The Training Course on
Post - Harvest Technologies on Grain

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COMBINE HARVESTER

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INTRODUCTION

Harvest is the last stage of crop production in the field and it significantly affects the output and quality of grain. If the crop is not harvested in time, grain losses will be increased due to not even or too much ripening, damaged by rats, birds, insects, wind and rain. Timely harvesting for rice ensures good grain quality, higher market price and consumer acceptance, with less broken grain when milled and higher germination rate. The rice crop is ready to harvest when 80% of the grains on lower ears are ripened hard and becoming yellow color, experienced farmers should judge and know the optimum time to harvest their crops.

Although the trailed combines have been made and introduced in 1935, and self-propelled combine appeared commercially in about 1939 in USA, these combines were used mainly on dry land for wheat harvesting. Some self-propelled combines might be used in USA to harvest rice crop in dry land condition. But they are not suitable for use to harvest the rice crop in wet paddy field condition. The yield of rice crop and straw would be double those of wheat, and the machine has to harvest rice crops not only in wet condition but also in feeding double quantities of material so that the systems and running parts of the rice harvester should be considered and designed to meet the needs.

There are three methods to harvest rice crop: separate harvest, combine harvest and indirect harvest. The method used must be depends on the local ambient condition, cultivation systems, the economical and technical level.

1. The separate harvest
The separate harvest is defined as that rice is reaped by hand or machine and lay down onto the land then bundled, threshed and cleaned in field or farmyard. For separate harvest, the machines of harvesting and threshing are simple, cheap, less requirement of operating technique and convenient to control the working process. More labors are required to bundle, transport, stack, feed in for threshing, and separate the grain from the straw. The disadvantages of this method are too much laborious needing, lower efficiency and high grain loss.

The main tools and machines used in the method are sickle, cutter-windrower, reaper binder, threshes, fans and manpower sieves.
2. **The combine harvest**

The combine harvest is defined as that all harvest work from reaping, threshing, grain separating and cleaning are all completed by one combine harvester. Comparing with the separate harvest, this method has higher working efficiency and lower labor consumption, and also save time. However, the machine is quite complicated and expensive. The combine requires a field with large enough area and flatness, and also qualified technicians to manage and service.

3. **The indirect harvest**

The indirect harvest is divided into two processes. The first process is that rice crop is cut and windrowed. This process is for post-ripeness after cutting and for reducing the moisture content of the grain. Post-ripeness is a process to let the grain at upper portion of ear mature gradually after cutting. The second process is to pickup the crop by combine with pickup attachment (or by labors), to thresh, separate and clean. Compare with the direct harvest, the indirect harvest has advantage of obtaining more matured grains with higher output as well as higher grain quality because of the post-ripeness and less moisture content of grains, with higher efficiency on threshing, separating and cleaning. The labor requirement is much more than that of the combine harvest. If there is a rain season in summer during harvest, the windrowed crop will be wet and germinated or becoming mildew. The main machine used is cutter-windrower and combine with pickup attachment.

**THE MACHINES USED FOR RICE HARVESTING PROCESS**

In most developing countries, rice harvesting is usually done by hand, and it accounts for about 30% of the total labor requirement for rice production.

There are many machines use for harvesting rice we use different machines for different work condition and different techniques.

The machines for harvesting rice can be classified as follows according to their purpose and structure:

1) Reaper: reaper (cutter-windrower), reaper bundle etc.
2) Thresher: Straight-through thresher and head feed thresher.
3) The combine: Straight-through feed combine harvester, Head feed combine, Mounted-type rice combine.
1. Cutter-windrower

1.1 Reaper: It is mainly composed of engine, moving parts and driving system, horizontal cutting bench and traversing conveyer, reel, reciprocating cutter, crop lifter, and divider board. (Figure 1) The progress of work of the machine: the crops pass the divider board and the reel and then they are cut by reciprocating cutter; after that, they are carried by traversing conveyer to one side of the machine.

The structure of the machine is compact and it can be operated and maintained easily, the work width of the machine is normally 1000 to 1500 mm. and its work efficiency is normally 0.3 to 0.5 hectare per hour.

Figure 1. Rice reaper

1.2 reaper bundles: The machine is mainly composed of engine, moving parts and driving system, conveyer and binder, reel, divider board. The work progress of the machine: the crops pass the divider board, reel and they are cut by reciprocating cutter; then they are carried into binder and bundled up by ropes; after that they are put to one side of the machine (Figure 2).

Compared with the reaper (cutter - windrower), the machine can bundle the crops, but its structure is more complex and its work width is narrower, its work width is normally less 60 mm. and its work efficiency is 0.06 to 0.15 – hectare.

