastic, which do not react chemically with the products. The material to be graded is passed over to the vibrating or rotary screen. This screen is perforated to pass the smallest material at the beginning then medium and lastly the largest material. In this way, it makes different grades of fruits like, apple, orange, kinow, and vegetables like potato, tomato etc. The material that passes the top of the screen can be rescreened, and the new fractions can be derived.

Roller grader: This type of graders is fast, accurate and causes little damage to fruit. These are extensively used in fruit industry. Each roller rotates in a counter clockwise direction. The fruit is continuously rotated so that each piece has an opportunity to register its minimum dimension with the space in the grader. Roller conveyers with fixed space between the rolls are used for removing small fruit, twigs and leaves.

Diverging belt grader: It is widely used grader, which consists of two belts. These belts diverge as they move. The fruit is carried on and between the belts. Since the distance between two belts increases gradually and systematically, the smaller pieces will drop between the belts at the beginning of travel whereas the larger pieces will be carried further and will be dropped later.

Weight grader: The grading is also done on the basis of weight of product. This method is accurate, fast and there is minimum damage to fruits or vegetables. This can be used for large size products like apples, oranges, kinnow, mango, potato, tomato, eggs etc. These are specially adapted for sorting material, which cannot be handled by other methods, due to their texture or shape. The material to be graded is placed in individual cups through automatic feed, which is then passed through the sorter where it gets indexed with the help of spring loaded trips. The spring tension is progressively weaker from beginning to end of movement. The heavier fraction discharge in the beginning whereas lighter fraction next and lightest at the end. This type of grading is not dependent on shape or size of material.

Expanding pitch rubber spool potato sizer: It consists of two driving rollers with helical grooves of progressively increasing pitch that moves the rods with rubber spool. The advantage of such mechanism is that as many grades of potatoes can be obtained as desired. The rods are carried together with two link chains and rubber spools are carried on them. Wrapping a mild steel strip of varying thickness over a GI pipe makes the expanding pitch helix. The length of sizing bed is 1.83 m to provide three sizing bed of 0.61 m each or four sizing bed of 0.46 m each. The frame is made up of angle iron sections and is designed to support two parallels running driving helix on the sides, an endless sizing conveyor and an arrangement to drive the sizing conveyor (Fig. 1). Two conveyors i.e. elevator feed conveyor and intermediate receiving conveyor convey the material from the receiving end and discharge it to the sizing conveyor. An inclined collecting platform facilitates the flow of material. The portions of platform can be adjusted to suit the requirements of different grades of potatoes. The machine can be operated by one horsepower motor and can grade 2-3 tonnes of potatoes in one hour. The mechanical damage to tubers is negligible.

Fig. 1: Expanding pitch rubber spool potato sizer.

Root crop combines

Self-propelled potato combines are also available commercially for harvesting of potatoes. The machine consists of a pointed blade to split the ridge, an elevator conveyer to lift the material and shake off soil, agitator sprockets to provide adequate agitation to material being carried over elevator conveyer, a rotary cage wheel for elevating and cleaning of tubers and bagging platform. It can dig the potato tubers, separate, clean and fill in the bags in one operation. It can cover about 0.6 ha/day. Losses are very heavy with this machine and ranges from 15-20% or even some times more. Potato tubers harvested at lower soil moisture suffer less damage than those harvested at higher soil moisture. Also potato tubers harvested in sandy loam soil suffers less damage as compared to those harvested in heavy soils.

MODULE 8. COTTON PICKING AND SUGARCANE HARVESTING EQUIPMENT

LESSON 18. COTTON PICKERS, CONSTRUCTION AND WORKING PRINCIPLES

Manual harvesting/picking of cotton is quite labour intensive operation. It requires 2-3 pickings and sometimes even more. Mechanical harvesting of cotton is widely used in USA, Russia, Egypt etc. There are two type of mechanical harvesting equipment popularly known as cotton pickers and strippers. Both these types of machines require the cotton variety with compact sympodial or semi-sympodial plants with synchronized boll opening.

Mechanical Pickers: The cotton picker performs the work of hand picker in that only the locks of seed cotton are removed from the plant. There are four ways of classifying cotton pickers. They are by method of mounting, by number of rows harvested, by height of picking drums and by type of spindle used. It can be tractor mounted machine (Fig. 1) or self-propelled (Fig. 2) of one or two-rows. In this, the cottonseed is removed from open bolls; whereas, green and unopened bolls are left on the plant to mature for later picking. A mechanical picker consists of a device to guide cotton plants to come into picker, device to remove cottonseed from open bolls; a conveying system for picked cotton and a storage basket. These machines should be capable of gathering mature cotton with a minimum of waste and without causing serious damage to the fiber plant and unopened bolls. The high yielding, long fibers and open-boll varieties of cotton are defoliated before the first picking.

Functional components of a mechanical picker

Following are the basic components of a mechanical picker

i) An arrangement for guiding the plants into the picking zone and providing necessary support while the seed cotton is being removed.

ii) Devices to remove the cotton from open bolls.

iii) A conveying system for picked cotton

iv) A storage basket or a container in which picked when is stored temporarily.

Spindles: The basic principle of a revolving spindle penetrating the cotton plant, winding the seed cotton from the open boll and retreating to a doffing zone is employed by all commercial pickers. The rearward movement of the spindles while in the picking zone is substantially the same as the forward movement of the machine so that the spindles do not move forward or backward with respect to the cotton plant. Each rotating spindle merely probes straight into the cotton plant from the side of the row, works on an open boll and then withdraws straight to the side with a minimum disturbance and damage to the remaining plant. The spacing of spindles (1½ x 1½) is such that they can slip past unopened boll and leave them onto the plant to mature for a later picking.

Drum type spindle arrangement: The mechanical cotton pickers have either tapered spindles or small-diameter straight spindles. Spindles are carried either on bars arranged in vertical drums or on vertical slats attached to endless chain. Tapered spindles, commonly employed on drum-type pickers, have 3 or 4 longitudinal rows of sharp barbs for engaging the cotton bolls. Tapered, barbed spindles enter the plant perpendicular to row and wound the exposed lint on the berbs. As the spindles passes slowly, faster rotating rubber-faced buffers remove lint. Speed of spindle varies from 1850 rpm at forward speed of 2.9 km/h to 3250 rpm at 5.0 km/h. Speed of spindle influences the picking efficiency for fluffy bolls and increases from 80% at 700 rpm to 95% at 2300 rpm. The loss at higher speed is mainly due to cotton thrown by spindles and loss at lower speed is mainly due cotton left in burs. Straight spindles are longer than tapered type but smaller in diameter. They may be round or square and may have smooth or rough surface. In general, picking ability of pickers depends upon the spindles being wet when they come in contact with cotton. A stationary cam and followers on the bar achieve the proper orientation of spindle bars in relation to crop row. The two drum picks up from the two sides of the row in succession spring loaded adjustable pressure plate opposite each drum crowds, the plants towards the spindle in the picking zone. In current high drum machines the front drum has 15 or 16 spindles bar and rear drum has 13 or 12 bars, with 20 spindle per bar. This gives a total of 560 spindles per row of cotton, each spindle requiring a precession fit sleeve bearing and being driven through the bevel gear by a shaft inside the spindle bar. They are suitable for low growing or medium height cotton. The proper orientation on the spindle bar in relation to row is obtained by means of a stationary cam and a follower in the bar.

Chain belt spindle arrangement: The picking process with a chain belt unit is essentially the same as with the drum type picker although the chain belt principle permits the spindle to remain in picking zone for a longer time. The spindle is normally straight. The standard-height-picking unit has 80 vertical slats each with 16 spindles. High units have 22 spindles per bar. Each spindle is rotated by means of a roller in contact with a stationary, rubber drive rail, but only while on the picking side of unit. Guide strip hold the chain in position between the main sprockets and provide a curvature for moving the spindles laterally into and out of row. Each slat is pivoted between the upper and lower chains. While the spindles are being rotated, the action on the drive rails maintains the spindle in a position normal to curvature of the drive rails.

Spindle moistening: Spindle of either type are moistened with waters for two reasons:

a) As an aid in picking because of cotton adheres better to a wet steel surface.

b) To keep spindle clean as some gummy substances stick while these are in picking unit. Some wetting agents are also used which reduces the amount of water required for moistening and at the same time makes it more effective.

A spindle moistening system is provided for each picking unit, water being metered in equal amount to each spindle. Application is made to each spindle just before it enters the taking zone, by means of a specially designed rubber wiping pad. Water is applied to each spindle just before entering the picking zone by means of a specially designed rubber-wiping pad. The seed cotton is removed from spindles by means of rotating doffer plates. The clearance between surface of spindle and rubber lugs on the doffer should be 0.25-0.75 mm. A pneumatic conveying system is used to move the cotton from the doffing area to storage basket on the picker. The cotton is blown through the discharge ducts against cleaning grates in the basket lid and during this process some of the trash from seed cotton is removed.

Removal of cotton from the spindle: On machine with tapered spindle, the seed cotton is removed from the spindle by means of rotating doffer plates. The cotton is forced off as the dogger lug moves over the spindle surface toward the tip. With small diameter straight spindles stripping is accomplished by moving the spindles axially through the space between the closely fitted stripper shoes. Tapered spindles are rotating when doffed, whereas small diameter straight spindles are not.

Conveying and carrying: A pneumatic conveying system is used to move the cotton from the doffing area to storage container. The cotton is blown through the discharge duct against cleaning grate in the storage basket lid. This action removes some of the trash from the seed cotton. Machine with dual picking unit have 2 separate elevating systems to provide more uniform and positive conveying from each unit. Some machine use off set arrangement to eliminate contact between the cotton and the fan blades. Storage basket is ordinarily carried on picker with capacities generally in the range of 900 to 1300 lbs for single row machine and 2000 to 3300 lbs for 2 row units. Basket is emptied by with hydraulic cylinder.

(a) Mechanical picker in operation

b) Unloading of mechanical picker

Fig. 2: Self-propelled mechanical cotton picker. (Courtesy: M/s John Deere)

Performance of cotton pickers: There are many factors that affect the performance of cotton pickers. Cotton pickers perform best when cotton plants are of medium size. Medium-sized plants flow through the machine and permit the spindles to engage the cotton better than large plants with many long limbs. The machine requires a well-opened boll with locks that are fluffy and fiber that is long enough to wrap around the spindle. Chemical defoliation is generally done before the picking operation, which helps the simultaneous opening of most of the cotton bolls. A delay in picking and early opening of cotton boll result in atmospheric damage to the exposed cotton fiber. A slight elevation of the soil at the base of plant and weed-free fields are essential for better performance of cotton pickers. Fairly thick and uniform spaced plants aid the performance of mechanical cotton picker.

Manually-operated Cotton Picker: Manually operated cotton picker using an endless chain with picking fingers has also been developed. The device is carried by operator and can remove 90-95% of cotton lint. As much as 2% of cotton lint is dropped on the ground. It can pick up to 18 kg/h of cotton lint with trash content of 18.5%.

LESSON 19. COTTON STRIPPERS, CONSTRUCTION AND WORKING PRINCIPLES

Cotton stripping machines are "once over" machines. In the stripper, all bolls whether opened or closed are removed from the plant in a single pass. Harvesting with a stripper is, therefore, usually delayed until the plants shed their leaves. Chemical defoliants are also some times applied to permit earlier stripping. An ideal variety for this type of machine is one with semi-dwarf plants with relatively short fruiting, short-nodded branches, storm-resistant bolls borne singly but having fairly fluffy locks for good extraction (stripping) and medium sized boll-stem. Stripping a variety that produces a widespread plant with numerous vegetative and fruiting branch results in low recovery of cotton and excessive field losses.

Cotton stripping machines are of single steel roller, double-steel roller or finger type. Double-brush nylon rollers used in place of steel rollers gives better performance. A plant population of 75-125 thousands per hectare in 1.2 m rows is commonly recommended for stripping harvesting. The double-roll cotton stripper may be centrally mounted on the tractor or it may be self-propelled. There are three different methods of conveying cotton from stripping unit viz. finger-beater rolls, augers and air. The finger-beater rolls are used with finger-type strippers. Auger-type of conveyer is suitable for roller-type strippers. Much dirt and trash can be screened out of the cotton through openings in the housing under the conveyers particularly where revolving beater conveyers are used.

Mechanical strippers

There are several factors that have contributed to popularity of strippers in preference to pickers. These are:

i) Lower initial investment & maintenance cost

ii) Better adapted to improved cotton varieties

iii) Improved ginning equipment for separating trash

iv) Trend toward closer row spacing

v) Good recovery of cotton in the field

vi) Higher harvesting speeds

vii) Suitable for picking and cotton suitable for stripping. Stripping a variety that produces a wide, spreading plant with numerous vegetative and fruiting branches results in low recovery of cotton and excessive field losses.

Varieties for narrow row planting should have the general characteristics indicated above for conventional row strippers varieties. However because of higher plant population fewer bolls per plant are needed to produce a given yield. Cotton bolls exhibiting too much of storm resistant characteristic although well adapted to striping are difficult to pick mechanically. The size of plant, the type of growth and the nature of the boll all have more influence on the efficiency of the mechanical picker than does yield. Where the plant characteristic are suitable, a machine will pick up high yielding cotton just as efficiently as it will low yield cotton.

Performance of mechanical cotton strippers: There are many factors such as plant characteristics, cultural practices etc affects the performance of all types of mechanical cotton strippers. The desirable plant type for cotton stripper is one which has relatively short-node fruiting branches 20-25 cm in length, less in height and has a stormy-resistant boll. The locks of story-resistant-type cotton are usually not very fluffy and are held tightly in the soil. Fluffy and loosely attached locks are easily caught and held between limbs and thus are pulled through the stripping space and lost. Every effort should be made to keep the field free of weeds, grass and vines. Pieces of grass collected with cotton are difficult to remove and if present in excess reduce the quality of cotton lint. The design and type of stripping unit also affects the performance of strippers.

Problem 1: A cotton picker is used for picking cotton bolls. The rotational speed of spindle is 1200 rpm at 2.5 km/h forward speed. Determine the revolution made by spindle of cotton picker in 500 m picking zone for chain belt arrangement.

Solution:

$$\text{Time required to move 500 m in field} = \frac{500 \times 60}{2.5 \times 1000} = 12 \text{ min}$$

In one minute spindle makes 1200 revolutions.

Number of revolutions made by spindle in 12 minutes = 12 x 1200 = 14400

Problem 2: How many revolutions will each spindle of cotton picker make in the picking zone for a chain-belt arrangement in which spindle has a rotational speed of 1200 rpm and remains in the picking zone during 100 cm of forward travel. Take the speed of cotton picker as 4.6 km/h.

Solution:

The time required to move 100 cm = $(100 \times 60)/\ (4.6 \times 10^5)$ minute = 0.01305 minute

In one minute the total number of revolutions made by spindle = 1200.

So, in 0.01305 minutes the number of revolutions made by spindle is:

= 0.01305 x 1200 = 15.65

Answer: Number of revolutions made by spindle = 15.65.

LESSON 20. SUGARCANE HARVESTERS - CONSTRUCTION AND WORKING PRINCIPLES

Sugarcane is a native crop of India. It is grown in tropical and sub-tropical climates of developing countries of Asia, Africa and Latin America. Australia and USA are the major sugarcane producing countries of the developed world. Sugarcane cultivation practices vary from country to country and within a country. For example, row to row spacing in India varies from 60 to 100 cm while in many other countries from 150 to 180 cm. Sugarcane is planted in furrows or on ridges or in flat fields. Varying cultivation practices introduce a number of design constraints on sugarcane harvesting machines. Most of the sugarcane harvesting in India and other developing countries is manual. Cutting knives of varying sizes and shapes are used (Fig. 1). De-husking, cleaning, bundling of cut cane and loading for transportation are done manually. Indian Institute of Sugarcane Research (IISR), Lucknow has developed a sugarcane stripper (Fig. 2) which does the job of detopping and dressing of the cane.

Sugarcane harvesting involves base cutting of the crop, detopping, detrashing, bundling, loading and transportation. Detopping and detrashing of crop itself takes about two-third of manpower required for harvesting. Several types of sugarcane combines and harvesters are used world over. They are normally used for crops, which are burnt in the field prior to harvesting for trash removal. Some harvesters are used in green crop and cane is burnt in windrow after harvesting. Some machines have been developed which can be used in the cane field without burning. This is particularly done where environmentalists object burning of cane. The sugarcane combine is a one-pass machine, which cuts the cane, detops, cuts in billets, cleans and conveys to transport cart/trolley. In case of sugarcane harvester, it cuts the crop, detop and put on the ground in windrow, which are loaded in trolleys by mechanical loader or grabber. Combine harvested cane must be processed within 16 hours to avoid deterioration and sucrose loss. Most of the sugarcane combines and harvesters is self-propelled machine. However, some tractor-drawn machines are also available. Some of the most widely used sugarcane harvesting systems are discussed below.

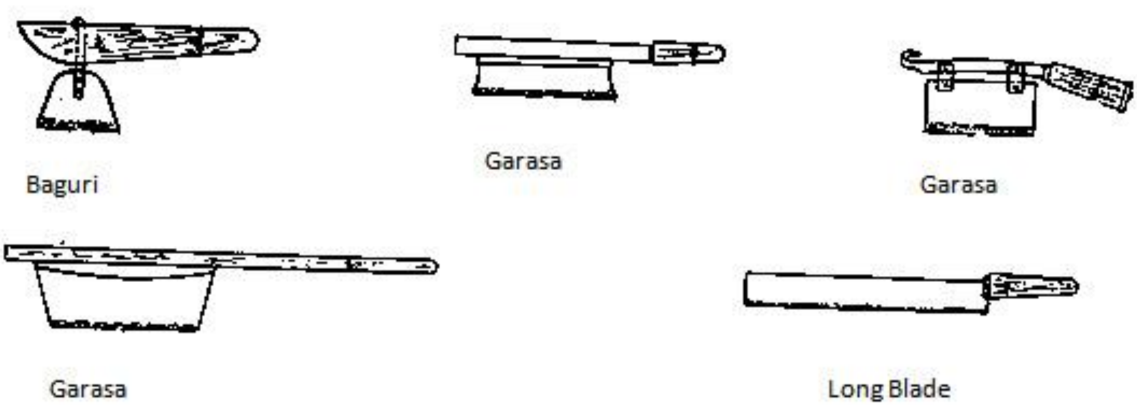


Fig. 1: Varying shape and size of cutting knives.

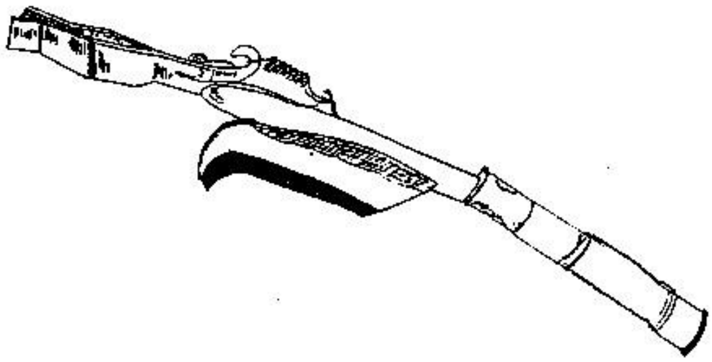


Fig. 2: Sugarcane stripper.

