DEVELOPMENT OF THE HEADER UNIT OF A TRACTOR-DRIVEN COMBINE HARVESTER

BY

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APPROVAL

Development of the Header Unit of a Tractor-Driven Combine Harvester

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This is to certify that this thesis has been read and approved as meeting the requirements of the Department of Agricultural Engineering, Federal University of Technology, Akure, for the award of Master of Engineering (Agricultural) degree.

20/8/98

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DEDICATION

This project is dedicated to my parents Mr. Patrick O. Elegbeleye and Mrs Theresa O. Elegbeleye, who gave me all the necessary supports that sustained this work till the end.

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All glory and thanks be to God Almighty for the success of this project work.

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ABSTRACT

Various methods of harvesting grains, type of grain losses and how to minimize them are discussed. The header unit of a tractor-driven combine harvester was designed, fabricated and tested. The unit consists principally of the stripping rotor which derives its peripheral speed from the tractor Power-Take-Off Shaft (P.T.O.) The power requirement was found to be 4.03 kw and stripper theoretical capacity 0.21kg/s. Stripper shaft diameter was calculated after determining the vertical and horizontal forces that acted on it. Pulleys and belts to transmit the calculated speed ratios were selected. Suitable materials were selected for the components of the machine and the cost of producing the machine was ₦22,384:27. The machine was tested at five peripheral speeds of 100, 140, 180, 220 and 260 rev/min at two forward speeds of 3 km/hr and 5 km/hr. A 60 kw Ford tractor was used for the test. Results showed that header total losses reduced with increasing peripheral speed with the highest reduction occuring between 100 rev/min and 140 rev/min for the two forward speeds. Machine field efficiency also increased linearly from 69.1% at 100 rev/min to 92.0% at 260 rev/min and from 77.7% to 90.2% at 3 km/hr and 5 km/hr respectively. Regression equations were obtained for shatter, unstripped and total header losses which could be used to determine the losses at different peripheral speeds. The machine is easy to disassemble for maintenance.

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NOMENCLATURE

Symbol	Definition	Unit
A	Area	m^2, ha
V	Volume	m^3
S	Speed	m/s, km/hr
ω	Peripheral speed, P.T.O speed	rev/min
y	Yield of Crop	Kg/m^2, Kg/ha
C_c	Field capacity	ha/hr
c	Constant	10
η_f, e	Field Efficiency	%
η_{fe}	Functional efficiency	%
Nm	Machine processsing width	m
M_t	Material capacity	kg/s
np	Number of points of stripper rows	–
nr	Number of rotations per second	rev/sec
s	Spacing of Crop	cm
$\pi d/np$	Distance between one row and next row of stripper	cm
F	Force	N

F_1	Force rotating the stripper alone	N
F_2	Resistance due to crop; weight of stripper elements and plates	N
F_3	Weight of pulley	N
m	Mass of components	g, kg
T	Torque	Nm
P	Power	kw
L	Total length of belt	mm
C	Centre distance	mm
D	Diameter of larger pulley	cm, mm
d	Diameter of smaller pulley	cm, mm

CHAPTER ONE

1.0 INTRODUCTION

1.1 Trend of Development in Grain Harvesting

As early as 500 BC , wooded implements were used for stripping ears of corn. The sickle was introduced in 280 BC. The scythe was developed later. It eliminated stooping and improved the speed of cutting (Fig. 1a). In the early 1800's, threshing was done by beating the grain from the straw with hand flails before the "ground hog" thresher was invented (Fig 1b). This machine was a small stationary thresher that knocked the grain from the straw. The grain still had to be separated from the straw and chaff by hand winnowing.

The McCormick reaper (Fig. 1c) mechanized the cutting and gathering of grain. This machine was introduced in the 1830's. It cut the grain and raked it from the platform into bunches. These bunches were collected onto a wagon by hand and taken to the "ground hog" for threshing. However, the Moore-Hascall harvester that was introduced later performed the basic functions of cutting, threshing and cleaning grain (Griffin, 1973).

In 1864 and 1886, the Marvin combined harvester and the Hauser harvester were patented. While in 1889 the steam-powered combine was patented by Daniel Best. The steam engine was mounted on the combine and a large steam tractor pulled the machine through the field. Horse-drawn tractor-driven combines were introduced in the 1890's. Some of these machines were equipped with a 12.80 m header and harvested from 36.42 ha to 50.59 ha in a day. In 1928, Samuel Lane was granted a patent on what was termed a combine harvester-thresher (Smith, 1955). Massey-Harris combine harvester and British Wallis tractor were demonstrated in 1929. Within this period Binders were used extensively to cut and gather small grains (Figs. 1 d, e, f).

The British Clayton harvester was demonstrated in 1932. The machine was hauled by a tractor, the cutter was set to the side of the thresher and the threshed grain delivered straight from the machine to be filled into sacks by a number of men (Brown, 1989).

Meanwhile, self-propelled combine harvesters were a feature in the 1930's. Massey Harris introduced two in 1941. They were tanker combines with widths of cut of 3.7 m and 4.9 m. These types eliminated the use for the sack-filling gang.

Since then there had been tremendous developments in the functional improvements of a known system of components in order to increase the efficiency and cost effectiveness of harvesting and threshing grain crops.

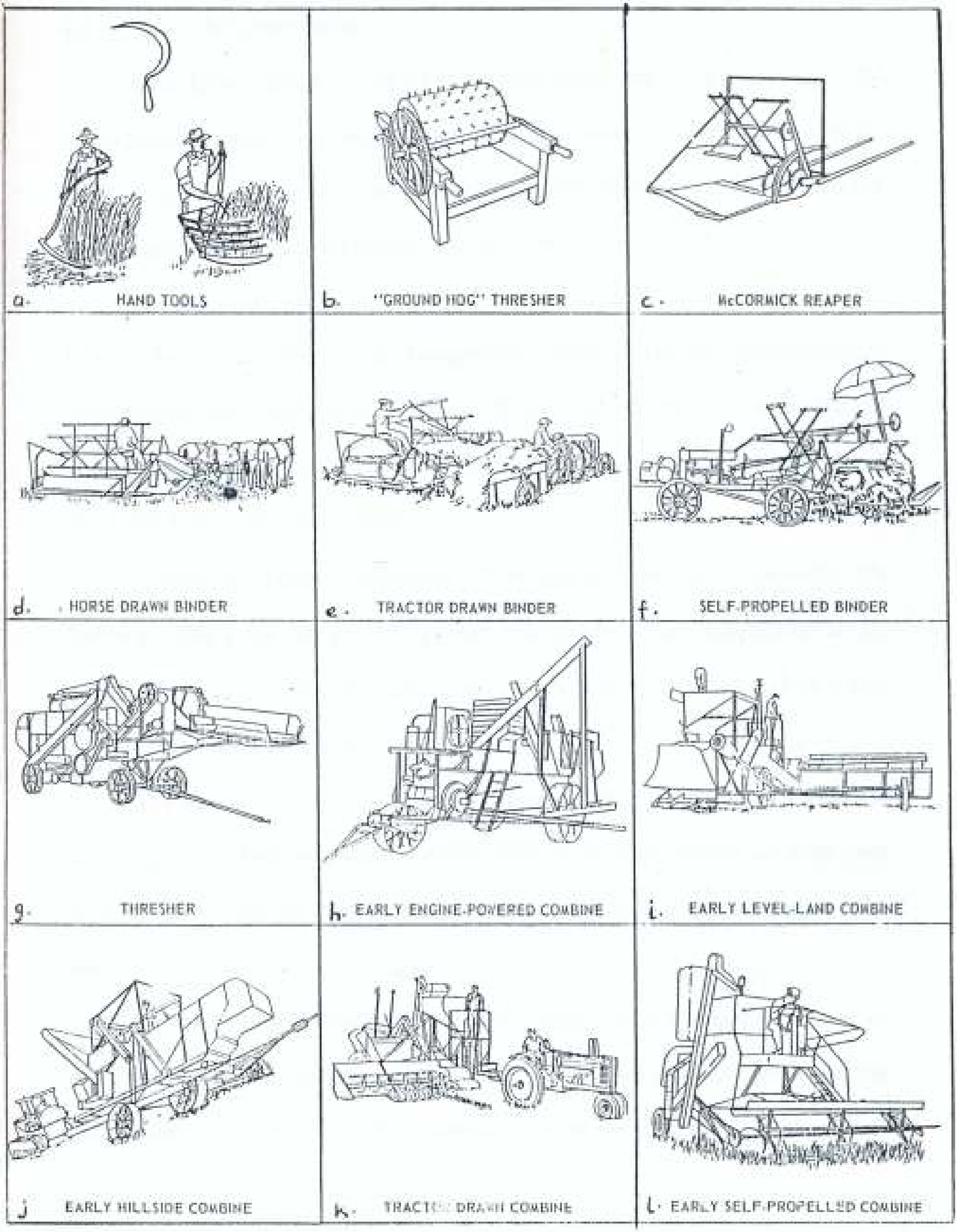


Fig. 1: Major Developments Leading to the Complete Combine

Source: Griffin, 1973.

1.2 Rice harvesting

Rice (Oryza sativa L.) is the most important cereal crop in the developing world and is generally considered a semi-aquatic annual grass plant. About 20 species of the genus Oryza are recognised but nearly all cultivated rice is oryza sativa L. A small amount of oryza glaberrima, a perennial species, is grown in Africa (FAO, 1993).

Because of its long history of cultivation and selection under diverse enviroments, O. sativa has acquired a broad range of adaptability and tolerance so that it can be grown in deeply flooded land to dry hilly slopes (Lu and Chang, 1980). Of the 147.5 million hectares of land devoted to rice production worldwide in 1989, developing countries contributed 141.1 million ha or 96% (FAO, 1990).

Tropical rice is usually harvested at 20% or more moisture about 30 days after 50% flowering, when grains will produce optimum total and head rice yields (Barker et. al., 1985). The actual period of dry-matter production is no more than 14 to 18 days after which the grain undergoes drying.

Harvesting is carried out by cutting the stems, sundrying and then threshing by hand by beating the rice heads on a slotted bamboo platform, by having animals or people tread on the crop or by the use of mechanical threshers. Combine harvesters are used in large areas.

Delayed harvest in rainy weather frequently leads to grain sprouting on the panicle, particularly for non-dominant japonica rice. (FAO, 1993). Research work has shown that grain cracking is minimal above 18% moisture content (Kunze et. al., 1985).

1.3 Project Justification

Rice production is one of the largest agricultural industries in both developed and developing countries. Traditionally, rice has been the staple food and main source of income for millions of people, and it will continue to be a mainstay of life for future generations (FAO, 1990).

In a developing country like Nigeria, up to 40 percent of the total labour required to produce rice is expended in the harvesting and threshing operations (Caruthers and Rodriguez, 1992). Problems such as drudgery and insecurity of hiring labour may result. Timeliness of harvesting operations may also be difficult.

Great losses are sustained due to pests and weather hazards because of late harvesting of the matured crops. Greeley (1982), stated that around 6 percent of output is lost to traditional and animal-based techniques of rice harvesting.

A lot of problems have been associated with the operation of combine harvesters imported into developing countries. These include high cost of procurement; lack of skilled operators to optimize its usage; maintenance and repair; and weather conditions that are not entirely suitable. Yet, between 1980 and 1993, the population of Nigeria had grown from 78.4 to 119.3 million (FAO, 1994). The annual growth rate is put at 3.21 million (Todaro, 1989) so also is the demand for food. Hence the need for increased agricultural mechanization.

Klinner et. al., (1987) reported that some shortcomings of existing strippers include high shatter losses caused by crop disturbance, incomplete grain detachment, failure to collect detached grains, blockages of essential crop aligning or stripping components, and inability to harvest tangled and lodged crops satisfactorily.

These limitations and that of the combine at large have necesssitated the design and construction of a combine harvester, starting from the header unit which utilizes a stripping mechanism.

1.4 Research objectives

The specific objectives of the project work are:

1. To develop the header unit of a tractor-driven combine harvester such that it affords low maintenance requirements, simplicity in operation and repairs and long life span.
2. To test the combine header unit to ensure that the component parts function well to obtain high efficiency and minimum crop loss.
3. To develop linear regression equations that can be used to predict header losses at varying forward and peripheral speeds.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Major Components of Combine Harvester

2.1.1 Header unit

This unit cuts the standing grain and delivers it to the feeding mechanism. It is called the header because grain is often cut just below the heads (Stone, 1977). Major parts of this unit are the reel, the dividers and the cutterbar and auger. Headers are pivoted on most machines near the threshing cylinder, they can be raised and lowered to regulate the cutting height. However some trailed-type combines employ a fixed header (Lovegrove, 1981)

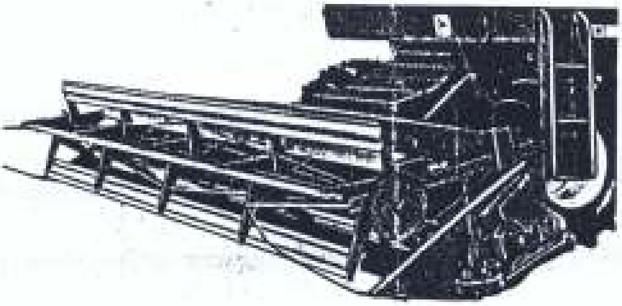
The Reel

This is the first part to touch the standing grain. It holds the head against the knife while the stalks are cut, and it delivers the cut grain to the cutting mechanism. There are two major types of reels namely; bat type, and pick-up type (tine-type).

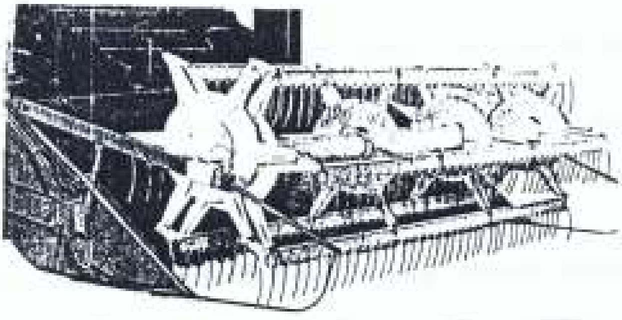
Bat Type (Slat-Type)

The bat type (Fig 2a) has 3 to 8 slats made of wood or steel which hold the crop when it is being cut. Then the slat lays the crop back in the path of the auger. It cannot be used for lodged crop. It has a slapping action which is not considered good for overripe crop as it makes the grain shatter. They are simpler and less expensive than the pick-up reels.

Pick-up Type (Tine-Type) This reel (Fig 2b) has a spring tine fitted to it, the angle of which can be changed. It is very effective for standing crops as well as for laid down crops. When used in laid down crops they should be lower and a little farther apart.



a. Slat-Type Reel



b. Pickup Reel

Fig. 2 Types of Reels

Source: Griffin, 1973.

Both power driven and ground driven reels are available. However the power driven employs, generally, 1¼ times more than the rate of ground travel (Nakra, 1990). With any of the reels, a reel index of 1.25 to 1.5 have given consistently satisfactory performance (Kepner et al, 1978).

The Dividers

These separate the standing grain and define the swath to be cut. They aid in picking up down or tangled crop and gather and guide the standing crop to the cutter bar. Special extension dividers can be secured for work in badly lodged crops (Stone, 1977).

The cutter bar

The function of the cutter bar is to cut the standing crop. The cutter bar and its reciprocating knife resemble the mower mechanism, but the knife sections are usually serrated and the guard plates are smooth. It consists of fixed fingers in which the knife blade runs. Power for operation could be supplied by any of the drive mechanisms. These are off-set crank mechanism, oscillating lever mechanism and lever crank mechanism. The off-set crank mechanism is common and found in use on most conventional harvesters. It is easy to adopt. The in-line mechanism is not common, it can be used on harvesters where cutting is required at certain height above the ground asurring sufficient land clearance. The oscillating lever mechanism is used for reducing the friction force on the cutter bar.

A knife with serrated teeth will work for long periods without sharpening, and are at their best in cutting dry, upstanding corn. The knife usually has a 76 mm stroke and driven at about 530 to 540 cycles/min. (Culpin, 1981). The drive to the knife can be immediately stopped when required (Nakra, 1990).Fig 3 shows a plan assembly of the cutter bar.

The Platform Auger

After cutting the crop it has to be transferred to the threshing component. This is achieved by either a retractable tine auger with a chain and slat elevator (Fig. 4) or with a canvas drapper-type elevator (Fig. 5). An alternative method make use of a series of beaters instead of a chain and slat elevator. The auger is a rotating cylinder webbed on the outside in such a way that the crop is drawn from both ends and towards the centre where it comes in contact with the tines that feed it on to the elevating mechanism.

2.1.2 Threshing unit

The threshing unit removes the grain or seed from the head or pod either by impact of fast moving member upon the material, rubbing, squeezing, or a combination of two or more of these actions. The major parts of this unit are the cylinder, the concaves, and the grates.

The cylinder or Drum

The cylinder consists of bars mounted on two hubs that are supported on a shaft that run the width of the threshing unit. Cylinders range from 381 to 558.8mm in diameter and from 610 to 1524mm in length. Cylinder speed is adjustable and may range from 200 to 1500 rpm (Jacobs and Harrell, 1983). Three different types of cylinders used are Spike-tooth, Rasp-bar and Angle-bar.

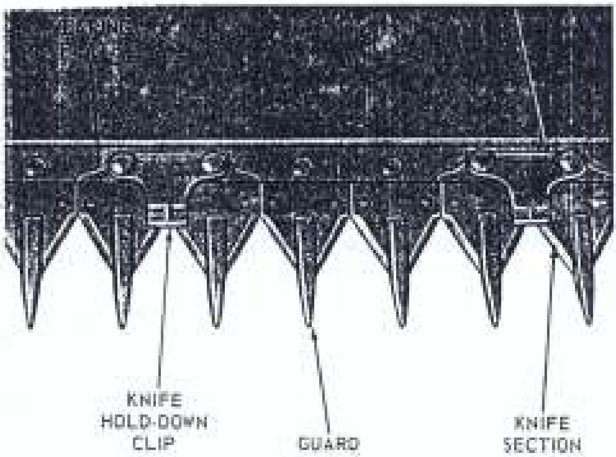


Fig. 3. Plan of Cutter bar Assembly.

Source: Griffin, 1973.

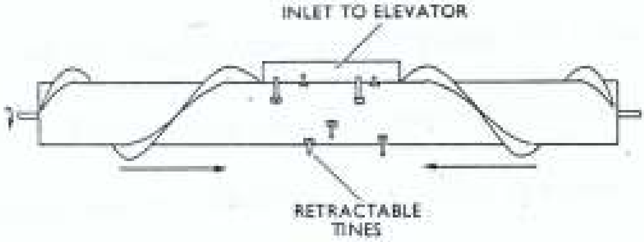


Fig. 4. A Retractable Tined Auger with a Chain and Slat Elevator.

Source: Shippen et-al, 1980.

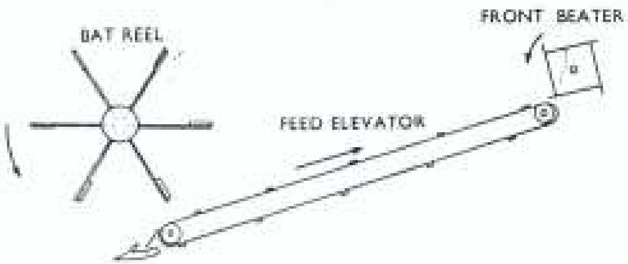


Fig. 5. A Drapper Conveyor Type Elevator.

Source: Shippen et.al., 1980.

Spike-tooth

These spike-teeth carried in the transverse bars of the cylinder, thresh out the grain as they revolve through similar teeth in the concave. It is quite satisfactory for threshing most grain crops (Stone, 1977). A schematic diagram of spike tooth concave and cylinder is shown in Fig. 6.

Rasp-bar

It has transverse bars with grooved metal faces. These grooves are cut diagonally, in opposite direction, across adjacent bars (Fig. 7). Threshing is achieved by the rasping action between the cylinder and the solid concave bars below the cylinder.

Angle-bar

In this cylinder, the spiral bars are rubber-faced, the rubber being vulcanized to the metal (Fig. 8). They flail out the grain between the revolving cylinder bars and the stationary shelling plate and stationary block rubber concaves. The threshing action is considerably more gentle than either the rasp-bar or spike-tooth cylinder (Griffin, 1973).

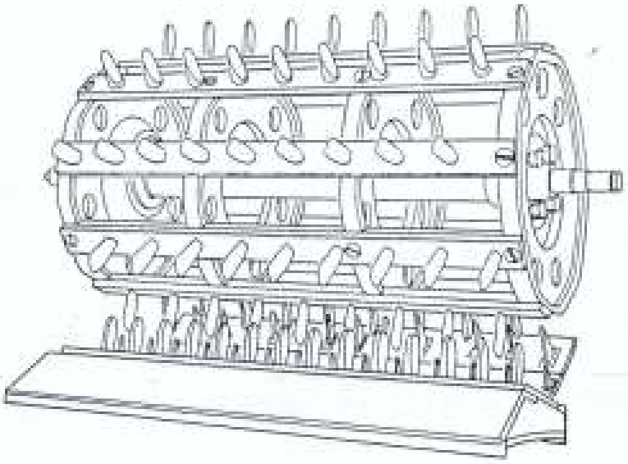


Fig. 6. A Spike-tooth Cylinder and Concave.