Figure 2. Reaper binder
2. Thresher

2.1 Whole feed thresher: It is mainly composed of engine, feed table, threshing drum which consists of bars spike tooth cylinder, a concaves sieve, oscillating screen, fan, and outlet(Figure 3). The engine drives the cylinder to rotate in high speed via the V-belt. The spike tooth cylinder and concave sieve are the main threshing parts to separate the grain from straw. The separated grains pass through the concave sieve into the grain collector. The auger collects the grain and then the grain thrower throws the grain out through to the grain outlet elbow. The straws, at the same time, are thrown out along the tangential direction of the rotating cylinder from the outlet on the ground by the reflecting plate. It is featured by its high ability of impact action, large output and suitability for wet crop and different species of rice.

![Figure 3. Whole feed thresher](image)

2.2 Head feed thresher: The machine is mainly composed of engine, feeder table and gripper chain, threshing drum (normally comb drum), concaves, oscillating grate, fan and rice outlet (Figure 4). The working progress of the machine is as follow: the top of the crops is feed into machine for threshing by hand or by gripper chain while the whole straw leaves. The working load is light and the energy consumption is low and it is easy to separate rice and straw because of the mode of half feed.

![Figure 4. Head feed thresher](image)
3. Combine Harvester

Combine harvester performs the following basic operations: cutting, conveyor and feeding the cut material to the threshing mechanism, threshing, separating and cleaning etc. are all completed one time by the combine in field. Hydraulic mechanism has been widely used in combine. Additionally, combine harvester adopts a lot of automatic regulators and monitors to improve the machine performance and the working condition for driver. It can be classified into wheel combine and claw track combine according to the moving parts and can be classified into straight-through feed combine and head feed combine.

The straight-through feed combine is that all the cut crop and stem is fed directly into cylinder for threshing, separating and cleaning. This type of combine is widely used in the world both for harvesting rice wheat corn been etc...

The head feed rice combine is to hold the cut straws of the crop by clamping chain and let only the ears contact the thresher mechanism. This type of combine is mainly used for rice harvesting to keep complete length of straw for other use.

3.1 Straight-through feed combine harvester

The straight-through feed combine harvester can be classified into self-propelled type, trailed-type and mounted type depending on the power supplied. For harvesting, self-propelled and mounted type is widely used.

3.1.1 Self-propelled combine: In self-propelled combine (Figure 5) the working parts including cutter, conveyor, feeder, threshers, sieve and the separator, transmission, hydraulic systems and running devices, Self-propelled combines have the following advantages: (1) saving of grain in opening up fields surrounded by fence, other crops etc.; (2) greater flexibility and better maneuverability.; (3) better visibility and control by the operator; (4) high transporting speed and higher efficiency in operation. It is the most widely used type in world.

![Figure 5. Consists of Self-propelled combine](image)
The crop flow through combine is as following: (Figure 6) when the machine moves forward, the divider separates the crop for cutting, the reel picks up the standing or laid crops and pushes them to the cutting mechanism and then pushes them down to the platform after cutting. The platform auger conveys crosswise to there, the retracting fingers throw the crop to the inclined conveyor chain which feeds the crop into the thresher. In the thresher, the cylinder and concave assembly play an important part to separate most of the crop into seed, chaffers that fall directly onto the grain pan or onto a conveyor. The cylinder beater tends to strip the threshed material from the cylinder, aids in further separation at this point, and directs the straw and remaining seed onto the straw carrier (osculating rack or rotary walker). The straw carrier agitates the material to separate out any remaining seed and un-threshed heads as the straw is moved rearward to be discharged from the machine. The material separated from the straw is collected by the grain return conveyor and delivered to the grain pan at the frond of the chaffer sieve.  The mixture of threshed grain with some chaff and small debris drops from the concave sieve comes to a vibrating sieve and to be cleaned by the combined operation of a fan and the vibrating sieve. After cleaning, the grain is delivered to the grain tank by a horizontal auger and a lifting auger. The tailings are then returned to the rear outlet by the vibrating sieve. After threshing, the straw in the thresher is thrown out through the straw outlet onto the ground. The threshed and clean grain will discharge at Sacking platform through grain delivery spout in the sack or grain tank.

Figure 6. Operation of straight-through feed Self-propelled combine harvester
Principal unit: We can better understand the construction and action of the combine by listing the major steps in the complete process (Figure 7)

1. Cutting the standing grain
2. Feeding the cut grain to the threshing unit
3. Threshing and re-threshing the grain or seed from the heads
4. Separating the grain from the straw and chaff
5. Cleaning the threshed grain for convenient handling
6. Collecting the threshed grain for convenient handling

Figure 7. Schematic cross-section of combine showing units that perform the six major operations.

1. Cutting unit or header

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. Major parts of this unit are the reel, the dividers, and the cutter bar and auger.

Reel: This is the first part to touch the standing grain. When adjusted properly, it holds the grain against the knife while the stalks are cut, and it delivers the cut grain to the feeding mechanism. The reel can be adjusted up and down and also forward and backward. The angle at which the reel bats enter the grain and the speed of the reel can vary to suit different crop conditions.

The reel may be one of two types and may be either power-driven or ground-driven.