Push-rake system: Push-rake system involves pushing and piling of sugarcane. It is made of very sturdy tines welded to a frame. It is mounted in front of tractor. When machine is pushed into standing cane in the field, it breaks the stalks off at the surface of ground and leaves them in piles. The piles of cane is then loaded into truck and delivered to the mills. The main drawback of this machine is that the cane is not topped and cane delivered to mill contains ¼ to one-third of trash. It uproots cane plants, which results in poor ratoon crop.

Windrow harvest system: In this system, sugarcane is cut and windrowed. It has V-cutter harvest system and soldier type harvester. The V-cutter harvest system has two circular horizontal blades spaced at 152.4 cm. The machine cuts the cane in the field and makes a windrow of two rows. The crop harvested by this machine has also a very high percentage of trash. The unit is mounted on a track-type tractor. The front end of the machine can be raised or lowered hydraulically for transport and field operations. The effective field capacity of the machine is about 0.8ha/h.

Soldier-type cane harvester tops the cane, cuts the cane from base and places in windrow for mechanical loading. It cuts one row of green cane at a time. A topper with a gathering chain and two discs remove the top from standing crop and drop towards right of row being harvested. Two sets of pick-up chains arranged in a V are used for picking and feeding the cane to the base cutter. The harvested cane is conveyed through a cane conveying system to the windrow. Both the operations of topping and base cutting are performed simultaneously. It does not uproot the cane and its capacity is about 0.4 ha/h.

McConnel sugarcane harvesting system: In this system, the machine is mounted on a tractor of 75-90 hp. The machine cuts the top green portion of sugarcane, harvests from the base, cleans the cane and places in a windrow. The cane is further cleaned by labour and loaded manually or mechanically in the truck. It harvests one row at a time.

Cut-crop-harvest or combine harvest system

All harvest system described so far namely push, pile and grab system and windrow harvest system have one operation in common. It is the cane being placed on ground for loading after cutting. This operation is partly responsible for cane left in the field and soil and rocks delivered to the mill. A combine harvest system eliminates this operation. The basic components of a sugarcane combine are:

(i) Gathering mechanism

(ii) Topping mechanism

(iii) Base cuter

(iv) Feed conveyor

(v) Chopper

(vi) Elevator

(vii) Cleaning by air blast

Gathering mechanism: Its function is to separate sprawled cane and align the row to be harvested. They are made of revolving scrolls fitted on gathering walls. It consists of two triangular walls, approximately 140 cm apart at the tips and converging to the throat width of the machine just forward of the base cutters. The tips of each wall are fitted with ground engaging points to get under and lift stalks that are lying on the ground.

Topping mechanism: Its job is to gather, cut and discard non productive tops. The gathering operation is performed by gathering chains while cutting is done by a horizontally rotating disc fitted with mower blades which cut against a fixed anvil.

Base cutter: Its function is to cut the stalk at or just below ground level. At least one manufacture uses twin contra-rotating discs fitted with a number of replaceable knife blades. Some use single diameter blades for base cutting the cane. Researchers have found that tip speeds below 304.8 m/min do a very poor job of cutting. Recommended tip speeds for Florida conditions is 1524 to 1828 m/min.

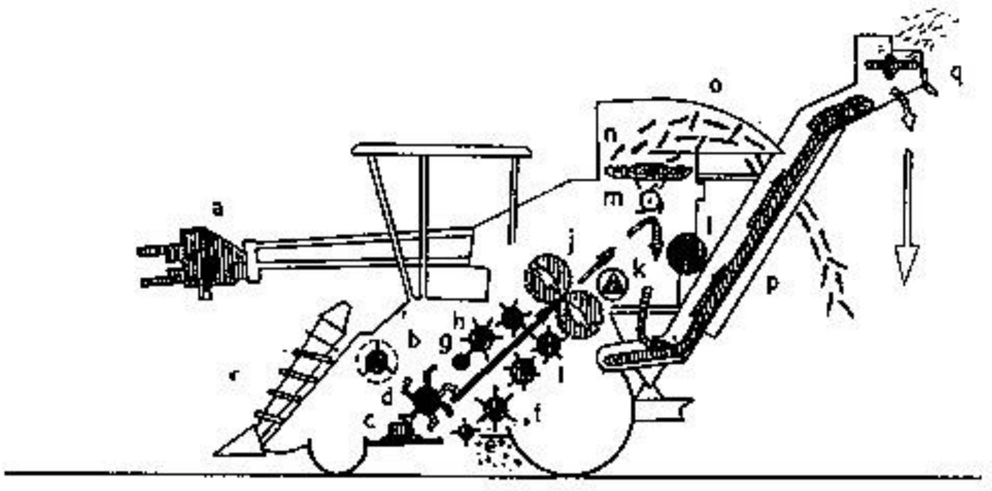
Feed conveyor: Its function is to convey the whole stalks of cane from the bass cutter to the choppers. In some machines it is made of endless chain slat conveyor. In others a series of rollers are used. In some machines augers are used for feeding cane to the chopper.

Choppers: Their function is to receive the whole stalks from the feed conveyor and chop them into short uniform billets. The design used by Massey Ferguson is a pair of parallel shafts each with paddle shaped blades, which as they rotated came together in the plane containing the shafts, and so gave a flying or travelling cut. There is other mechanism used for chopping. However, flying cut mechanism has the advantage of being aggressively self-feeding, and that once the swath is engaged by the chopper; it will be pulled in continuously until broken or forcibly interrupted.

Elevator: Its function is to receive the billets from the choppers and convey them into a receptacle for transporting to the mill. An inclined chain and slat conveyor is used. The elevator can be rotated 180 degrees in most machines. This facilitates in opening of the field and harvesting in either direction.

Air-blast cleaning: One of the biggest problems with mechanically harvested cane is the foreign matter in cane delivered to the mill. Foreign matter consists of leaves, tops, dirt, stones and many other materials picked from the field. In some machines one while in others two fans are being used for extracting leaves and dirt from the cane. M.F. 205 has two extractors one at each end of the Elevator.

The basic components combined in a frame and provided with a power unit and vehicle, constitute a cane combine (Fig. 3). It is generally powered with an engine of about 150 hp.



a. Topper b. Forward feed roller c. Base cutter d. Feed roller
e. Butt lifter f. Intermediate feed roller g. Smooth top roller h. Floating feed roller
i. Fixed feed rollers j. Chopper system k. Chopper delivery roller
l. Air inlet roller m. Anti-trash roller n. Primary extractor o. Trash directional control
p. Elevator q. Secondary extractor

Fig. 3: Details of sugarcane combine.

Mechanical harvesters may be of bin type of 1.5 to 2 tonne capacity or whole stalk harvesters windrower type. Windrowing type harvesters may be backed up by grab loaders. These machines includes Case Austoft, Moller bin type, Cameco whole stalk, tractor operated Carib, Bonnel & Bunmai harvester windrower. Presently production of this type of machine is almost stopped.

LESSON 21. SUGARCANE HARVESTERS - DESIGN CRITERIA

Design criteria

Following points cover the expectations of the farmers/users;

- Sugarcane harvester should be able to cut the whole cane from base, detrash it, detop it and may put the cut cane in the container attached behind or may windrow the cut crop.
- Row to row spacing be adjustable to cut cane grown at a spacing of 60 to 150 cm.
- The sugarcane harvester to be developed should preferably be operated by 70 to 80 hp tractor.
- The capacity of machine should be 1.5 to 2.0 ha/day or even more.
- The cost of the machine should be within Rs. 25-30 lakhs with total cost of harvesting operation less than Rs. 150 per tonne (Including base cutting, detrashing and detopping).
- The machine should be light in weight with low turning radius.
- Trash content should not be more than 5%.

While designing the sugarcane harvester agronomical practices followed in the different parts of the country and other details as given below should be kept in mind:

(i) Agronomical practices followed in the different part of the country

(ii) Height of cane (range)

(iii) Stem diameter of cane (range)

(iv) Row-to row spacing beig followed (range)

(v) Moisture content during harvesting (range)

(vi) Method of planting- Ridge planting or flat planting

(vii) Lodging conditions

(viii) Expectations of the farmers/users about field capacity, speed, price and cost of operation

Recently Heera Sugar Industries village Sherewad, Sangheshwar District Belgaum claimed to develop single row whole cane sugarcane harvester operated by 60 hp tractor. The machine cuts the crop, detopps, de-trashes, collects the whole cane on the rear and deloads at one place while operating in the field. About 80 acres crop was harvested. The unit developed has been patented as informed by the firm. Machine is suitable for sugarcane crop with row to row spacing of 3 feet.

The Single row Self-propelled whole cane sugarcane harvester was developed and demonstrated at the farm of Mr. Pratap Rane near Pune (Fig. 1). The performance of machine was satisfactory. The following points emerged from the demonstration:

(i) The forward speed of machine was very low and hence the field capacity of machine. The field capacity of machine was 1.0 ha/day only.

(ii) Frequent back and fro was observed during operation.

(iii) Trolley at back was swinging towards right and hence posed the balancing problem.

(iv) Choking of cane in trolley was observed.

(v) Cutting of cane tops was not proper mainly because of cane guides were far apart and cane height was not uniform.

(vi) Though the cane detrashing was satisfactory, however trash cleaning was not proper and needs blower speed adjustments.

Further the Billet type sugarcane harvester developed under NATP scheme by M/s Rane Agro Pvt. Ltd., Pirangut, Pune in collaboration with ICAR and VSI Pune was demonstrated (Fig. 2). The following points emerged from the demonstration:

1. The forward speed of machine was very low and hence the field capacity of machine was 1.0 ha/day only.
2. Cutting of cane tops was not proper mainly because of cane guides were far apart and cane height was not uniform.
3. Though the cane detrashing was satisfactory, however trash cleaning was not proper and needs blower speed adjustments.
4. There was damage to crop by tractor tyre on the left of tractor.

Sugarcane combine harvester: In this system, sugarcane is cut first from the top and then from the base and it is cut into billets and is loaded in transport cart. It does not required separate loader for loading purpose. The machine consists of gathering mechanism, detopping mechanism, base cutter, feed conveyor, chopper, and elevator and cleaning unit (Fig. 3). The machine is generally powered by the engine of 150 hp. Pre-harvest burning is being practiced where harvester is to be used. Mostly it can harvest cane grown at a row-to-row distance of 90 cm. The average capacity of the machine is about 0.4 ha/h. It is most sophisticated machine among all types of sugarcane harvesters.

Engine operated sugarcane leaf stripper: This is a portable engine operated machine used for the detrashing and leaf stripping from whole cane. The sugarcane without leaf require less space for storage as well as transportation.

Whole stalk sugarcane harvesters: These harvesters are quite suitable for those areas where sugarcane crushing is not possible within short period of harvesting. Delay during transport, loading, unloading, waiting at one or the other stage is unavoidable. Use of whole stalk sugarcane harvesters is also useful for those areas where green tops recovered are used for cattle feed. Such machines are either tractor operated or self propelled. Introduction of such machines in phases is possible even in those areas where sugarcane is not lodged, canes may be bent up to 10 - 15^0. There are only few designs of whole stalk harvesters in use in the world because of difficulty in handling of lodged cane by these machines. Therefore, whole stalk harvesters with base cutting, de-topping and partial de-trashing for erect, medium to low tonnage crop areas may be introduced, especially under those locations where self stripping / erect type cane varieties are common. Windrowing type harvesters (Fig. 3) may be backed up by grab loaders. These machines includes Case Austoft, Moller bin type, Cameco whole stalk, tractor operated Carib, Bonnel & Bunmai harvester windrower. Presently production of this type of machine is almost stopped.

A system of chopper harvester consists of one chopper harvester of a particular capacity and size, two articulated trailers of 4-5 tonne capacity (depending upon the site), transport trucks of 8-10 tonne capacity and mobile repair van along with spare parts (Fig. 4). Complete package of these machines cost in the range of 110 to 170 lakhs depending upon the specifications of the harvester. These machines may be introduced in phases without affecting the existing system of sugarcane management.

Fig. 1: VSI RANE whole cane sugar harvester

Fig. 2: VSI-RANE Sugarcane chopper combine harvester

Fig. 3: CARIB (Barbadoes) cane cutter

Fig. 4: New Holland sugarcane harvester

MODULE 9. PRINCIPLES OF FRUIT HARVESTING TOOLS AND MACHINES

LESSON 22. PRINCIPLES OF FRUIT HARVESTING MACHINES

Some of the fruits are highly perishable products and required to be harvested in a very narrow range of time. These may be processed, graded, stored or consumed fresh, soon after harvesting. Because of these reasons, it is very important to mechanize the harvesting of fruits. High yielding and uniformly maturing varieties need to be harvested mechanically. Mechanical harvesting can result in an extremely high rate of product output in which case material handling methods are of major importance. Handling of fruits should be such that, there should be minimum damage to the product. In general, mechanically harvested fruits contain considerable quantities of trash, immature or damaged fruit, which has to be removed either during harvesting itself or separately and later on manually.

In India, very little efforts have been made to mechanize harvesting operation on fruit and vegetables. It is mainly due to availability of abundance of labour and lack of organized large-scale fruit or vegetable farming. However the nation's cereal requirements are now being met through systematic approach and importance of fruit and vegetables production is in the process. Now the trend is emerging towards the organized fruit and vegetable farming. As this trend will continue, there is a need to develop simple mechanical devices for harvesting fruit and vegetable. In traditional method of harvesting tall tree fruits such as mangoes, palm, coconut etc many serious accidents happen every year. By developing simple mechanical harvesting devices may avoid such accidents or reduce it.

A lot of efforts have been made towards the fruit and vegetable harvesting, abroad. Harvest mechanization has reached a high level of success and acceptance for number of crops. Successful mechanization of these operations requires a systems approach and need the joint efforts of engineers, plant physiologists, food scientists and others. Mechanical harvesting often causes a reduction in harvested crop value per unit area mainly due to

- Crop do not mature uniformly,
- Fruit and vegetable damage,
- Actual field losses, and
- Reduction in quality.

Fruit Harvesting: There are varieties of fruits available, which need to be harvested at their maturity. Many fruits do not mature uniformly, which needs several pickings to obtain maximum yields. In general fruits can be categorized into three types, namely, tree fruits, vine fruits and bush fruits. Tree fruits are mangoes, apples, papayas; vine fruits watermelon, muskmelons etc and bush fruits are raspberries, blueberries, cranberries etc. Various principles and devices have been tried for harvesting fruits and are described below:

Tree fruit harvesting using shake and cater principle

This type of machine works on the principle of accelerating each fruit so that inertia force developed will be greater than bonding force between the fruit and the tree. The shaking machines based on this principle are already in use for fruits like walnut, almonds etc. Tractor mounted cable shakers, fixed stroke boom shakers and boom type impact knockers are basically used for nuts. Impact knockers are preferred for almonds, because they are large and rigid trees. An impact knocker makes impulses with the help of mechanical, hydraulic or pneumatic means. An electric wheel or crank on the tractor drives fixed stroke boom shakers clamped to the limb of tree. It may also be powered through self-propelled unit.

Fruit like apple, mangoes and pears can be harvested by shaking and catch method. The tree trunk or limb is shaken with a vibratory member and fruits are caught on canvas aprons. In some of the machines fruits may be dropped right on the ground. The methods for fruit removal from tree are limb shaking boom and inertia type, trunk shaking, and persuading air and vibration. Inertia type shakers are preferred over the stroke shakers. In an inertia shaker, the exciting force is derived from acceleration of a reciprocating mass or two opposite rotating eccentric weight. Both arrangements are so designed that it provides sinusoidal or nearly too sinusoidal force vibration. The shaker is generally mounted on the catching frame itself and therefore needs other vehicle. In the trunk shaker type machines, the fruit removal occurs simultaneously over the entire tree and the falling fruits are distributed over the entire catching space. It requires a considerable amount of power and is not suitable for very large trees.

The clamp stroke length for inertia shaker having exciting frequency larger than the fundamental frequency of tree component, can be computed by using the following equation:

$$L = \frac{2\, r\, W}{W_s + W_t}$$

Where,

L = Length of stroke, m

r = Eccentricity of the unbalanced mass, m

W = Total weight of unbalanced mass, kg_f

W_s = Total weight of shaker, including the unbalanced mass, kg_f

W_t = Effective weight of the tree component being shaken (limb/tree) kg_f

It has been observed that, usually the effective weight 'W_t' of tree component of trunk having a diameter of 12 to 28 cm varies from 365 to 450 kg_f and for limbs of diameter 5 to 15 cm ranges from 10 to 30 kg_f. Operating frequencies vary from 400 to 1200 cycles per minute for limb shaker and 800 to 2500 cycles per minute for trunk shakers. For delicious fruits, stroke length ranges from approximately 10 to 20 mm for trunk shakers and 38 to 51 mm for limb shakers. The catching units have low profile collection surfaces that extend under the tree, covering all or most of the area to the outer periphery of the tree. Some of the most commonly used catching arrangements are the inverted umbrellas wrap around type and the pained catching units. A good catching design minimizes the fruit damage.

Manual fruit harvesting device: There are two types of manual fruit harvesting devices. One unit works on the principle of individual cutting of fruit by sickle or blade and collecting it in a bag. In this unit, there is a telescopic boom, which can be fixed at required height through adjustable mechanism. Cutting units consists of two blades, one fixed and other movable. The movable blade is moved with the help of wire string. The individual fruit is cut and collected in the attached bag. This mechanism is very much suitable for fruits, which may get damaged if they fall freely on the ground like coconut, orange, mango, papaya and similar such fruits.

The other type of manual fruit harvester is based on the principle of shaking the branches or trunk of the tree. It consists of two tongs, adjustable to different heights by means of extension bars. A crank arrangement, to be operated manually and provided with flywheel to shake the tree at proper frequency, is connected to tongs and placed on the ground. The tongs are fixed with main branch of the tree and shaken to detach fruit. In order to save fruit from damaging, a net around tree can be stretched to collect falling fruits.

Harvesting of tree fruits with man positioners: Fresh fruits for marketing in the fruit markets are picked up by using a device called man position. In this device, a self-propelled machine is used which has an arrangement to position the worker's platform at three-dimensional direction. Picking platforms and other types of man positioners may reduce harvesting cost. This type of machine can have multilevel picking platforms, which can move along continuously and worker can pick the fruits. The fruits can be put in bin or conveyors.

Citrus harvesting: Citrus fruit like orange, kinnow, malta and similar such fruits can be harvested by using inertia type limb shakers. It can also be harvested by using an oscillating air blast. In one arrangement, air at very high speed is discharged from 2 outlets, which is directed towards one side of tree as the machine moves down the row. This system is attractive because of its high potential capacity. Fruit removal percentage varies from 60 to 90%.

Grape harvesting: Development of grape harvesting machine is complicated due to number of reasons, like variety difference, raising methods, topography etc. Attempts have been made to harvest grapes with vertical stroke harvesters, which have one impacter per row. This is a self-propelled machine, which may have a stroke of 12 cm or more, with frequency of 250 to 500 rpm. In this machine, shaking is carried out by slopping the vines from the sides.