Source: Jacobs and Harrell, 1983.

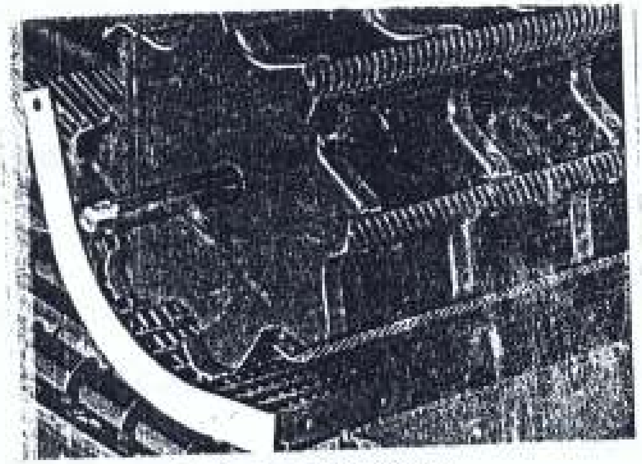


Fig. 7 . A Rasp-bar Cylinder and Concave.

Source: Griffin, 1973.

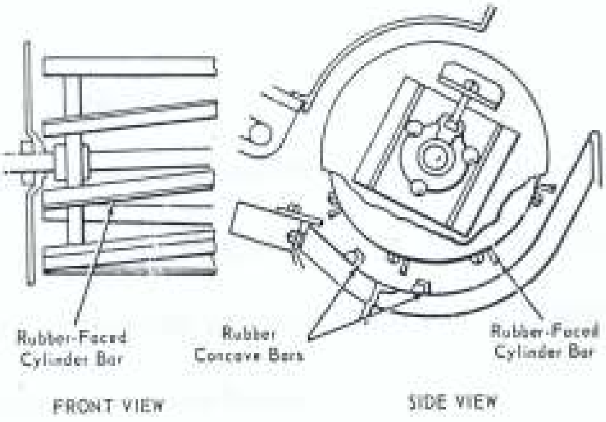


Fig. 8. Angle-bar Cylinder and Concave.

Source: Griffin, 1973.

Concaves and Grates

Concave is the stationary part of the threshing system. It extends across the full width of the cylinder, and surrounds about one-quarter of its circumference. The concave separates the seeds from the ears by passing the ears through a rapidly revolving cylinder and a stationary surface. Spike-tooth concaves are used with spike-tooth cylinders (Fig. 6), rasp-bar or channel-bar concaves with rasp-bar cylinders (Fig. 7), and rubber-block concave bars with rubber-bar cylinders (Fig. 8). The concave grate permits the threshed grain to escape from material-other-than-grain (MOG). Front to rear concave clearance is typically 2½ : 1 with the front adjustable from 1.6 to 32 mm (Culpin, 1981).

2.1.3 Separating unit

The separation operation removes the threshed grain from MOG. Up to 90 percent of the grain is separated from the straw at the concave (Jacobs and Harrell, 1983). But some is mixed with the mass of straw thrown from the rear of the combine (Stone, 1977). The grain that is suspended in the straw is separated by the beater, finger grate, and straw walker.

The Beater

The beater is a small-diameter drum that is located to the rear and above the cylinder. Its teeth help slow down the material going off the cylinder and concave. It also deflects the material down to the front of the straw walker and the finger grates. The beater and the cylinder stripper help to prevent straw from wrapping around the cylinder. Fig.9 shows the most commonly used beaters.

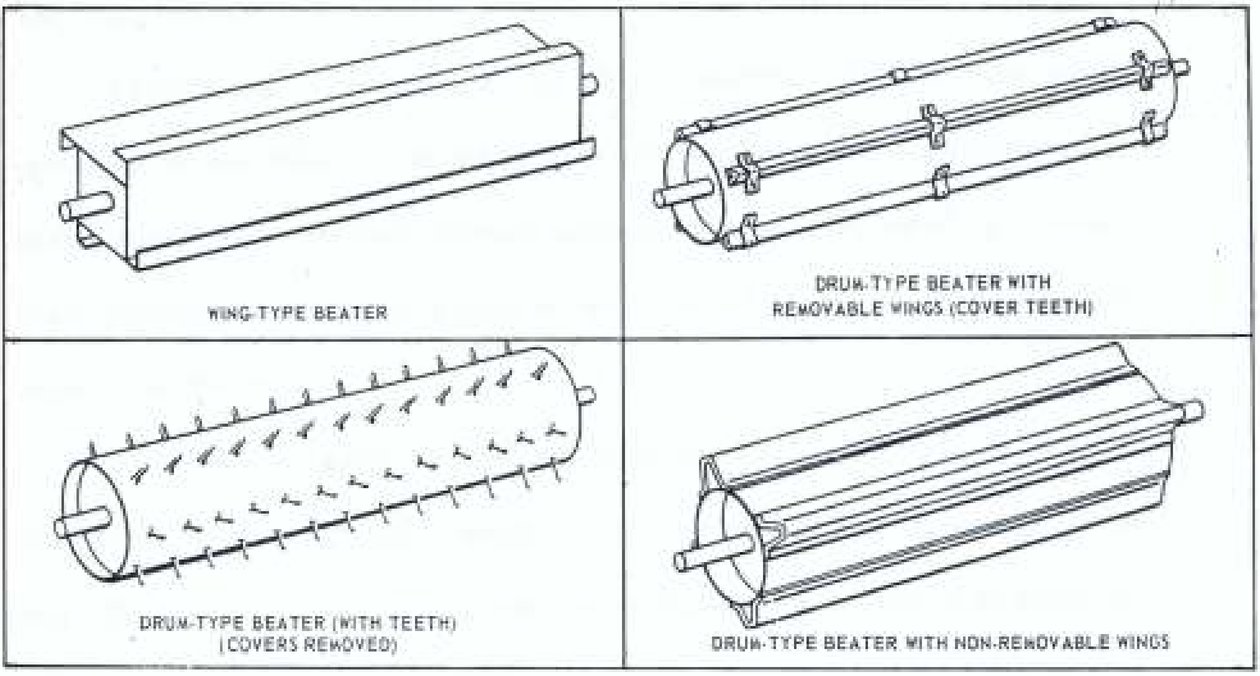


Fig. 9. Most Commonly used Beaters.

Source: Griffin, 1973.

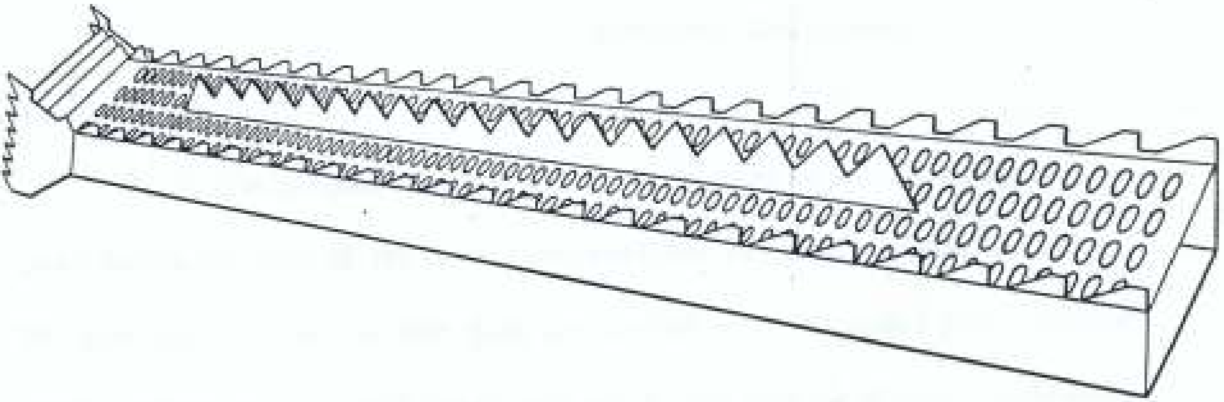


Fig. 10. Step-type Straw Walker.

Source: Griffin, 1973.

The Straw Walker

Straw Walker or racks may be one piece or multiple. The whole unit slopes upwards to the rear of the combine and, being mounted on a crankshaft, a rearward shaking motion is given to it. They shake the straw as they move it out of the rear of the combine. Grain suspended in the straw falls through the walker and is carried by the grain pan or gain augers to the cleaning shoe.

Different straw walkers are used in different crop conditions. The most common straw walker is a step-type walker which provides excellent tumbling and walking action (Fig. 10). Most straw walkers have crank throws of about 102 mm and crank speeds of 185 to 225 rev/min (Kepner et. al., 1978).

Crank speed should be determined from the relation

$$r\omega^2 = 2g$$

Where r = crank radius

ω = crank speed in rad/s

g = acceleration due to gravity

The Grain Pan

This is situated beneath the concave. It usually takes the form of a stepped plate occupying the full width of the cleaning unit and it also has a rearward shaking motion. The grain pan is a common floor point fot threshed grain, unthreshed grain, unhulled kernels, unthreshed heads, chaff, bits of straw and dirt that enter the cleaning unit (Shippen et. al., 1987).

2.1.4 Cleaning unit

This unit removes chaff and fine residue from the threshed grain. It consists of two sieves which also have a rearward shaking motion and an air blast which can be directed up and through these sieves. The two sieves are the chaffer and the grain sieves both referred to as the cleaning shoe.

Chaffer Sieve

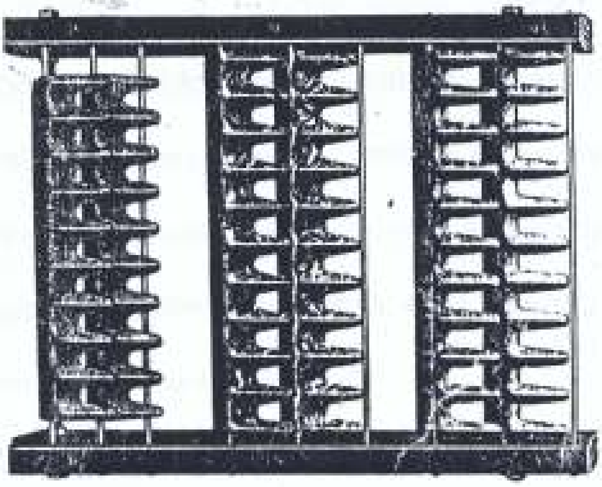
This is the top sieve. It extends from the grain pan and is adjustable so that the size of the aperture can be increased or decreased to suit different crops. Grain and trash pass from the grain pan onto the chaffer sieve, which is a flat oscillating rack made up of a series of cross-pieces that have overlapping metal lips or louvres. Air from the fan blows up and through the light chaff and straw, while the grain falls through the aperture. Figs. 11a and b show adjustable and non-adjustable chaffer sieves.

Grain Sieve

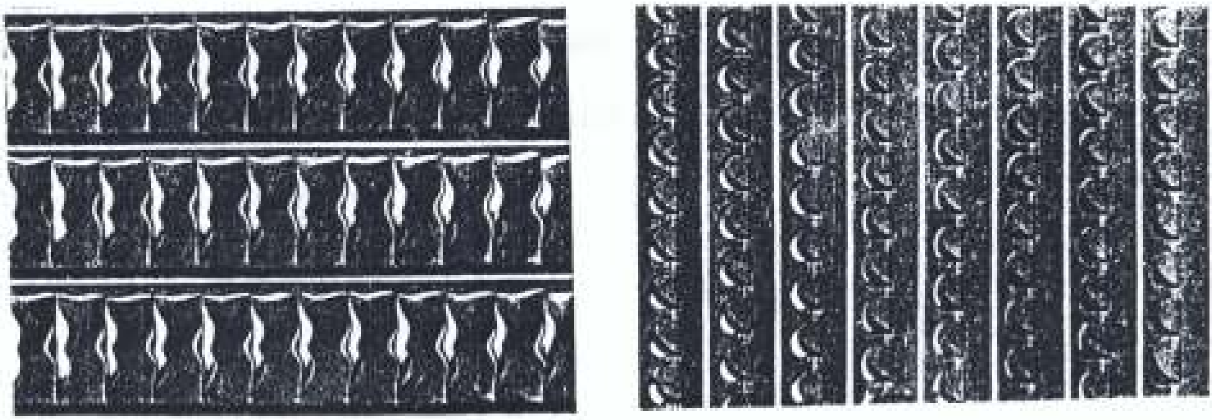
The purpose of the grain sieve is to carry out further separation of grain from trash should any trash have come through the chaffer sieve. It has smaller openings when compared with the chaffer sieve. There are different types of grain sieves available to suit the characteristics of the crops being harvested (Jacobs and Harrell, 1983).

The Augers

Grain and other matter that are small and heavy enough to fall through the sieve are carried by the clean grain auger to either a grain tank or to a cleaning and bagging platform. Light materials move out of the rear of the combine. Materials such as broken or unthreshed heads that are too heavy to be suspended by the air blast, and too large to drop through the sieve are transferred to a position where they can either be returned to the threshing drum for rethreshing or put back over the cleaning unit. These function are carried out by the auger (Shippen et. al., 1987)



a. Adjustable Chaffer Sieves



b. Non-adjustable Chaffer Sieves

Fig. 11. Adjustable and Non-adjustable Chaffer Sieves.

Source: Griffin, 1973.

The Fan

The fan is located at the lowest part of the cleaning shoe. The function of the fan is to subject the grains and other residues to natural air current, enabling the grains to fall under gravity. Light chaff are drifted by the air through the sieves (Ademosun, 1993). Paddle-bladed centrifugal fans similar to the one used by Ademosun (1993), are generally employed. Air volume is controlled by a variable-speed fan or by shutters (choke). Air ppressure is different for various crops. Fig. 12 shows a schematic arrangement of components in the Cleaning Unit.

2.1.5 Grain handling unit

The grain handling unit includes the clean grain elevator or auger, which moves the grain to the grain tank, the grain tank, and the unloading auger. Grain tanks have a capacity which ranges between $1.4m^3$ to $10.6m^3$ on the larger self-propelled machines (Jacobs and Harrell, 1983). Unloading augers can be used to unload up to $3.5m^3$/min onto trailers whilst the combine is stationary or working (Jacobs and Harrell, 1983). A bagging platform is provided where a grain tank is not used. Bagging of the grain is done manually. The grain passes through a rotating screen which takes out any weed seeds which may have escaped the cleaning unit.

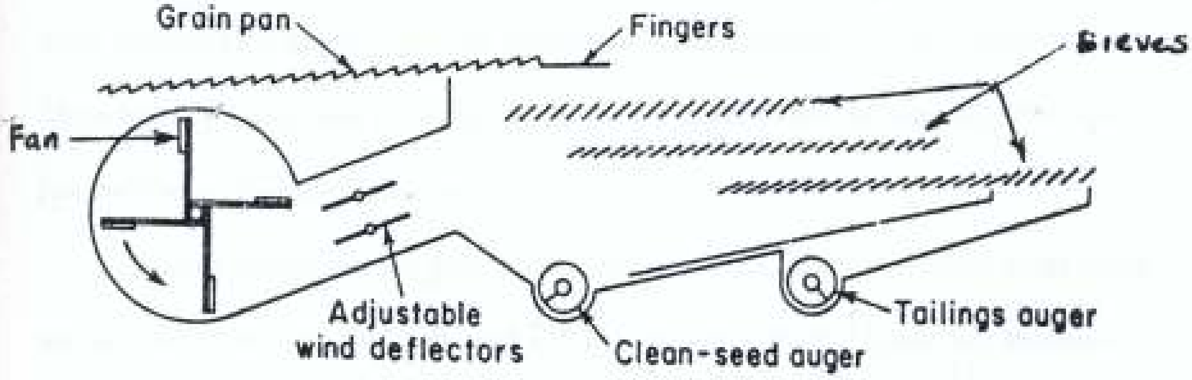


Fig. 12. Schematic Arrangement of Components in the Cleaning Shoe.

Source: Kepner et. al., 1978.

2.2. Mechanism of operation of the combine

The mechanism of operation of the combine is basically the same. Fig. 13 shows crop flow through a self-propelled combine harvester. The reel guides the crop to the cutter mechanism. The cut crop falls into the pan of the cutterbar which has an auger with right and left hand flights made on it; this brings the crop to the centre where there are prongs. The prongs help in transferring the cut crop to the elevator which takes it to the threshing unit assisted by the front beater.

Threshing is accomplished at the adjustable gap between the cylinder and the concave. A stone trap is provided in front of the threshing drum and concave so as to catch the stone caught by the cutter bar and fed along with crop. Because stone is heavier, it drops by gravity into the stone trap and remains there to be taken out during the service of the machine.

The rear beater helps in guiding the threshed straw onto the straw walkers and the straw travels its full lenght. Grain that passes through is collected by a full width grain pan. The mixture of clubs, chaft and grain passes into the sieves, where an adjustable blast blows the chaft out of the back of the machine.

A return pan brings the grain to the grain auger. Pieces of unthreshed heads which are not blown out with the chaft and will not pass through the sieves may be returned either to the drum, or on some machine to a special re-thresher.

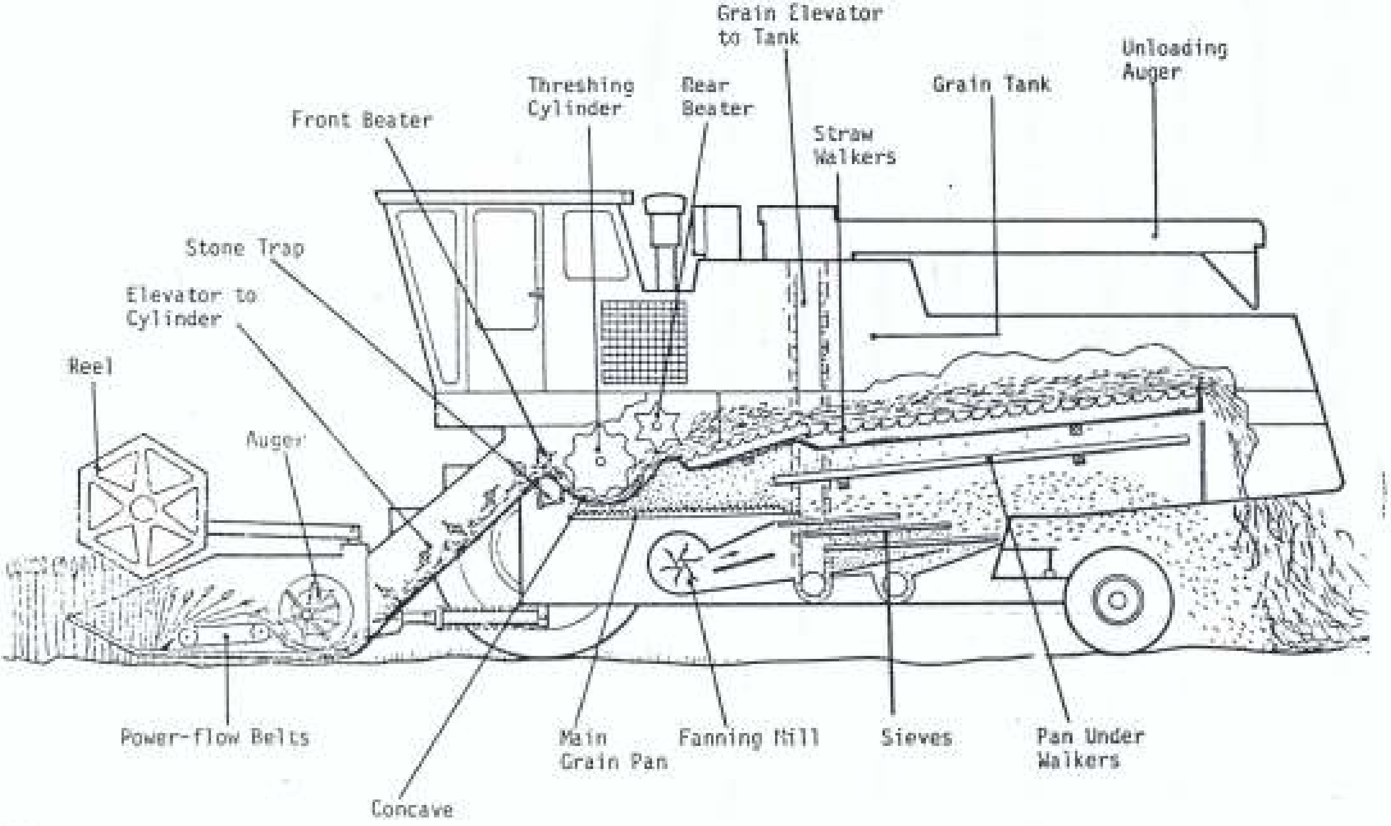


Fig. 13. Crop Flow through a self-propelled Combine Harvester.