1) Bat type: the bat type reel as illustrated in (Figure 5 - 6) may have four or six bats. On some machines the angle at which the bat strikes the grain may be adjusted.
2) Pick-up type: Pick-up reels as shown in Figure 8 are available for many combine models. The slats and teeth are kept parallel by means of an eccentric-and-spider arrangement. They may be pitched to point slightly rearward to pick up lodged crops. The reel speed should be about 1.25 times faster than ground speed.

![Figure 8. Pick-up Reel for combines.](image)

**Dividers:** These separate the standing grain and define the swath to be cut (Figure 9). They aid in picking up down or tangled grain and gather and guide the standing grain to the cutter bar. Special extension dividers can be secured for work in badly lodged grain.

**Cutter Bar:** The cutter bar (Figure 9) is reciprocating knife (sickle) is like that of the mower. But the knife sections are usually serrated and the guards plates are smooth just the opposite of the construction often used in mowers. Hence the knife sections cannot be re-sharpened but are replaced when worn.

The cutter bar and head unit is spring-balanced so that it can be easily adjusted for height of cut. In the larger sizes the height of cut is adjusted hydraulically. A wide range of adjustment from about 2 inches to as much as 3 feet is essential because combines are used for so many different crops.

The knife makes about 400 strokes per minute. It is driven by a pitman which receives power from a V-belt-driven pulley. The motion of the pitman is transmitted through a bell crank to the knife: a shock-proof rubber bushing is used at the knife connection. This rubber bushing should never be oiled.

2. Feeding Unit:

This assembly if properly adjusted promptly carries away the cut grain from the cutter bar and feeds it evenly into the cylinder (Figure 9).

The scoop-type feeder is used in small combines. A canvas conveyor (draper) of the same width as the cylinder conveys the cut grain upward to the cylinder.
The upper feeder canvas travels faster than the lower; it tends to comb and straighten the grain and feed it into the cylinder. Even uniform feeding is needed for efficient combining.

In the larger combines the cutter bar is much wider than the cylinder. In these, a horizontally placed auger or canvas conveys the cut grain to the inclined feeder conveyor.

![Figure 9. Cutting and feeding unit using a feeding auger, Feeding beater, and undershot feeder.](image)

3. Threshing Unit:
Threshing removes the grain or seed from the head or pod. The major parts of this unit are the cylinder, the concaves and the grates.

**Cylinder:** Three different types are used:
1. Spike tooth (Figure 10): This is the oldest type; it was used in stationary threshers that preceded the combine. It has proved quite satisfactory for threshing most grain crops. The spike teeth, carried in the transverse bars of the cylinder, thresh out the grain as they revolve through similar teeth in the concaves.
2. Rasp - bar (Figure 11): This type has transverse bars with grooved metal faces. These grooves are cut diagonally, in opposite directions, across adjacent bars. Threshing is done by the rasping action between the cylinder bars and the solid concave bars below the cylinder.
3. Angle - bar (Figure 12): The spiral bars of this cylinder are rubber - faced, the rubber being vulcanized to the metal. They flail out the grain between the revolving cylinder bars and the stationary shelling plate and stationary block rubber concaves.
Concaves and grates: These stationary bar and open grates extend across the full width of the cylinder (Figure 13). They are located below the cylinder and surround about one quarter of its circumference. Hence they are called “concaves”

Various types are used but all do the same work. Together with the cylinder, the concaves apply a basic principle used in all models, that of passing the grain between a rapidly revolving cylinder and a stationary surface.

Spike – tooth concaves are used with spike – tooth cylinders, rasp – bar or channel – bar concaves with rasp – bar cylinders and rubber – block concave bars with rubber – bar cylinders.

Open grates with slotted holes or perforations are placed between the concave bars. Much of the threshed grain falls through these openings to the grain pan beneath.

4. Separating Unit:
Most of threshed grain is separated from the straw at the concave and at the finger grate at the rear of the cylinder. But some is mixed with the mass of straw thrown from the rear of the cylinder.

Removing the threshed grain from the mass of straw is accomplished by the straw rack (Figure 14) which tosses and tumbles the straw and propels it to the rear. This
aggressive motion separates threshed grain from the straw, the grain falls through openings in the bottom of the rack to the grain pan or to the grain conveyor. The straw travels the full length of the rack and is discharged at the rear of the combine.

A revolving beater strips the straw from the rear of the cylinder and distributes it to the straw rack. Deflectors or rotary beaters above the rack regulate the movement of the straw and deflect the flying kernels.

In some models, the straw rack has four longitudinal sections. These are driven by a four-throw crankshaft which gives an alternate lifting and dropping motion as the straw is “walked” toward the rear. (Figure 15) shows the flow of material from these straw “walkers” into a straw-chopping attachment which brings important advantages under certain field conditions.

5. Cleaning Unit:

This unit (Figures 16 and 17) removes chaff and fine residue from the threshed grain. It cleans by the combined action of sieves and air blast.