Can fruits, bush and strawberry harvesting: Machines that provided with vibrating devices could harvest bushy fruits such as blueberries, blackberries, and raspberries. One type of harvesting machine has radial, vertical vibrated fingers on free turning vertical cylinders. In other type of design, horizontal stroke peddles or panels of fingers vibrated vertically or horizontally. In such devices leaves are taken out with the help of air blast. It also removes other lighter materials from harvested fruit. It has been observed that blueberries and can fruits ripening takes several weeks and hence it makes necessary to have multiple harvesting. Selective mechanical harvesting is possible because mature fruits detach more easily than immature fruits. Strawberries are low growing, easily bruised and highly perishable and require multiple harvesting when picked manually by hand. Because of above problems, most of such harvesting machines have some stripping or combing type of mechanism. Leaves and other lighter materials are cleaned with air blast. In this type of harvesting machines some immature fruit also comes up which are removed by hand.

LESSON 23. TYPES OF FRUIT HARVESTING MACHINES

Manual Fruit Harvester

It consists of one fixed blade and another moving blade actuated by a spring. There is a net basket attached to it to collect plucked mango fruits. The long handle facilitates reaching fruits from ground. During harvesting, the fruit pedicel is adjusted to rest on fixed blade and pressing the lever at the grip end of the handle actuates the moving blade. The overall length of the tool is about 3000 mm and the weight of the cutting head is 1.3 kg. The blades are made from carbon steel. The device is also used for harvesting oranges apple and sapota



Hold on and twist type

It is a manual-harvesting tool with which individual fruit is first held between two jaws of the device and then twisted to shear off the stock. The jaws are made of 14 gauge mild steel sheet. These are held together by a tension spring on a pivot fitted on 10 mm mild steel rod. A handle can be fitted to the tool. One of the jaws has a lever bracket and rope arrangement for operating the jaw. Three mm thick rubber sheet padding is provided on inside of the jaws to avoid any skin damage while holding the fruits. After its detachment, fruit is released by pulling the cord in to a ring. A cloth conveyor or net is provided below the jaws for collection of harvested fruits at ground level without any damage. The tool is suitable for harvesting peach, pear and orange. Its field capacity is 250-300 fruits /man-h.

A manual-harvesting device has been also developed and commercialised for harvesting mango fruit with panicle. It consists of an oval shaped rings. The bottom ring is meant for fastening nylon net. A cutting mechanism is provided at the top of the ring and it consists of double bladed triangular plate together with toothed wheel. This toothed wheel is riveted at the center of the two fixed cutting blades. The wheel rotates freely about its central rivet and acts as a conveyor of a mango stock. For fixing a bamboo handle of desired length, a holder is provided to the harvester opposite to the cutting mechanism. A plastic divider rod bisecting the cutting mechanism is provided in the ring to guide the stalk of fruits either to the left or to the right side of the cutting blade. For harvesting mango, the harvester is raised and fruit is taken in the ring by pulling the harvester. The pedicels of the fruit are taken in between the toothed wheel and blade. On rotation of a toothed wheel, the pedicle is guided over the sharp edge of the blade where it is sheared. Field capacity of the device is 140 fruits/h. The devices are used for harvesting of fruits.

Manually Operated Sapota Harvester

The harvester is used for harvesting of small fruits like lemon, sapota etc. It consists of main body of PVC having cylindrical shape. The upper end of the body is closed while bottom end is open to which nylon net for collecting the fruits is tied. A stretched string closes the other end of the net. A gate is made on the body for entry of the fruits to be harvested. On the lower surface of the body a metal holder is fixed to hold the bamboo of required length. Two fingers cut in V-shape and with small sharp blades are provided at the closed end of the body of the harvester. The fingers help to select and hold the fruit to be harvested from the bunch. By pulling the harvester, fruit is detached from the bunch, which falls in the body and rolls into the net. To unload the harvested fruits in the net a stretched string at the closed end of the net is loosened.

LESSON 24. HARVESTING OF FRUITS FROM TALL TREES

The Coconut Palm

The coconut palm grows luxuriantly in India. India ranks second in the world in production of coconuts with the Philippines ranking first. The coconut palms are grown in the coastal areas of Maharashtra, Karnatka, Tamil Nadu, Odisha, Andhra Pradesh and Kerala. Under suitable conditions the coconut palm yields more than 200 nuts annually throughout its life of about 80 years. Three-fourths of the production in India is consumed as tender nuts, particularly in summer months. While coconuts are harvested the year around, but there are seasons of higher yields such as in 1st quarter of year 30% of crop is harvested, in 2nd quarter of year about 40% and in 3rd and 4th quarter of year only 30% of crop is harvested. The coconut trees are very tall trees. Mostly harvesting of coconuts is done using long bamboo poles through which nuts fall on the ground and then they are collected manually. Mechanical harvesting of palm trees is still done using buckets. A lot of work is going on in improvements of mechanical harvesting, husking, shelling, shredding, and drying.

Tree climber

In order to harvest coconut and arecanut at faster rate with proper safety, TNAU, Coimbatore center has developed a tree climber. The developed tree climber is free from any accident risk during its operation.

Constructional Details: The climber made of M.S. square pipe consists of two components. Adjustable belts connect the components. The upper component is provided with a seating arrangement and lower component is having provision for holding the foot. The rubber cushioning is provided at the portion of frames, which comes in contact with tree to avoid any damage of tree.

Performance of machine: By standing on the lower component, the upper component can be moved up or down over the tree (Fig. 1). The operator can safely climb a tree of 10 m height in 1.5 min without any risk.

Fig. 1: Tree climber in operation.

Manual climbing device for Palmyra

Harvesting of palmyra fruits and neera is done by trained labour who climb the 60 foot tree, which is an accident prone operation demanding a strenuous effort. Moreover skilled tree climbers are rarer nowadays because of the drudgery involved in this operation. A coconut tree climbing device was developed successfully at TNAU Coimbatore during 2006, which is a simple device facilitating any untrained person to safely climb the coconut trees and do the required operations. However unlike coconut trees, the variation in the girth of palmyra tree from base to top is considerable and hence the developed device was re-designed so as to adjust the frame width on-the-go to correspond with the girth of the tree at each height. To accommodate a wider girth range, the mechanism was improved by providing two number of sliding inclined bushes, which provide V shape to grip on the tree. Simple cranks and flexible shafts provided for easy adjustment (Fig. 2). Adjustment is now very easy, but the range of girth variation could not be accommodated yet. The average time taken for climbing up and down was about 6.30 min for a 40 feet tree with time for fixing and removing the device on the tree being 4 min.

Fig. 2: Palmyra tree climber in operation

Mechanized Harvesting of Palm Fruits

Mechanized harvesting of palm fruits not only reduces the working time of harvesting but also improves the quality of fruits and reduces harvesting loss. The machine improves the working condition of person engaged in harvesting of fruits in terms of safety and comfort. The machine requires two men one tractor driver and another platform operator. The machine consists of a crane, telescopic arm, chute for fruit, self lever along x and y-axis, harvest body, balancing axle, open and closed platforms, moving blade, fixed blade, displacement controls, working lever and working piston. The machine is brought near to the palm tree and platform is raised to the desired height. Fruits are cut using fixed and movable blades at the top of telescopic arm. Then, platform is lowered and machine is moved to next palm tree and fruits are harvested repeating the above steps. Once the container is filled with palm fruits, unload the container. The performance of machine can further be improved by suitable modification in the design. The oscillating axle device can be revised to reduce soil compaction and to reduce the angle of inclination when machine passes through depressed area, holes and other obstacles. The hydraulic system can be improved to reduce the time for lowering and raising the platform.

Aerial access hoist for coconut and tall tree crop management

All existing tools and devices involve the operator to climb up the tree for harvesting and carrying out other management practices at the crown. Farmers who own large areas are interested in having a system which can elevate a person up to the tree crown by a portable aerial access platform. The existing aerial access platforms are having the following limitations.

(i) The access is vertically upward and not in the side wards

(ii) The machines are designed to operate by resting on firm surface

(iii) Most machines have very wide stabilizing legs which cannot be operated under field conditions.

(iv) Require long time for setting up and operating

Keeping the above constraints in view and after a thorough study of the planting pattern and space requirements the following technical requirements of a tractor mounted aerial access hoist were formulated.

Lifting capacity	120 kg
Platform size	1000 x 700 x 1000 mm
Working height	16 m
Platform access height from the ground	15 m
Platform outreach	6 m
Rotation/slewing angle	360 degrees
Stabilizer	Hydraulically operated 4 nos. to provide absolute stability
Power	PTO of tractor, with exclusive hydraulic system and controls

The design of individual sub systems and structure were done by M/s Vanjax, Chennai in collaboration with TNAU Coimbatore. Since this is the first machine of its kind which was tractor mounted, the method of mounting the hoist to the tractor and the limitations of the

PTO drive were taken into account during the design (Fig. 3). A full length chassis was extended from the front of the tractor to the rear and bolted to the tractor chassis. This forms the support for the hoist and provided for mounting of all stabilizers. The entire weight of the hoist and moments were transmitted through the chassis to the stabilizers without transferring to the tractor chassis. The following tests were conducted for confirming the performance.

(i) Reach test without load

(ii) Reach test with load

(iii) Preliminary field test

Fig. 3: Tractor operated aerial access hoist for coconut and tall tree.

The results of preliminary field evaluation shows that the tractor mounted aerial access hoist can be taken into the coconut field and four trees can be accessed from a single position. The time required for locating unit and operating stabilizers was 1 min. The time required for positioning against a tree of 10 m height was 2 min. Suitable safety devices were incorporated to ensure stability of the hoist. The positioning of the operator platform can be done by the operator himself using electro hydraulic controls.

Multi-utility elevator platform

Close aerial access to the fruits provides better control on the harvesting operation thereby reducing the damage to fruits and tree branches. The tractor operated elevator attachment is a versatile and reliable worker-positioning platform from which the delicate fruits can be picked up or harvested very safely and efficiently from the trees (Fig. 4). The positioning is adjustable by the operator himself both vertically and horizontally. Hence selective picking of superior quality fruits with negligible fruit drop and higher capacity of harvesting fruits is achieved as compared to the traditional methods. Used for safe and efficient harvesting of fruits. Also used for efficient spraying, pruning, training of orchard crops.

Specifications

Capacity of fruit harvesting (kg/hr)	:	70 -150
Maximum height of harvesting (cm)	:	762
Load bearing capacity (kg)	:	200
Power requirement	:	Hydraulic system of any tractor
Labor requirement	:	Two including tractor driver

Fig. 4: Multi-utility elevator platform

Tractor mounted telescopic hoist

The tractor-mounted hoist can be used in orchards and plantation crops for trimming, pruning, plant protection and harvesting operations. It consists of two square aluminium ladders, each made of U-section as frames and round hollow pipes as cross members (Fig. 5). The U-sections of the outer ladder are inward facing while U-sections of the inner ladder face outward, sliding one over the other. Two wire ropes are provided, which are driven with a hydraulic motor. The motor, while running in clockwise direction helps in lifting the inner ladder and while running in anti clockwise direction, lowers the inner ladder down. A support frame fitted to the platform on the top end of the inner ladder helps as a safety frame. While transporting, the hoist can be folded and tilted to horizontal position over tractor canopy.

Specifications

Maximum height of platform (mm)	:	9500
Minimum height of platform (mm)	:	5500
Plant to plant spacing (m)	:	10
Field capacity, min/tree	:	30

Fig. 5: Tractor mounted telescopic hoist

MODULE 10. HORTICULTURAL TOOLS AND GADGETS

LESSON 25. HORTICULTURAL TOOLS AND GADGETS AND GARDEN TOOLS

The need for special types of power units and/or cultivating implements arises when it is necessary to work between fruit trees, where planting distance has already been decided and equipment has to confirm it. Narrow rows of fruits sometimes necessitate the use of small tractors with matching equipment. There are special ploughs called hop ploughs suitable for very narrow work and turns two furrows to right and two to left simultaneously. Another type of implement desired is which can work as close to trees/plants on one side as possible without destroying the roots. Some of these implements are discussed here.

Horticultural hand tools (Fig. 1)

Hand tools are widely used in horticulture because many of the areas cultivated are too small or it is almost impossible for other machines to do the job near plants/trees efficiently. One such hand tool is spade, which can be used for digging, trenching and removing soil. Spades are available in normally two different sizes viz. one has blade 280 mm long and 190 mm wide and weighs 2.0-2.5 kg and another has blade 220 mm long and 140 mm wide and weighs 1.5-2.0 kg. The selection of spade depends on the type of soil and work to be done. The blade is made from tempered steel; however, some spades are also made of stainless steel. The blade should be kept vertical during digging, as it requires minimum efforts.

The forks are also commonly used as horticultural tools. They are available in different types depending upon the type of job to be done. Digging forks are used for digging in the soil already turned by spade. They normally have four prongs, which can be either round or square in section. Border forks are used as weeders in the border area of field. They are narrower and lighter than digging forks and normally have 3 or 4 prongs. Potato forks are specially made for lifting the potatoes in the field. While lifting the potatoes in the field soil automatically drops through and not much damage is made to tubers. In this tool, the prongs are much broader than digging fork and usually have 4 or 5 in numbers.

Garden rakes are commonly used as a horticultural tool to break the soil to fine tilth, and to gather the grass, stone and hedge clippings in the field. It has about 10 rigid teeth. Lawn rakes and hay rakes are also used for collecting grasses and tree leaves in the orchard, which are necessary to keep the area clean. They have normally 12-20 teeth depending upon the size.

Hoes are used to destroy the weeds and loosen the soil around the trees. There are two types of hoes; draw-hoe being pulled by the worker and push-hoe. Triangular headed hoes are also used as horticultural tool for making shallow drill usually in conjunction with a garden line. Garden line is generally used when seed sowing, trenching, lawn edging and transplanting operations is performed in the garden. It has 6-20 m nylon twine with a pin at one end and reel at other end where it can be wound for storage.

Shears are used for cutting grasses and hedges. They are of two types viz. hand shears and edging shears. Hand shears have blade 200-300 mm long with wooden or plastic handles. The cutting action takes place between the two blades, which are pivoted and material to be cut is sheared between them. Some shears have a pruning notch near the pivot of the blades so that thick twig can easily be cut. Edging shears are used for cutting lawn edges because they have handles about 1 m in length and attached at an angle to the blades. Secateurs are also small hand tools used for pruning bushes and shrubs. Turfing iron and turf lifters are used for edging lawns.

Pruning secateurs also known as pruning shears resembles a multipurpose combination pliers used in a workshop. The need of secateurs arose to cut the branches or twigs, which are difficult to cut by pruning knives. Being handy and easy to operate, it is considered to be an essential tool of the gardener in plant propagation. Various types of pruning secateurs are fabricated for removing or cutting of unwanted branches or twigs, cutting of scion sticks, defoliation of leaves from the sticks and topping of small trees. These are single cut, double cut, parrot nose cut, roll cut, bes cut, supa cut, replaceable blade type, easy cut, kiln cut etc. The pruning secateurs consist of two cutting blades or one cutting blade and an anvil, handle, volute spring to keep the blade and handle in open position and a locking device for keeping the secateurs in closed position. The blade is important part of the tool and is made from high carbon steel, tool steel or alloy steel. The blades are forged to shape, ground sharp at the cutting edge and hardened to 460-510 HB. Handles are made from aluminium or mild steel and in some cases a cover of plastic is provided on the arms of the handle. Usually the arms of the handle follow a fixed path during cutting operation but in some secateurs one of the arms of the handle is made rotating type for easy operation. For operation the branch or the twig is held in between the blades and handles pressed together which produces shearing action and cutting of the material. The secateurs are selected according to the operation and size of the twig or branch. The pruning secateurs are known by various names depending upon the shape of blades and are available in various sizes (150, 175, 200, 225, and 250 mm). The size refers to overall length of the secateurs. Cutting capacity is up to 20 mm diameter. Used for cutting of the unwanted branches or twigs of the orchard tree, vines, scion sticks, defoliation etc.

Chain saw: Chain saws are used in horticulture to trim dead or diseased wood from the field, to remove inconveniently placed branches and to fell undesired trees. They are also called power saws. It has an endless chain fitted with cutters, which run around a flat plate called the guide bar and does the cutting job. Chain saw is either manually operated or operated by a small two-stroke petrol engine. A sprocket fixed on engine shaft drives the chain, to which the guide bar is rigidly bolted. An electric motor or hydraulic power unit can also operate it.

Hedge cutters: It is also called hedge trimmer. A small petrol engine, compressed air, electric motor or 12 V batteries can operate portable hedge cutters. Cutting takes place between two blades, one of which reciprocates in close contact with a stationary one at a rate 33-66 strokes per minute. Some hedge cutters have an extension like a small saw on the end of moving blade, which can be used to cut branches that are too thick to be cut by blades. One type of hedge trimmer can be mechanically driven through a flexible drive. Some hedge trimmers have circular cutting head.

Pneumatic secateurs: The pneumatic secateurs, also known as pneumatic pruning shears, are used for pruning vines using pneumatic power. Gripping blade of the shear is stationary and shearing action is imparted by the other blade through the movement of piston, at the end of which it is fixed, with high-pressure air carried in a portable cylinder. The device offers effortless, accurate and swift cutting, at the same time ensuring the quality of vines. The double acting piston facilitates easy pruning of even large branches. The extension member helps access to branches inside canopy. The cutting head of the shear can be adjusted as needed across 360°.

Tree pruner: The tree pruner is a manually operated pruning tool for cutting of the branches or twigs of the orchard trees or plants in standing positions, which are beyond the reach of human hands for aeration and giving a shape for facilitating harvesting and adequate lighting. It essentially consists of a hooked anvil, spring actuated cutting blade, links for actuating the blades and a socket. A long wooden handle is inserted in the socket in order to access the high branches or twigs for cutting. A rope is attached to the link for actuating the cutting blade. The blade is important part of the tree pruner and is made from high carbon steel, tool steel or alloy steel. The blade is forged to shape and the cutting edge grounded sharp. The blade is hardened to 425-450 HB. For cutting operation the branch or twig is brought under the hook. The blade is actuated by pulling the rope, which cuts the twig due to shearing action. When the rope is held loose the blade returns to its original position due to spring action. The tree pruners are available in various sizes. The size of the tree pruner is known by its overall length. One of the typical sizes is 360 mm including the length of the socket. The cutting capacity of the tree pruner is about 20 mm diameter branch or twig.

Pruning saw: The pruning saw is manually operated hand tool for cutting or trimming of the branches, which are beyond the capacity of the secateur or tree pruner. Like carpenter saw it essentially consists of a serrated blade and a handle. The blade has a longer pitch to avoid clogging during operation in cutting of green branches. The blade comes in straight and curved design and is made from tool steel having a carbon content of more than 0.7 %. The cutting teeth are made sharp and hardened to 45-48 HRC. For efficient cutting the blade is provided with adequate rake and gullet angles. The handle is made from good quality wood and riveting joins the blade. For cutting the blade is repeatedly moved over the branch and cutting is done in forward stroke.