Source: Culpin, 1986.

2.3. Grain losses with combine

Losses with harvesting combine are usually between 1 and 2 percent, but this is lower than losses during manual harvesting which is averagely 12 to 15 percent (Nakra, 1990). Some of the major losses associated with combining are preharvest losses, header losses, threshing losses, and cleaning losses (Jacobs and Harrell, 1983).

2.3.1 Preharvest losses

Preharvest losses occur before the crop is harvested. These may be due to overmaturity of the crop, weather damage or crop disease. There is no control over these losses because the grain is already lost. Corn and Soyabeans are two common crops which may have large preharvest losses (Griffin, 1973).

Preharvest losses can be determined by using several $0.093m^2$ areas in the field, using a standard frame of that dimension. The number of seeds found is counted and averaged. Table 1 presents data on seeds per $0.093m^2$ that is equal to $0.086m^3$ loss per hectare for different crops.

Table 1: Approx. Number of Seeds per $0.093m^2$ that is Equal to $0.086m^3$ Loss per Hectare

Crop	Number of seed
Barley	14
Corn	3
Rice	22
Soyabeans	5
Wheat	19

Source: Jacobs and Harrell, 1983.

2.3.2. Header losses

Header losses occur mainly at the reel and cutterbar. These losses include grain heads missed by the cutting mechanism; shattering of grain during the process of cutting; and shattering of grain when the reels strike the standing crops. If windrowing is practised, header losses include the loss for the widrower's cutterbar and the combine's pick-up attachment (Hunt, 1983).

Header losses are slightly higher than any other part of the machine (Nakra, 1990). Lamp et. al., (1961) stated that losses at the combine header commonly average 10 percent of the total crop in Soyabean. Field studies by Dun et. al., (1973) indicated that over 80 percent of Soyabean harvesting loss is caused by the cutterbar. The same study also showed that 64 percent of the harvesting loss occured as shatter. Quick (1973) also found that about 80 percent of the header loss was caused by the cutterbar when operating a laboratory test stand.

In checking for header losses the seeds are counted in several $0.093m^2$ areas that were under the combine. The checkes are averaged. The preharvest losses is subtracted and the remainder is expressed in relation to Table.1.

2.3.3. Threshing losses

Threshing losses are due to incomplete removal of the seed from the seed head (underthreshing) or excessive cracking of the seed or grain (overthreshing). Proper cylinder speed, concave spacing, and ground speed all affect threshing losses. Also, the stage of maturity of the crop and its moisture content affect threshing. Nakra (1990), stated that any reduction in cylinder losses will cause an increase in rack and shoe losses. Hence the settings of cylinder - concave clearance, cylinder speed, dimensions (lateral) and rate of feeding of heads must be optimum. Table 2 shows typical cylinder peripheral speeds and

Table 2. Typical Cylinder Peripheral Speeds and Clearances for Various Crops.

	Peripheral Speed (Rasp-bar or Spike-tooth) m/s	Mean Clearance for Rasp-bar Cylinder mm
Barley	23 - 28	6 - 13
Bean, edible	8 - 15	8 - 19
Corn, field	13 - 20	22 - 29
Rice	23 - 28	5 - 10
Soyabeans	15 - 20	10 - 19
Wheat	25 - 30	5 - 13

Source: Kepner et.al., 1978.

Most of the seed damage caused by a combine occur in the threshing unit, primarily becuase of impact blows received during the threshing process. Drag conveyors and close-fitting augers can also cause damage to some types of seeds (Kepner et. al., 1978).

To determine the threshing unit loss, after backing the lenght of the machine, the ground in a few places directly behind the separator is checked using the frame of 0.093m^2 (Fig. 14). All the kernels remaining on the partially threshed heads are counted. Kernels lying loose on the ground should not be counted (Griffin, 1973). The machine loss chart for small grains (Table. 3) is then checked to determine the loss in m^2/hectare.

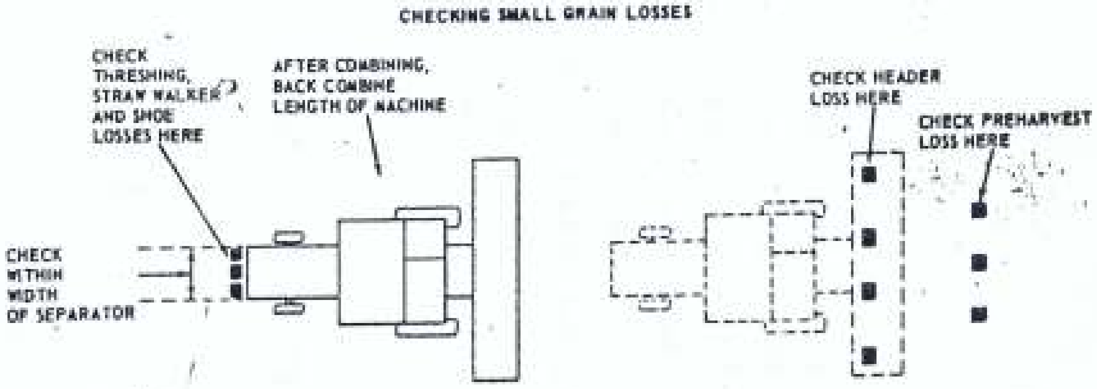


Fig. 14. Checking Small Grain Losses.

Source: Griffin, 1973.

Table. 3. Machine Loss Chart for Small Grain

Approximate Number of Kernels Per $0.093m^2$ To Equal 35 kg Per Hectare

Crop	Separator	Cutting Width (cm)								
	Width (cm)	3.05	3.96	4.27	4.57	4.88	5.49	6.10	6.71	7.32
Barley	74	73	94	102	109	-	-	-	-	-
	97	-	71	76	82	87	98	109	-	-
	112	-	61	66	71	76	85	95	104	-
	140	-	49	53	57	61	68	76	83	91
Beans-Red Kidney	74	6	7	8	9	-	-	-	-	-
	97	-	5	6	6	7	8	9	-	-
	112	-	5	5	6	6	7	8	8	-
	140	-	4	4	5	5	5	6	7	7
Beans-White Pea	74	9	12	13	14	-	-	-	-	-
	97	-	9	10	10	11	12	14	-	-
	112	-	8	8	9	9	10	12	13	-
	140	-	6	6	7	8	8	9	10	11
Oats	74	39	51	55	58	-	-	-	-	-
	97	-	38	41	44	47	53	58	-	-
	112	-	33	35	38	41	46	51	56	-
	140	-	26	28	30	32	36	41	45	49
Rice	74	71	92	100	107	-	-	-	-	-
	97	-	69	75	80	85	96	107	-	-
	112	-	60	65	69	74	83	92	102	-
	140	-	48	52	56	59	67	74	82	89
Rye	74	154	200	216	231	-	-	-	-	-
	97	-	151	163	174	186	209	232	-	-
	112	-	131	141	151	161	181	201	221	-
	140	-	105	113	121	129	145	161	177	194
Sorghum	74	81	106	114	122	-	-	-	-	-
	97	-	80	86	92	98	110	123	-	-
	112	-	69	74	79	85	95	106	117	-
	140	-	55	60	64	68	76	85	94	102
Soyabeans	74	15	20	21	23	-	-	-	-	-
	97	-	15	16	17	18	20	23	-	-
	112	-	13	14	15	16	17	19	21	-
	140	-	10	11	12	13	14	16	17	19
Wheat	74	80	105	113	121	-	-	-	-	-
	97	-	79	85	91	97	109	121	-	-
	112	-	68	73	78	84	94	105	115	-
	140	-	55	59	63	67	76	84	92	101

Source: Griffin, 1973.

2.3.4 Separation losses

The grains which have not been separated from the straw and find their way out over the straw walker along with the straw are known as separation, straw walker or rack losses. They may be caused by too much straw entering the machine at slow cylinder speeds, improper straw walker drive speed, or improper curtain adjustment when threshing lighter seeds. Plugging of the holes or slots in the walkers by excessively broken straw may also cause separation losses.

Walker losses generally account for the major portion of total losses with cereal grains (Nyborg et. al., 1964) but may be negligible in small-seed crops such as alfalfa (Bunnelle et. al, 1954).

To determine straw walker and cleaning shoe losses, after backing the length of the machine, the standard frame is placed on the ground directly behind the separator. The kernels lying loose within the frame is then counted (kernels on partially threshed heads are not included). The header and preharvest loss checks are subtracted leaving the number of kernels lost over the straw walkers and shoe. Loss in m^3/hectare is estimated using the loss chart (Table 3).

2.4 Minimization of grain losses with combine

2.4.1 Header unit

Improper reel adjustment is one of the greatest sources of loss when harvesting cereal grains. Goss et. al. (1958), presented in Fig 15 the losses associated with reel adjustment. The two solid curves at the top show the effect of having a fixed-bat reel too low. The pickup reel was also misplaced for standing grain. They recommended that a fixed-bat reel should be 15 -25 cm forward and at an optimum height. They also recommended that reel speed index should not be more than 1.5 as increasing it from 1.5

to 1.8 have increased barley shatter losses from 3% to 6% of yield. The speed of the reel can be adjusted using variable-speed V-belt or hydraulic-motor drives.

Lamp et. al., (1961) Dun et. al., (1973) and Quick (1973). showed that losses at the cutterbar of a combine can be up to 80 percent of the header losses. However, Tate and Nave (1973) proved that harvesting loss with a floating cutterbar header (Fig. 16) is 25 percent less than with a standard header. The addition of air jets to the floating cutterbar reduced soyabean harvesting loss by another 45 percent (Nave and Yoerger, 1975).

Klinner et. al., (1987), reported that a saving of 23% of yield over the conventional cutterbar was obtained when using a stripper header (Fig. 17) in the harvesting of spring barley and winter wheat. Fig. 18 shows the sieve and walker losses in the stripper and conventional header in spring barley harvesting.

Slippage of wheels in a tractor-driven harvester is another factor which can cause great losses in a stripper header, due to the timing of the forward and peripheral speeds of the tractor and rotor respectively. Shebi et. al., (1988) stated that the higher the power of a given tractor the less the slippage and that slippage decreases with an increase in tractor speed.

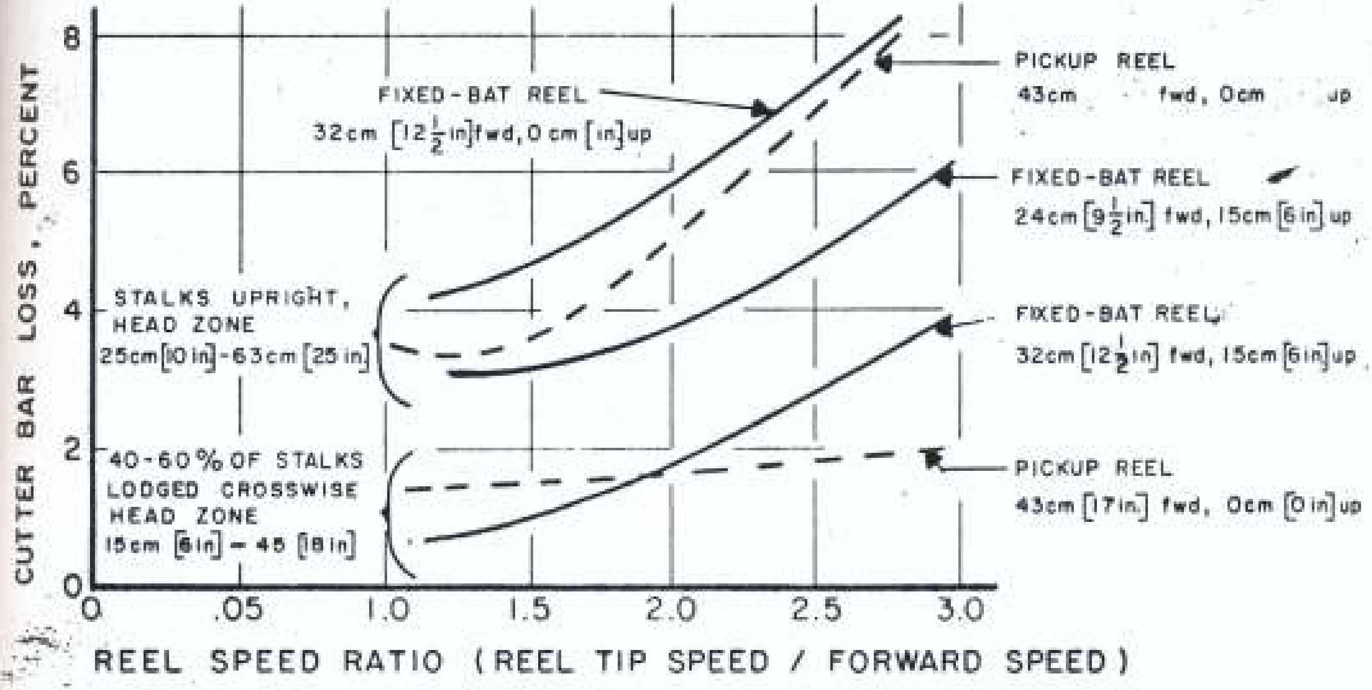


Fig. 15. Losses Associated with Reel Adjustment.

Source: Hunt, 1983.

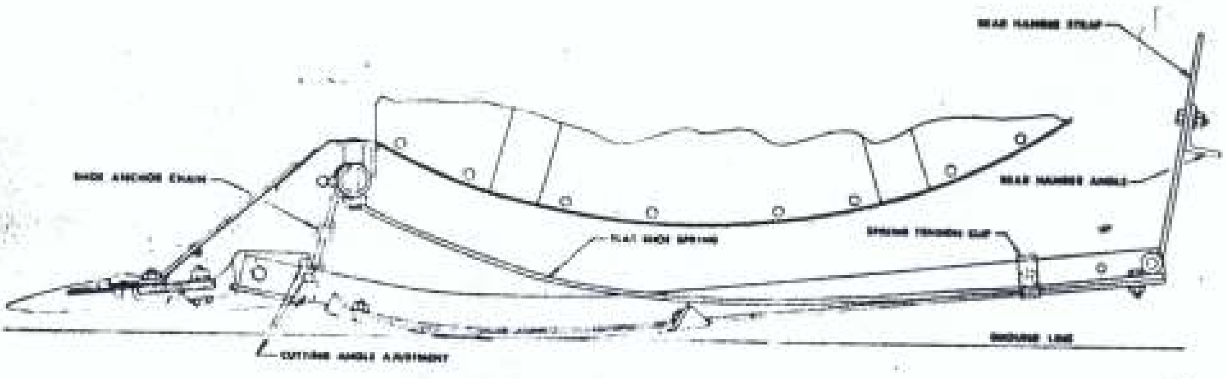


Fig. 16. Floating cutter bar construction.

Source: Hunt, 1983.

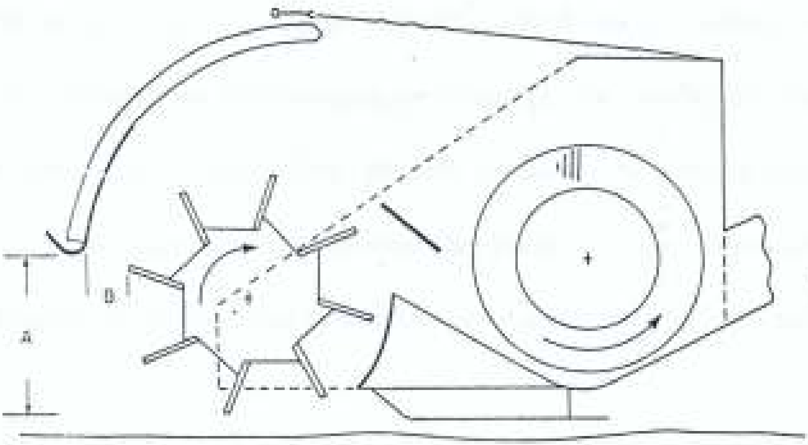


Fig. 17. Cross-sectional diagram of the stripping header with principal components.

Source: Klinner et. al., 1987.

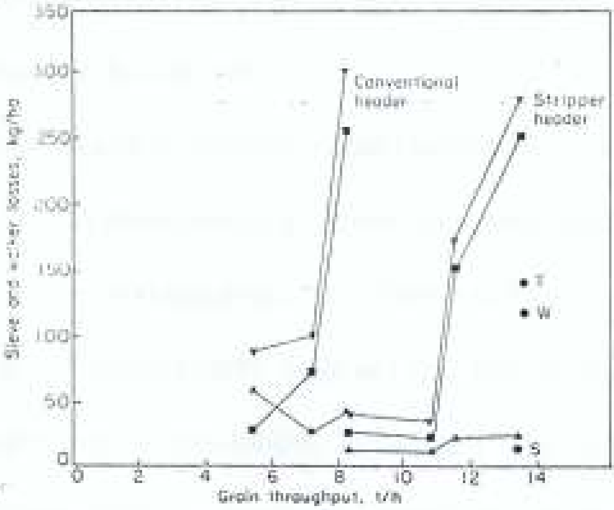


Fig. 18. Effect of grain throughput on sieve + straw walker losses in spring barley, var, kym. Stripping rotor speed 580 rev/min, ground clearance 178 mm. Grain yield 5.1 t/ha, grain m.c. 18.8%, straw m.c 23.1% ▼, total losses T; ■, walker losses W, ▲, sieve losses S, ●, at reduced concave clearance.
Source: Klinner et. al., 1987.

2.4.2. Threshing unit

The basic performance parameters of a threshing unit are threshing effectiveness and the percentage of seed damaged. Threshing effectiveness is related to the perpheral speed of the cylinder; the cylinder-concave clearance; the number of times the material passes the concave (as in helical-flow cylinder); the number of rows of concave teeth used with a spike-tooth cylinder, the type of crop, the condition of the crop in terms of miosture content, maturity etc; and the rate at which material is fed into the machine (Kepner et. al., 1978).

The speed of cylinders and concave clearance have a considerable impact on grain damage. Delong and Schwantes (1942) submitted that the best peripheral speed for the three cylinders range from 1,524 to 1,828 m/min. Arnold (1964), tried various combination of concave clearances and cylinder peripheral speed to reduce the extent of grain damage. Sarwar and Khan (1987) discovered that wire loop cylinders have higher threshing efficiency at lower speed and at all concave settings. However, the rasp-bar gave higher percentage of husked grain.

Feeding heads first with stalks parallel and the heads on top of the layer resulted in twice as low cylinder losses as feding the butts first, with wheat and barley (Arnold, 1964). However, Csukas (1964) stated that this is difficult to do on a field machine.

Vas and Harrison (1969), explained that though cylinder speed is the primary influencing parameter on threshability, an increase feed rate resulted in a decrease in mechanical damage which was described as a result of cushioning effect at higher feed rate. They concluded that mechanical parameters causing significant variation in percentage mechanical damage were cylinder speed, concave clearance and feed rate. Neal and

Cooper (1970), discovered that at a flow rate of 90kg/min approximately 72% of grain was separated by the rasp-bar-concave grate as against 50% separated by the spike tooth grate.

Arnold (1964), concluded that cylinder diameter was not of major importance in regard to performance and that diameter should be chosen to suit the concave length.

2.4.3. Separation unit

Non-grain feed rate and grain/ non-grain ratio are the major factors affecting walker losses with a given crop (Kepner et. al., 1978).

Comprehensive tests were conducted by Reed and Zoerb (1972), to determine the effects of walker crank speed, crank throw, grain/ non-grain ratio and feed rate upon the efficiency of grain separation with straw walkers. The dimension of the straw walker were 203 mm wide and 2.44 m long. Crank throws were 102 mm and 152 mm at different crank speeds. The lowest losses were at 200 rev/min with the 102 mm throw and at 150 rev/min. with the 152 mm throw. They explained that the tests are not directly comparable because two different types of walkers were used. Fig. 19 shows the effect of both grain/non-grain ratio and feed rate upon grain loss (wheat), based on the grain and non-grain feed rates onto the walkers stated earlier. Losses increased rapidly at walker non-grain feed rates above 90 kg/min. The grain loss at a given feed rate was reduced when the grain/nongrain ratio was increased.

Reducing the cylinder-concave clearance tends to reduce cylinder losses and increase seed damage, but the effects are generally rather small in comparison with the effects of increasing cylinder speed. In laboratory tests with wheat conducted by Vas and Harrison (1969), changing the clearance from 19 mm to 6 mm reduced the cylinder loss from 2.1% to 1.2% and increase visible damage from 5.4% to 7.8%. Decreasing the non-grain feed rate decreases cylinder losses. Field tests have indicated that the relation is often about linear (Nyborg, 1964 and Nyborg et. al., 1969).