**Grain Pan:** The grain pan is so located that all threshed grain may fall into it both that which passes through the concaves and that which sifts through the straw rack. The grain pan extends from beneath the cylinder to a point well back toward the rear. The motion of the grain pan moves the grain toward the rear.

**Chaffer:** This is an extension of the grain pan. It has relatively large, adjustable openings. Threshed grain drops through these openings to the cleaning sieve, but un-threshed heads and larger pieces of residue are carried back to the chaffer extension.

**Chaffer Extension:** This short unit is hinged to the rear of the chaffer. The grain pan, chaffer, and chaffer extension are usually a single unit.
The chaffer extension has adjustable openings that can be raised or lowered. When it is properly adjusted, un-threshed heads fall through the openings into the tailings auger. But large particles and coarse residue are carried out and dropped at the rear.

In some models there is a tailboard at the end of the chaffer extension. This can be raised, if necessary, to prevent grain from being blown out.

**Figure 16. Cleaning Unit**

**Figure 17. Grain pan, chaffer and chaffer extension**

**Tailings Auger:** This conveys the un-threshed heads across the rear of the combine into the tailings elevator. The elevator returns the “tailings” to the cylinder for re-threshing.

**Shoe Sieve:** Located below the chaffer, this adjustable sieve permits the grain to fall through it; then the grain moves down the inclined surface of the shoe to the grain auger. The shoe sieve has an oscillating or shaking motion. This aids in cleaning and sifts the grain through the sieve openings.

The position or angle of this sieve in the shoe is adjustable, as is the size of its openings. The sieve is usually placed in the shoes with a slight angle downward, toward the fan and grain auger. For cleaning dirty grain, you can raise the rear of the sieve and increase the air blast.

**Fan:** In most designs the blast of air from the fan passes through the shoe sieve, the chaffer and the chaffer extension. It is regulated by doors (blinds) at the fan housing. The air blows the light straw and chaff out of the combine but permits grain to sift through the chaffer and shoe sieve to the grain auger.

**6. Grain Handling Unit**

This power driven unit conveys the threshed, cleaned grain to the point at which it is taken from the combine (Figure 5). It includes these parts; clean grain auger; clean grain elevator; and grain tank and tank un-loader, or bagger and bag chute.
The clean grain auger collects the clean grain at the bottom of the shoe and conveys it across the combine to the elevator.

The clean grain elevator extends upward along one side of the combine. It elevates grain from the auger and discharges it into the grain tank or bagger.

The grain tank retains the cleaned grain until a truckload or wagonload has accumulated. Capacities of grain tanks vary from 18 to 60 bushels or more depending on the size of the combine. A power-driven auger unloads the tank quickly, delivering the grain through an adjustable spout into the wagon or truck.

Where it is customary to sack the grain, a two-spout bagger attachment replaces the grain tank. One bag is filled while the other is being removed, ties or sewed. A platform is provided for the operator, and there is a chute down which he slides the full sacks to the ground.

### 3.1.2 Mounted-type rice combines

The machine is mounted on a tractor to utilize its power (Figure 18). The platform of crop combine is in front of the tractor. The thresher is in rear. The conveyor mechanism is positioned sidewise to connect the platform and thresher. All power supplied to the combine is from the tractor via P.T.O. shaft. On platform there are cutter, pickup reel and conveyor auger. Threshing and separating mechanism are tooth-rasp bar cylinder and grid-type concave. Cleaning mechanism is fan-sieve type. The machine can open cut by itself because the platform mounted in front of the tractor so it has the advantage as in the self-propelled rice combine.

The working procedure is nearly as same as the self-propelled rice combine.

![Figure 18. Mounted-type rice Combine Harvester](image)
3.2 Head feed combine:

This type of combine was developed in Japan (Figure 19). It feeds only panicle part of reaped paddy into threshing parts of the machine. Threshed grain is either bagged or poured into a grain tank. The flow of crop in rice harvesting is as follow: the crop is held by a grain lifter or a reel before cutting; the crop is cut while its stalk is holding. For horizontal platform, reel slat of pickup reel pushes the crop down onto the platform. For vertical table, the crop lifter is used to lift the laid crop and then transmits the crop to star wheel or other kind of reel. The star wheel or reel is holding the crop while the crop is cut. After cutting, the crop is conveyed to aside and clamped by the middle conveyor mechanism and is than fed to the thresher. Only the upper part of crop heads and ears are fed into the thresher for threshing. The separated material gets through the concave sieve and down to the cleaning mechanism to be cleaned. The cleaned grain is conveyed to grain discharge mechanism. The straws stalk after threshing is discharged by the clamp chain conveyor in windrowing or stacking onto the stubble land.

The machine is complex and highly automatically. The combine is most suitable to reaping rice, it is moved by rubber belt claw track and the pressure between wheel and field is normally 0.17 to 0.21 kpa. so that it is suitable to walking in dry field, the table of the machine is vertical so it not good for harvest local high stem varieties. The energy needed is increased and because the feed quantity is decreased for using half feed mode.