Chain saw: The chain saw is used to trim dead or diseased wood from trees, to remove inconveniently placed branches or fell trees. It is also called power saw and is a light and portable machine normally and operated by one person. Cutting is done by an endless chain fitted with cutters, which runs around a flat piece called the bar. The drive link of the chain runs in a groove, machined in the edge of the bar and is pulled along by the teeth of a sprocket, which engage them. The sprocket in turn is driven at full speed either by small two- stroke petrol engine or electric motor. The power to the chain is transmitted through a centrifugal clutch mounted on crankshaft of the engine. The chain is of roller type and has left and right hand cutters spaced alternately along its length. In front of each of the cutters is a small projection called a depth gauge whose purpose is to control the depth of cut made by the cutter.

Hedge shear: The hedge shear is used for pruning and trimming of hedge and giving it desired shape. It is also used for cutting of shrubs and removing of haphazard growth in gardens and lawns. The tool essentially consists of two blades with tangs. The tangs are inserted in the wooden handle and secured by ferrule. The cutting action takes place between two blades, which are pivoted, and the material to be cut is sheared between these blades. The blades are forged to shape and edges are ground to obtain a bevel angle just less than 90 degrees. It is important to maintain the desired cutting while sharpening these blades to obtain clean cut. The blade and tang are made in single piece from high carbon steel, tool steel or alloy steel and hardened to 420-470 HB. The handles are made from high quality wood. For operation the handles are pulled apart to open the blades. The material or hedge twigs to be cut are brought in between these blades and moving the handles inward shears the twigs. This action is repeated fast for trimming of the hedges and shrubs. Some of the models are provided with pruning notch near the pivot of blades for cutting of thick twigs.

Hedge trimmer: Hedge trimmer is used for trimming hedges, shrubs and brambles. It is also used for contouring plants in desired shapes and sizes for enhancing the aesthetics of the garden. Hedge trimmer consists of a cutter bar having two sets of reciprocating blades. The teeth along the top blade are diamond round and double edged to stay sharp for long. It can cut even branches of up to 16 mm in diameter. The cutter bar is driven either by engine or motor. The unit can be moved in various directions- to the left, right, upwards or downwards. A baffle guard is provided to protect the user from flying leaves, stems or branches. The motor power unit is provided with flexible chord, which permits the movement of the trimmer to all places in the garden. An extra trigger switch is integrated in the handle for quick, error free operation.

Axe

Dah

Budding knife and grafting knife

Budding

Grafting knife and slashing knives

Pruning

Pruning secateurs

Pneumatic secateurs

Tree pruner

Pruning saw

Hedge trimmer

Chain saw

Fig. 1: Horticultural tools and equipment

LESSON 26. VEGETABLE HARVESTING TOOLS AND EQUIPMENT

Potato harvesting machines are widely used in India and elsewhere also. Harvesting of green peas, beans etc. is widely accepted in countries like USA and Australia. Considerable progress has being made in developing harvesters for many other vegetable crops. But their acceptance rates are different and depend upon the problems involved and potential economic gain from mechanization.

Tomato Harvesting: Tomato is an important vegetable crop after the potato. Some of the tomato crop is needed for processing to make various products and other is used as fresh vegetable. Tomato harvesting machines are generally once over machines. Selective picking type of machines is not popular. In a once over machine, the following unit operations are involves.

(i) Uprooting or cutting of the plant stem at or just below the ground surface

(ii) Conveying the entire plants into the machine

(iii) Detaching the fruit from the plant by shaking

(iv) Cleaning the detached fruit with blowers

(v) Manual separation of ripe tomatoes from green ones, clods and other debris, and

(vi) Conveying sorted fruits into bins or a special trailer.

Usually vine is cut with the help of a pair of stationary knives or a special sickle-bar type of cutter bar. Two overlapping, counter rotating, powered disc blades can also cut it. Another arrangement has a rotating square bar that operates beneath the ground and uproots the plants. Conveying of plant is accomplished by either rubber covered rod-link chains employed as elevating conveyor or by using two draper-type elevating conveyors in series, with an arrangement between the conveyors that removes dirt and loose tomatoes onto special sorting belts.

Fruit detachment from plant is accomplished by shaking. In one arrangement the vines are carried on a chain and rod type conveyor that has sections oscillated either in a fore-and-aft direction or vertically. In another arrangement, shaking units have continuously moving chains spaced laterally a few centimetres apart with vertical fingers that move the vines towards the rear as the entire assembly is vibrated horizontally in a fore-and-aft direction. Since the tomatoes are quite susceptible to impact damage, the shakers and conveyors must be designed to minimize drop distances and impact force resulting from fruit inertia. It is very important to provide cushioning at all critical points to avoid fruit damage.

Other vegetable harvesting machines: Green pea harvesting machine cut the entire plant near the ground with an oscillating cutter bar and load them into trailer or truck pulled either behind or at side of the machine. The crop is then handled to a processing plant. Harvesting of beans has become easier with the development of varieties that mature a large percentage of the beans at one time. Due to this it is possible to harvest entire crop in one operation. These machines usually harvest 2 to 3 rows each time. The leaves and stems are grasped between rollers and the beans are separated from the plants.

A harvester which is mounted on a large trailer or tractor chassis harvests crops like cabbage and lettuce. It moves slowly through the field as the vegetables are cut by hand and placed onto the conveyor belts. The belts extend out on either side of the machine to bring the hand cut vegetables to a control location. They are finally loaded into trucks or trailers. A great difficulty is forced in harvesting this type of crop, because it has to handle wide range of head sizes and considerable variation in alignment of plants along the row. It causes variation in alignment of plants along the row. Therefore, obtaining a satisfactory cut is a problem.

Cucumber harvesting is done by machines, which have platform on which pickers are carried. Mechanical harvesters have been developed in the USA to harvest the cucumber crop. The machine gathers the cucumbers from the vine and leaves the vine practically undamaged. In order to harvest the crop with machines due care has to be taken during planting of crop, so that vine must be in condition for easy machine harvesting.

Bhindi plucker

It is used for plucking of bhindi (ladies finger) from plant. The tool is ergonomically designed. The plucker consists of two arms hinged together, cutting blades joined to open ends of arms and two rings joined to the arms (Fig. 1). The blades are made of medium carbon steel or low alloy steel, hardened and tempered to suitable hardness. Panicles are cut individually using this tool. The operator is spared of drudgery, discomfort and itching to skin of his hands, which are associated with conventional method of manual plucking without any aid. It fits in to the hand properly with the help of two rings, one over thumb and another over index finger. Force to cut the pedicle is exerted by pressing these two fingers against each other. Pedicle is sheared between two straight blades, one of which is notched for better grip.

Fig. 1: Bhindi plucker

Onion Harvester: Onion is another important vegetable crop, which has a lot of consumption the world over. Mechanical harvesting of such crop is required for timely vacating of fields. The principal functions of mechanical onion harvester are digging, elevating, topping, and bagging or bulk handling. Onion harvesting can be successfully carried out with the help of modified potato harvesting machine. Some commercially available machines lift the onions with a modified potato harvester before they are topped. Toping is done with the help of pairs of parallel, counter rotating spiral rolls, which orients the onions and pulls the tops downward between the rolls. Rotating blades just below the rolls remove the tops leaving a short stem on each onion. The spiral rolls deliver the onions to an elevator. The onions are undercut with blade about three weeks prior to harvest to ensure that the tops get dry enough for the rolls to operate effectively.

Tractor mounted onion harvester-cum-elevator

Onion harvester-cum-elevator was developed for digging onion and other root crops. It consist of a digger blade made from high carbon wear resistant steel. The width and thickness of the blade is 1144 mm and 16 mm. The blade is mounted on the machine at an angle of 20° with the horizontal. An elevator chain conveyor has been attached behind the blade. The spacing between the MS rods used for the fabrication of the elevator conveyor is 20 mm. The slope of the elevator conveyor was kept at 18°. Two oval agitators were provided in the conveying system for separation of soil particles from the onion bulbs. The power to the elevator conveyor has been provided through a gear box (speed ratio 5:27). Two coulter discs are provided in front of the blade at the outer ends, which helps in easy slicing and lifting of soil by the blade. A vie of machine working of digging different crops is given in Fig. 2 and performance results in Table 1. The field capacity of the machine is 0.28, 0.24, 0.21 and 0.21 ha/h for digging carrot, potato, garlic and onion crop respectively when operated at a speed of 2.78, 2.41, 2.10 and 2.10 km/h whereas respective damage is 1.98, 1.92 1.22 and less than 1.0% respectively. The saving in labour ranged from 62 to 71%. The performance of the machine was highly satisfactory for digging these crops except excessive soil coming over the conveyor. Saving in cost of operation and labour for harvesting onion, carrot and, garlic was 52.28, 46.71, 52.28% and 69.05, 59.29 and 69.05% respectively as compared to manual harvesting. There was no saving in labour and cost in case of potato digging as compared to digging of potato using potato digger. However due to more use per year the overall cost of operation will reduce.

Table 1: Performance results of root crop digger cum elevator for digging carrot, onion, garlic and onion crops.

S. No.	**Parameter**	**Onion harvester**				**Farmer's Practice**
		Onion	**Carrot**	**Garlic**	**Potato**	**Onion**
1.	Location of trials	PAU Research Farm				-
2.	Variety of crop	Pb Red Round	Doctor Seed Red	Pb Garlic No.1	Kufri Pukhraj	Harvesting of onion, carrot and garlic manual or using tillers and of potato using potato digger. So comparison is done with manual and of latter with digger.
3.	Age at time of harvesting, days	142	100	160	90	
4.	Operational speed of the machine, km/h	2.11	2.78	2.05	2.41	
5.	Machine capacity,	0.21	0.28	0.21	0.24	

	ha/h					
6.	Effective digging width, cm	105	105	105	105	
7.	Percent of exposed bulbs	99.0	97.3	97.6	96.4	
8.	Percent of cut bulbs	<1.0	1.95	1.22	1.92	
9.	Field efficiency, %					
10.	Fuel consumption, l/h	4.5-5.0	4.5-5.0	4.5-5.0	4.5-5.0	
11.	Yield, q/ha	126.7	356.0	190.0	316.2	
12.	Labour requirement, (man-h/ha) a) For harvesting b) For collection c) Total	 4.80 150.0 154.8	 3.59 200.0 203.6	 4.86 150.0 154.9	 4.13 220.0 224.2	 500
13.	Cost of operation, Rs./h	1002.00	1419.80	1002.00	1428.00	-
14.	Cost of operation, Rs/ha	4772.00	5328.00	4772.00	5950.00	10000.00
15.	Saving in cost of operation,%	52.28	46.71	52.28	0.00	
16.	Saving in labour, %	69.05	59.29	69.05	0.00	
17.	Breakdown of equipment	Nil				

18.	Remarks of the farmers	Machine in development stage

Fig. 2: Onion harvester being used on different crops.

LESSON 27. MISCELLANEOUS HORTICULTURAL TOOLS AND EQUIPMENT

Horticultural tools and equipment mostly manually operated of different types for various operations. It is hand operated equipment and operated by human being. They are simple in operation. Working capacity depends on type of tools used. Cost of operation is very nominal mostly used by gardeners. Overall dimensions depend on type of equipment. Beside manually operated machines power operate machines have also been developed for various horticultural operations performed now a days. Some of them are discussed here.

Compost shredders and mixers: It has an inclined hopper lower side of which consists of high speed combing belt. The endless rubber belt is covered with steel teeth and driven by a built-in electric motor or petrol engine. As the belt moves upward through the hopper, its surface combs and shreds the material until it is fine enough to pass out in a thin layer through the opening between the belt and upper end of hopper. The shredded material is thrown out from the machine by the speed of belt and may be delivered into a large heap. Mixing may be achieved by putting the various constituents through the machine together. When the manure compost is ready for application, it can be spread in the field using farmyard spreader.

Elevators and loaders: Elevators and loaders are very important component of fruit production system. It is essential for bulk loading of fruits and vegetables. General-purpose elevators usually consist of a simple conveyor of chain and slats running on a bed, which may be solid, or in the form of a grille. A hopper and cleaning mechanism can be fitted at base. The angle of bed is adjustable depending upon need. These machines have either two pneumatic wheels or four depending upon the size and capacity. Many elevators and loaders are easily adjustable in height at the lower end as well as at the upper end. They are generally operated by a small engine or motor of 1.0-1.5 kW capacity and are mounted on chassis beneath the elevator.

Tree lopping machine: Lopping of tree is highly labour-intensive and difficult task. It is necessary for having good growth of trees and also from an aesthetic point of view. There is high risks involve in doing this job because the man has to climb the large trees and branches. A power tiller mounted tree-lopping machine can alleviate the problems associated with lopping of tall branches of trees. The machine consists of a circular saw as a cutting unit, a flexible shaft as power transmission unit and a GI pipe frame to support the shaft (Fig. 1). Power is taken directly from the engine crankshaft. The machine with an optimum operating speed of 1800 rpm can cut branches up to 5 cm thick at a maximum height of 5.4 m from the ground. The average capacity of machine is 0.393 m^2/h, which is higher than manual labour (0.057 m^2/h). On an average, the machine can cut 312 numbers of branches in an hour if all the branches are of 40-mm diameter.

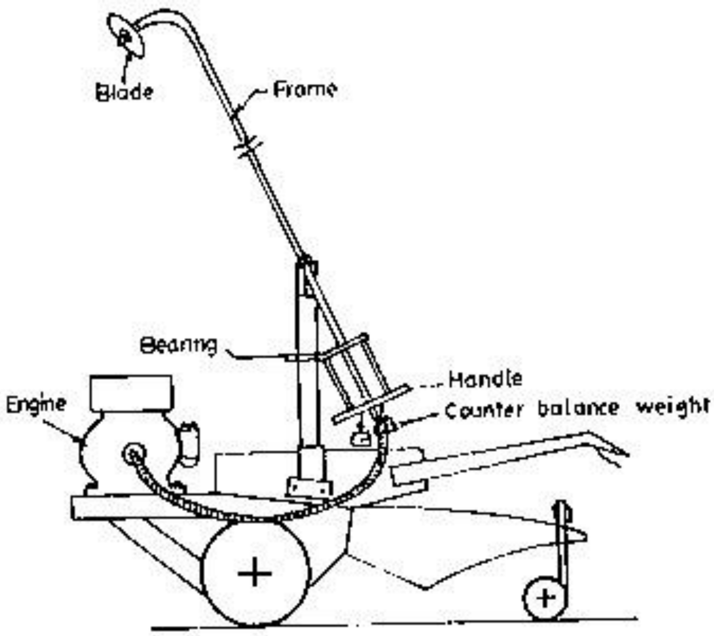


Fig. 1: Power tiller operated tree lopping machine.

Shelling: There are three steps involved to accomplish the stripping of oil palm fruit lets in the field. The first step is to reduce the strength of fruit-stem joint by applying ethephon on fresh fruit bunch just after harvest. Then prepare threshed materials by producing spike lets from the bunch stalk, and finally detach loose fruit lets from cut spike lets using a drum thresher. The removing of woody shell from coconuts with reasonable protection of meat against damage is tedious job. When meat is to be used for copra then the shell is broken by striking with a large knife either manually or mechanically. However, when meat is to be used for shredding, different kinds of knives or saws are used. Variations in size of coconuts, thickness of shells, curvature of the surface and method of holding the coconut are some of the parameters, which affects the peeling.

A number of machines are available for peeling of coconuts. The first peeler developed consisted of convex and concave cylinders and correspondingly concave-convex cutter and endless band bearing on the surface for paring coconut meats. The second machine developed consisted of a suitable frame and table of revolving curved comb-toothed-radial cutters arranged around and at a distance from the central shaft for support and was driven to remove shells from coconuts. Another machine developed had blades connected with a rotating head for cutting the shell from a coconut. A desirable machine is one that (a) removes the shell from a coconut in a clean-cut and facile manner without injury to the nutmeat and to remove the skin with minimum of waste; and (b) has a duplex cutter mechanisms one for producing a saw-like cut on the coconut from end-to-end at a predetermined depth and other for paring the skin from the nut. The machine is motor-driven, compact, inexpensive and simple to use. It has a provision of disposing of the shell-dust and skin fragments during the operation. In yet another machine, a knife is inserted into an eye of coconut and then it is engaged by a toothed endless chain, the teeth of which penetrates into the shell and move on the knife to remove the shell from meat.

The most of the machines for shelling coconuts involve the use of clamps and employ pressure against the surface to hold the nuts. Whether these clamps were smooth or pronged, many of them are ineffective in holding the nut adequately for smooth shelling. Many of the shelling methods involve complex and expensive equipment requiring constant maintenance. The manner of shelling the nuts includes parallel as well as helical cuts of hard shells, either of which results in inefficient separation of nutmeat and consequently high losses occurs. To minimize the losses, a machine was developed for shelling of whole coconuts. The machine comprises of gripping mechanism to hold the nut rigidly at its ends with grippers that penetrate into shell. The grippers are locked into an axially fixed position and rotated with nuts. Rotary cutter cuts the shell layer-making spiral cut around the central portion of nut while it is in rotation.

Shredding: Large quantities of shredded coconuts are used throughout the world. To prepare it, the shell is clipped from the fresh nut with a sharp axe and the brown cover is shaved off the kernel. It is then washed in water several times, shredded and dried in ovens. It is graded on the basis of fineness of grain and packed for further use. The hand knives are generally used for cutting the kernel or meat from coconuts. The nuts are split in halves and then skilled man cuts the meat from the shell by holding the half in one hand and manipulating the knife with other. This is slow and extremely tiring work and sometimes it becomes necessary to cut the meat into small pieces.

The commonly used mechanical device for shredding large quantities of coconut meat consists of a rotating disc having tangential arranged series of perpendicular comb teeth just above the plane of disc. As the disc rotates, chunks of fresh coconut meat are pressed against it and are squeezed between the comb teeth and the cutting knife to form the coconut shred. This causes a large degree of compression of nutmeat. The coconut shreds are then dried for further use by the consumers.

POST-HOLE DIGGER

The perennial crops require specialized operations like digging and pitting at the time of planting. Pitting is necessary to provide favourable conditions for early establishment and growth of young plants. In the conventional pits, the roots of tree seedlings are unable to penetrate deep into the hard soil and results in uprooting during high-speed winds. In the conventional method, the pits are dug with spade, pick axe etc. which are laborious and time consuming.

Auger digger: It is a high speed machine fitted 1.3 kW single cylinder two stroke engine (Fig. 2). It consists of auger, engine and handle. The weight of equipment is 8 kg, which is easy to handle. For hill region it is efficient equipment for horticulture crops. The auger has length of 680 mm diameter of 60 mm. Capacity is 30 pits/h. It is very efficient equipment for horticultural cultivation.

Fig. 2: Auger digger,

The post-hole digger is an implement that drills/digs a hole of varied sizes and depths, which are required for plantation of trees and samplings, fencing, erection of marking stones etc. It can be attached to a 3-point hitch of a tractor. It saves a lot of time as compared to manual digging. It is safer and most economical method of drilling/digging the holes for plantations, nurseries etc. It consists of an auger, which is driven through bevel gears by the tractor PTO. Auger points and leading blades are replaceable.