Neal and Cooper (1970) and Reed et. al., (1974), discovered that when harvesting cereal grains with combine having rasp-bar cylinder and open grate concaves, 60 to 90% of the seed is usually separated through the grate. As indicated in Fig 20, 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.

Fig. 20. summarises the effects of concave length, cylinder diameter, cylinder speed, concave clearance, feed rate and moisture content upon cylinder performance.

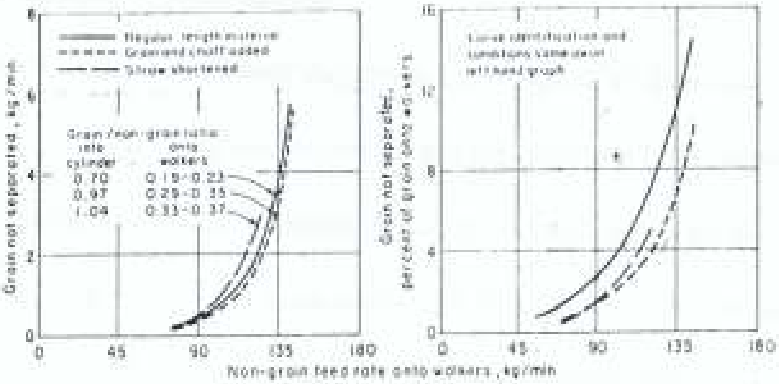


Fig. 19. Effect of grain/non-grain and walker non-grain feed rate upon walker seed loss in laboratory tests with wheat having a straw moisture content of 9 to 10%. Walkers were fed by a rasp-bar cylinder.
Source:Reed et. al., 1972.

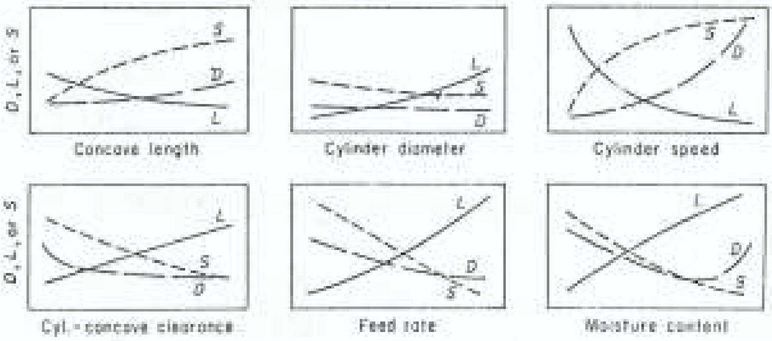


Fig. 20. Graphical characterization of some of the performance relations for a rasp-bar cylinder with an open-grate concave. L = cylinder loss, D = grain damage, and S= percent of grain separated through concave grate.
Source: Kepner et. al., 1978.

2.5. Evaluation of performance of the combine

2.5.1. Evaluation of grain damage

Ajav (1989) defined seed damage as the weight of all grains having breaks, cracks or other injuries in their seed coat expressed as a percentage of total weight of grains. Ige (1978), evaluated mechanical damage to grains by sorting them in the following categories:

1. Splits - those grains with little fracture or separated cotyledons.
2. Checks - those with checked or cracked skins.
3. Cuts - those with sharp narrow indentation in the skins and cotyledons.
4. Smashed - those with crushed cotyledons.
5. Sound grains - undamaged grains.

The total losses of a thresher can be obtained using the combination of the following relations reported by Ajav (1989):

i. Total grain input = Feed rate + Grain content ......(1)

ii. Percentage of unshelled

$$= \frac{\textit{Quantity of Unshelled grains(kg)}}{\textit{Total grain input} \quad (kg)} \times 100 \quad ....(2)$$

iii. Percentage of cracked and broken grains

$$= \frac{\textit{Cracked op broken grains} \quad (kg)}{\textit{Total grain received at outlet (kg)}} \times 100 \quad ....(3)$$

iv. Percentage of blown grain

$$= \frac{\textit{Quantity of clean grain} \quad (kg)}{\textit{Total grain input} \quad (kg)} \times 100 \quad ....(4)$$

v. Total losses = sum of losses obtained at (ii),(iii) and (iv).

Seed damage increases as moisture content is reduced (Arnold, 1964). Goss et al (1958), stated that when harvesting barley at 7 to 9% seed moisture content, visible damage amounted to 5% at 19.3m/s, 10% at 24.4m/s and 15 to 20% at 29.5m/s. Cylinder losses were 1.5 to 2% at 19.3m/s and negligible at higher speeds. Fig 21 shows the effect of cylinder speed upon seed damage and cylinder loss in laboratory tests with wheat.

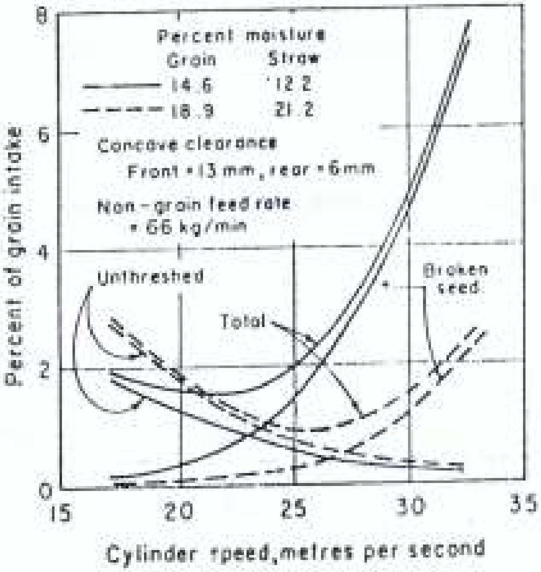


Fig. 21. Effect of cylinder speed upon seed damage and cylinder loss in laboratory tests with wheat , using a cross-flow rasp-bar cylinder.
Source:Kepner et al, 1978.

5.2. Evaluation of machine efficiency

Field Efficiency

This is the ratio of the overall rate of work to the theoretical spot rate of work (theoretical area capacity)

Overall rate of work, C_o $= \dfrac{V \times Wm \times \eta f}{100}$ (Witney, 1988) .... (5)

Where V = Operating speed, km/hr

Wm = Machine processing width, m

ηf = Field efficiency, %

Functional Efficiency

This is the measure of the effectiveness with which a machine performs its intended function.

Functional efficiency,

$$\eta_{fe} = \frac{P_o}{P_m} \times 100 \qquad \text{.......................................(6)}$$

For a grain combine;

P_o = separated grain delivered to the hopper

P_m = total yield

Quality Performance Efficiency

It is a measure of the quality of work done

$$= \frac{P_o - P_d}{P_m} \times 100 \qquad \text{..................................(7)}$$

P_d = damaged grains

2.5.3 Evaluation of machine capacity

The capacity of farm machine is the rate of work. A knowledge of the capacity of a machine is required to determine the duration of a production operation. Capacity of a machine may be measured in terms of area covered per unit time as in tillage operation, referred to as field capacity, or in terms of quantity of yield per unit area as in harvesting operation, referred to as material capacity.

a. Effective field capacity

$$Ce = eSw \quad \text{.......................................} \quad (8)$$

b. Effective material capacity

$$Me = eSwy \quad \text{.......................................} \quad (9)$$

Where e = field efficiency

S = speed of operation, km/hr

w = width of implement, m

y = crop yield per unit area.

CHAPTER THREE

3.0 DEVELOPMENT OF THE COMBINE HEADER

3.1.0 Design considerations

The following were considered in the design of the stripper components :

1. The stripper is a tractor-driven machine to be used for combing or stripping the seed from the rice stem with minimal straw intake.
2. The operating speed of a grain combine is between 3.2 to 5.6 km/hr (Kepner et. al., 1978). Thus 5 km/hr is the forward speed preliminarily considered for this design.
3. The dimension of the top cover, lower and upper side plates were chosen to suit the existing dimensions of the slanting conveyor such that they will arrest flying grains; the clearance between them ensures that air is not trapped.
4. The stripping elements are spaced such that the teeth make contact with the crop at every 25 cm within row spacing. Medium carbon steel is used enabling the elements to spring back to position when they encounter obstructions.
5. The slenderness of the teeth is considered for close spacing, bearing in mind the tillering characteristic of rice. A 13 cm tooth length is specified, considering the average panicle length of rice. Also, the diameter of the hole at the base of the teeth is taken as 27 mm , after considering the maximum diameter of paddy stem per stand.
6. The vertical clearance of the leading edge of the rotor cover relative to the bottom-dead-centre level of the stripping rotor is considered as 0.4m and the bottom-dead-centre level of the stripping rotor to the ground level, 0.2m. Thus the height of commencement of harvest is 0.6m. However, provision for adjustment of height is made using the adjustment screw which also acts as support for the header.

3.2.0. Material Selection for Components

The materials selected for the stripper components and reasons for selecting such materials are stated in Table 4.

Table. 4 Material Selection for Stripper Components.

S/No	Component	Material Selected	Reasons for Selection
1.	Stripper blade	2mm thick mild steel plate (SWG14)	Satisfies the strength requirement and is readily available.
2.	Angle bar	2 mm thick mild steel plate (SWG 14)	Strong and relatively lighter than the same length of 50.8mm X 50.8mm X 3mm thick angle iron.
3.	Frame	50.8mm X 50.8mm X 3mm thick angle iron	Does not twist easily.
4.	Stripper hanger	25.4mm x 25.4mm x 3mm thick angle iron	Strong and does not twist easily.
5.	Stripper shaft	30 mm _ High speed steel (HSS)	High torsional strength High critical speed Resistance to wear
6.	Side and Centre Plates	2 mm thick mild steel plate (SWG 14)	Will not deflect under load.
7.	Bottom pan	Mild steel sheet (SWG 16)	Can be formed into the required shape and is readily available. Relatively light and satisfies its requirement
8.	Left, lower side Plate	- do -	- do -
9.	Right, lower side Plate	- do -	- do -
10.	Left and right top plates	Mild steel sheet (SWG 18)	- do -
11.	Top back cover	- do -	- do -
12.	Adjustable top cover	Mild steel sheet (SWG 20)	Very flexible, light nd formable.
13.	Conveyor cup	Mild steel sheet (SWG 18)	Formable and light,can be fastened to the conveyor by riveting
14.	Pillow Block bearing	25 mm internal diameter pillow block	Easily adjusts to shaft misalignment. Can be easily bolted directly to frame
15.	V-belts	Impregnated rubber	Available, have reasonably high allowable shear stress, interchangeable.

3.3. Design analysis

3.3.1 Determination of the number of points of stripper rows

This is based on the standard spacing for the crop under consideration - ITA 150.

Consider the cross-section of the stripper drum.

np = number of points of stripper rows

nr = number of rev/sec

s = spacing of crop

= 25 cm within row

Π d/np = distance between one row and next row of stripper.

Time to cover s must be equal to the time to cover Π d/np

Time to cover s = distance/forward speed

= s/v ....(1)

The forward speed for grain combine ranges from 3.2 to 5.6 km/hr (Kepner et. al., 1978). A forward speed of 5 km/hr is selected

Time to cover s = $25 \times 10^{-2}/1.39$ [5 km/hr = 1.39m/s]

= 0.18 seconds

Time to cover Π d/np

= 1/nr X Π d/np

= Π d/nrnp ....(2)

Table 5: Iteration of parameters nr, d and np to give 0.18 seconds

	1	2	3	4	5	6
nr(rev/s)	5.92	5.92	5.92	3.33	3.33	2.33
np	8	6	6	8	6	6
d (cm)	60	60	80	60	60	80
Π	3.142	3.142	3.142	3.142	3.142	3.142
Π d/nrnp (sec)	0.04	0.05	0.07	0.07	0.09	0.18

The value of parameters nr, np and d chosen are respectively 2.33 rps (140 rpm), 6 and 80 cm.

3.3.2 Determination of the power required to drive the stripper.

F_1 = force rotating the stripper alone

F_2 = resistance due to the crop

$$F_1 = \frac{mv^2}{r} \quad \text{……………………………………(3)}$$

m = mass of rotating member

v = linear velocity of rotating member

r = base circle radius of stripper cross-section

The mass of stripper components were determined using electronic weighing machine.

Mass of stripper blades (m_1)

= [(1171) x 6] g

= 7026g

= 7.026kg

Mass of angle bars (m_2)

= [(769) X 6]g

= 4614g

= 4.614kg

Mass of side and centre plates (m_3)

= [(1803) X 3]g

= 5409g

= 5.409kg

Total mass m = $m_1 + m_2 + m_3$

= 7.026 + 4.614 + 5.409

= 17.049kg

$v = \omega r$ .... (4)

$\omega = 2\Pi n/60$ .... (5)

$n = 140$ rpm

From equation (5)

$\omega = 2 \times \Pi \times 140/60$

$= 14.66$ rad/s

$r = 0.26$ m

From equation (4)

$v = 14.66 \times 0.26$

$= 3.8116$ m/s

From equation (3)

$F_1 = 17.049 \times (3.8116)^2 / 0.26$

$= 952.66$N

$T_1 = F_1 r$ .... (6)

$= 952.66 \times 0.26$

$= 248$Nm

$= 0.248$ KNm

F_2 was determined experimentally (Appendix A)

The maximum force required to strip one panicle of paddy in-situ was found to be 15N. [Smith and Jones (1948) submitted that a medium-size cotton boll stem can be pulled from the limbs with a force of 13 to 22N].

But the maximum number of panicles per stripper recess is 7.

$F_2 = 15 \times 7$

$= 105N$

$= 0.105\ KN$

$T_2 = 0.105 \times 0.26$

$= 0.0273\ KNm$

$\text{Power} = 2\Pi n\ (T_1 + T_2)$

$= 2 \times \Pi \times 2.33\ (0.248 + 0.0273)$

$= 4.03\ kw$

3.3.3 Determination of theoretical stripper capacity

The theoretical material capacity (M_t) of the stripper.

$(M_t) = fwv$ (Wiseny, 1988) .... (7)

Where $f =$ crop population in kg/m^2

$= 1.5$ tonnes/hectare for ITA 150

$= 1{,}500 kg/10{,}000 m^2$

$= 0.15 kg/m^2$

$w =$ width of stripper

$= 1m$

$v =$ forward speed of stripper (km/hr)

$= 5\ km/hr$

$= 1.39\ m/s$

From eqn. (7)

$M_t = 0.15 \times 1 \times 1.39$

$= 0.21 kg/s$

3.3.4. Design of stripper shaft

First determine the forces acting on the shaft.

F_1 = crop resistance

= 15N (Appendix A)

F_2 = weight of stripper elements and plates

$= m \times g$

$= 17.049 \times 9.81$

= 167N

F_3 = weight of pulley

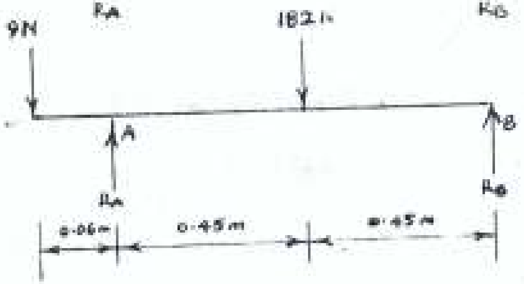
= volume x density x 9.81

$$= \frac{\Pi d^2}{4} \times 0.015 \times 7840 \times 9.81$$

$$= \frac{\Pi \times 0.1^2}{4} \times 0.015 \times 7840 \times 9.81$$

= 9N

Consider that F_1 and F_2 are evenly distributed load over the length of the shaft:



$\Sigma F\uparrow \quad = \quad \Sigma F\downarrow$

$R_A + R_B \quad = \quad 9 + 182$ .... (8)

$= 191N$

Taking moment about R_B

$(9 \times 0.96) - R_A(0.9) + (182 \times 0.45) = 0$

$0.9 R_A = 8.64 + 81.9$

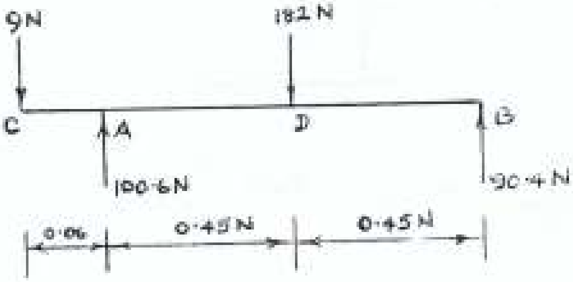
$R_A = 100.6N$

Substituting in eqn. (8)

$100.6 + R_B = 191$

$R_B = 90.4\ N$

Vertical Loading



Vertical Bending Moment

VBM $M_{BV} = 0$

At B $M_{HV} = 0$

At D $M_{BV} = 182 \times 0.45$

$= 81.9$ Nm

At A $M_{HV} = (182 \times 0.45) - (100.6 \times 0.9)$

$= 81.9 - 90.54$

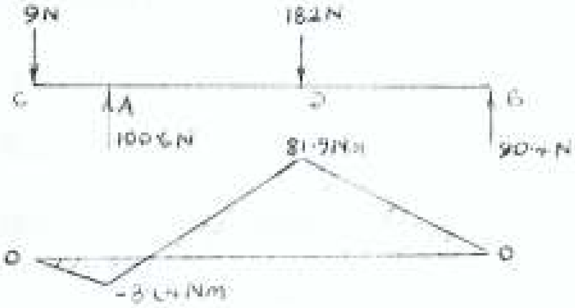
$= -8.64$ Nm

At C $M_{HV} = (182 \times 0.45) - (100.6 \times 0.9) + (9 \times 0.96)$

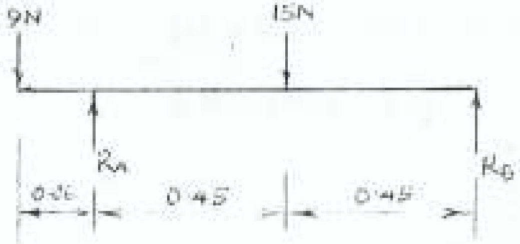
$= 81.9 - 90.54 + 8.64$

$= 0$

VBM Diagram



Horizontal Loading



$\Sigma F\uparrow = \Sigma F\downarrow$

$R_A + R_B = 9 + 15$ .... (9)

$= 24$ N

Taking moment about R_B

$(9 \times 0.96) - (0.9 \times R_A) + (15 \times 0.45) = 0$

$8.64 - 0.9 R_A + 6.75 = 0$

$0.9 R_A = 15.39$

$R_A = 17.1$N

Substituting in eqn. (9)

$17.1 + R_B = 24$

$R_B = 6.9$ N

Horizontal Bending Moment

HBM $M_{HH} = 0$

At B $M_{BH} = 0$

At D $M_{BH} = 15 \times 0.45$

$= 6.75$ Nm

At A $M_{BH} = (15 \times 0.45) - (17.1 \times 0.9)$

$= 6.75 - 15.39$

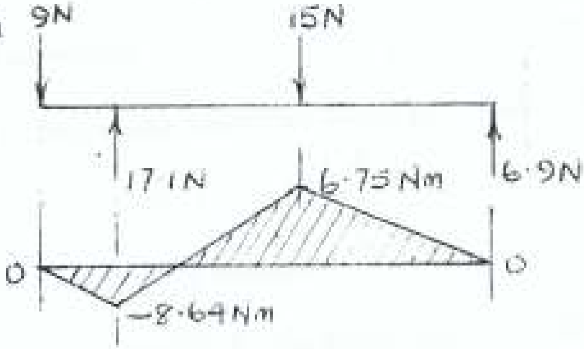
$= -8.64$ Nm

At C $M_{BH} = (15 \times 0.45) - (17.1 \times 0.9) + (9 \times 0.96)$

$= 6.75 - 15.39 + 8.64$

$= 0$

HBM Diagram



$$Mb(max) = \sqrt{(81.9)^2 + (6.75)^2}$$

$$= 82.2 \text{ Nm}$$

$$M_t = \frac{9550 \times KW}{rev/min}$$ (Hall et-al, 1982) .... (10)

$$= \frac{9550 \times 4.03}{140}$$

$$= 274.9 \text{ Nm}$$

$$d^3 = \frac{16}{\pi \times \sigma_S} \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$ (Hall et.al, 1982) .... (11

$$d^3 = \frac{16}{\pi \times 66.6 \times 10^6} \sqrt{(1.5 \times 82.2)^2 + (1.5 \times 274.9)^2}$$

$$d = 0.032 \text{ m}$$

$$= 32 \text{ mm}$$

Select 30 mm standard diameter.

3.3.5 Fits and tolerances

Fits and tolerances are determined for proper running and assembly of the stripper shaft and bearing hole.