Figure 19. Head feed Combine Harvester

THAI RICE COMBINE HARVESTER

Rice combine harvesters were initially introduced in Thailand during 1957-1963. The first rice combine harvester was fabricated by M.R. Deberiddhi Devakul, Engineering Section, Department of Rice (Figure 20), but the farmers at that time did not pay much
attention to it. In fact, the farmers were satisfied with the use of sickle and animal power for rice harvesting and power for rice harvesting and threshing respectively. This may be due to the fact that the agricultural sector was not facing any labor shortage in those days.

Figure 20. First rice Combine Harvester

In 1978, Agricultural Engineering Division received two reapers; TNAU Indian and Mametora front - mounted reaper for testing and modifying (Figure 21). The result came out that small reaper was appropriate farm machinery and urgently need by Thai farmers. Therefore, some manufacturers requested the prototype for copy and develop. However, Chinese reaper and Kubota reaper and cutter binders were imported and introduced to Thai farmers. The first lot of Chinese reaper which is more effective was imported in the end of 1980, because, the importers claimed that distribution few thousands units were sold and six local manufacturers started producing. Although, it seem to be a rapid adoption of new machine but it is not appropriate development. Some farmers who had purchased this type of machine are suffering, because it unable to work in the first main rice crop when the fields which is the local high stem rice varieties and the fields during harvesting season are usually still wet.

Figure 21. Mamitora Power collection type reaper
In 1982-1983, local manufacturer in Ayutthaya fabricated a prototype of rice combine harvester by attaching a modified Chinese reaper with a locally produced axial flow rice thresher (Figure 22). But no commercialized production.

During the previous Sixth Five-Year National Economic and Social Development Plan, the economic structure of Thailand rapidly changed from agriculture to industry. Expansion in other sectors had drawn labor force from agricultural sector resulting in shortage of labor for some farming operations. The shortage became critical in rice cultivating areas. Under this situation, some small workshops in the areas realized that farmers were urgently in need of rice harvester. Few of them produced rice combine by using parts from used machine such as cutter bar from used grass mowers or imported combine, track drive set from earth-moving machines matched with locally produced thresher. The rice combine was produced one by one should be classified as “prototype” rather than commercial product. Each workshop produced only a unit and took the machine out for testing and earning money by providing custom-hire service to the farmers. The machines were rapidly and widely adopted although they were not at technically acceptable level. It frequently broke down during operation or performed in efficiently as happening in every prototype testing. These weak points were covered by labor shortage. Therefore, the machine was acceptable to farmers.

As all prototype rice combine were rapidly adopted by farmers and the demand increasing, most of pioneer workshops increased number of their prototypes and gained good profit (Figure 23). However at the stage, it still not production as commercialized manufacture because it was produce by order. Mass production of rice combine started in
1987 when a pioneer workshop joined with a business group to establish a factory. At the same time rice thresher manufacturers whose productions were affected by the adoption of the combine changed some of their production lines to produce this newly developed machine. (Figure 24)

![Figure 23 pioneer workshops “prototype”](image)

![Figure 24 Mass production of Thai rice combine](image)

**Description of Thai Rice combine harvester.**

The rice combine harvester is a self-propelled machine consisting of eight major components: Prime mover, undercarriage, transmission and steering, harvesting, feeding, threshing, cleaning and separating, and output units (Figure 25). It requires three persons to operate for the sacking model; one for operating the machine and the other two for packing and sacking the threshed rice and one for operating the machine for the grain tank model. It mainly consists of the following units:
1. **Prime mover unit**: An imported reconditioned diesel engine with a rating of 100 - 145 hp is normally used as tie prime mover for the rice combine harvester.

2. **Undercarriage unit**: The chassis of the undercarriage unit is similar to heavy duty equipment but it has a sprocket and chain type power transmission system. It consists of five main components: track, track frame, idler wheel, carrier roller, and track roller unit. The track unit consists of sprockets and chains. At the beginning the shoe tracks are made of wood, due to low cost and easy availability. Wide tracks are used to prevent the combine from sinking in wet paddy field. The wooden track shoe is covered with a thin metal sheet to protect the wood track from being damaged when moving across the field during transportation of the machine. However, the steel and cast iron tracks were instead rapidly.

   The idler unit is used to guide and support the sprocket and chain unit of the machine. The carrier rollers are used to adjust the tension of the sprocket wheel and the track. The track roller unit consists of 8 - 12 rollers on each side are used to support the weight of the machine.

3. **Transmission and steering unit**: The rice combine harvester has two types of transmission systems, the direct drive and the hydrostatic drive. The direct drive system is normally used due to lower cost. The ratio between engine speed and sprocket wheel ranges from 1:28 up to 1:32 depending on the model of the rice combine harvester.

4. **Harvesting unit**: The harvesting unit consists of three main parts, a reel, front auger, and cutter bar. The hexagonal reel with reel fingers feeds the paddy crop on the cutter bar for cutting. A hydraulic lever is provided at the operator’s seat to change the position of the reel by lifting it up or down.