A soil counter-sinking attachment to the tractor-operated post-hole digger can be used for making conical pits. The soil counter-sinking attachment is fitted on co-operating auger of the post-hole digger (Fig. 3). It includes a sleeve to which three ties of equal lengths are attached. The inner wall portion of sleeve is so designed that it just engages the outer wall portion of co-operating auger of the post-hole digger. Three soil cutting blades extending in the upward direction are welded with three equally spaced ties. The struts made of MS angle hold these ties. The whole assembly is then coupled to the propelling shaft of post-hole digger. The post-hole digger fitted with counter-sinking attachment is placed in a vertical position in the soil and drive is given through PTO shaft. The auger portion makes a cylindrical hole and counter-sinking attachment enlarges the hole in the form of an inverted truncated cone. The pits so made are suitable for planting and growing coconut palms and rubber. The auger gets drive from the tractor PTO through a propeller shaft and bevel gear box. The perpendicularity of digging auger is maintained with four-bar linkage formed by hitching system the tie rod provided at the top. The tip of the auger is either diamond shaped or pointed with wings to suit to different soil conditions. The diameter and depth of hole can be changed by changing the auger assembly.

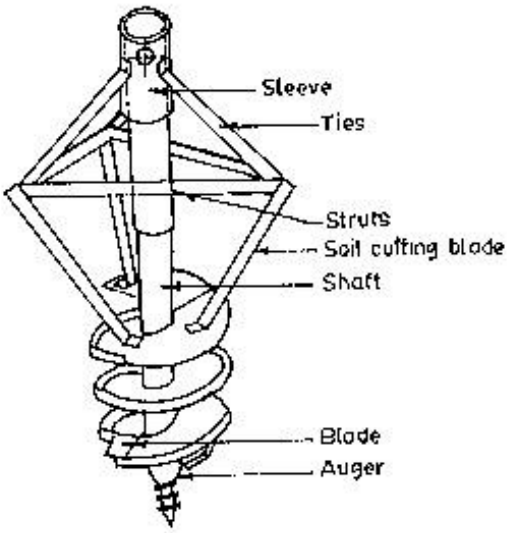


Fig. 3: Post-hole digger (tractor operated)

A power tiller operated auger digger can also be used to dig the holes for planting tree-seedlings. The machine consists of a spiral auger actuated by a rack and pinion arrangement (Fig. 4). The auger can be moved up and down with the help of a rotating hand wheel. The drive for circular motion of auger is affected through belt and pulley and bevel gear transmission from engine directly. The entire assembly can be mounted on a rectangular frame. The hand wheel provided at the side of unit can be used for depth control. It can be used where tractor cannot be used. Power tiller operated auger digger consists of a small frame with the provision to lower and raise the soil-working element. Drive is provided to the unit with the help of a set of bevel gears and belt pulleys. Lowering and raising is accomplished by means of a rack and pinion arrangement which is operated by a hand wheel. It has two depth adjustment wheels, which support the weight of the implement, and provides stability. Pits can be dug up to a depth of 45 to 60 cm and the diameter of the posthole is 30 cm. For operation the auger is mounted on a power tiller and is lowered with the help of a steering. The auger is lifted when the desired depth of the hole is achieved. The machine can dig 35-40 holes/h.

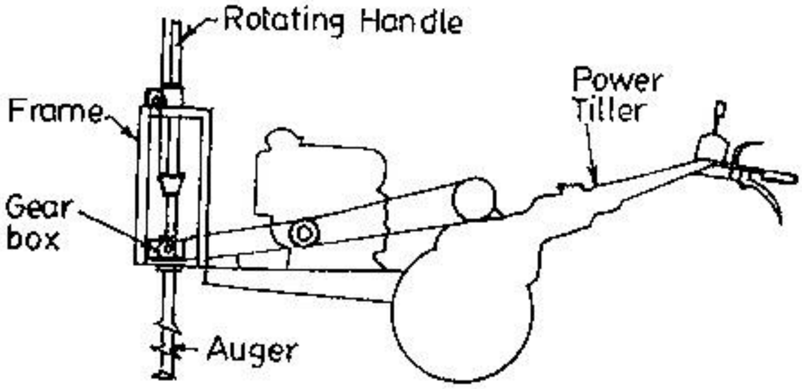


Fig. 4: Power tiller operated post-hole digger.

Tractor mounted banana Stem shredder

Banana is a major cash crop of the country, cultivated on 4.4 lakh hectares. Out of the total of about 10.4 million tonnes produced, the state of Maharashtra alone accounts for 63,000 ha under this crop. In India about 20 cultivars viz., Dwarf Carvendish, Rabusta, Monthan, Proven, Nandran, Red banana, Nyali, Safed Vekhi, Basarao, Ardhapuri etc are cultivated. Banana is mostly check row planted with the spacing varying from 125 x 125 to 150x150 cm, depending upon the variety. Plant population is about 4,500 per ha. After the harvest of the banana bunch, the stem is manually cut and left in the rows. After the harvest of the whole field, these are collected and left near the boundary for drying and subsequent burning. This process is tedious and time consuming. The banana stem shredder helps in disposing of the stem immediately after harvest. Shredded material is suitable for mulching in the banana garden and also for vermi compost. The average diameter of banana stem is 225 mm at the bottom and 100 mm at the top with the average height of 2400 mm. The banana stem consists of 95% of water and only 5% of fiber.

The shredding unit consisted of 4 blades placed perpendicular to each other at 225 cm distance. Additionally, 12 nos. of spikes with flat cutting edge are fitted with a gap of 120 mm between the rows. The whole device is mounted on a frame made of MS angle. The blades are driven by the PTO of the tractor with a bevel gear box and the hopper is trapezoidal in shape with a height of 800 mm. The stem is cut into small pieces and the water and fibre are separated. During field trials it takes 1.2 minutes to shred the stem having average height of 2400 mm (Fig. 5). About 52 stems are required for shredding in one hour. The shredded material can be used for mulching in the banana garden. The shredded material takes 3-4 days to dry. The shredded fibre can be used for preparing vermi compost.

Fig. 5: Tractor mounted banana stem shredder.

Plant shredder for vermi compost

Vermi compost is a major ingredient in organic cultivation prepared from animal dung or biogas slurry. Though cattle population is increasing still there is shortage of dung as it is mainly used by farmers for cooking stove thereby reducing its availability for vermi compost. There is several biomass weeds material grown in nature rich in NPK content but not being used for productive purposes. A plant shredder is an effective machine for shredding of biomass weeds into small pieces which can supplement dung to prepare vermi compost. A plant shredder (Fig. 6) was tested in shredding of two weeds biomass i.e. Casia tora and Lantana camera and mixed with cow dung in 60:40 and 40:60 proportion and vermi compost was prepared with time treatment of 45 and 60 days. The weed biomass was shredded by shredder in 2 to 4 cm pieces with output of 175 kg/h. The vermi compost was prepared and its NPK was determined using standard procedure. The result showed that after 60 days of time vermi compost with 40 percent cow dung and 60 percent biomass weed gave significantly higher NPK content over control treatment of vermi compost with plain cow dung.

Fig. 6: Operation of plant shredder.

Tractor mounted banana clump remover

Banana crop is maintained for two years to get the benefit of two harvests. The crop needs removal of clumps (plants along with root portion) after two years. During the process of removal of the clump, the entire mother plant along with the rhyzome and side suckers as a whole mass has to be removed so as to prepare the land for the next crop. Manual labourers using crowbars and spades do this operation. The labourers have to dig to a depth of up to 450 mm to remove the clumps and hence the operation is cumbersome.

In view of above, a tractor operated banana clump remover was developed at TNAU, Coimbatore to mechanize the clump removing operation and to reduce human drudgery involved. The nine-tyne cultivator frame has been adopted for the development of the equipment. Two numbers of 100 x 15 x 1000 mm sub-soiler shanks with shares of size 190 x 40 x 5 mm are fitted in the nine tyne cultivator frame at 225 mm spacing. These two sub-soilers perform as a fork while removing the banana clump. A deflector has been provided to push the soil sideways. The equipment is attached to the 3-point linkage of a 26 kW tractor. For removal of banana clump the sub soiler shank is positioned behind it, and pressed into soil with the hydraulic system and the tractor is gently moved forward, simultaneously lifting the sub-soiler (Fig. 7). This combined action removes the entire clump along with its root portion as a whole mass. The field capacity of machine is 0.5 ha/h.

Fig. 7: Tractor mounted banana clump remover in operation.

MODULE 11. TESTING OF FARM MACHINES, RELATED TEST CODES AND THEIR USE, INTERPRETATIONS OF TEST RESULTS

LESSON 28. INTRODUCTION TO FARM MACHINERY TESTING, TYPES OF TESTS, TESTING PARAMETERS

Protocol for Testing of Agricultural Machinery

Objectives

- To test agricultural machinery, engines, pumps, etc. manufactured in the country with a view to assess their functional suitability and performance characteristics under different agro climatic conditions, so that, the published test results would:

  a) Serve as a basis to decide the type of machinery best suited for Indian conditions, which could be encouraged for production and popularization.

  b) Help the farmers and other prospective purchasers in determining the comparative performance of machinery available in the market.

  c) Provide material to researchers/designers for undertaking development work on agricultural machinery, engineers and extension workers for guiding farmers and other users in the proper selection of equipment.

  d) Form basis for standard specifications to be used by the manufacturers and distributors.

  e) Help financial Institutions in recommending financial assistance to the manufacturers as well as the farmers.

- To carryout trials on machinery and implements which have proven successful in other Regions of the World with a view to explore the possibility of their introduction in the Region/Country.

- To provide feedback to the manufacturers through "Users' Survey" aiming at the farmers response and the standard of after sales service provided by them.

- To assist Bureau of Indian Standards in the formulation of various Standards on agricultural implements and machines.

- To carry out allied research development on agricultural machines and implements.

Farm machinery testing involves the determination of:

- Functional performance characteristics of machine
- Power requirement of a particular component of whole machine
- Durability
- Wear testing of some of soil engaging tools

- External forces such as soil forces acting on soil engaging tools, and
- Stresses developed in different parts of machine due to static or dynamic loading.

Farm machinery manufacturers are very much concerned to know the above details about their products. Tests conducted by various state and central agencies and institutions involve the functional performance tests, power measurement, durability test, wear test and forces acting on tillage tools. Proper planning and careful execution of tests is extremely important. Wherever feasible, tests may be designed to permit statistical analysis of results to accelerate durability tests in the laboratory and functional tests in the field.

Testing of farm machines is useful to both buyers i.e. farmers as well as to the manufacturers. Testing encourages improvement in quality and functional suitability. Testing of machines helps farmers in proper selection of implement, suitable power source and required adjustments in machines. It helps manufacturers in commercial publicity of product, better design and sales promotion. Comparable data for similar machines is available to manufacturers, which help them in improving the design of their product.

Different countries have established various organizations and institutions, which test the farm equipment, supplied by the manufacturers and submit the confidential reports. The foremost duties of such organizations are to first develop the standard test codes for different types of farm machines, which forms the basis for testing of the machines. Government of India has established Bureau of Indian Standards, which does the job of preparing standard test codes. Other countries in the world have also similar organizations; some of them are Nebraska Testing Center in USA, British Standards Institutions London, in U.K., Organization for the Economic Co-operation & Development (O.E.C.D.), Paris and International Organization for Standardization (ISO) etc.

Bureau of Indian Standards, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi has develop standard codes for agricultural tractors and power tillers, agricultural produce processing equipment, crop production equipment, farm transport equipment, forestry and plantation crop machinery, harvesting and threshing equipment, horticultural equipment, soil working equipment and sowing, fertilizer and manure application equipment.

International Organization for Standardization (ISO) was formed in 1947 with headquarter at Geneva, Switzerland to promote the development of standardization and related activities with a view to facilitate international exchange of goods and services and to develop cooperation in the share of intellectual, scientific, technological and economic activities. The organization consists of Technical Committee (TC) and Technical Advisory Group (TAG). ISO comprises of National Standard Bodies of 91 countries including India, which is represented by the Bureau of Indian Standards (BIS). The tests are conducted by the Farm Machinery Training and Testing Institutes under the jurisdiction of Ministry of Agriculture, Government of India. Currently, there are four institutes located at Budni in Madhya Pradesh, Hissar in Haryana, Anantpur in Andhra Pradesh and Vishwananth Chariali in Assam. The development of International Standards on quality Management systems led to ISO 9000 series of standards in 1987. In all following six standards were issued:

ISO 8402 : Quality Management and Quality Assurance – Vocabulary

ISO 9000 : Quality Management and Quality Assurance – Guidelines for selection And usage

ISO 9001 : Quality System Model for quality assurance in design, development, Production, installation and servicing

ISO 9002 : Quality System Model for quality assurance in production, installation and servicing

ISO 9003 : Quality System Model for quality assurance in final inspection and test

ISO 9004 : Quality Management and quality system elements – guidelines

Types of Tests

Two categories of test viz. **(1) Commercial** and **(2) Confidential** can be carried out at for performance evaluation of agricultural machinery.

- Commercial Tests are for establishing performance characteristics of machines that are already in commercial production or ready for commercial production.
- Confidential Tests are for providing confidential information on the performance of machines, whether ready for commercial production or not or to provide any special data that may be required by the manufacturer/applicant.

General regulations governing all tests

- Machines may be tested at the request in writing of the manufacturer/accredited importers referred to as applicant herein after.

- All the tests should be conducted as per IS Test Codes. If for any machine/component, the IS test code is not available; the test code shall be framed by the Testing Authority whose decision shall be final.

- The amount of test fee, service tax and other estimated expenditure will be intimated to the applicant who will deposit it in advance through a Bank Draft with the particulars as mentioned in the application form.

  a) All charges on account of test fees, stores, fuel, oils, lubricants, spare parts, general stores, work-shop charges, other items as laid down by the Ministry of Agriculture, Labour overhead charges incurred during the test shall be borne by the applicant and the machinery will be delivered by the applicant at the testing Institute at their own cost.

  b) If a machine is withdrawn by any reason, the permission of the Testing Authority will have to be obtained. In such a case the test fee plus all the other expenditure as indicated above for test conducted shall be charged.

  c) Parts of assemblies of machines worn out or damaged during test shall be replaced/repaired by the applicant free of cost within the time specified by the Testing Authority and may be handed over at the discretion of the Testing Authority only after the test report has been released.

d) The cost of laying foundation, fixtures, etc. which are not normally available at the Institute and which are found necessary for working of the machine under test and all special store items shall be borne by the applicant.

- The applicant will make his own arrangement to collect the machine within one month of intimation by the Testing Authority.
- If a machine submitted for confidential test has been tested as per relevant commercial test procedure and the procedure followed for commercial testing has been observed in all respects, then on the request in writing of the applicant, the confidential test report may be converted to commercial report.

Additional regulations governing commercial tests

- The applicant may mention in advertisements that the machine/component has been tested at the Farm Machinery Institute (as the case may be) and invariably quote the number of the Test Report in the advertisement. All the pamphlets or advertisements meant for public should indicate only performance values observed by the Testing Authority.
- The Government of India reserve the right to publish or to communicate to any person or body the results either wholly or in part together with such comments and additional information as they think desirable.
- In case of machines which are marketed and are not tested for the benefit of the farmers, the Institute on the direction of the government, reserves the right to carryout commercial test on any such machine sold in the country and to publish the results thereof.
- In case of damage to or breakdown of any particular component during the course of testing, the applicant may replace the part with a new one having the same specifications. Replacement of complete assemblies shall not be permitted. If major breakdown occurs, necessitating replacement of major assemblies, the applicant is allowed to withdraw the machine.
- In case the machine is withdrawn from test because of reasons stated above, the applicant shall have to submit another machine after incorporation of required changes or replacements. The test report of the first machine containing the results of test conducted and clearly stating the reasons for non-completion of tests shall be released immediately after withdrawal of the machine from test. The test report of second machine shall contain a reference to the testing of the earlier machine.

Additional regulations governing confidential tests

- Results obtained will be the property of the applicant and will not be communicated to any person or body without the applicant's consent. The applicant shall neither publish the report not any extract from it nor divulge test results to any other person or body without prior written approval of the Testing Authority. The report shall not be used for commercial purposes.

- In case of confidential tests, adjustment, modification or alteration in the machine may be permitted at the discretion of the Testing Authority.

General conditions

- The applicant shall supply in English (and if available, also in Hindi) three copies each of published literature, detailed specifications, operator and service (workshop) manuals and illustrated parts catalogue of the machine. Any other details required by the Testing Authority shall also be supplied. These shall be retained at the Institute.
- The operation, maintenance and servicing of the machine shall be carried out according to the procedure laid down in the manufacturer's printed literature unless otherwise specified by the applicant prior to the commencement of the test. Where choice of adjustments or operating conditions is made by the applicant, the guide in making such choices will be the one suitable for general operations. In case of doubt, the opinion of the Testing Authority will be deemed as final.
- It will be the responsibility of the applicant to ensure that the machine is in good condition. In case the machine requires running-in, the same will be carried out, in consultation with the Testing Authority before submission of machine for testing. Details of running-in should be supplied by the applicant at the time of submitting application.
- Facilities to tune-up, adjust and initially set up and run-in of the machine before the actual tests commence will be allowed to the applicant. In case of commercial testing, no adjustments shall ordinarily be permitted during the actual test.
- The representative of the applicant with proper letter of authority will be permitted to witness the test at the discretion of the Testing Authority. The representatives may be allowed to collect necessary factual data about the performance of the machine on the clear understanding that name of the Testing Authority shall not be associated with any data so collected by the representative or published by the applicant.
- Permission to collect the data on performance of machine during the tests shall be granted at the discretion of the Testing Authority.
- Neither the Testing Authority nor anybody engaged on his behalf for conducting tests will be held responsible for any accident, damage or loss whatsoever, to the machine/component/equipment which may occur while in custody, storage, transit and/or during the tests.
- When special tests are required to be carried out, all expenditure be payable by the applicant.
- The schedule of fees may be reviewed and altered if necessary with reference to cost of maintenance of equipment and apparatus used and labour and time spent on testing, with the approval of the Ministry.
- The applicant shall also supply special tools, if any, required for servicing, adjustments, and major repairs of the machine along with list thereof.

- In the case of machines which during tests are also required to be run on public roads, the applicant will arrange for necessary permission under the Motor Vehicles Act, if so required.

- For components tests such as agricultural discs, ploughs, shares, cultivator tines, etc. The applicant should supply a complete unit of the standard machine for which the components are meant to be fitted. In case of agricultural discs, a complete disc harrow and/or also plough should be submitted if required by the Testing Authority.
- The testing of machine/components shall be commenced by the Testing Authority only after completion of al formalities by the applicant as indicated in these regulations. On completion of test and payment of testing charges in full, a copy of the draft test report shall be made available to the applicant for scrutiny and comments. In case the applicant fails to submit comments within the stipulated time, the Testing Authority may release the final test report. In case of commercial test report, such of the applicant's comments which contribute technically to the contents of the test report will be included in the test report under a separate chapter referred to as "Applicant's

Comments' at the discretion of the Testing Authority.