The following procedure were employed:

i. Selection of the type of fit for the stripper shaft and bearing.

ii. Determination of fit and tolerance values corresponding to the fit type.

iii. Calculation of limit dimensions from:

$$\frac{\text{Nominal value} \pm \text{Upper limit}}{\text{Nominal value} \pm \text{Lower limit}} \qquad \frac{+\text{Hole}}{-\text{Shaft}}$$

iv. Determining the tolerance for the hole and shaft which equals the difference between the upper and lower limits.

v. Calculation of the allowance between the hole and shaft ------ minimum clearance. Clearance = largest hole dia. - minimum shaft dia.

vi. Determining the grade of machine work (Hall et. al., 1982)

Clearance required = Normal running

Shaft tolerance chosen = f7

Hole tolerance chosen = H8

Shaft minimum clearance, ei = 0.041 mm

Hole minimum clearance, EI = 0.000 mm

Shaft maximum clearance, es = 0.020 mm

Hole maximum clearance , ES = 0.033 mm

Shaft diameter = 30.000 mm

Limit dimension for shaft $= \dfrac{30.000 - 0.020}{30.000 - 0.041} = \dfrac{29.980}{29.959}$

Limit dimension for hole $= \dfrac{30.000 + 0.033}{30.000 + 0.000} = \dfrac{30.033}{30.000}$

Tolerance for shaft = 29.980 - 29.959 = 0.021 mm

Tolerance for hole = 30.033 - 30.000 = 0.033 mm

Therefore, allowance between hole and shaft

= 30.033 - 29.959

= 0.074 mm

Grade of work = 10 ; for turning, boring or reaming.

3.3.6. Power transmission to the stripper

Power transmission from the P.T.O. coupling to the stripper shaft is presented in Fig. 24. The transmission of power is through belts and pulleys of different sizes. At one point speed is reversed with a combination of two spur gears to achieve the required clockwise rotation of the stripper shaft.

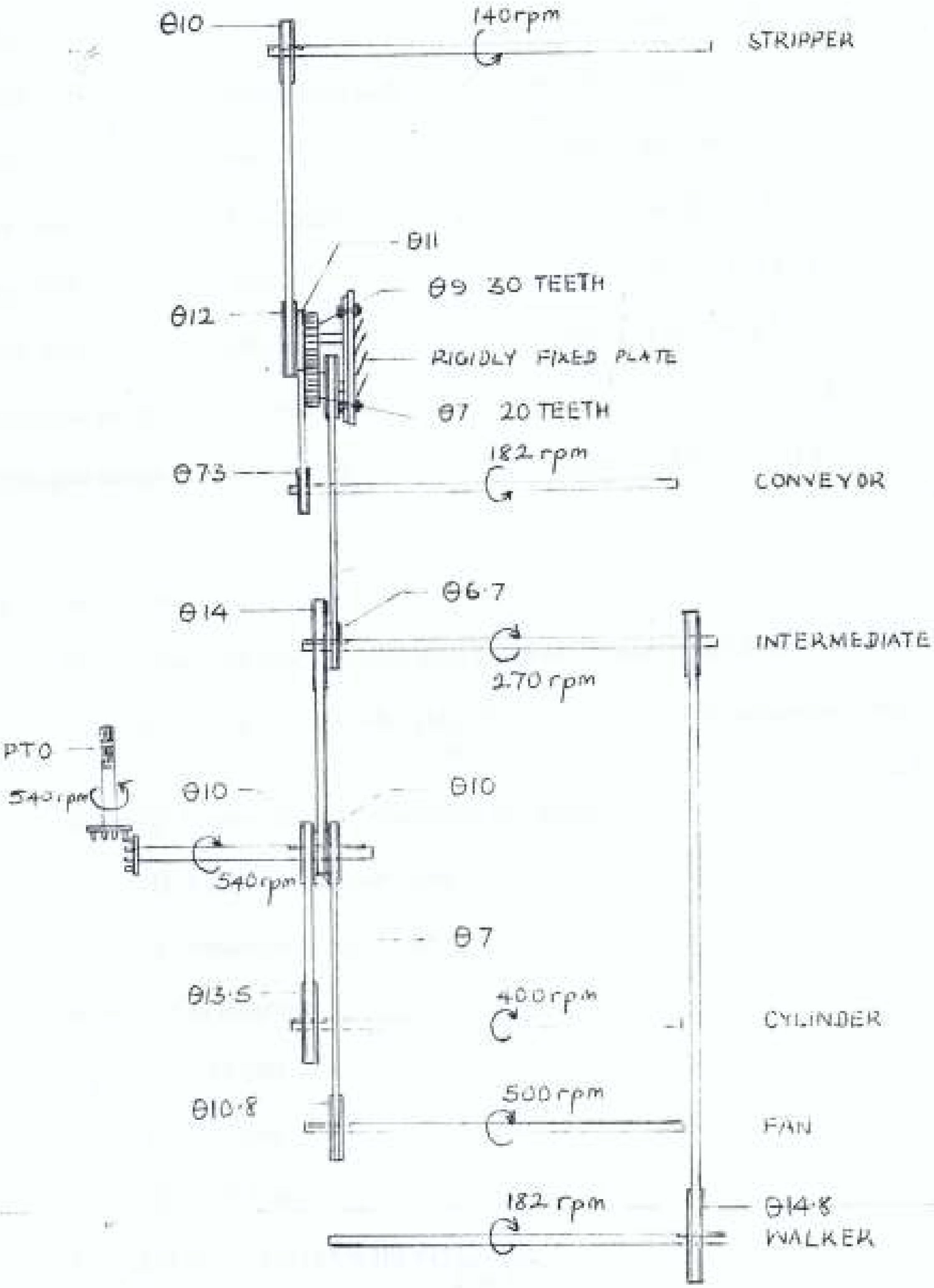


Fig. 24. Top view of Power Transmission from P.T.O. to the Stripper.

Transmission Ratios

P.T.O.	:	Cylinder	= 540 : 400	= 1.4 : 1
P.T.O.	:	Intermediate shaft	= 540 : 270	= 2 : 1
P.T.O.	:	Fan	= 540 : 500	= 1.1 : 1
Inter. shaft	:	Driver gear	= 270 : 180.9	= 1.5 : 1
Inter. shaft	:	Walker	= 270 : 182	= 1.5 : 1
Driver gear	:	Driven gear	= 180.9 : 121	= 1.5 : 1
Driven gear pulley	:	Conveyor shaft	= 120.6 : 182	= 1 : 1.5
Driven gear pulley	:	Stripper shaft	= 120.6 : 140	= 1 : 1.2

3.3.7. Belt selection

This is achieved by determining the total length of the required belt from

$$L = 2C + 1.57\,(D + d) + \frac{(D - d)^2}{4C} \quad \text{..................} \; (12)$$ (Avallone and Baumeister, 1978)

Where C = center distance between the two shafts

D = diameter of larger pulley

d = diameter of smaller pulley

a. From P.T.O to cylinder

$D = 13.5\text{cm}$

$d = 10\text{ cm}$

$C = 78.5\text{ cm}$

$$L = 2(78.5) + 1.57\,(13.5 + 10) + \frac{(13.5 - 10)^2}{4(78.5)}$$

$= 193.9\text{ cm}$

$= 1939\text{ mm}$

The next available size in the market was A - 74 (1925 mm) which was selected.

b. P.T.O to Intermediate shaft

$D = 14\text{cm}$

$d = 7 \text{ cm}$

$C = 30 \text{ cm}$

$$L = 2(30) + 1.57\,(14 + 7) + \frac{(14 - 7)^2}{4(30)}$$

$= 93.38 \text{ cm}$

$= 933.8 \text{ mm}$

A- 34 (925 mm) was selected.

c. P.T.O to Fan

$D = 10.8\text{cm}$

$d = 10 \text{ cm}$

$C = 34 \text{ cm}$

$$L = 2(34) + 1.57\,(10.8 + 10) + \frac{(10.8 - 10)^2}{4(34)}$$

$= 99.1 \text{ cm}$

$= 991 \text{ mm}$

A- 37 (1000 mm) was selected.

d. Intermediate shaft to Driver gear

D = 10cm

d = 6.7 cm

C = 54 cm

$$L = 2(54) + 1.57\,(10 + 6.7) + \frac{(10 - 6.7)^2}{4(54)}$$

= 134.3 cm

= 1343 mm

A- 51 (1350 mm) was selected.

e. Intermediate shaft to Walker

D = 14.8cm

d = 10 cm

C = 82.5 cm

$$L = 2(82.5) + 1.57\,(14.8 + 10) + \frac{(14.8 - 10)^2}{4(82.5)}$$

= 204 cm

= 2040 mm

A- 79 (2050 mm) was selected.

f. Driven gear pulley to conveyor

D = 11cm

d = 7.3 cm

C = 23.5 cm

$$L = 2(23.5) + 1.57\,(11 + 7.3) + \frac{(11 - 7.3)^2}{4(23.5)}$$

$= 75.9$ cm

$= 759$ mm

A- 23 (750 mm) was selected.

g. Driven gear pulley to Stripper

$D = 12$cm

$d = 10$ cm

$C = 31.5$cm

$$L = 2(31.5) + 1.57\,(12 + 10) + \frac{(12 - 10)^2}{4(31.5)}$$

$= 97.6$ cm

$= 976$ mm

A- 36 (975 mm) was selected.

CHAPTER FOUR

4.0 FABRICATION OF MACHINE

4.1.0. Fabrication procedure

After determining the component dimensions, the materials required were procured and actual fabrication commenced. The component parts were fabricated one after the other in line with the supporting drawings.

1. **Stripper Blade**

Material - 2 mm thick mild steel sheet SWG 14.

Six 20 cm x 90 cm marks were made on the mild steel sheet with a steel rule and a metal scriber. Cutting was done with a maunally operated thin metal shearing machine. The six plates were cut and separated. Because of irregularities of hand cutting, the plates were grinded to precision on a grinding machine, following the marked lines. Sharp edges were also smoothened.

After determining the diameter of holes to be drilled, their centre distances were marked on each plate. The larger holes of diameter 27 mm will serve as a recess into which the rice plants will enter for 360^0 stripping. The smaller holes of diameter 6 mm are for fixing the stripper blades to the angle bar on the stripper drum. At the marked centre distances, punch marks were made with a centre punch and hammer. The plates were then carried to the vertical drilling machine, where the holes were drilled. Preceeding this operation was the construction of a wooden template of the stripper teeth. The template was placed on each plate and the teeth marked out. With a hacksaw, the teeth were carefully cut out to precision (Fig.23). The plates were mounted on the vice with wooden packs to prevent deflection due to the flexibility of the plate.

2. Angle Bar

Material - 2 mm thick mild steel sheet.

Six plates each of dimension 7 cm x 90 cm were marked on the mild steel sheet and cut with the manual shearing machine. Six holes of diameter 6 mm were drilled along the length of plate. A line was marked to divide the width of the plate into 3 cm and 4 cm (Fig. 24). The plates were then taken to the folding machine which was used to fold along the marked line until 90° was subtended. Rough egdes were smoothened on the grinding machine.

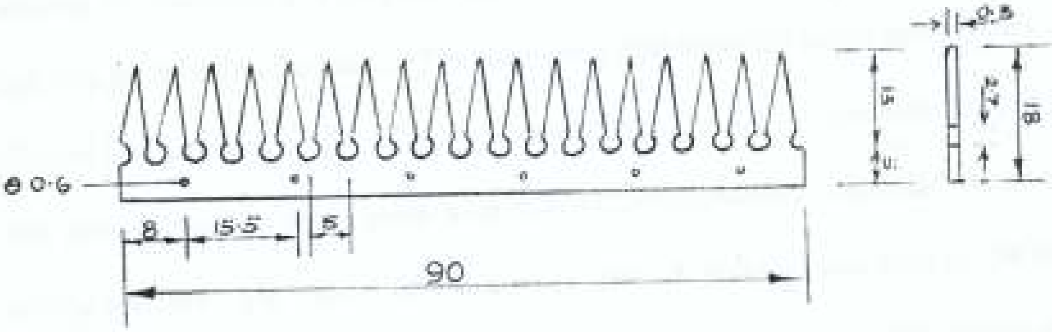


Fig. 23. Schematic Diagram of the Stripper Blade.

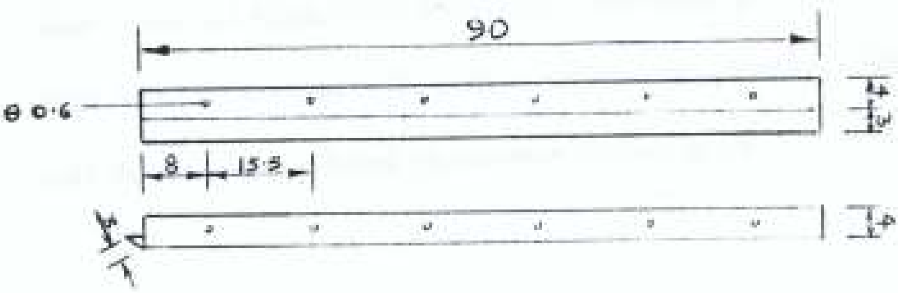


Fig. 24. Schematic Diagram of Angle Bar.

3. Side and Centre Plates

Material - 2 mm thick mild steel sheet (SWG 14)

A metal divider was used to inscribe three circles each of diameter 56 cm to account for 3 cm folding of the plate - this thickness allows for placement of the angle bars and stripper blades on the plates. The plates were then patterned out as shown below (Fig. 25) and cut, such that the 3 cm thickness was achieved by folding along the dotted lines. The geometric centre of the plates were marked, centre-punched and drilled on a vertical drilling machine. The hole is of diameter 25 mm. A hacksaw was used to cut off the hatched part of the plate. The orientation of the sides did not permit the plate to be cut with the shearing machine. Six, equilateral triangular slots of sides 10 cm were created on each of the three plates for weight reduction. This was done by first marking out the dimensions and closely line-drilling with 5 mm drill bit, hitting off with a hammer and manually filing off the rough edges.

4. Stripper Pan

Material - 1.5 mm thick mild steel sheet.

The stripper pan of the dimension in Fig. 26. was marked out and cut from a full sheet of size 121.92 cm x 243.84 cm with a hand shearing machine. 6 mm diameter holes were drilled at the edges of the plate to enhance easy assembly. The pan was then bent until the shape that followed the conveyor profile was got.

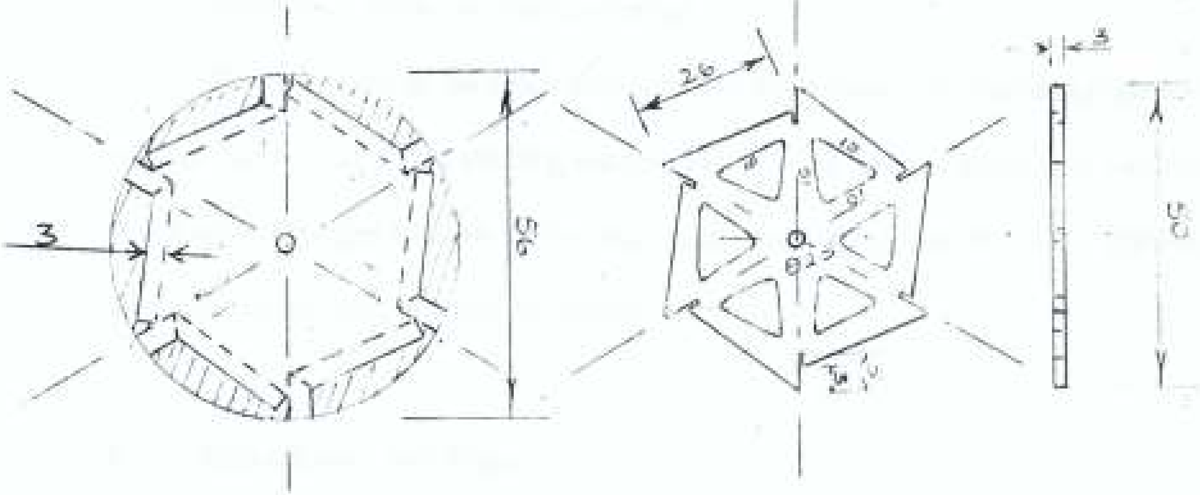


Fig. 25. Schematic Diagram of Side and Center Plates.

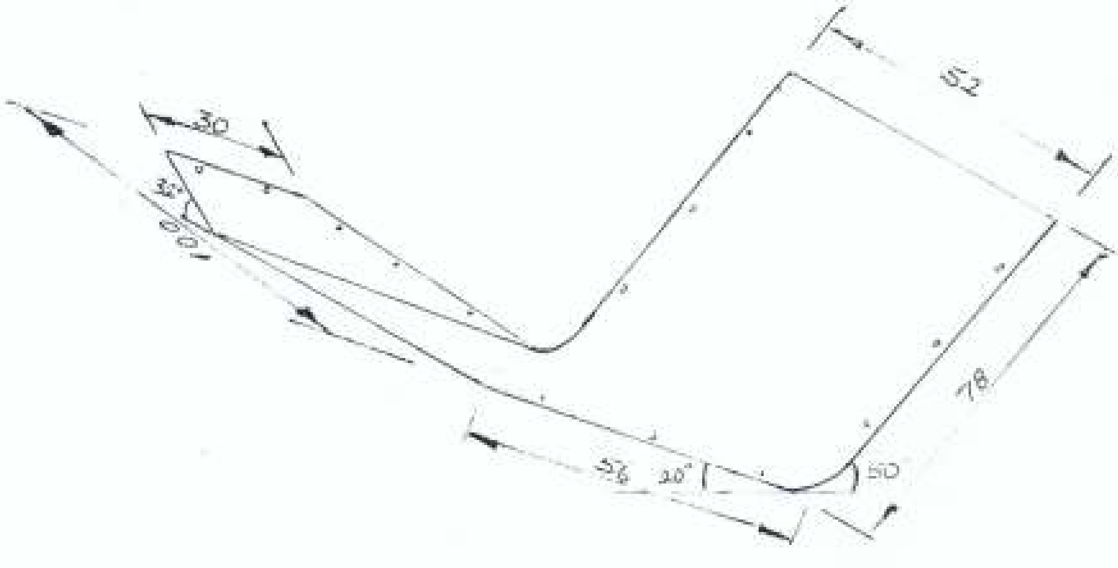


Fig. 26. Schematic Diagram of Stripper Pan.

5. Left, Lower Side Plate

Material - 1.5 mm thick mild steel sheet.

This was made of the above material. The dimensions were marked on the sheet and the size cut out with a shearing machine Fig. 27. 12 holes of diameter 6 mm were drilled along the edges to allow for fastening. The lower edges were folded at 3 cm width with a folding machine, to allow the bottom plate to rest on.

6. Right, Lower Side Plate

The dimensions in Fig. 28. were marked on the sheet with a scriber and cut on a shearing machine. 12 holes of diameter 6 mm were drilled along the edges. 3 cm of the lower edges were folded so that the stripper pan could be bolted onto it.

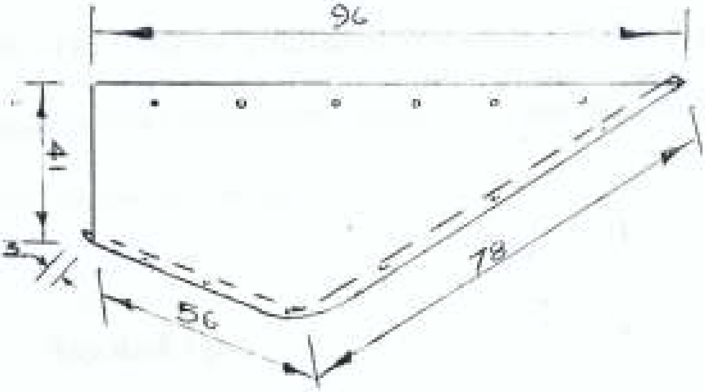


Fig. 27. Schematic Diagram of Left, Lower Side Plate.

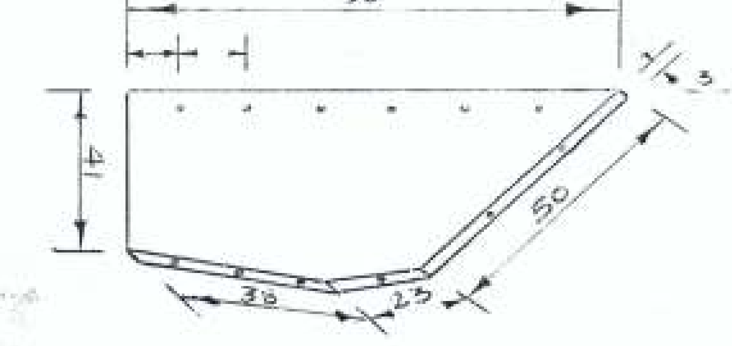


Fig. 28. Schematic Diagram of Right, Lower Side Plate.

7. Left and Right Side Top Plates

Material - mild steel sheet (SWG 18).

After marking out the specified dimensions with a scriber, the sheet was cut and folded 3 cm inwards Fig. 29. The open ends were welded close with gas welding. Thus rigidity of the cover was achieved to some extent. The inward folding also provided points of attaching other components. Hence 12, 6 mm diameter holes were drilled across the edges of the two side covers.