   The cutter bar unit consists of a set of 39 knives and guards and has a width of three meters. The rated speed of knife is 176 strokes per min. For the harvesting of thickly grown plants, lower values of speed are recommended.

   The front auger for three meters long and is made by mounting a helical coil to a 35 cm. outside diameter pipe. The slit between the auger’s tip coil and the platform is approximately 1 cm. The optimum width of the slit depends on the volume of the material drawn at the platform or the density of the plants and the working speed of the machine.

5. **Feeding unit**: The feeding unit conveys the harvested crop to the threshing unit. It is driven by a sprocket and chain mechanism and the conveyor is made of mild steel angle bars.
Figure 25. Component parts of Thai rice combine

6. **Threshing unit:** An axial flow rice thresher is used as a threshing unit. The threshing mechanism consists of a peg-tooth cylinder which rotates inside a double section cylinder concave (Fig...). The upper concave has incline louvers which move the threshing material axially between the threshing drum and the steel rod concave. The material is conveyed by chain conveyor and fed into the opening between the cylinder and the lower concave. The peg on threshing cylinder hit the material, separating the grain from the straw, and at the same time accelerating the grain them around the cylinder. The majority of the grain is threshed during the initial impact but further threshing is performed while the material moves axially, until the straw is discharged by the straw paddles at the opposite end.

7. **Cleaning and separating unit:** The cleaning unit consists of two blowers and an oscillating screen. This unit is a built-in unit of an axial flow thresher. The machine separates and cleans the grain in three stages. In the first stage, preliminary grain and straw separation occurs at the concave. In the second stage, the un-threshed material passes over the oscillating screen and is returned to the threshing drum for re-threshing by means of a broken ear elevator. In the third stage, threshed crop is subjected to a blast of air from the...
blower with adjustable air control, located beneath the threshing drum. It blows the lighter impurities, such as chaff and unfilled grains from the good grains.

8. **Output unit**: The threshed rice from the threshing unit is conveyed to the output unit by a grain auger elevator. The speed of the grain auger and the revolution of the grain auger elevator were around 350 rpm and 470 rpm respectively.

**Reasons for manual and rice combine harvesting in Thailand**

Although, it seems to be a rapid adoption of new machine which is combine harvester but in the beginning period many farmers were not satisfy the machine. From the analysis of the responses of the survey, the important reasons would be concern were given by the farmers who not used the combine harvester at that time are following;

a) Small land holding size:
b) Lack of confidence in machine’ performance
c) Non availability of machines
d) The farmers felt that the machine causes more grain losses than manual method
e) The farmers felt that the grain harvested by the machine has poor germination
f) That period of time, the grain drying facilities was not available.

The important reasons would be concern were given by the farmers who not used the combine harvester at that time are following;

a) Shortage of agricultural labor
b) High wages of labors
c) The farmers felt that the machine saves time
d) The farmers felt that it is an easy and convenient way of harvesting rice when compared with the manual method
e) Economic in operation, the farmers felt that the machine saves money when compared with the manual method system
f) Lesser grain losses as compared with manual harvesting

**Operating the combine harvester**

1. **Field conditions for manual and rice combine harvesting**: The rice combine harvesters were used and popular among the farmers having irrigated areas. Farmers having irrigation facilities generally grow rice twice or more a year. These fields were soft and deep
clay soil and are in the central part of Thailand. However, these were used in the other part rapidly because of labor shortage especially in the north east part to avoid of losses for local rice varieties which must be harvesting in timeliness.

2. Crop Condition: Before good work can be done with a combine, the operator should have a thorough understanding of the fundamentals of combine harvesting. One of the basic fundamentals is to harvest only when the crop is ripe. This should be an obvious statement, yet failure to observe this rule is often the cause of “combine troubles”.

3. Check the moisture content: The straw should not be too green, and the crop should be ripe. If the threshed grain feels damp or is easily dented with the fingernail, the moisture content is probable too high for safe storage. Grain crops containing 14 % moisture or less are considered dry enough for safe storage.

4. Combine Speed: On a tractor-drawn combine, the tractor engine must be operated at all times to maintain full power tank-off speed so that the combine mechanism operates at a constant and uniform speed. Any reduction in travel speed should be handled by shifting to a lower gear instead of throttling down the tractor engine.

   In making the first round of the field, keep the combine forward speed as slow as possible to reduce the volume of materials entering the combine.

   Select the ground speed that will not overload the combine. Excessive travel speed is one of the most frequent causes of trouble. Traveling at a high rate of speed over rough ground can cause extra wear and breakage that would not occur if the combine was traveling at a more reasonable speed.

   Overloading, resulting in a loss of grain is another evil of fast ground travel. More straw is taken in than the machine can handle. Grain is carried through the machine if the layer of material passing over the rack and sieve is too heavy.