- Three copies of the test report shall be supplied to the applicant free of cost. Additional copies shall be supplied on payment of the cost that maybe fixed by the Testing Authority from time to time.
- The test report issued by the Testing Authority on a particular model or sample of machine/implement/component, etc. applied only to that particular model/brand submitted for test.
- The test reports issued by the testing Authority contain only the data obtained on the particular sample of a model/brand tested by the Testing Authority but these do not in any way signify the approval of the Government or the testing authority of the models/samples tested.
- No interim test report shall be issued on a machine while under test.
- The Government of India reserved the right to change these regulations at any time as may be found necessary without any notice to anybody and such changes will be binding on all concerned.

Additional regulations governing the expression of opinions

- A fee equal to half of the amount of test fees fixed in respect of the tests carried out on the machine will be charged for each expression of the opinion issued. It is in the discretion of the Testing Authority to issue the expression of opinion or not. Director/The Head of the Institute shall obtain the approval of the Government of India before issue of such expression of opinion.
- The expression of opinion is confidential to the applicant who will not publish it except with the prior approval in writing obtained from the Testing Authority.

What can be tested

- ✓ Tractor drawn/power operated Agricultural Machines/Equipments
- ✓ Power Tiller drawn/self propelled Crop Reapers/Transplanters
- ✓ Animal drawn Agricultural Implements/Equipments
- ✓ Manually operated Agricultural Implements/Equipments
- ✓ Power operated Threshers, Decorticators, Sheller, Winnowers
- ✓ Components of Agricultural Machinery
- ✓ Agricultural Hand Tools

Beneficiaries

- ✓ Manufacturer's of Agricultural Machinery
- ✓ Research and Development Organizations
- ✓ Agricultural Universities
- ✓ State Agro Industries
- ✓ Rural Financial Institutions
- ✓ Rural Development Agencies engaged in Farm Mechanization
- ✓ Distributors and users of Agricultural Machinery

LESSON 29. PROCEDURE FOR TESTING FARM MACHINERY. BIS,ISO,RNAM TEST CODES

Procedure of testing of farm machinery – an example

POWER REAPER

(Self Propelled) [Commercial]

1 SCOPE OF TEST

1.1 LABORATORY TEST

- Checking of specifications

- Engine performance

- Noise measurement

- Mechanical vibration measurement

- Turning ability

- Hardness & chemical analysis

- Wear analysis

1.2 FIELD TEST

- Rate of work

- Quality of work

- Labour requirement

- Ease of operation & adjustments

- Defects, Breakdowns & Repairs.

2 METHOD OF SELECTION

The machine was selected from manufacturing unit from a lot or it may be directly submitted for test.

TEST PROCEDURE: The following Test Codes were referred for testing of Self Propelled Power Reaper:

(i) IS: 11467-1995 (Reaffirmed in Jan. 2001) (Test Code for Cereal Harvesting Machine)

(ii) IS: 6025-1982 (Reaffirmed in Dec. 1999) (Specification of knife section)

(ii) IS: 10378-1982 (Reaffirmed in Jan. 2001) (Specification of knife back).

SPECIFICATIONS to be recorded

-

4.1 General: -

Manufacturer	:	
Name of machine	:	
Make	:	
Model	:	
Type	:	
Serial number	:	
Year of manufacture	:	
Size of Reaper (mm)	:	
Type of crops recommended	:	

Constructional details may be given (Fig. 1)

4.2 Details of prime-mover:

Type	:		
Make	:		
Model	:		
Serial number	:		
Country of origin	:		
		As specified	**As observed**
Maximum horse power kW (Ps)	:		
Rated Power kW (Ps)	:		

Engine speed (Manufacturer's recommended setting) (rpm):

- High idle	:		
- Rated engine speed	:		
- Low idle speed	:		

- Speed at max. torque :
- Rated engine speed for field :

4.2.1 Cylinder:

Number :

Disposition :

Bore/Stroke (mm) :

Capacity as specified by the applicant (cc) :

Compression ratio :

Type of cylinder liner :

Arrangement of valves :

Valve clearance (cold) (mm): :

- Inlet valve :
- Exhaust valve :

No. of compression rings :

No. of oil ring :

4.2.2 Fuel Supply System:

Type of fuel feed :

Type of fuel filter :

Capacity of fuel tank (l): :

Location of fuel tank :

Provision of draining of Sediments/water :

4.2.2.1 Fuel Injection Pump:

Type :

Make :

Model :

Method of drive :

4.2.2.2 Injector nozzle:

Number & type :

Make & Model :

Injection pressure, (kg/sq. cm) :

Injection timing, (deg.) :

4.2.3 Governor:

Make :

Type :

Range of speed governed (rpm) :

Rated speed (rpm) :

4.2.4 Air Intake System:

4.2.4.1 Pre cleaner: :

4.2.4.2 Air Cleaner:

Make :

Type :

Location :

Suction pressure kPa (mm of Hg) :

Recommended service schedule :

4.2.5 Exhaust:

Type :

Location :

Pressure kPa (mm of Hg) :

4.2.6 Lubrication system:

Type :

Oil capacity (l) :

Oil change period (h) :

4.2.7 Cooling system:

Type :

Details of blower :

Size (OD/ID x W), (mm) :

Size of fin (mm):

Height/Width :

Number of fins :

4.2.9 Starting System:

Type :

4.2.10 Electrical System:

Ignition timing :

4.3 Transmission system

Mode of power transmission from engine to transmission box :

Reduction ratio :

Size of drive pulley, (mm) :

Size of driven pulley, (mm) :

Nos., size and type of belts :

4.3.1 Main Transmission Box:

Make :

Model :

Type :

Batch number :

Mode of power transmission:- It transmits power to the bevel box and final drive through the fourth and second shaft respectively.

Reduction ratio :

No. of speeds

- Forward :

- Reverse :

Nominal speed

Direction of motion	Nominal speed) (kmph)	
	At rated engine speed (2600 rpm)	At field engine speed (2600)
Forward	3.36	3.36
Reverse	2.28	2.28

Lub Oil Capacity (l) :

Method of lubrication :

4.3.2 Final drive

Type :

Mode of power transmission:- It takes drive from the bevel shaft of transmission box and transmits it to the axle shaft. For the reverse speed the power is routed through an idler sprocket.

Details of Sprockets

No. of teeth on drive sprocket :

No. of teeth on driven sprocket :

Reduction ratio :

Details of chain

Type	:	
Length (mm)	:	
- No. & Size of links (mm)	:	
- Size of roller (mm)	:	

4.3.4 Wheel equipment

Type of tyre	:	
Make	:	
Model	:	
No. of tyres	:	
Size	:	
Inflation pressure (Kpa)	:	
Rolling radius (mm)	:	
Track width (mm)	:	

4.4 Steering

Type	:	Double handle, with steering clutches

Constructional details:-.

Method of operation	:	
Spacing of handle grips (mm)	:	
Material of handle grip		
Size of grip (mm)	:	
Height of handle grip from GL, (mm)	:	
Height adjustment of steering	:	

Method of fixing:- Each handle arm is bolted to the reaper frame with two nut and bolts.

4.4.1 Steering clutches:

Numbers	:	

Type	:	
Make	:	
Location	:	
Method of operation	:	

4.5 Reaper Transmission:

4.5.1 Reaper Clutch:

Location	:	
Type	:	
Mode of power transmission	:	
Method of operation	:	

4.5.2 Reaping bevel box:

Type	:	
No. of gears	:	
Reduction ratio	:	

Mode of power transmission:

Type of lubricant	:	MP Grease

4.5.3 Reaper frame:

Constructional details: -.

4.5.4 Cutter-bar assembly:

Working width (mm)	:	
Effective width (mm)	:	
No.& spacing of knife guards (mm)	:	
No. & type of knife blades	:	

Knife stroke (mm)	:
Stroke per min	:
Knife speed corresponding to 2600 rpm of engine (m/s)	:
Details of knife drive	:
Height of cutter bar from G.L. in horizontal position (mm)	:
Method of adjustment	:

4.5.5 Crop divider:

Type	:
Numbers	:
Distance between adjustable shoes, (mm):	
-Maximum	:
-Minimum	:

Details of shoe:

Constructional details: -

- Length (mm)	:
- Width at rear (mm)	:

4.5.6 Crop guide (star) wheel:

No. of wheels	:
Material	:
No. of projections on each wheel	:
Dia of wheel (mm)	:
No & type of bearings if any	:

Method of mounting & its drive: -

4.5.7 **Divider guide**

Numbers & type: -

4.5.8 **Knife: Specification of knife section as per IS: 6025-1982**

Type	:	Top serrated
Total numbers	:	23

4.5.9 **Knife back (Specification of knife back as per IS: 10378-1982)**

4.5.10 **Knife clips:**

Material	:	
Size, (mm)	:	
No. of clips	:	
No., Type & size of bolts fixing knife clips, (mm)	:	
Spacing of knife clips, (mm)	:	
Provision for adjusting the clearance between clip and cutter bar	:	

Method of fixing: - Knife clips are tightened to ledger plate with the help of 2 nos. bolts & nuts to hold the knives & knife backs.

4.5.11 **Ledger Plate Assembly:**

Constructional details:

Size of ledger plate assembly	:	

Ledger plate:

No of plates	:	
Type	:	
Shape	:	
Length (mm)	:	

	Width at base (mm)	:
	Width at top (mm)	:
	Thickness (mm)	:
4.5.12	**Knife Head:**	
	Number	:
	Material & size (mm)	:
	Height of head from cutter bar (mm)	:
	Size of slot for the movement of crank pin (mm)	:
	Method of fixing:	
4.5.13	**Reaping Crank Assembly**	
	Size of crank, (mm)	:
	Size of roller pin, (mm)	:
	Drive safety arrangement	:
4.5.14	**Crop Conveyor:**	
	Number of conveyors	:
	Type	:
	Vertical distance between two Conveyors (mm)	:
	Speed of conveyor chain corresponding to 2600 rpm of engine(m/s)	:
	Provision for tensioning	:
	Drive safety arrangement	:
	Details of Conveyor Chain:	
4.6	**Details of controls:**	

- Steering handle with side clutches
- Throttle lever on RHS handle
- Reaper operating clutch on LHS of reaper frame..
- Main gear shifting lever at center

4.7 Overall dimensions (mm):

Length :

Width :

Height :

4.8 Ground Clearance (mm) :

4.9 Mass with all reservoirs filled (kg) :

4.10 Colour of machine:

- Sheet metal :
- Chasses & other components :
- Handle bar :
- Engine :

5 FUEL AND LUBRICANTS

5.1 Fuel : The High-speed diesel oil supplied *by* M/s Hindustan Petroleum Corporation Limited having density of 0.830-g/ c. c. at 15°C was used.

5.2 Lubricants: As recommended by the manufacturer

6 RUNNING-IN: The machine was run-in at load for 1.0 h in paddy crop before starting the test in consultation with the applicant's representative. The running-in trial was conducted at 2600 rpm of the engine as recommended by the Applicant for field work.

7 TURNING ABILITY

Minimum turning diameter, (m)

Minimum clearance diameter, (m)

8 FIELD PERFORMANCE TEST

SUMMARY OF CROP PARAMETERS

SUMMARY OF FIELD PERFORMANCE

Harvesting of other crops: The applicant requested for evaluating the performance of the machine for harvesting paddy crop only. Thus, the performance evaluation of the machine was limited to only one crop.

Wear of cutter-bar

S. No.	Before Operation	After Operation (26.3 h)	Percent wear	Percent wear per hour
1				

Remarks: - The hourly percentage wear was recorded as 0.05% after the operation of 26.3h.

9. DEFECTS, BREAKDOWNS AND REPAIRS

10. APPLICANT'S COMMENTS

Signature of Testing Authorty

LESSON 30. SAFETY REQUIREMENT IN AGRICULTURAL MACHINES

There has been a phenomenal increase in the number of engines, tractors and different types of farm equipment. In large number of cases, the farm equipment in use is based on imported designs and has been evolved by following the re- versed engineering approach. By no means can these designs be considered as state of the art design. It has been observed that the safety aspects in the existing prime movers and equipment in use in India are far from satisfactory. Consequently, a large number of human accidents are taking place year after year and their number is on the rise. Among the most accident-prone farm machines in India, at present, are power threshers, sugarcane crushers, chaff-cutters, tractors, sprayers etc. Alarmed by the high incidence of human accidents on power threshers, the Indian Parliament promulgated the Dangerous Machines (Regulation) Act No. 35 of 1983. This Act has made it mandatory for farm machinery manufacturers, traders and users to ensure the conformance of the threshers to the provisions of the following BIS-Standards:

i) IS: 9019-1979: Code of practice for installation, operation and preventive maintenance of power threshers.

ii) IS: 9020-1979: Safety requirements for power threshers.

iii) IS: 9129-1979: Technical requirements for safe feeding systems for power threshers.

Excepting the above, there are only few other safety related standards or test codes for farm equipment in India as of now. Hence, there is a great need to focus attention on the safety aspects to minimize the incidence of accidents.

WHOSE CONCERN IS SAFETY?

Safety is an aspect, which is covered under the discipline of Ergonomics and it is the concern of the farm machinery designer, manufacturer, distributor, user, government, public and national standards organization of a country. Each of these agencies can play an important role in minimizing the number of accidents and promoting safety consciousness. For instance, the designer can provide different safety devices, such as guards, shields, safe distances and fail-safe mechanisms. A manufacturer similarly, can ensure adherence to the available standards and use safe and sound materials of construction. Likewise, the distributor and the user can promote farm machinery safety by ensuring that they propagate and use only such machines which are equipped with proper safety provisions. The standards organization of a country has an important role to play by formulating relevant safety standards, codes and test procedures. The Government has to play an important role by making it mandatory to adopt available safety standards by all concerned to minimize the number of accidents.

COMMON CAUSES OF MACHINERY ACCIDENTS: Following are the basic causes of farm machinery accidents:

a) Design errors

b) Failure to install adequate safety devices

c) Employment of safety devices, which failed in use (Brake failure)

d) Failure to make a safety-check after manufacture

e) Use of unsafe/unsuitable material in construction

f) Use of inferior/improper manufacturing processes, which led to defective parts

g) Failure to plan for such uses which were unintended by the manufacturer

h) Improper maintenance & failure to foresee consequences of ordinary wear and tear.

i) Failure to stick to proper standards

j) Addition of undesired/un-required part to the product

k) Failure to warn of the dangers arising from the defective design.

TYPES OF AGRICULTURAL MACHINERY ACCIDENTS: Following are the common types and causes of farm machinery accidents:

Overturns: Machines working at steeper slopes or at higher speeds, quick turning and quick starting.

Run-over: Person inspecting the machine or certain components without turning off the engine.

Trap: Person wearing loose clothes gets wrapped in moving belts, chains, shafts etc.

Cut: Body parts touching the cutting knives, blades, sharp edges etc.

Crush: Person sitting or standing between the machine and its attachment or machine and wall or carrying out under attachments in the tractor or machine.

Fall: Person slipping from the machine platform or steps.

Burn: Body part touching the exhaust manifold pipe or opening the radiator cap when the engine is hot.

Fire: Careless use of fire, smoking, exhaust emissions, carbon particles etc.

Health hazard: Noise, vibration, chemical spray etc.

Hits: Thrown objects.

TECHNICAL REQUIREMENTS FOR ENSURING MACHINERY SAFETY

a) **Safety guards:** These are protective devices designed and fitted to a machine to minimize the possibility of machinery hazards as well as to restrict access to hazardous area.

b) **Safe distances:** These are a means to provide the guard where the possibility of contact with the hazard is minimized by the combination of the guard configuration and proper size of openings, if any.

c) **Safety devices:** A safety device is provided to minimize the incidence of machinery hazards like unintended movement. Therefore, safety-starting device, emergency stopping switch and similar other safety provisions are provided to eliminate the accidents.

d) **Safety signs and warnings:** This includes the information affixed on equipment to alert/warn the operator and others working in its surroundings against hazards, which can cause body injury. The sign/caution/warning plate should be permanently fitted/attached to the machine such that it is readily visible and cannot be easily removed.

e) **Operational ease and comfort:** The operating controls need to be designed and installed in such a way that these could be operated with ease and safely from the operator's seat or work place. Maximum actuating force values required to operate various controls are shown in Table 1.

TESTING OF AGRICULTURAL MACHINERY FOR SAFETY

The main objective of safety testing is to ensure the safety of all those who work on the machine and to prevent human accidents. All technical safety requirements as specified in relevant standards need to be checked and verified thoroughly and reported in the test report. Given in Table 2 is a list of some of the available safety standards and codes formulated by different agencies and organizations.

Table 1: Maximum actuating force required for operating controls as per ISO recommendations.

Controls	Type of control	Maximum actuating force to operate control (N)	Type
Service brake[1]	Pedal operated	600	Pressure
	Hand lever	400	Traction
Parking brake	Pedal operated	600	Pressure
	Hand lever	400	Traction
Single clutch	Pedal	350	Pressure
Duel clutch	Pedal	400	Pressure
PTO coupling	Pedal	300	Pressure
	Hand lever	200	Traction
Manual steering system[2]	Steering wheel	250	-
Power-assisted steering system with failure of power assisted steering force	Steering wheel	600	-
Hydraulic power lift system	Hand lever	70	Pressure & traction

1. It should be possible to achieve effective braking performance when these forces are applied.
2. Force required to achieve a turning circle of 12 m radius.

Table 2: Selected safety standards and test codes formulated by different agencies.

1) OECD Standard Code for the Official Testing of Safety Cabs and Frames Mounted on Agricultural Tractors, OECD Directorate for Agriculture and Food, 2, rue Andre-Pascal, 75775 Paris Cedex 16, Paris, 1974, France.

2) Occupational Safety and Health Standards for Agriculture, Part 1928, Applicable Standards from 29 CFR 1910, US Department of Labour, USA.

3) BIS 11442-1985: Operator's Field of Vision, Method of Test, Bureau of Indian Standards, New Delhi, India.

4) BIS 11821-1986: Protective Structures, Method of Test, Bureau of Indian Standards, New Delhi, India.

5) BIS 12061-1987: Braking Performance Test, Bureau of Indian Standards, New Delhi, India.

6) BIS 12180-1987: Noise Measurement, Method for. Bureau of Indian Standards, New Delhi, India.

7) BIS 9019-1979: Safety requirements for power threshers, Bureau of Indian Standards, New Delhi, India.

8) BIS 9020-1979: Safety requirements for power threshers, Bureau of Indian Standards, New Delhi, India.

9) BIS 9129-1979: Technical requirements for safe feeding systems for power threshers, Bureau of Indian Standards, New Delhi, India.

10) BIS 10740-1983: Operating Requirement for PTO Driven Implements, Recommendations for, Bureau of Indian Standards, New Delhi, India.

11) BIS 12239-1988: Safety and Comfort of Operator, Guide. Bureau of Indian Standards, New Delhi, India.