8. Top Back Cover

Material - mild steel sheet (SWG 18)

The dimensions shown (Fig. 30) were marked on the flat sheet with the same method as other sides. Cutting was done with the shearing machine. 14, 6 mm diameter holes were drilled at the edges of the plate. The plate was then folded such that it follows the slanting end of the two top side covers.

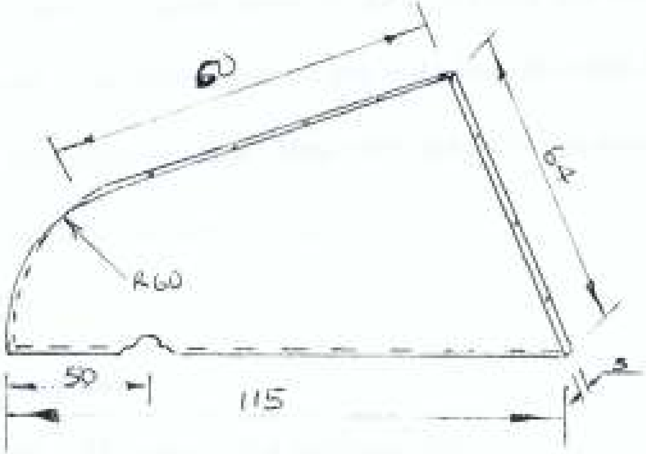


Fig. 29. Schematic Diagram of Left and Right Side Top Plates.

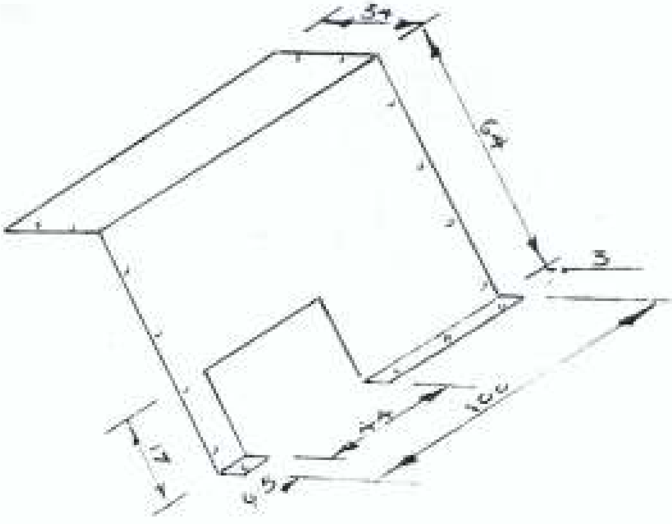


Fig. 30. Schematic Diagram of Top Back Cover.

9. Slanting Conveyor Cup

Material - mild steel sheet (SWG 18)

The required dimensions were cut out of the mild steel sheet (Fig. 31). Two rivet holes of diameter 4 mm were drilled on one side. Then the sheet was folded into the right shape. Six of this part were made. They were equidistantly spaced at 42 cm and riveted to the belt using the hand operated riveting gun.

10. Stripper Hanger

Material - 25.4 mm x 25.4 mm Angle iron

- 50.4 mm x 50.8 mm Angle iron

The materials were cut into the their sizes (Fig. 32). Three, 6 mm diameter holes were drilled on one of the two lengths and four on the other such that they can slide on each other for adjustments. At both ends of the hanger a flap made from 50.8 mm x 50.8 mm angle iron with three 10 mm diameter holes was welded to allow for fastening to the stripper housing.

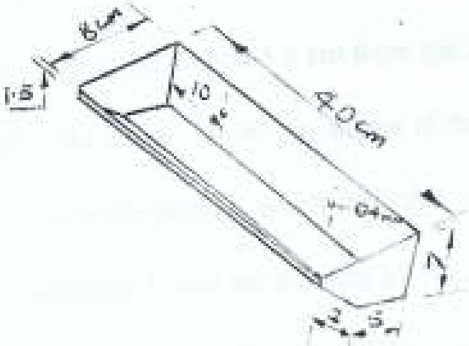


Fig. 31. Schematic Diagram of Slanting Conveyor Cup.

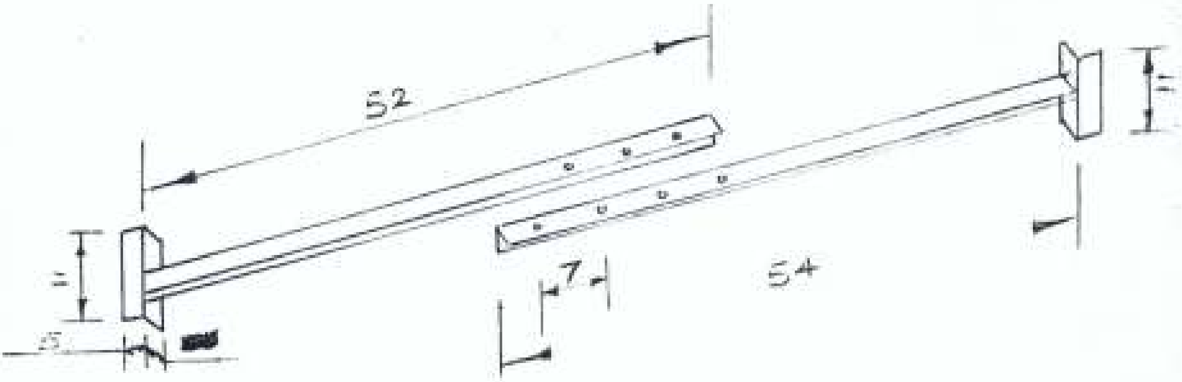


Fig. 32. Schematic Diagram of Stripper Hanger.

11. Stripper Frame

Material - 50.8 x 50.8 x 6096 mm angle iron.

The angle iron was cut with a hacksaw into the sizes (Fig. 33). Two holes of diameter 12 mm were drilled 6 cm from the tip of each frame to allow for the pillar block bearings to be fitted. At 60 cm, a hole of diameter 16 mm was drilled on each side of the frame. This is the point at which the frame will be bolted to the slanting conveyor. Other holes of diameter 6 mm were drilled on both flaps of the frame. These are provisions for fitting the side plates and covers. The frame acts as a single unit when fitted to the conveyor frame.

12. Stripper Shaft

Material - High speed steel (HSS).

A lathe machine was used to turn the 27 mm diameter rod. Keyways of length 7 cm were slotted at both ends of the shaft with the vertical milling machine (Fig. 34).

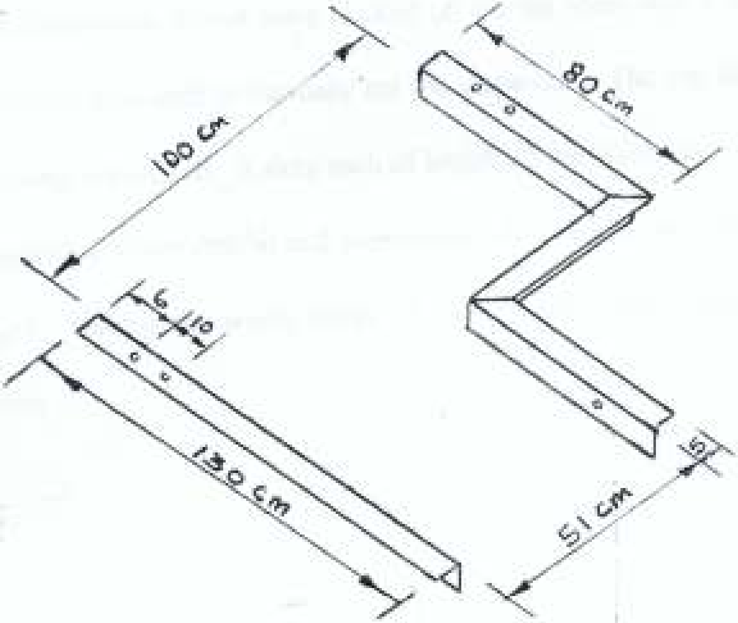


Fig. 33. Schematic Diagram of Stripper Frame.

Fig. 34. Schematic Diagram of Stripper Shaft.

13. Adjustable Top Cover

Material - mild steel sheet (SWG 20).

The dimensions shown were marked on the flat sheet with a scriber (Fig. 35). A shearing machine was used to manually cut the shape out. The top flange was bent while the lower flange was rolled. 8 slots each of length 15 cm were made on the plate by first line drilling with a 3 mm drill bit and then 6 mm. A thin flat file was used to remove the rough edges. Placing the whole cover on the top side plates makes it to follow their configuration.

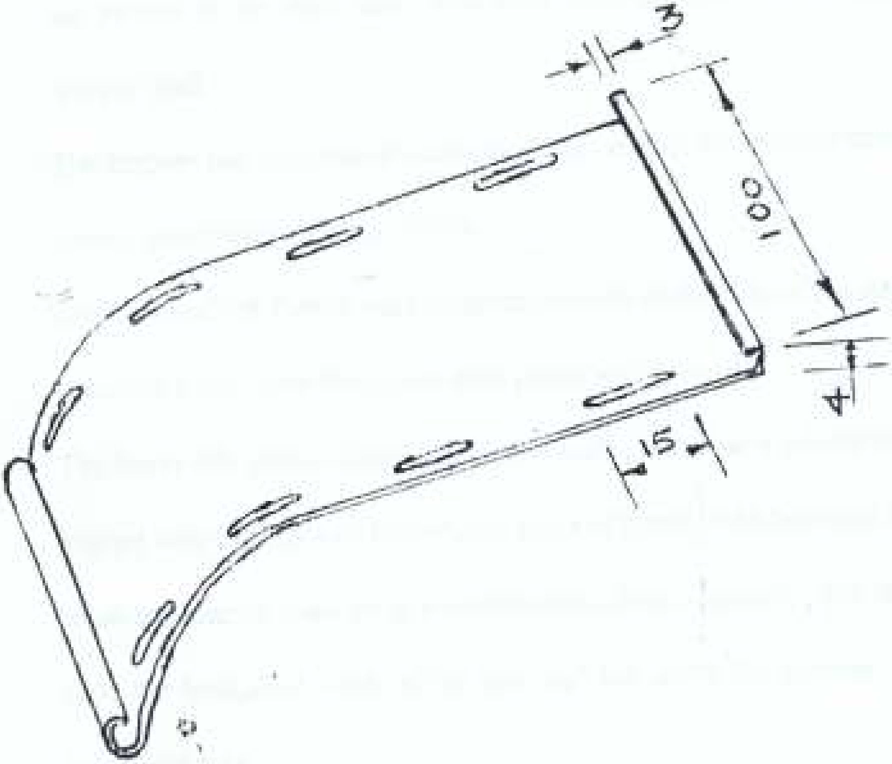


Fig. 35. Schematic Diagram of Adjustable Top Cover.

4.2.0 Assembly of Machine

The following procedure were employed in the assembly of the stripper:

1. The side plates were rightly positioned on a work bench in the workshop and the stripper shaft passed through them.
2. The six angle bars were slotted and rigidly secured to their positions on the side plates by tacking. The angle bars were then welded to the plates making sure they run parallel to the shaft axis. The pillar bearing were fitted to each side of the stripper shaft.
3. The stripper pan was placed under the lower end of the existing conveyor, slightly bent to completely follow its profile.
4. The right and left frames were screwed securely to the side of the slanting conveyor frame, with the longer ends projecting forward.
5. The lower side plates were positioned in such a way that the holes on their sides aligned with the holes on the stripper pan and frame. M6 bolts and nuts were used to secure them in place using a combination of two spanners - one ring spanner to hold the hexagonal head of the bolt and the other flat spanner to tighten the hexagonal nuts.
6. Next the stripper drum was placed in the position provided for it on the frame. The pillow block bearings were adjusted until their holes were concentric with those on the frame. They were securely bolted with M12 bolts and nuts. The stripper drum was then rotated until contact with any of the side plates did not take place.
7. At this stage the stripper blades were bolted to the angle bars one after the other until all were securely in place. The shape of the side plates provided additional

hold for the stripper blades. Standing at a safe distance from the sharp teeth, the drum was manually rotated to ensure that no contact was made with the side plates and stripper pan. The shaft was then keyed in position thereby preventing any side thrusts.

8. Six conveyor cups were riveted to the conveyor belt at an equidistant 42 cm to one another, and in a way that a clearance of 7 mm was made between the cup and the stripper pan.

9. The two top side plates were tightened to their positions on the frame with M6 bolts and nuts. Care was taken to ensure that there was sufficient clearance between the plate and the surface profile of the pillow bearings, but not to the extent of permitting flying grains which could subsequently increase machine losses.

10. 20 SWG cover plate which was slotted in four places on each side was fixed in position with M6 bolts and nuts. The bolts were positioned face up and welded to form a stud. This allows for loosening the nut and sliding the top cover up or down as may be required during harvesting. Hence washers were placed to allow for safe tightening of the bolts.

11. With all the components in place the stripper shaft was turned manually to ensure that the drum functioned properly.

12. A 17 cm x 17 cm x 1 cm mild steel plate with four θ12 hole was welded to the side of the conveyor frame. Another mild steel plate - gear plate - of size 16 cm x 16 cm x 1 cm was bolted to the welded plate. This was to facilitate easy maintenance. The required pulleys were also attached accordingly.

13. Pulleys and belts were connected in the following order

    1st - P.T.O. shaft to intermediate shaft

    2nd - P.T.O. shaft to cylinder shaft

    3rd - P.T.O. shaft to fan shaft

    4th - Intermediate shaft to walker shaft

    5th - Intermediate shaft to driver gear

    6th - Driver gear to driven gear

    7th - Driven gear pulley to conveyor shaft

    8th - Driven gear pulley to stripper shaft.

14. Having finished the connection of the drive units, the P.T.O. shaft was then rotated to ensure that all the component parts rotated without any interference. Misaligned belts were realigned. Loose bolts and nuts were re-tightened.

15. The already deflated wheels of the combine were inflated and the supspension screw lubricated. Finally, the whole machine was properly cleaned and put in a position ready for field test.

4.3.0 Mechanism of Operation

The machine is coupled to the tractor via the drawbar with drawbar pin securely in place. The P.T.O. extension shaft is then connected to the splined ends of the shaft on the tractor and the combine gear box (Fig. 36).

When the P.T.O. lever is engaged speed is reversed at the gear box by a pair of bevel gears from anticlockwise to clockwise. Power is transmitted from the P.T.O. shaft to the cylinder, fan and intermediate shafts at different speed ratios (Fig. 22).

The intermediate shaft, rotating at 270 rev/min, supplies power to the walker and the pair of spur gears. Speed is reversed and reduced at this point to the stripper shaft which finally rotates at 140 rev/min. Speed can be increased or reduced by either changing the pulleys and belts or increasing the P.T.O. speed from the tractor.

The principal component is the single horizontal rotor. The stripping elements consist of transverse arrays of slender and closely spaced teeth, with a hole at the base between each pair. At work it gives 360 degree stripping of paddy and some materials other than grain from the stems and directs them rearwards to be picked by the cup conveyor to the entry of the threshing drum. Grains falling on the remaining width of the stripper pan fall towards the conveyor by gravity bacause that portion of the pan is inclined at an angle of 30° which is greater than the dynamic angle of repose of paddy: they are also picked up and fed into the threshing drum.

The header can be lowered or raised in work using the suspension screw. Fig. 37 shows the stripper header in transport position.

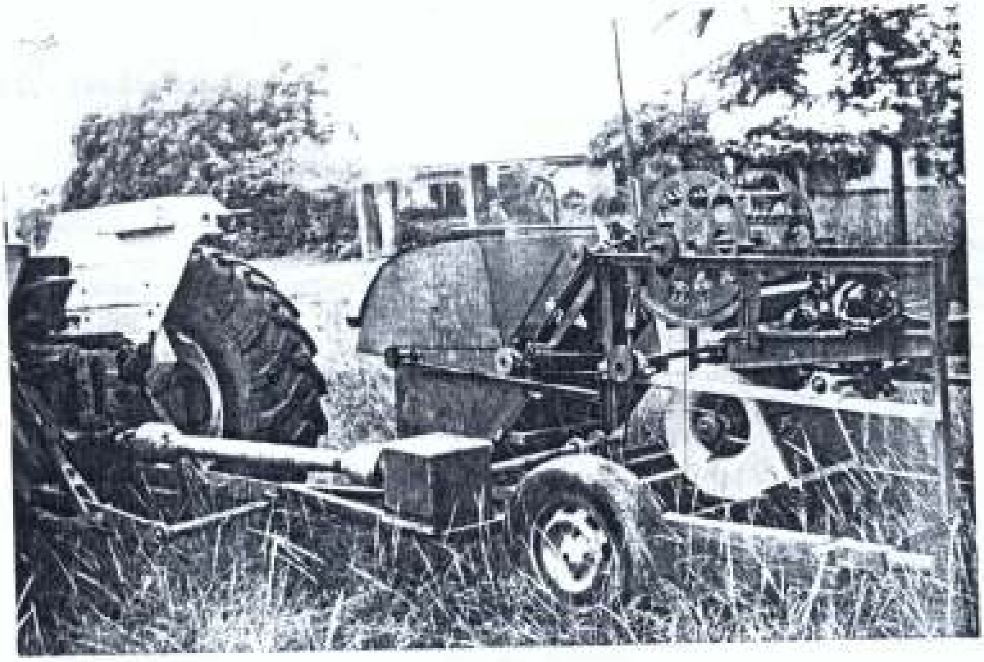


Fig. 36. Power Transmission from the Tractor P.T.O. to the Harvester.

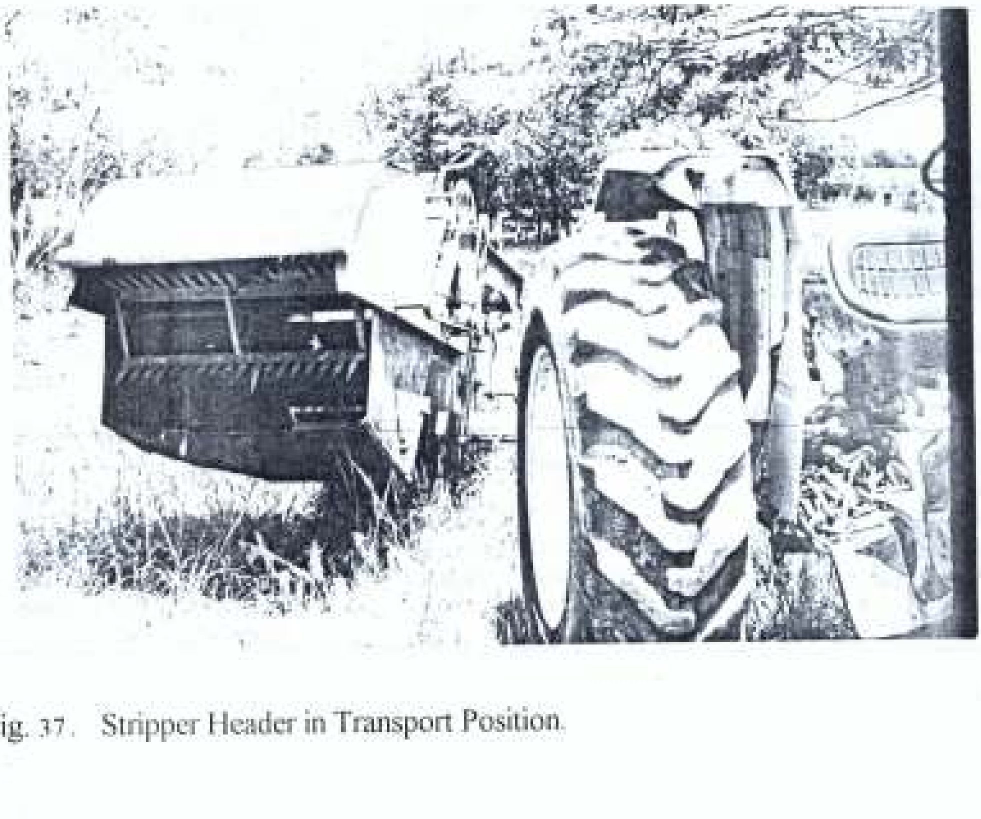


Fig. 37. Stripper Header in Transport Position.