   The tractor or combine operator should vary the travel speed to meet all crop conditions. As he approaches a very heavy, down or tangled condition, he should slow down to give the combine a chance to do a thorough, clean job of separating. In some conditions, it may be advisable to cut less than a full swath, giving the combine every opportunity to do good work. By listening constantly to the sound of the engine, the operator can tell approximately how fast he should travel.

5. Height of Cut: One of the important jobs for the operator is to note carefully the condition of the crop and adjust the cutting platform accordingly. The height of the cutter
bar should be set so that just enough straw is cut to get all the grain; this means set just low enough to get all the heads.

The combine operator should not only adjust his machine to hold threshing losses to a minimum, but he should also adjust and operate the platform and reel to reduce cutting losses. He should watch for stones and other foreign material that the platform may gather, and stop his machine before such obstructions reach the cylinder and cause damage.

When stopping the tractor for any reason, the combine should be cleared of grain before disengaging the power take-off. If it is necessary to stop in the middle of the field, the combine should be backed up a few feet before proceeding ahead. This will allow the combine to come up to speed before grain enters.

6. Operation in Weedy Conditions: Combining in fields where weeds are numerous is particularly troublesome for every operator. Weeds tend to gum up the sieves; also, moisture in the weeds is imparted to the grain. Naturally, weeds should be disposed of quickly and not broken any more than necessary.

When operating in weedy conditions, cut the grain as high as possible. Try to avoid weeds and undergrowth. Check frequently to be sure the cylinder is operating at proper speed. Use as much air blast on the shoe as possible without blowing grain over; lower the rear end of the adjustable chaffer.

The combine should be thoroughly cleaned out before leaving one field and going to the next in order to reduce the spread of noxious weed seeds.

When through cutting in a field, sweep trash and straw off the outside of combine; open doors at bottom of elevators; and run machine until all possible straw, trash, and grain are removed from inside of combine before moving to the next field or placing the combine in storage at the end of the season.

Adjusting the Combine Harvester

The operator should familiarize himself with servicing and operating instructions so that he can operate his equipment with greater efficiency.

The maximum saving of grain and the quality of work done in all conditions depend upon the best use of the adjustments provided for varying conditions. The grain in the tank, the tailings, and the straw coming over the straw walkers or racks, reveal the quality of work being done and indicate what adjustments are necessary.
The operator must understand the functioning of each of the principal parts of the combine and be acquainted with the adjustments.

The upkeep expense on a combine will be greatly reduced if all belts are kept tight, and belts, canvases, and chains are operated at correct tension. Regular inspection of the entire machine will save delays and reduce operating costs.

Reel: The reel must be square, level, and at the proper height and position to feed the grain uniformly and steadily.

The exact position of the reel depends upon the height of the grain, quantity of straw cut, and the condition of the straw. Ordinarily the reel should be set so the slats, when in their lowest position, will strike the straw 6 to 10 inches above and slightly ahead of the knife.

Usually you will get good results by setting it so that the reel bars strike the grain well above the center of the stalk. If you do not want to save the straw, set the reel as high as possible.

In grain that is down and tangled, the reel should be set low and back so that it will just clear the knife and auger-type platform. Proper setting will eliminate reel wrapping.

If the grain “slobbers” over the front of the cutter bar, the reel is probably too far forward and too high. Move the reel back so that it is directly over the knife; also lower the reel. Cut as low as possible and increase the reel speed.

Changing the speed of power-driven reels is accomplished by changing the reel-driving sprockets; two or more sprockets are furnished for this purpose. Ground driven reels usually maintain proper relation to the forward speed.

Adjustments are provided for raising and lowering the reel. This may be done hydraulically or mechanically, depending upon the particular combine.

If the reel-raising parts tend to bind on the reel racks, lubricate the racks liberally and be sure all paint and dirt is removed from the racks. Replace any broken reel slats. A missing slat will cause uneven delivery in the platform auger and uneven feeding to the cylinder.

Height of Cut: Unless the straw is to be saved, set the cutter bar (header) just low enough to get all the heads. Cutting too low (too much straw) may overload the combine, slow up your rate of work, and make separation difficult.

Feeding: Keep the tension of the upper and lower feeder conveyor just tight enough to prevent slippage. Be sure these conveyor run squarely in their frames.
The auger should be set with approximately \( \frac{1}{8} \) - inch clearance between the auger flights and the bottom of the platform and 3/8 – inch clearances between the auger flights and the stripper. The auger should be raised when combining coarse stemmed crops or when using belt pickup for windrowed crops. The auger should be lowered when combining light crops. Whenever, the position of the auger is changed, always check to see that there is clearance between the retracting fingers and the platform bottom. Also be sure there is equal clearance between auger ends and the platform side sheets.

**Cylinder Speed and Concave Adjustment**: Correct cylinder speed and cylinder and concave clearance are all-important for good threshing; these vary according to the crop and crop condition. Cylinder speed should be as low as possible and cylinder and concave clearance as high as possible for thorough threshing without excessive cracking of grain.