12) ASAE Standard (S350): Safety-alert symbol for Agricultural Equipment, American Society of Agricultural Engineers, St. Joseph, Michigan, USA

13) ASAE Standard (S365T): Brake Test Procedures and Brake Performance Criteria for Agricultural Equipment, American Society of Agricultural Engineers, St. Joseph, Michigan, USA

14) ASAE Standard (S338): Safety Chain for Towed Equipment, American Society of Agricultural Engineers, St. Joseph, Michigan, USA

15) ASAE Standard (S318.6): Safety for Agricultural Equipment, American Society of Agricultural Engineers, St. Joseph, Michigan, USA

16) ASAE Standard (S355.1): Safety of Agriculture Loaders, American Society of Agricultural Engineers, St. Joseph, Michigan, USA

17) ASAE Standard (354.1): Safety for Farmstead Equipment, American Society of Agricultural Engineers, St. Joseph, Michigan, USA

18) ASAE Standard (S351): (Safety) Hand Signals for use in Agriculture, American Society of Agricultural Engineers, St. Joseph, Michigan, USA

19) ASAE Standard (S335.2): (Safety) Operator Controls on Agricultural Equipment, American Society of Agricultural Engineers, St. Joseph, Michigan, USA

20) ASAE Standard (EP371): (Safety) Preparing Granular Application Calibration Procedures, American Society of Agricultural Engineers, St. Joseph, Michigan, USA

21) ASAE Standard (S383): (Safety) Roll-Over Protective Structures (ROPS) For Wheeled Agricultural Tractors, American Society of Agric. Engineers, St. Joseph, Michigan, USA.

22) ASAE Standard (S276.3): (Safety) Slow-Moving Vehicle Identification Emblem, American Society of Agricultural Engineers, St. Joseph, Michigan, USA

METHODS OF SAFETY TESTING

a) General principles for guarding

i) Conform to relevant legal/standard organization requirements.

ii) Be considered a permanent part of the machine.

iii) Afford maximum positive protection

iv) Prevent access to danger zone during operation

v) Not weaken the machine

vi) Should not interfere with the efficient operation of the machine

vii) Should not cause discomfort to the operator

viii) Be designed for specific job/machine with provisions for proper adjustment, maintenance and repairs

ix) Be durable

x) Be constructed strongly enough to resist normal wear and withstand long use with minimum maintenance. It should not itself be a source of hazard.

xi) If possible it should be interlocked with the machine so that the mechanism can not be operated unless the guard is in place.

b) Parts to be inspected for proper guards/shields

(i) All shafts including joints, shaft ends, crankshafts, universal joints, keys, pins, set screws etc. that protrude from moving parts.

(ii) Pulleys, flywheels, gears, chains, sprockets, belts, clutches, couplings, cables etc.

(iii) Working parts of machines such as rotary tines, cutting blades of stubble shavers and mowers, cutter-bars, knotter mechanism of binder and baler, digging blades, conveyers, oscillating linkages, sieves etc.

(iv) Ground wheels, tyres, and tracks of crawler type tractors adjacent to the operator seat.

In all machines received by a Testing Centre, the above components need to be carefully inspected and observations regarding the provision of guards/shields ought to be included in the test report.

c) Strength of guards: The guards should be sufficiently strong. The test engineer may refer to the following standard while testing the guard:

1928.57 -Guarding of farm field equipment, farmstead equipment and cotton gins-Occupational safety and health standards for agriculture, US Department of Labour, USA

According to this standard, the guards need to be provided and located to protect against inadvertent contact with the hazardous components being guarded. Unless otherwise specified, each guard and support shall be capable of standing the force that a 114 kg individual, leaning on or falling against the guard could exert upon the guard. The guards shall be free from burrs, sharp edges and sharp corners and shall be securely fastened to the machine.

d) Guards for PTO-Shaft: The PTO-shaft shall be guarded by a casing cap, which shall be firmly screwed and bolted to the machine body. A casing throughout its length shall guard the PTO-shaft as well as the universal joints. The casing shall be secured firmly and held in stationary position.

e) Requirements for safety devices

The following points shall be carefully checked in respect of the safety devices provided in different types of farm machines during the course of testing of such equipment:

(i) Each stationary machine shall have the provision to disengage the power drive shaft. The control of the device shall be located within easy reach of the operator.

(ii) Machines such as a stubble shaver and brush cutter shall be provided with adequate means of disengaging the power to the cutting knives easily and promptly.

(iii) A portable type power unit such as the power knapsack sprayer shall be provided with a quick release clutch to enable the operator to disengage the power.

(iv) Power driven machines shall be equipped with a provision to stop the prime mover instantly.

(v) All machines with lifting members shall be provided with a locking device to keep the member in raised position and prevent accidents due to fall.

(vi) The combine shall be equipped with a device to disengage the power to the knife-bar automatically in the event of clogging.

f) Braking devices: The following points shall be checked in respect of the braking devices for testing from the safety point of view:

a) The towed equipment such as trolleys shall be provided with the parking brakes.

b) Self-propelled machines shall be provided with both the service brakes and the parking brakes.

g) Requirements for operator's work place: The following points shall be checked in respect of the operator's work place while testing a machine for safety:

a) All machines requiring the presence of an operator/worker shall be provided with handles/hand-holds to ensure the safety and convenience during mounting and dismounting.

b) All machines requiring an operator/worker to sit *on* the machine shall be provided with a comfortable seat with adequate footrest. The seat shall be adjustable and it shall adequately support the operator/worker in all working and operating modes and shall prevent the operator from slipping off the seat.

c) The platform on which the operator/worker is required to stand during operation shall be levelled and have a non-slippery surface. It shall be provided with guards/rails around it.

h) Requirements for operating controls: The operating controls such as steering wheel or lever, gear selection lever/brake, clutch and switch shall be arranged and fitted in such a way as to allow the safe and easy control by an operator while standing or sitting in the normal operating position. The function and the operating method of these contr01s shall be marked clearly.

TESTING OF ROLL OVER PROTECTIVE STRUCTURES (ROPS): ROPS are now a mandatory requirement for all agricultural wheel tractors in all developed countries for the protection of the operator in the event of accidental overturning. The ROPS are tested in accordance with the following standards/test codes:

1) 1.0ECD Standard Code for the Official Testing of Safety Cabs and Frames Mounted on Agricultural Tractors, Directorate for Agriculture and Food Organization for Economic Cooperation and Development, Paris, France'-1974.

2) Part 1928, Sub part C- Roll Over Protective Structures-Test Procedures and Performance Requirements. Applicable Standards from 29 CFR 1910, Occupational Safety and Health Standards for Agriculture, OSHA, US Department of Labour, USA.

GUARDS FOR HOT PARTS AND FIRE PROTECTION: For testing of the engine/prime mover/equipment with hot parts, the following observations shall be recorded:

i) Any hot part, which may cause burns to the operator or any other person working on the machine shall be fitted with proper guards.

ii) Hot parts such as exhaust pipe shall be designed and fitted in such a way that these do not pose any hazard to the operator.

iii) Spark arrester shall be provided with the exhaust silencer to arrest the glowing carbon particles.

PROTECTION AGAINST THROWN OBJECTS: While testing a machine, it shall be ensured that there are no working parts of the machine, which may produce lead to throwing of such objects, as stones, fragments of the crop or cutting knives. All such parts shall be guarded adequately to ensure the safety of the operator.

PROVISION OF SAFETY SIGNS: While testing a machine, it shall be ensured that the safety signs have been provided adjacent to the following parts:

(i) Dangerous parts which are difficult to protect by safety guards.

(ii) All hazardous parts, which need alerting the operator against hazards.

MEASUREMENT OF NOISE LEVELS: During testing, the noise levels produced by a prime-mover/ machine shall be measured by a sound level meter at the operator's ear level. Exposing the ear to excessive noise results in shifting of the hearing threshold levels of the operator upward. Frequent exposure leads to permanent threshold shift and eventually to the hearing loss. The permissible noise levels and the effects of vibrations on humans are shown in the Table 3.

Table 3: Permissible sound levels for occupational safety of ears.

Duration/day (h)	Sound level dB(A)
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.5	110
0.25 or less	115

POSITIVE PRINCIPLES FOR SAFE USE OF FARM EQUIPMENT: Following points need to be kept in view to avoid the accidents while operating a farm machine:

(i) Proper environment, which should reduce fatigue and stress

(ii) Proper placement of controls and instruments to ensure easy accessibility.

(iii) Proper identification of controls & instruments

(iv) Isolation of operator and any other person coming into contact with the machine from dangerous mechanisms, e.g. cutters, rollers thrashing cylinders etc.

(v) Provide adequate guarding where persons are likely to approach within reach of dangerous mechanisms.

(vi) Guard against falls with adequate rails, etc.

(vii) Provide clear and easy path to the operating position.

(viii) Design mechanisms and controls to "failsafe", i.e. to revert to safest state in case of mechanical/operational failure.

(ix) Provide "Overload" and similar devices to avoid critical operating state.

(x) Ensure adequate operator visibility of possible hazardous situations.

(xi) Proper latches/devices to ensure that the equipment is not ~ set in operation by accident (eg. chaff cutters)

(xii) Provide interlocks to minimize unsafe operation.

(xiii) Provide easily reached and operated "emergency-stop" facilities.

(xiv) Avoid heavy lifting/carrying of equipment.

(xv) Provide adequate supports so that hazards due to the equipment overturning are minimized.

(xvi) Prepare clear and unambiguous operating instructions.

(xvii) Design lubrication and other maintenance facilities so that the work can be easily accomplished.

(xviii) Provide labels laying down clear instructions on methods of carrying out maintenance and routine repairs & overhauls.

(xix) Design components for easy & safe removal.

(xx) Provide proper earthing and guarding for all electrical circuits.

(xxi) Where a hazard is unavoidable, provide warning signboards to ensure that operators and others recognize the danger.

(xxii) Insist on regular inspection and maintenance.

MODULE 12. SELECTION AND MANAGEMENT OF FARM MACHINES FOR OPTIMUM PERFORMANCE

LESSON 31. COST OF OPERATION OF MACHINERY FOR OPTIMUM USE

One of the most important items influencing the profitability of farming operations is the cost of owning and operating the farm machines. Accurate cost estimates play an important role in every machinery management decision, namely, when to trade, which size to buy, how much to buy, etc. There are two types of machinery costs viz. fixed and variable costs. Fixed costs depend on how long a machine is owned rather than how much it is used. It includes depreciation, interest, taxes, shelter and insurance. Variable costs also called operational costs vary in proportion to the amount of machine used. It includes repair and maintenance, fuel, oil or lubrication and labour costs.

FIXED COSTS

Depreciation: Depreciation costs mean a loss in the value of a machine due to time and use. Often, it is the largest of all costs. Machine depreciate, or have a loss of value, for several reasons such as age, wear and tear of machine and obsolescence. There are several methods to calculate the depreciation. These methods are estimated value, straight-line, declining-balance, sum-of-the year's digits, and sinking-fund methods.

Estimated Value Method: It is the most realistic determination of depreciation. At the end of each year the value is compared with the value of machine possessed at the start of the year. The difference is the amount of depreciation (Table 1).

Table 1: Estimated values of depreciation at the end of year.

Machine	% of purchase price									
	1	2	3	4	5	6	7	8	9	10
Tractor	36	6	5	5	5	4	4	3	3	3
Self-propelled combine	41	7	6	6	5	5	4	4	3	3
Tractor-drawn combine	46	7	6	5	5	4	4	3	3	2

Straight-line Method: In the straight-line depreciation method, an equal reduction of value is used for each year the machine is owned. This method is used to estimate costs on a specific period of time, provided the proper salvage value is used for the age of the machine. The annual depreciation value can be calculated by:

$$D = \frac{P - S}{L}$$

Where,

D = average annual depreciation, Rs/annum

P = purchase price, Rs.

S = salvage value, taken as 10% the purchase price

L = life of machine, years

The straight-line depreciation method is not accurate. The cost of machine depreciates much faster in the first few years than in the later years.

Sum-of-the Years Digits Method: It is a much more accurate method of estimating the true value of a machine at any age because the annual depreciation rate decreases as the machine gets older. The amount of depreciation can be determined by

$$D_{n+1} = \frac{L - n}{Y_d} (P - S), \text{ Rs./year}$$

Where,

Y_d = Sum of the years digits = L (L + 1)/2

N = age of the machine in years at the beginning of year in question

L = life of machine, year

P = purchase price, Rs.

S = salvage value, Rs.

Declining-Balance Method: It reflects the actual value of a machine at any age. A machine depreciates different amount for each year, but the annual percentage of depreciation is the same. Depreciation can be calculated by:

$$D_{n+1} = V_n - V_{n+1}$$

$$V_n = P (1 - X/L)^n$$

$$V_{n+1} = P (1 - X/L)^{n+1}$$

$$D_{n+1} = P (1 - X/L)^n (X/L)$$

Where,

D_{n+1} = amount of depreciation charged for year n+1, Rs./year

V = remaining value at any time

P = purchase price, Rs.

N = age of machine in years at beginning of year in question

L = life of machine, years

X = ratio of depreciation rate. It may be any number between 1 and 2.

If X = 2 the method is called double-declining-balance method.

For used machine X is taken as 1.5.

Sinking-Fund Method: It is primarily advantageous for use with a planned replacement internal policy. By formula the values for the sinking fund annual payment (SFP) and the value at the end of the year n are:

$$SFP = (P - S) \frac{i}{(1 + i)^L - 1}$$

$$V_n = (P - S) \left[\frac{(1 + i)^L - (1 + i)^n}{(1 + i)^L - 1} \right] + S$$

$$D_{n+1} = V_n - V_{n+1}$$

Where,

D_{n+1} = amount of depreciation charged for year n+1, Rs./year

V_n = remaining value at the end of the year n, Rs.

V_{n+1} = remaining value at the end of the year n+1, Rs.

P = purchase price, Rs.

S = salvage value, Rs.

i = interest rate, fraction

L = life of machine, years

Interest on Investment: A large expensive item after depreciation for agricultural machinery is the interest. It is a direct expense item on borrowed capital. Even if cash is paid for purchased machinery, money is tied up that might be available for use elsewhere in the business. Interest rates vary considerably but usually are between 12 and 16 percent. Annual interest is calculated on an average investment by using the prevailing interest rate by the following formula:

$$I = \frac{P + S}{2} \times \frac{i}{100}$$

Where,

I = annual interest charge, Rs./year

P = purchase price, Rs.

S = salvage value, Rs.

i = interest rate, per cent

Insurance and Shelter: Insurance and shelter charges together are taken @ 2% of the purchase price per year.

VARIABLE COSTS

Repair and Maintenance Costs: Repair and maintenance costs are considered as an essential and significant part of machinery ownership. Occasional repairs and periodic maintenance are required to maintain a machine in good working order and ensure a high degree of reliability. The more a machine is used, the greater is its need for repair. The factors necessitate the repairs in a machine are routine wear, accidental breakage or damage, operator's negligence and periodic overhauls. Repair costs consists of the expenditures incurred for the spare parts and the labour for repairs made in a shop or on the farm. Repair costs vary from one geographical region to another because of the differences in machinery use, labour wages and prices of spares. Repair costs increases with the age of a machine but tends to level off, as a machine becomes older. The accumulated repair and maintenance costs (TAR) at any point in a machine's life can be estimated by using the following formulae (IS: 9164 - 1979):

For four - wheeled and crawler tractors $TAR = 0.100\ X^{1.5}$

For stationary power units and two-wheeled tractor $TAR = 0.120\ X^{1.5}$

For agricultural trailer $TAR = 0.127\ X^{1.4}$

For PTO-driven combine, seed drill and Sprayer $TAR = 0.159\ X^{1.4}$

For plough, planter, harrow, ridger and cultivator $TAR = 0.301\ X^{1.3}$

For seed cleaner $TAR = 0.191\ X^{1.4}$

For self-propelled combine, dozer and scraper $TAR = 0.096\ X^{1.4}$

Where,

TAR = total accumulated repair cost divided by purchase price of machine, expressed as percentage

X = 100 times the ratio of the accumulated hours of use to the wear Out life

Fuel and Oil Cost: With tractors and other powered farm equipment, the cost of fuel and oil must be included in the total machine charge. Power required may be estimated as follows:

$$Dbhp = \frac{D\,S}{270}$$

Where,

Dbhp = drawbar horse power, hp

D = draught, kg_f

S = speed, km/h

Or,

$$dbhp = \frac{D\,S}{3.6}$$

Where,

Dbhp = drawbar power, kW

D = draught, kN

Fuel consumption can also be estimated by the following equation:

F = LCF x RHP x SFC/1000

Where,

F = fuel consumption, l/h

LCF = load coefficient factor for the operation

RHP = rated horsepower of the power source, hp

SFC = specific fuel consumption, ml/hp/h

The values of LCF and SFC for different operations and power sources are given in Table 2.

Table 2: Values of LCF and SFC for different operations and power sources.

Power source	Type of work	LCF	SFC (ml/hp/h)
Stationary diesel engine	- Water lifting	0.6	220
	- Threshing	0.7	220
Tractor	- Light works e.g. transport, water lifting e	0.4	210
	- Medium work e.g. secondary tillage, sowing, inter-culture etc.	0.5	210
	- Heavy works e.g. primary tillage, Sheller, cane crusher, combine etc.	0.6	210
Self-propelled combine	-	0.6	210
Small petrol engine	- spraying, dusting etc.	0.8	500

Oil costs = 0.20 x Fuel costs

Labour Charge: The cost of operator and labour is calculated from the actual operator and labour charges paid in Rupees per day at the prevailing rates in that region.

LESSON 32. MANAGEMENT OF FARM MACHINERY; REPLACEMENT, BREAK-EVEN POINT ETC

The importance of farm machinery management has increased in modern farming operations because of its direct relations to the success of management in combining land, labour and capital for a satisfactory profit. The size of a tractor is identified by its power rating in horsepower (kilowatts). Manufacturers give each tractor a power rating. This rating is stated as the maximum rated horsepower produced at power-take-off (PTO) and at the drawbar. The size of tractor is chosen on the basis of power requirements of the farm equipment to be used. Power requirement is directly related to the area to be covered per hour to get the job done in time. Indian agriculture has been mechanized and a variety of power sources in different horsepower range and machinery (matching implement) are available these days. Hence today, farmer has various options for selection of tractor as a power source. Optimum tractor size is defined as the size that can complete the required farm operations in time and results in total minimal cost. There are many factors that need to be considered while selecting the tractor of different size and matching equipment. These factors are land holding, crops to be grown, cropping pattern (single, double and triple), topography and soil condition, operating and repair and maintenance cost, after sales and service facilities and resale value.