4.4.0. Production Cost

Table 6. Components and Parts Fabricated

	Components				Materials used	
S/No	**Name**	**Function**	**Specification**	**Qty**	**Name**	**Dimension**
1	Stripper blade	Strips paddy panicle	width = 1.8cm length = 90 cm Hole = 2.7cm	6	mild steel plate	1219 mm x 2438 mm x 2mm (SWG 14)
2.	Angle bar	To hold the stripper blade	length = 90 cm width = 4 cm thickness = 3 cm	6	- do-	- do-
3.	Side and centre plates	To hold the angle bar with the stripper	diameter = 50 cm hexagon = 26 cm side 10cm x 10 cm x 10 cm trian. Hole dia = 25 mm	6	- do-	- do-
4.	Stripper pan	To collect the stripped grain for the slanting conveyor	width = 100 cm length = 134 cm	1	- do -	1219 mm x 2438 mm x 1.5 mm (SWG 16)
5.	Left,lower side plate	To prevent losses and form stripper housing	length = 96 cm height = 41 cm 12 hole 6 mm dia.	1	- do -	- do -
6.	Right, lower side plate	To prevent grains from flying out. To form stripper housing	length = 90 cm height = 41 cm 12 hole 6 mm dia.	1	- do -	- do -
7.	Left and right side top plates	Collect flying grains, form profile for top and back covers	length = 115 cm height = 64 cm	2	- do -	1219mm x 2438mm x 1.2mm (SWG 18)
8.	Top back cover	Completes the stripper housing collects flying grains	height = 64 cm length = 100 cm flap width = 34 cm 14 hole 6 mm dia.	1	- do -	- do -
9.	Conveyor cup	Transfers the stripped grain into the threshing drum	length = 40 cm	6	- do -	1219mm x 2483mm x 1.5mm (SWG 16)
10.	Stripper hanger	Stabilizes the stripper header	length = 80 cm	1	angle iron	25.4 x 25.4 mm 50.8 x 50.8 mm angle iron
11.	Stripper frame	To support the components	length = 130 cm width = 100 cm	1	- do-	50.8 mm x 50.8 mm angle iron
12.	Stripper shaft	To rotate the stripper drum	length = 110 cm dia. = 25 mm	1	High speed steel (HSS)	dia 25 x 110 cm
13.	Adjustable front top cover	To cover the stripper mechanism and guide grains rearwards	length = 100 cm width = 100 cm slot = 15 cm	1	mils steel sheet	1219mm x 2438mm x 1mm (SWG 20)

Table 7. Off-the-Shelf Components . A.

S/No	Name	Function	Specification	Qty	Unit Cost (₦)	Cost (₦)
1.	Pillow block bearing	smooth rotation of the stripper shaft, shaft-aligning	25 mm inside diameter	6	400.00	2,400.00
2.	Canvas belt	Conveyance of stripped paddy to the threshing drum	width = 10 cm length = 2.8 m			500.00
3.	Lubrication oil	Lubricating moving parts	SAE 90	1 tin	300.00	300.00
4.	Bolts and nuts	To tighten components to the frame and stripper	M6	100	5 .00	500 .00
			M10	20	10 .00	200 .00
			M12	10	10 .00	100 .00
			M16	4	15 , 00	60 .00
5.	Riveting pins	for riveting the cup to the conveyor belt	dia 4 mm	30	3 .00	90 .00
6.	V - belts	Power transmission	A - 79 (12.5 X 205 mm)	1	350.00	350.00
			A - 74 (12.5 X 1925 mm)	1	300.00	300.00
			A - 51 (12.5 x 1350 mm)	1	250 .00	250 .00
			A - 37 (12.5 x 1000 mm)	1	200 .00	200 .00
			A - 36 (12.5 x 975 mm)	1	100 .00	100 .00
			A - 34 (12.5 x 950 mm)	1	100 .00	100 .00
			A - 23 (12.5 x 925 mm)	1	80 .00	80 .00

Sub - Total = ₦5,530 .00

Table.8 Cost of Materials . B .

S/No	Material	Size of Piece	Qty. Reqd	Unit Cost (₦)	Amount (₦)
1	Angle Iron	50.8 mm x 50.8 mm x 3 mm	¼ length	1,200 .00	786 .00
2.	Angle Iron	25.4 mm x 25.4 mm x 3mm	1 m	400 .00	66. 67
3.	Mild steel sheet (SWG 14)	1219 x 2438 mm x 2 mm	1	2,500 .00	2,500.00
4.	M.S Sheet (SWG 16)	1219 mm x 2438 mm x 1.5 mm	1	1,500 .00	1,500 .00
5.	M.S.Sheet (SWG 18)	1219mm x 2438 mm x 1.5 mm	1	1,200 .00	1,200 .00
6.	M.S.Sheet (SWG 20)	1219 mm x 2438 mm x 1 mm	½	900 .00	450.00
7.	Electrodes		½pkt	850 .00	425 .00
8.	Hacksaw blades		10 piece	80 .00	800-00
9.	High speed steel rod	diameter 25 mm	1.10m	2,000 per L 9 m length	244.00
10.	Grinding disc	dia 18 cm	1	300 .00	300.00
11.	Plywood	18 cm x 90 cm	1	50 .00	50.00
12.	Jigsaw blades		3	200 .00	600.00
			Sub - Total		**₦8,921.67**

Table.9 Machining Jobs .C .

S/No	Material	Type of Job	Machine Used	Time spent (min)	Labour Cost/hr (₦)	Machine Cost/hr	Total Cost (₦)
1.	25.4 mm x 24.4 mm x 3mm angle	Cutting	Hacksaw	30	25.00	20.00	22.50
		Drilling	Pillar drilling m/c	10	25.00	137 .44	27 .07
		Grinding	Pedestal grinding m/c	10	25.00	88 .09	18 85
2.	50.8 mm x 50.8 mm x 3 mm angle iron	Cutting	Hacksaw	60	25.00	20.00	45.00
		Drilling	Pillar drilling m/c	60	25.00	137.44	162.44
		Grinding	Pedestal grinding m/c	30	25.00	88.00	56.55
3.	M.S Sheet (SWG 14)	Cutting	Manual shearing m/c	60	25.00	20.00	45.00
			Hacksaw	960	25.00	20-00	
		Drilling	Bench drilling m/c	480	25.00	82.04	720.00
			Pillar drilling m/c	600	25.00		881.32
		Bending	Bending m/c	300	25.00	137.44	
			Hammer	320	25.00	84.69	
		Filing	Hand flat file	240	25.00	20.00	1624.40
		Grinding	Pedestal grinding m/c	120	25.00	20.00 88.09	548.45 239.33
							180.00
							226.18
4.	M.S Sheet (SWG 16)	Cutting Bending	Manual shearing m/c	30.	25.00	20.00	22.50
		Drilling	Bending machine	45	25.00	84.69	82.27
		Riveting	Bench drilling m/c	30	25.00	84.69	54.85
			Riveting gun	20	25.00	20.00	15.00
5.	M . Sheet (SWG 18)	Cutting Bending	Manual shearing m/c	45	25.00	84.69	33.75
		Drilling	Bending machine	50	25.00	137.44	91.41
			Pillar drilling m/c	40	25.00	20.00	108,29
6.	M .S Sheet (SWG 18)	Cutting	Manual shearing m/c	10	25.00	20.00	7.50
		Bending	Manual	10	25.00	20.00	7.50
		Drilling and Slotting	Pillar drilling m/c	60	25.00	137.44	162.44
		Filing	Manual filing	120	25.00	20.00	90.00
7.	High speed steel rod dia 27mm	Size reduction	NUT Centre Industrial lathe	160	25.00	235.89	696.50
		Grooving	Vertical milling m/c	80	25.00	300.00	432.33
8.	10 mm Thick Plywood	Templating	Jigsaw	60	25.00	20.00	45.00
			Hacksaw	60	25.00	20.00	45.00

Sub - Total = ₦6,691.23

Table. 10 **Non-Machining Jobs** **.D.**

S/No	Job	Time Spent (hr)	Labour Cost/hr(₦)	Equipment Cost/hr(₦)	Total Cost (₦)
1.	Marking out	14	25.00	20.00	630.00
2.	Sanding	1	25.00	20.00	45.00
3.	Welding - Arc	4	25.00	50.86	303.44
	- Gas	½	25.00	25.43	37.93
4.	Machine assembly, setting and test running	5	25.00	20.00	225.00

Sub - Total = ₦1,241.37

TOTAL COST OF PRODUCTION = A + B + C + D

= 5,530 + 8,921.67 + 6,691.23 + 1,241.37

= ₦22, 384.27

4.5.0. Machine Test Procedure

The test was carried out in accordance with the combine capacity test procedure (ASAE S396.1) .

Determination of yield per hectare of test crop

A wooden frame (!m x 1m) was used to estimate the number of grains in five areas. Actual yield of ITA 150 paddy was calculated by weighing and finding the mean of the total number of grains found in the area bound by the square frame at five randomly selected locations. (Table 11).

Determination of Preharvest Loss

This was carried out before the actual harvesting. All grains found within the 1m x 1m square frame in five locations were hand picked, counted, weighed and recorded (Table 12). The mean was found and the total preharvest loss estimated as a percentage of actual yield previously determined.

Actual yield = 1,410 kg/hectare

Preharvest loss = 32 kg/hectare

$$\%\text{Preharvest loss} = \frac{32}{1,410} \times 100$$

$$= 2.3$$

Determination of Machine Losses

The machine was allowed to operate in a no-load position for about 3 minutes. Harvesting of paddy rice was carried out at the forward speeds of km/hr and 5 km/hr and stripper peripheral speeds of 100, 140, 180, 220 and 260 rev/min respectively. The moisture content of the rice was determined using the speedy moisture meter to be 18% wet basis.

Determination of Shatter losses

By definition, shatter losses are losses resulting from machine contact with the crop. The same method as preharvest losses was used.

For each of the four peripheral speeds, five 1m x 1m areas were used for estimating the shatter losses. The mean of the preharvest loss was subtracted from the mean of the weight of the total grains counted in the frame. The remainder represented the shatter loss (Table 13). This is then estimated as a percentage of the total yield earlier estimated.

$$\%\ \text{Shatter loss} = \frac{\text{Shatter loss}}{\text{Total yield}} \times 100$$

Determination of Unstripped losses

This was done by manually stripping the residual heads and finding the weight within the 1m x 1m areas and estimating the mean as a percentage of the total yield of the crop. In each test, the grains were usually collected in a nylon bag labelled for that purpose, taken to the lab and the weight of grains determined on an electronic weighing machine. This test was carried out for all the peripheral speeds stated earlier (Table 14).

Determination of stripped grains

The mean values of losses were tabulated (Table 16), having known the preharvest loss and actual yield to be 32 kg/ha and 1410 kg/ha respectively.

Stripped grain = actual yield - (preharvest loss + shatter loss + unstripped loss)

This was calculated for the two forward and five peripheral speeds.

Determination of Machine Functional Efficiency

This is equivalent to the percentage of stripped grains.

$$\text{Functional efficiency} = \frac{\text{Stripped grain}}{\text{Total yield}} \times 100$$

The values obtained at different speeds were tabulated (Table 16).

Determination of Machine Material Capacity (M_t)

From eqn (7)

$M_t = fws$

Where f = 0.141 kg/m^2 (Table 11)

w = width of stripper = 1m

s_1 = forward speeds of stripper

= 5 km/hr = 1.39 m/s

s_2 = 3 km/hr = 0.83 m/s

$M_{t1} = 0.141 \times 1 \times 1.39$

= 0.20 kg/s

$M_{t2} = 0.141 \times 1 \times 0.83$

= 0.12 kg/s

Determination of Machine Field Capacity

$$C = \frac{swe}{c} \quad , \text{ha/hr}$$

s_1 = forward speed 1 = 3 km/hr

s_2 = forward speed 2 = 5 km/hr

w = width of stripper

= 1m

e = field efficiency

The results for each peripheral speed are presented in Table 16.

CHAPTER FIVE

5.0 RESULTS AND DISCUSSION

5.1 Results

The results obtained from the test carried out with the machine are summarised in Tables 11 to 16 and Figures 40 to 43.

Table 11. **Actual Yield per Hectare of Test Crop (ITA 150 paddy) at Test Site**

	Sample area ($1m^2$)						
	1	2	3	4	5	Mean	
Average no of grains/head	44	42	46	44	40	43	
No of heads/m^2	42	40	40	43	42	41	
Weight (kg)	0.143	0.136	0.136	0.146	0.143	0.141	
Yield (kg/ha)							1,410

Table 12. **Preharvest Loss at Test Site**

	Sample area ($1m^2$)						
	1	2	3	4	5	Mean	
No of grains/m^2	41	44	48	34	38	41	
Preharvest loss g/m^2	3.2	3.4	3.7	2.6	2.9	3.2	
kg/ha							32
% loss							2.3

Table 13. **Effect of Peripheral Speeds on Mean Shatter Losses at two Forward Speeds**

Forward Speed km/hr	Peripheral Speed rev/min	Mean kg/ha	Shatter loss % of yield
3	100	175	12.7
	140	125	9.1
	180	81	5.9
	220	29	2.1
	260	38	2.8
5	100	85	6.2
	140	38	2.8
	180	31	2.3
	220	29	2.1
	260	28	2.0

Table 14. Effect of Peripheral Speeds on Mean Unstripped Losses at two Forward Speeds

Forward Speed km/hr	Peripheral Speed rev/min	Mean kg/ha	Unstripped Loss % of yield
3	100	229	16.2
	140	123	8.7
	180	113	8.0
	220	78	5.5
	260	43	3.1
5	100	198	14.0
	140	132	9.4
	180	123	8.7
	220	91	6.5
	260	78	5.5

Table 15. **Effect of Peripheral Speeds on Total Machine Losses at two Forward Speeds**

Forward Speed km/hr	Peripheral Speed rev/min	Mean kg/ha	Total Machine Loss % of yield
3	100	404	28
	140	248	17.6
	180	194	13.8
	220	107	7.6
	260	81	5.8
5	100	283	20.1
	140	170	12.1
	180	154	10.9
	220	120	8.5
	260	106	7.5

Table 16. Effect of Peripheral Speed on Field Efficiency and Field Capacity.

	Mean of Losses													
	3 km/hr				5 km/hr									
Peripheral Speed rev/min	Shatter Losses		Unstripped Losses		Shatter Losses		Unstripped Losses		Stripped grains (kg)		Field Efficiency (%)		Field Capacity (ha/hr)	
	kg./hr	% of Yield	kg/hr	% of Yield	kg/hr	% of Yield	kg/hr	% of Yield	3km/hr	5km/hr	3km/hr	5km/hr	3km/hr	5km/hr
100	175	12.7	229	16.2	85	6.2	198	14.	974	1095	69.1	77.7	0.21	0.39
140	125	9.1	123	8.7	38	2.8	132	9.4	1130	1208	80.1	85.7	0.24	0.43
180	81	5.9	113	8.0	31	2.3	123	8.7	1184	1224	84.0	87.8	0.25	0.44
220	29	2.1	78	5.5	29	2.1	91	6.5	1271	1258	90.1	89.2	0.27	0.45
260	38	2.8	43	3.1	28	2.1	78	5.5	1297	1272	92.0	90.2	0.28	0.45

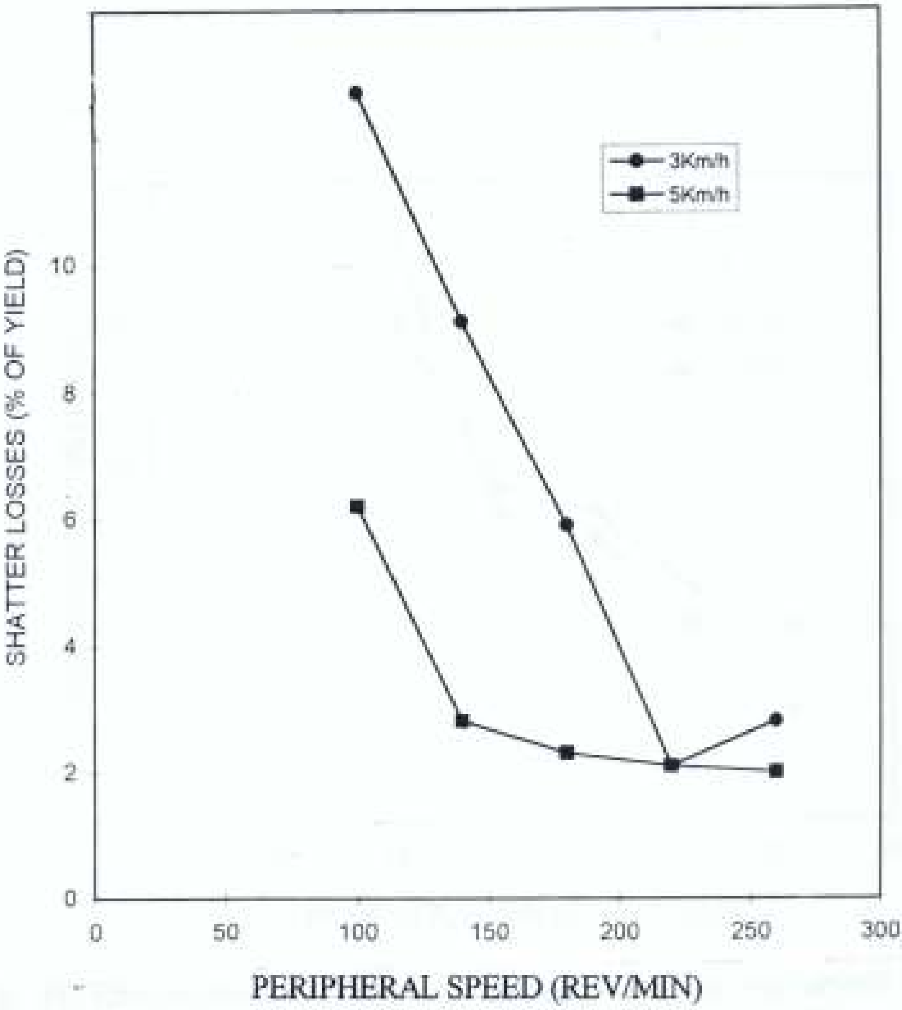


Fig. 38. Effect of Peripheral Speed on Shatter Losses at two Forward Speeds.

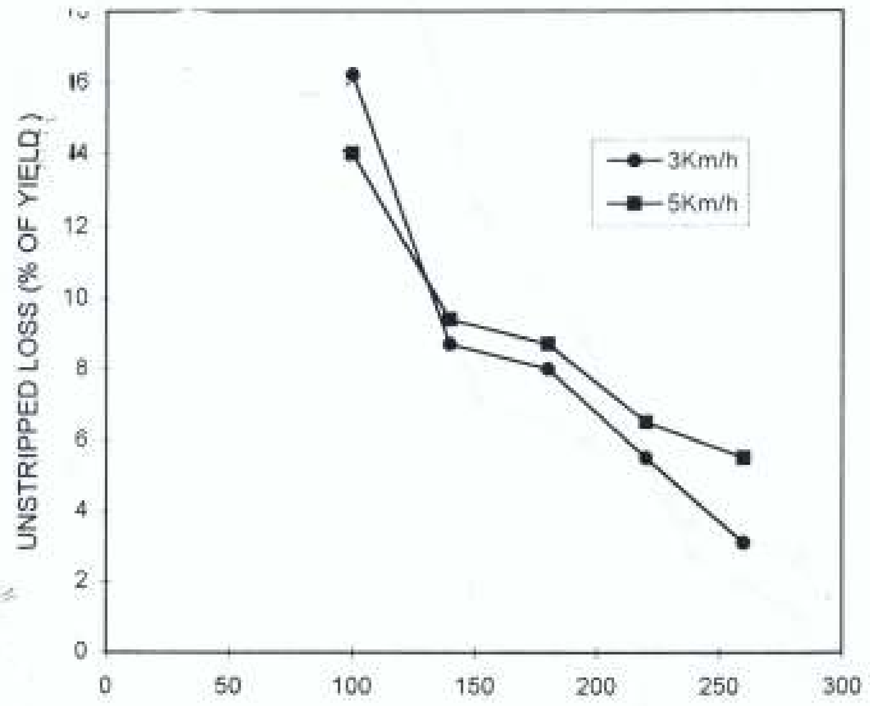


Fig. 39. Effect of Peripheral Speeds on Unstripped Losses at two Forward Speeds.