**Cylinder Speed**: If the speed is too fast and the clearance too close, “over threshing” results and kernels of grain will be cracked and the straw broken and chopped up. This overloads the straw rack and sieves, and grain may be blown out with the straw. If the cylinder speed is too slow, or the clearance too great, the grain may not be threshed well.

As crop conditions change through the day, the cylinder speed may need to be adjusted. At noon the straw may be dry and brittle, and a fairly slow speed will work, but in early morning, or late in the day, the straw may be damp and tough. Then higher cylinder speed for good threshing is required.

**Problems and constraints of contractors about rice combine harvester**

Generally, the rice combine harvester was transported to the field by truck or tractor trailer. Moreover the truck price is one investment for the owner of combine harvester. Transportation of the machine on the road was a serious problem because the total width of the machine was more than the width of the truck and such widths are in violation of the highway traffic rules. Therefore, the contractor had to pay ransom during traveling on the highway, which also increases the hiring charges of the machine.

One of the common problems faced by both contractors and farmers was frequent breakdown of the components. The replacement and repair of which needed a considerable time and effort and this was one of the most serious drawback of the machine for effective
operation. However, the frequency of breakdown at the start of the season was more than that at the end of the harvesting season.

Serious accidents with rice combine harvester during operation

Many accidents were reported while working with the rice combine harvester in the field. The main reasons for their occurrence were the operator’s skill, machine design, and the condition of surroundings. Direct drive rice combine harvesters used the belt – pulley and chain – sprocket mechanisms in their transmission system, which were one of the reasons of accidents. The operators had many accidents due to failures in the other moving parts of the machine such as clogging in the re-threshed grain auger and front auger. The operator had to de-log these faults in the field during harvesting only. Below is a list of serious accidents in the field;

a) The fingers of the operator were cut in the re-threshed grain auger
b) The hand of the operator was cut by the pulley and belt. In such cases, the operators did not stop the moving parts of the machine while setting the V-belt onto the pulley.

c) The body of operator was hit by the finger feeder of the front auger while releasing the jammed auger. In such cases, the operators generally did not stop the jammed header and used their legs to move the front auger.
d) The machine fell down, while loading it into the trailer or truck for transporting the machine to the field. In such cases, the operator was not careful and lacked skill when moving the machine back to the trailer or truck by means of a ladder.

Thai Maize combine harvesters

Maize cultivation have been innovated to Thai farmers for more than sixty five years. In the beginning stage, all farm practices were relied on human and animal power with some simple tools. Machinery especially tractors with land preparation implements were introduced after the Second World War. Mechanization for maize production since then has been gradually developed step by step, from labour intensive machines such land preparation implements, shellers, chemical sprayers etc. to control intensive machines such as seed and fertilizer drills, high capacity husked maize shellers, harvesters, dryers etc. At present, it can be cited that maize production in Thailand is fully mechanized but at different level for each farm activity. For instance, land preparation, seeding and fertilizer
application, and, shelling are nearly 100 percent mechanized with locally manufactured machines and implements. Nevertheless, only about 50 percent of cultivated area are harvested with imported combine harvesters.

For decades, manually picking and de-husking has been the only maize harvesting practice in Thailand. Efforts have been put to develop and manufacture picker, picker with de-husker (Figure 26). None appropriate prototypes had been adopted. However, due to the increasing problems of labour shortage and has become the critical problem of maize production in some particular areas. Imported large combine harvesters for maize had been tested, evaluated and demonstrated for popularization. Although, there are some technical problems to be remedied for instance, the bulky huge machines had some difficulties to work in wet season harvesting conditions. However, in areas having critical labour shortage problem, some western Maize combine harvesters had been imported (Figure 27). These maize combine harvesters are being operated on custom-hire contracting basis with an increasing trend.
In 2005 - 2008, in order to alleviate labor shortage problem in maize harvesting by mean of expending the use of combine harvesters, local developed and manufactured Thai paddy combine harvester has been modified to be able to handle maize by Agricultural Engineering Research Institute. Two models had been developed, one with minor modification on harvesting head and threshing system. The second model; the harvesting head with cutter bar was replaced by 4 rows combine maize - head snapping unit and modification on threshing system. The first model (Fig. 28) has capacity around 0.32 - 0.64 hectare per hour depending upon cutting width. The other (Fig. 29) has capacity 0.8 - 0.96 hectare per hour. Both have been put into commercial production.

**Figure 28 Cutting Thai Maize combine harvester**

**Figure 29 Snapping Thai Maize combine harvester**

Mechanization in Thailand is rolling forward from power intensive to control intensive machines. Thai mechanization system can be cited as one of high efficient pattern.
Farmers are needless to invest high cost to own an expensive machine. Farmers normally own small simple machines and equipment. Custom-hire contracting with large farm machinery in Thailand happens to be a reliable and appropriate service for most farmers. More than 99 percent of Combine Harvesters are operated on custom-hire service basis. With this pattern of farm machinery utilization, mechanization for Agricultural production will keep expanding and will catch up with the requirement of farmers.

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