SELECTION OF TRACTOR

A successful farm machinery system is one that must perform in such a manner that profit to the farm is maximized. Maximization is not always accomplished by minimizing costs, and such is true with the selection of a farm machinery system. Considerations have to be given to the economic value of operating machinery at that correct moment in time when the soil, the crop, the weeds, and the insects are most affected. The need for timely operations is a rather unique economic constraint on the farm machinery system. Agronomic practices, enterprise and topographic variability require that machinery selection must be made on an individual farm basis. This requirement implies that such a programme must be adaptable to a large number of input data and should accommodate many special circumstances. Machine capacity can be described as:

Theoretical field capacity, Ct

$$C_t = \frac{S\,w}{10}, \text{ ha/h}$$

Where,

S = average speed of machine, km/h

w = rated width of machine, m

Effective field capacity, Ce

$$Ce = \frac{S\,w\,E_f}{10}, \text{ ha/h}$$

Where,

E_f = field efficiency of machine, fractions

Selection of an appropriate machinery system may be stated simply as the process of determining those individual machine capacities, which will optimize the economic performance of the whole system. Consideration must be given to machine costs, power costs, operational costs etc. An appropriate cost of operation model is essential to the validity of the selection problem analysis. This analysis uses fixed and variable costs. Variable costs increase proportionally with the operational use of the machine, while fixed costs are independent of use. Considering the fixed and variable cost, the total cost of operation of tractor is given by

$$Ac = Fc\,Pt + At\,(RM + L + O + F + Tc) \quad \text{------------} \quad (1)$$

Where,

Ac = Annual costs of operating the tractor, Rs/Yr.

Fc = Annual fixed costs, fraction of purchase price

Pt = Purchase price of tractor, Rs

At = Annual use of tractor, h/Yr.

RM = Repair and maintenance costs of tractor, Rs/h

L = Labour costs, Rs/h

O = Oil costs, Rs/h

F = Fuel costs, Rs/h

Tc = Timeliness costs, Rs/h

Yr = Year

Since RM, O, F = f (A) where A is cropped area, therefore, RM, O, F = f (E) where E is energy spent to cover the area. As energy requirement is expected to be a constant for a specific farm operation, therefore, RM, O and F costs will have no influence on the optimum size of the tractor. Thus, only important variables are labour costs (L) and timeliness costs (Tc) . More specifically, the annual costs of tractor is expressed as the sum of the fixed costs and the total labour and timeliness costs for each of two types farm jobs viz. field operations and transport operations.

$$Ac = Fc\,Pt + (\text{Field hours})(L + \text{timeliness cost}) + (\text{transport hours})(Lt) \quad \text{-------} \quad (2)$$

Where,

L = Tractor operator's wages for field work, Rs/h

Lt = Labour cost for transport work, Rs/h

Probably, there should be a timeliness charge for transport work but for simplicity it may be assumed that this does not limit field operation.

The optimum size of tractor is considered to be one, which will perform all the desired operations at minimum costs. The annual hours of work required for each class of tractor operation are given by:

$$\text{Field Time} = \frac{(\text{Area})\ (\text{Energy required per unit area})}{r \times (\text{Rated Power})} = \frac{A\ Eo}{r\ Rp}$$

Where,

A = Area

r = Ratio of drawbar power to rated engine power for drawbar loads and ratio of PTO power to rated engine power for PTO loads.

Eo = Energy required per unit area

Rp = Rated power

Thus field time is proportional to energy required per unit area per rated power i.e.

Field Time = C_1 Eo / Rp

Where,

C_1 = Constant = A/r

Similarly;

$$\text{Transport Time} = \frac{(\text{Energy required per unit distance})(\text{Distance})(\text{Amount to be transported/Yr.})}{r \times (\text{Rated Power})}$$

$$\text{i.e. Transport time} = \frac{0.53\ (\text{hph/km})\ (D)\ (Wt\ /\ Yr)}{r \times Rp}$$

Where,

Wt = Amount of material to be transported, tonne

D = Distance to be travelled, km

r = Ratio of drawbar power to rated engine power taken as 0.4 For transport operation

Thus, transport time is also proportional to the energy required to transport one tonne of produced through one kilometre distance per rated power i.e.

Transport time = C_2 Et / Rp

Where,

C_2 = Constant Wt/yr/r

Et = Energy required by tractor for transport operations = 0.53 (hph/km) D

Substituting above values in equation 16.9, the annual costs of operating a tractor can be written as

$$Ac = Fc\ Pt + \frac{C_1\ Eo}{Rp}(L + Tc) + \frac{C_2\ Et\ Lt}{Rp} \quad \text{---------- (3)}$$

Writing purchase price of tractor, Pt = Rp Pu

Where,

Pu = Price per unit power of tractor, Rs/hp

$$Ac = Fc\ Rp\ Pu + \frac{C_1\ Eo}{Rp}(L + Tc) + \frac{C_2\ Et\ Lt}{Rp} \quad \text{---------- (4)}$$

Differentiating the equation 16.11 with respect to Rp, we get

$$(RP)_{opt} = [\{1/\ (Fc\ Pu)\}\ \{C_1\ Eo\ (L + Tc) + C_2\ Et\ Lt\}]^{1/2} \quad \text{------------ (5)}$$

Differentiating equation 5 once again w.r.t. Rp, we get

$$\frac{d(Ac)}{d(Rp)^2} = \frac{2\, C_1\, Eo\, (L + Tc)}{(Rp)^3} + \frac{2\, C_2\, Et\, Lt}{(Rp)^3}$$

Which is a positive quantity, indicating that the calculated (RP)opt would have a minimum cost of operation.

Timeliness of a field operation must be considered in selection of optimum power required of a tractor. Total timeliness cost for an operation depends upon the scheduling of operations (delayed, premature and balance). So, the total timeliness cost (Tc) can be estimated as:

$$Tc = \frac{K\, Y\, V\, A^2}{X\, U\, Z} \qquad (6)$$

Where,

Tc	=	Timeliness costs, Rs./h
K	=	Timeliness loss factor
Y	=	Crop yield, t/ha
V	=	Value of crop, Rs./t
A	=	Total area under crop, ha
U	=	Ratio of total working days to total days, fraction
Z	=	Effective machine capacity, ha/day
X	=	2 for premature or delayed scheduling
	=	4 for balanced scheduling

Total timeliness costs for an operation depend on the scheduling of operations with respect to time and duration of operation. There are basically three types of scheduling of operations viz. Delayed, premature and balanced. In delayed scheduling, operation starts at optimum time whereas operation is planned to be completed by the optimum time in premature scheduling. In the balanced scheduling, operation is planned in such a way that it spreads over equally on both sides of the optimum time. Therefore, time devoted in case of delayed and premature scheduling is half of that of balanced scheduling. Thus, X is taken as 2 for premature or delayed and 4 for balanced scheduling.

The cost of untimely operations can be included in the basic cost model as a cost for each hour the machine is used. The absolute costs depend on the value of the crop. Therefore, a relative timeliness factor called K has been developed to give some generality to the analysis

(Table 1). K is defined as the decimal reduction of the quantity and quality of the potential crop per hour of machine operation.

Table 1: Timeliness loss factor for different operations and crops under Indian conditions

Crop	Operation	K value
Wheat	Tillage & sowing	0.00456
	Harvesting & threshing	0.00650
Barley	Tillage & sowing	0.0067
	Harvesting & threshing	0.00437
Paddy	Tillage & sowing	0.00625
	Harvesting & threshing	0.0066
Maize	Tillage & sowing	0.0047
Soybean	Tillage & sowing	0.0179
	Harvesting & threshing	0.0189
Moong	Tillage & sowing	0.0052
	Harvesting & threshing	0.066
Oil seeds	Tillage & sowing	0.0138
	Harvesting & threshing	0.0351

Thus,

$$(Rp)_{opt} = \left[\left(\frac{A_c E_i}{Fc\ r_i\ Pu} \right) \left(L + \frac{K_{ic}\ Y_c\ V_c\ A_c^2}{X\,U\,Z} \right) + \left(\frac{0.53\ Lt\ D\ Wt}{Fc\ Pu\ r_i} \right) \right]^{1/2} \text{------ (7)}$$

Where,

Fc = Fixed cost percentage of a tractor

Pu = Price per unit power of tractor, Rs/hp

A_c = Area under crop, ha.

E_i = Energy required for operating an implement for a particular crop

K_{ic} = Timeliness loss factor of an implement for a particular crop

Yc = Yield of crop, q/ha

V_c = Value of crop, Rs./q

X = Constant equal to 2 for premature or delayed schedule and 4 for Balanced schedules

U = Fractional utilization of time

Lt = Labour rate for transportation, Rs./h

D = Distance to be traveled, km.

Wt = Weight to be transported, t

r_i = Ratio of drawbar power to rated engine power for drawbar load and ratio of PTO power to rated engine power for PTO loads for a particular crop

Note that repairs, fuel and oil costs have been dropped from considerations. Only labour and tractor fixed costs remain in the equation 16.14. Equation 16.14 may be used without reservation for self-propelled implements and for selection of implements to fit into an existing machinery system where the tractor fixed costs are known and are constant. In fact, the optimum implement width may be more dependent upon the size of tractor than upon any of the other factors in equation 16.14. Selection of an economic system of machines is highly dependent upon the horsepower level of the tractor or tractors.

REPLACEMENT OF FARM MACHINERY

Good guidelines are available for making management decisions on when to replace the farm equipment. Important reasons for replacing a machine are:

i) Accidents have damaged the implement beyond repair

ii) Field capacity of the machine is inadequate

iii) A new machine or farm practice has made the old machine obsolete

iv) Performance of a new machine is significantly superior

v) Anticipated costs for operating the old machine exceed those for a replacement machine, and

vi) The machine is worn out.

The time of replacement decisions depends on the accumulated costs over a period of years. The annual cost curve as well as the accumulated average cost curve for a machine is shown in Fig. 1. Both the curves intersect at a point. Theoretically, the time to replace a machine is when the annual cost starts to exceed the average accumulated cost. However, machine repair rate really determines the time of replacement. One method of establishing the time of replacement is to determine that the cost per unit of use has reached its lowest value.

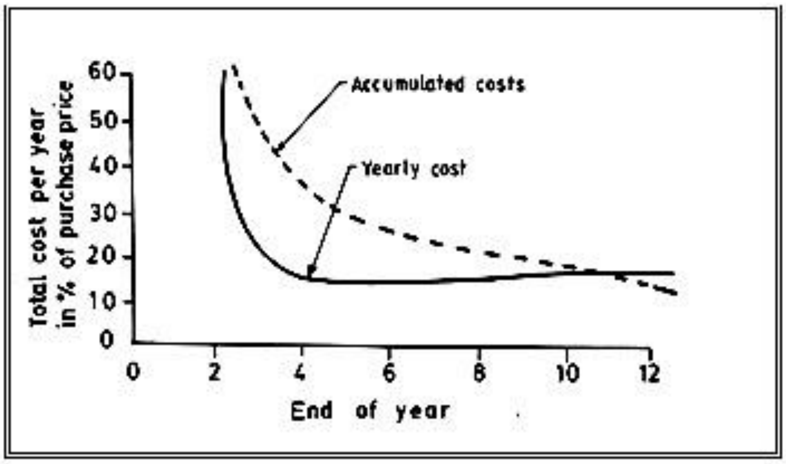


Fig. 1: Time of replacement, where yearly cost equals accumulated cost

Case I: Repair is proportional to use

Total cost, C = FC + RC X

Where,

C = Total repair cost

FC = Fixed cost

RC = Repair cost

X = Number of ha of machine used

$$\text{Cost/ha} \quad \frac{C}{X} = \frac{C}{X} + RC$$

In this case, the lowest cost/ha can only be attained with indefinite use of machine as shown in Fig. 2.

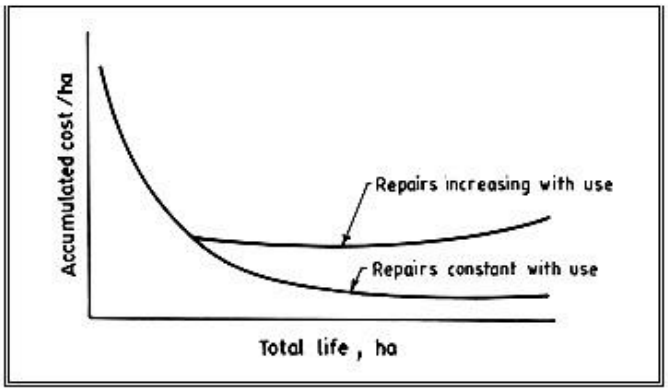


Fig. 2: Effect of repair cost on accumulated cost.

Case II: Repair cost increases with use

$C = FC + R_1 C X + R_2 C X^2$

Where,

C = Total repair cost

FC = Fixed cost

R_1C = Repair cost rate proportional to use

R_2C = Repair cost rate that increases with use

X = Number of hectare of machine use

Repair cost per hectare is given by

$$\frac{C}{X} = \frac{FC}{X} + R_1C + R_2C\,X$$

The time of replacement is defined by the minimum cost point. If replacement is delayed beyond this point, costs are expected to rise due to the increasing repair cost.

For minimum cost

Or, $X = [\,FC/R_2C\,]^{1/2}$

The accumulated repair cost will depend upon the type of repair rate. For constant repair rates, the effect of repair on replacement is ignored. For implements, which have an increasing repair rate, the repair cost is given by

$$Cr = \frac{1}{2} \times \frac{Rr}{10000\ Ah} \times n^2 H^2$$

Where,

Cr = Accumulated repair cost up to Year n, Rs

Rr = Value of repair rate at a given accumulated hours of use, expressed in %P/100 hours

P = Purchase price, Rs

Ah = Accumulated hours

H = Average hourly use per year

Obsolescence should be considered in determining the proper time of replacement. Accumulated cost of obsolescence can be expressed as

$$Co = 1/2\ (Fo\ n^2)$$

Where,

Co = Accumulated cost of obsolescence, Rs

Fo = Obsolescence factor, Rs/year

N = Number of years

In this case, the depreciation can be expressed in terms of percentage of purchase price at the beginning of year n as

Vn = 68 - 4.2 n for tractors

Vn = 60 - 4.6 n for other implements

Where,

Vn = Remaining value at any time, Rs

n = Number representing age of machine in years at the beginning of year in question

The accumulated depreciation cost can be calculated as

Cd = (100 -Vn) %P

Where,

Cd = Accumulated depreciation cost up to year n, Rs

P = Purchase price, Rs

Optimum replacement time (n) would be in the year when the total accumulated cost of depreciation; repair and obsolescence per year would be the minimum and can be calculated by:

$$n = \left[\frac{0.32\,P}{\frac{1}{2} \times \frac{Rr}{10000\,Ah} \times H^2 + \frac{1}{2}(Fo)} \right]^{1/2}$$ **for Tractors**

Similarly we can find the replacement age for implements also,

$$n = \left[\frac{0.40\,P}{\frac{1}{2} \times \frac{Rr}{10000\,Ah} \times H^2 + \frac{1}{2}(Fo)} \right]^{1/2}$$ **for Implements**

BREAK-EVEN USE

Hiring custom operators is one important alternative to owing machinery. In some cases, using custom operators provides faster completion of work provides the least-cost method and does not require the capital needed for owing a machine. But when considering hiring a custom operator, do not forget timeliness of operations. Waiting for a custom operator to arrive is expensive in terms of timeliness, if it means not getting crops planted or harvested at the optimum time. Always consider timeliness in making a decision to use either a custom operator or an alternative method.

Determining when to use a custom operator is one of the most important decisions made in machinery management. To take a decision in this regard, the knowledge of break-even-use of a farm machine is a must. The break-even-use is the amount of use where the cost of using a machine owned would be the same as the cost of hiring a machine (Fig. 3). If a machine were used for less than the break-even-use, custom rate would be profitable. Otherwise owning a machine would be profitable.

Break-even-use can be determined by the following formula:

$$BEU = \frac{AOC}{CR - OPC}$$

Where,

BEU = Break-even-use, ha

AOC = Annual ownership cost (fixed cost), Rs

CR = Custom rate, Rs/ha

OPC = Operating costs, Rs/ha

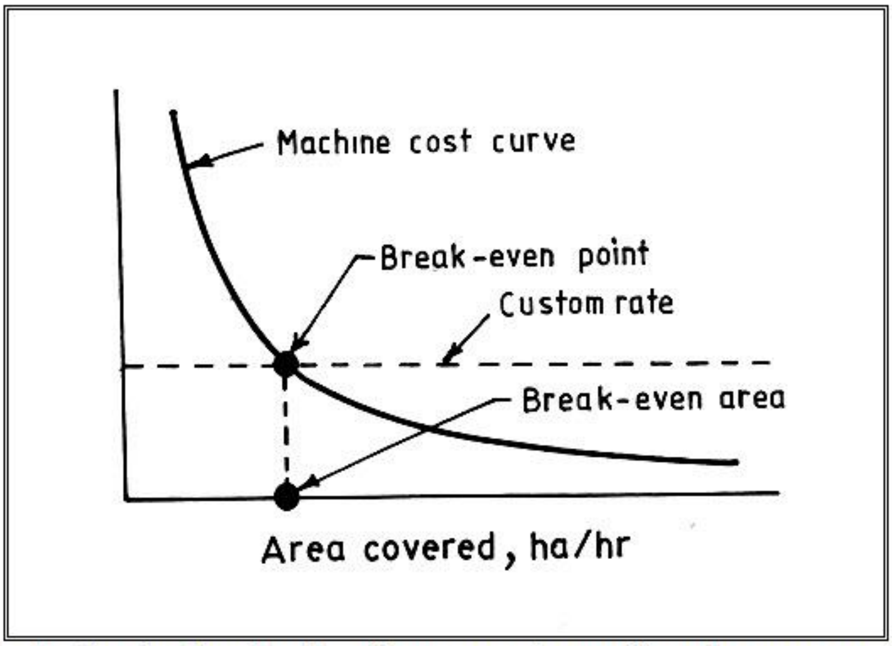


Fig. 3: Graph showing break-even-point and break-even area.

UTILITIES AND RELIABILITY INDEX

Utility index: It is a direct indication of work machine contact hours. With an increase in the utility index the cost of operation and the non-operating hours decrease. This in turn, results into a net increase in the total power available for farm work. Utility index (K) can be calculated as

$$K = \frac{\text{Number of actual working hours/year}}{\text{Number of expected working hours/year}}$$

Reliability index: This index measures the percentage of assurance of proper working of tractors. It is determined as follows:

$$RI = \frac{A_1 P_2}{A_2 P_1}$$

Where,

RI = Reliability index

A_1 = Breakdown charges available = 0.04 nP

A_2 = Breakdown charges - actual incurred

P_1 = Penalty for breakdown = 0.25×10^{-3} B P

P_2 = Money blocked in storing the requisite spare parts

P = New cost of tractor

n = Number of years of breakdown occurrence since purchase

B = Number of breakdown hours

Thus,

$$RI = \frac{0.04\ n\ P}{0.25\times10^{-3}} \times \frac{P_2}{B\ P\ A_2} = \frac{160\ n\ P_2}{B\ A_2}$$

The optimum reliability index is determined by assuming $P_2/A_2 = 1$. Although P_2/A_2 is not exactly equal to 1 and it keeps on fluctuating but in an Indian condition through previous experience it has been observed that on an average P_2 is more or less equal to A_2. Thus, above equation can be rewritten as

$$RI = \frac{160\ n}{B}$$

If we take reliability index 1, then B = 160 n

If n = 15 years for tractor

B = 160 x 15 = 2400 hours

This indicates that in order to maintain an optimum reliability index, the total number of breakdown hours in the life time of tractor must not exceed 2400 hours.