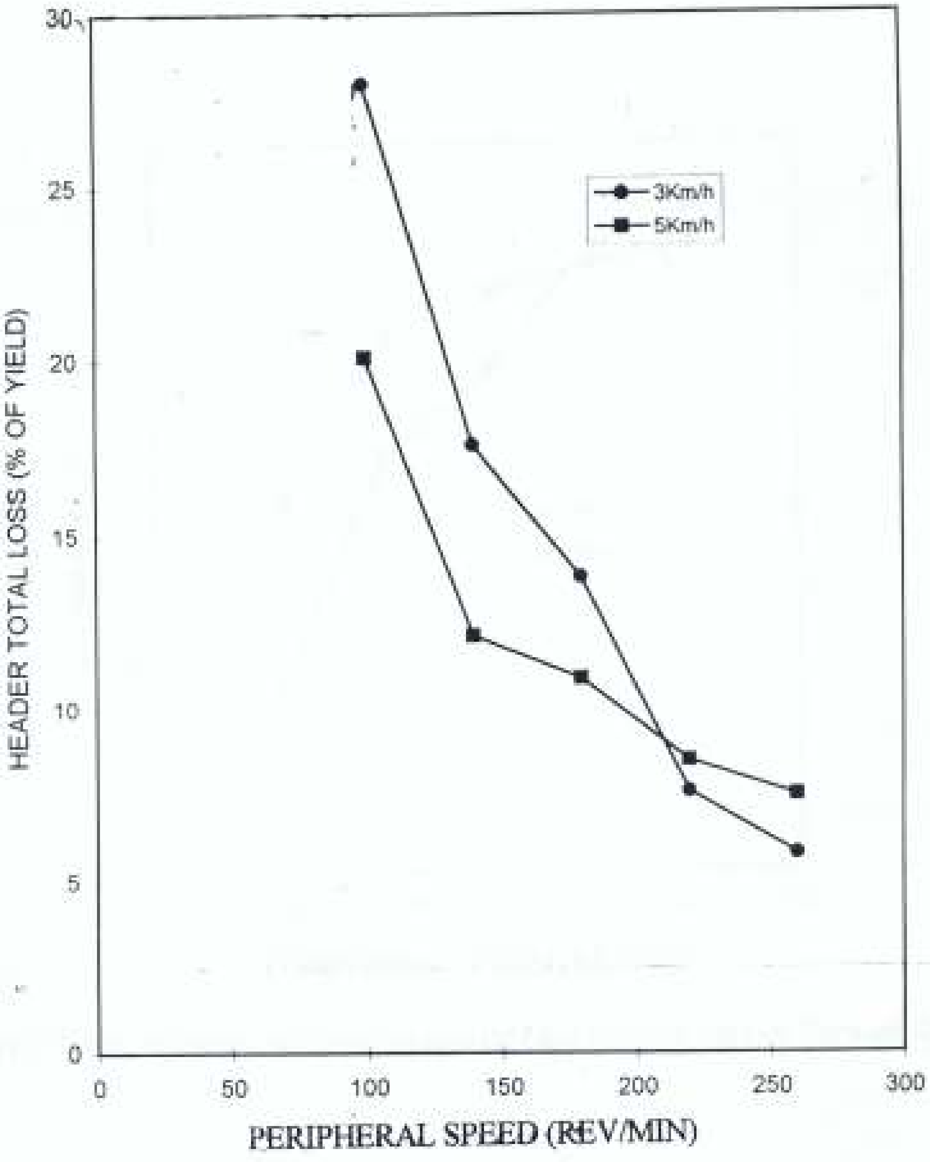


Fig. 40. Effect of Peripheral Speed on Header Total Losses at two Forward Speeds.

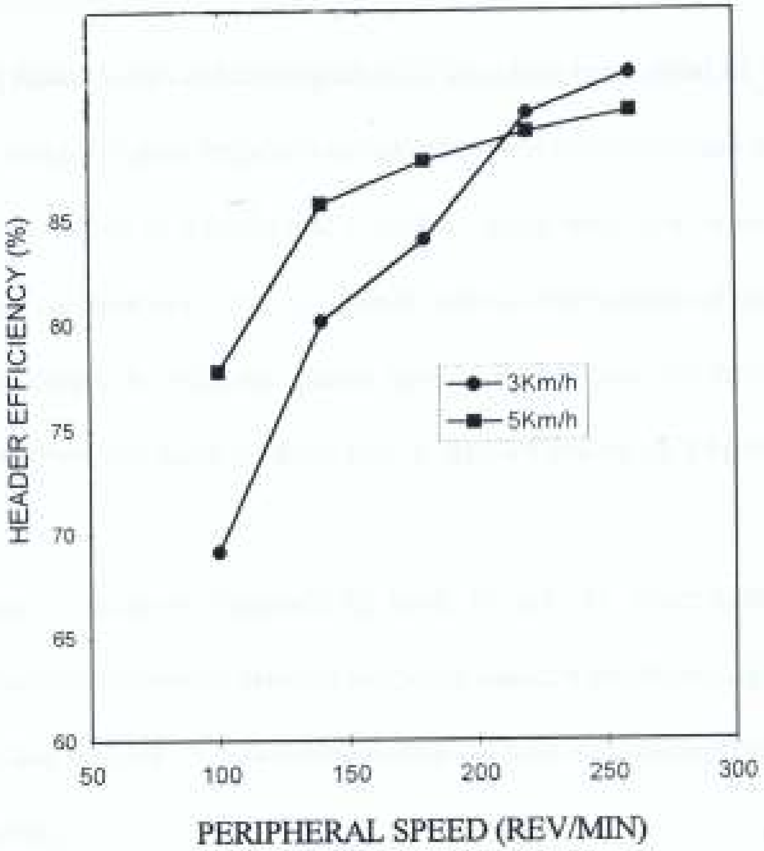


Fig. 41. Effect of Peripheral Speed on Header Field Efficiency at two Forward Speeds.

5.2 Discussion

The grain yield of ITA 150 paddy was 1,410 kg/ha for the test site. This value is 6% less than 1,500 kg/ha from standard crop data. This reduction may be because the cultural practices were not strictly adhered to.

Preharvest loss was calculated as 32 kg/ha, representing 2.3% of the yield per hectare. The reason for this could be predominantly due to the prevailing wind characteristics of the site.

Mean shatter losses reduced significantly from peripheral speed of 100 rev/min to 260 rev/min, with the highest reduction occuring between 100rev/min and 140 rev/min for the two forward speeds of 3 km/hr and 5 km/hr. Thus, there is an inverse relationship between peripheral speed in rev/min and shatter losses as a percentage of yield (Fig. 38). Operating the stripper at peripheral speeds equal to or less than 100 rev/min resulted in 12.7% or more loss and 6.2% or more loss at forward speeds of 3 km/hr and 5 km/hr respectively.

Regression equations (Appendix C, Eqns. 13 and 14) which could be used for predicting mean shatter losses at selected peripheral speeds were developed using the mean shatter losses data in Table 13. R^2 values of 0.91 and 0.66 were obtained at 3 km/hr and 5 km/hr respectively.

Mean unstripped losses reduced from 16.2% of grain yield at 100 rev/min to 8.7% at 140 rev/min and 14.0% of grain yield at 100 rev/min to 9.4% at 140 rev/min at 3 km/hr and 5 km/hr respectively. A more linear relationship was obtained under the same conditions from 140 rev/min to 260 rev/ min at both forward speeds.

The regression equations (Appendix C, Eqns. 15 and 16) for unstripped losses have R^2 values of 0.89 and 0.91 respectively at 3 km/hr and 5 km/hr forward speeds.

The peripheral speeds stated previously were plotted against header total losses from Table 15 and followed the same inverse relationship as for mean shatter losses and mean unstripped losses (Fig. 39). For the header total losses, R^2 values of 0.94 and 0.83 were obtained for the regression equations developed (Appendix C, Eqns. 17 and 18).

Header total losses reduced considerably from 28% at 100 rev/min to 5.8% at 260 rev/min when operating the harvester at 3 km/hr. But increased vibrations were observed in the component parts of the header with increasing peripheral speed. Thus a peripheral speed of 100 rev/min and above 260 rev/min is not recommeded. At 5 km/hr, total losses reduced from 20.1% at 100 rev/min to 7.5% at 260 rev/min. These results are similar to the former results, except that percentage loss increased from 5.8% at 3 km/hr to 7.5% at 5 km/hr.

The intercept of the graphs in Fig. 40 gives the optimum header total losses and peripheral speed. They are 8.5% and 215 rev/min. The highest machine field capacity of 0.45 ha/hr was obtained when the machine was moving at 5 km/hr and 260 rev/min peripheral speed (Table 16). The lowest field capacity of 0.21 ha/hr was obtained at 3 km/hr and 100 rev/min.

CHAPTER SIX

6.0 CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

The header unit developed consisted principally of the stripping rotor which is an alternative to the conventional cutterbar mechanism; from observation, the straw intake reduced considerably.

Results of tests carried out on the machine at two forward speeds of 3 km/hr and 5 km/hr showed that mean header total losses reduced greatly with increase in peripheral speed of stripper from 100 rev/min to 140 rev/min and steadily from 140 rev/min to 260 rev/min. The same pattern was obtained for field efficiency which increased from 69.1% to 92% and 77.7% to 90.2% at 3 km/hr and 5 km/hr; and field capacity which increased from 0.21 ha/hr to 0.28 ha/hr and 0.39 ha/hr to 0.45 ha/hr respectively for the two speeds. Optimum header total losses and peripheral speed were 8.5% of yield per hectare at 215 rev/min for both speeds.

The machine should not be operated at any speed lower than 140 rev/min or greater than 260 rev/min because of the great losses sustained due to poor stripping of grains from panicle on one hand and vibrations of machine members on the other.

6.2 Recommendations

The remaining units of the harvester should be completed and tested in subsequent work. The header unit should be provided with a land wheel that will act both as a support and a vibration damper.

A three-point hitch attachment should be provided for the machine as a whole to facilitate easy transportation to and adjustments in work.

A resilient material that will spring back to its original position after contact with obstructions should be selected for the stripper blade. This will prevent the permanent deflection at work as was observed during the test period.

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APPENDICES

Appendix A

Title : Determination of the resistance due to ITA-150 paddy during stripping.

Aims: To determine the maximum force required to

- remove one grain of paddy rice from panicle.
- strip the panicle
- shear the stalk

Materials: Spring balance, 1 mm diameter spring wire, 0.2 mm diameter thread.

Method:

1. A noose was formed around a paddy grain with the thread and pulled at the other end with the spring balance. This was done 10 times and the results recorded.
2. Another noose was formed around the neck of the panicle base with the spring and pulled with the spring balance such that a stripping action was ensured. The corresponding force was indicated on the scale. This was performed 10 times.
3. In similar manner, the force required to shear the stalk was determined.

Observation: A maximum of 7 stalks of paddy was found per stand. This is the number expected to occupy the recess between the teeth. Hence the diameter of a bunch of seven rice stalks was measured and found to be 2.5 cm maximum.

Other relevant data

Maximum length of panicle - 22 cm

Maximum height of paddy - 108 cm

Maximum height up to the base of panicle - 70 cm

Minimum height of paddy plant - 60 cm

Minimum height up to the base of panicle - 55 cm

Moisture content - 18%

Status - Matured for harvesting (103 days).

APPENDIX B

Table 20: Shatter Losses: M.C. 20%, Forward speed 3 km/hr; Peripheral speed 100 rev/min.

	Sample area (1m^2)						
	1	2	3	4	5	Mean	
No of grains	256	271	259	260	267	263	
Weight (g)	20.1	21.3	20.4	20.5	21.0	20.7	
Preharvest loss (g)	3.2	3.4	3.7	2.6	2.9	3.2	
Shatter loss (g/m^2)	16.9	17.9	16.7	17.9	18.1	17.5	
(kg/ha)							175
% shatter loss							12.4

Table 21: Shatter Losses: M.C. 20%, Forward speed 3 km/hr; Peripheral speed 140 rev/min.

	Sample area (1m^2)						
	1	2	3	4	5	Mean	
No of grains	201	213	192	196	198	200	
Weight (g)	15.8	16.3	15.1	15.4	15.6	15.7	
Preharvest loss (g)	3.2	3.4	3.7	2.6	2.9	3.2	
Shatter loss (g/m^2)	2.6	13.4	11.4	12.8	12.7	12.5	
(kg/ha)							125
% shatter loss							8.9

Table 22: Shatter Losses: M.C. 20%, Forward speed 3 km/hr; Peripheral speed 180 rev/min.

	Sample area (1m^2)						
	1	2	3	4	5	Mean	
No of grains	152	145	142	142	133	143	
Weight (g)	12.0	11.4	11.2	11.2	10.5	11.3	
Preharvest loss (g)	3.2	3.4	3.7	2.6	2.9	3.2	
Shatter loss (g/m^2)	8.8	8.0	7.5	8.6	7.6	8.1	
(kg/ha)							81
% shatter loss							5.7

Table 23: Shatter Losses: M.C. 20%, Forward speed 3 km/hr; Peripheral speed 220 rev/min.

	Sample area (1m^2)						
	1	2	3	4	5	Mean	
No of grains	82	72	77	86	71	78	
Weight (g)	6.5	5.7	6.1	6.8	5.6	6.1	
Preharvest loss (g)	3.2	3.4	3.7	2.6	2.9	3.2	
Shatter loss (g/m^2)	3.3	2.3	2.4	4.2	2.7	2.9	
(kg/ha)							29
% shatter loss							2.1

Table 24: Shatter Losses: M.C. 20%, Forward speed 3 km/hr; Peripheral speed 260 rev/min.

	Sample area (1m^2)						
	1	2	3	4	5	Mean	
No of grains	89	92	84	94	87	89	
Weight (g)	7.0	7.2	6.6	7.4	6.8	7.0	
Preharvest loss (g)	3.2	3.4	3.7	2.6	2.9	3.2	
Shatter loss (g/m^2)	3.8	3.8	2.9	4.8	3.9	3.8	
(kg/ha)							38
% shatter loss							2.7

Table 25: Shatter Losses: M.C. 20%, Forward speed 5 km/hr; Peripheral speed 100 rev/min.

	Sample area (1m^2)						
	1	2	3	4	5	Mean	
No of grains	150	144	152	156	140	148	
Weight (g)	11.8	11.4	12.0	12.3	11.1	11.7	
Preharvest loss (g)	3.2	3.4	3.7	2.6	2.9	3.2	
Shatter loss (g/m^2)	8.6	8.0	8.3	9.3	8.2	8.5	
(kg/ha)							85
% shatter loss							6.0

Table 26: Shatter Losses: M.C. 20%, Forward speed 5 km/hr; Peripheral speed 140 rev/min

	Sample area ($1m^2$)						
	1	2	3	4	5	Mean	
No of grains	92	89	92	91	84	90	
Weight (g)	7.2	7.0	7.2	7.1	6.6	7.0	
Preharvest loss (g)	3.2	3.4	3.7	2.6	2.9	3.2	
Shatter loss (g/m^2)	4.0	3.6	3.5	4.5	4.0	3.8	
(kg/ha)							38
% shatter loss							2.7

Table 27: Shatter Losses: M.C. 20%, Forward speed 5 km/hr; Peripheral speed 180 rev/min.

	Sample area ($1m^2$)						
	1	2	3	4	5	Mean	
No of grains	84	86	81	86	79	83	
Weight (g)	6.6	6.8	6.4	6.8	6.2	6.3	
Preharvest loss (g)	3.2	3.4	3.7	2.6	2.9	3.2	
Shatter loss (g/m^2)	3.4	3.4	2.7	4.2	3.3	3.1	
(kg/ha)							31
% shatter loss							2.2

Table 28: Shatter Losses: M.C. 20%, Forward speed 5 km/hr; Peripheral speed 220 rev/min.

	Sample area ($1m^2$)						
	1	2	3	4	5	Mean	
No of grains	79	85	76	75	70	77	
Weight (g)	6.2	6.7	6.0	5.9	5.5	6.1	
Preharvest loss (g)	3.2	3.4	3.7	2.6	2.9	3.2	
Shatter loss (g/m^2)	3.0	3.3	2.3	3.3	2.6	2.9	
(kg/ha)							29
% shatter loss							2.1

Table 29: Shatter Losses: M.C. 20%, Forward speed 5 km/hr; Peripheral speed 260 rev/min.

	Sample area ($1m^2$)						
	1	2	3	4	5	Mean	
No of grains	76	76	75	78	79	78	
Weight (g)	6.0	6.0	5.9	6.1	6.2	6.0	
Preharvest loss (g)	3.2	3.4	3.7	2.6	2.9	3.2	
Shatter loss (g/m^2)	2.8	2.6	2.2	3.5	3.3	2.8	
(kg/ha)							28
% shatter loss							2.0

Table 30: Unstripped Loss: M.C. 20%, Forward speed 3 km/hr; Peripheral speed 100 rev/min.

	Sample area (1m^2)						
	1	2	3	4	5	Mean	
Average no of Unstripped grains	274	288	301	292	300	291	
Weight (g)	21.6	22.7	23.7	23.0	23.6	22.9	
Unstripped loss (kg/ha)							229
(%)							16.2

Table 31: Unstripped Loss: M.C. 20%, Forward speed 3 km/hr; Peripheral speed 140 rev/min.

	Sample area (1m^2)						
	1	2	3	4	5	Mean	
Average no of Unstripped grains	152	157	155	169	169	160	
Weight (g)	12.0	12.4	12.2	13.3	13.3	12.3	
Unstripped loss (kg/ha)							123
(%)							8.7

Table 32: Unstripped Loss: M.C. 20%, Forward speed 3 km/hr; Peripheral speed 180 rev/min.

	Sample area ($1m^2$)						
	1	2	3	4	5	Mean	
Average no of Unstripped grains	144	160	132	140	143	144	
Weight (g)	11.3	12.6	10.4	11.0	11.2	11.3	
Unstripped loss (kg/ha)							113
(%)							8.0

Table 33: Unstripped Loss: M.C. 20%, Forward speed 3 km/hr; Peripheral speed 220 rev/min.

	Sample area ($1m^2$)						
	1	2	3	4	5	Mean	
Average no of Unstripped grains	101	100	100	92	102	99	
Weight (g)	7.9	7.8	7.8	7.2	8.0	7.8	
Unstripped loss (kg/ha)							78
(%)							5.5

Table 34: Unstripped Loss: M.C. 20%, Forward speed 3 km/hr; Peripheral speed 260 rev/min.

	Sample area ($1m^2$)						
	1	2	3	4	5	Mean	
Average no of Unstripped grains	52	57	61	57	49	55	
Weight (g)	4.1	4.5	4.8	4.5	3.9	4.3	
Unstripped loss (kg/ha)							43
(%)							3.1

Table 35: Unstripped Losses: M.C. 20%, Forward speed 5 km/hr; Peripheral speed 100 rev/min.

	Sample area ($1m^2$)						
	1	2	3	4	5	Mean	
Average no of Unstripped grains	250	252	261	250	243	251	
Weight (g)	19.7	19.8	20.5	19.7	19.1	19.8	
Unstripped loss (kg/ha)							198
(%)							14.0

Table 36: Unstripped Losses: M.C. 20%, Forward speed 5 km/hr: Peripheral speed 140 rev/min

	Sample area ($1m^2$)						
	1	2	3	4	5	Mean	
Average no of Unstripped grains	180	164	160	172	166	168	
Weight (g)	14.2	12.9	12.6	13.5	13.1	13.2	
Unstripped loss (kg/ha)							132
(%)							9.4

Table 37: Unstripped Losses: M.C. 20%, Forward speed 5 km/hr: Peripheral speed 180 rev/min

	Sample area ($1m^2$)						
	1	2	3	4	5	Mean	
Average no of Unstripped grains	160	153	150	167	152	156	
Weight (g)	12.5	12.0	11.8	13.1	11.9	12.3	
Unstripped loss (kg/ha)							123
(%)							8.7

Table 38 :Unstripped Losses: M.C. 20%. Forward speed 5 km/hr: Peripheral speed 220 rev/min.

	Sample area (1m^2)						
	1	2	3	4	5	Mean	
Average no of Unstripped grains	124	112	111	111	122	116	
Weight (g)	9.8	8.8	8.7	8.7	9.6	9.1	
Unstripped loss (kg/ha)							91
(%)							6.5

Table 39 : Unstripped Losses: M.C. 20%, Forward speed 5 km/hr; Peripheral speed 260 rev/min.

	Sample area (1m^2)						
	1	2	3	4	5	Mean	
Average no of Unstripped grains	94	87	113	121	82	99.4	
Weight (g)	7.4	6.8	8.9	9.5	6.5	7.8	
Unstripped loss (kg/ha)							78
(%)							5.5

APPENDIX C

The results of linear regression analysis of mean machine losses (using MS-Excel 5.0 software package) .are as follows:

1. Shatter Losses

Forward speed : 5 km/hr

R^2 = 0.659946

Y = 7.175 - 0.02275 X .... (13)

Where, X is the peripheral speed (rev/min) and Y is the shatter losses (% of yield)

Forward speed : 3 km/hr

R^2 = 0.913698

Y = 18.58 - 0.067 X .... (14)

Where, X is the peripheral speed (rev/min) and Y is the shatter losses (% of yield)

2. Unstripped Losses

Forward speed : 5 km/hr

R^2 = 0.90853

Y = 17.775 - 0.04975 X .... (15)

Where, X is the peripheral speed (rev/min) and Y is the unstripped losses (% of yield)

Forward speed : 3 km/hr

R^2 = 0.88616

$$Y = 21.53 - 0.0735X \quad \text{.............} \quad (16)$$

Where, X is the peripheral speed (rev/min) and Y is the unstripped losses (% of yield)

3. Total Machine Losses

Forward speed : 5 km/hr

$$R^2 = 0.82791$$

$$Y = 25.22 - 0.074X \quad \text{.............} \quad (17)$$

Where, X is the peripheral speed (rev/min) and Y is the total machine losses (% of yield)

Forward speed : 3 km/hr

$$R^2 = 0.937598$$

$$Y = 39.04 - 0.136X \quad \text{.............} \quad (18)$$

Where, X is the peripheral speed (rev/min) and Y is the total machine losses (% of yield)