

## Development of a Small Rice Combine Harvester

R. Kalsirisilp<sup>1</sup>, V.M. Salokhe<sup>2</sup>, C. Youprasobchok<sup>3</sup>, C. Polwong<sup>3</sup>, E. Fanchaiyapoom<sup>3</sup>, S. Baisaengchan<sup>3</sup> and W. Panyawan<sup>3</sup>

### Abstract

The objective of this research was to design, fabricate and evaluate the performance of the small rice combine harvester. This machine was designed based on the local needs especially suitable for small farm. Presently, the Thai-made combine harvester without grain tank weights at least 5-6 tons. The total weight of the small combine was designed approximately 2.8 tons. The machine consists of harvesting unit, threshing unit, undercarriage unit and cleaning unit. A 72 hp, diesel engine was used as a power source of the machine. The cutting width of the machine was 1.8 meter. The diameter of the threshing cylinder was designed to be 360 mm with the length of 1,000 mm. The blower fan has five paddles. The peripheral speed of threshing cylinder was designed as 9.4 m/s. Performance parameters for the study were effective field capacity, field efficiency, harvesting losses, fuel consumption and the cost of harvesting.

The test results indicated that the effective field capacity was 0.37 ha/h at the engine speed of 1,700 rpm. The corresponding field efficiency was 78%. The total grain losses was 5.4% of grain yield at the engine speed of 1,700 rpm. The average percent grain purity was 95%. The fuel consumption of the small combine harvester at the engine speed of 1,700 rpm was 15.5 liter/ha. The total cost of using the machine was calculated as Baht 1,328/ha.

**Keywords:** Combine harvester, Rice, field capacity, field efficiency

### Introduction

Harvesting is the most labor-intensive operation in rice production. In Thailand, it is traditionally done by sickles and threshing also done manually or by using animals. With the advent of industrialization, the Thai-made combine has been fabricated and widely used in the country. It is estimated that about 10,000 units are being used in Thailand. These machines are very big and powered by 145-290 hp engines. The average cutting width of the locally-made rice combine harvester is about 3.0 meter with the average field capacity of 0.5 ha/h [1]. The total weight of the locally-made combine harvester without grain tank varied between 5-6 tons. Whereas the total weight of the combine harvester with grain tank varied between 9-10 tons. The average capacity of the grain tank of the rice combine harvester is about 2.5 tons. The price of Thai-made combine harvester is between 1.5-2.0 million Baht depending on the options and models of the machine.

At present the rice combine harvesters are widely used in the central region of Thailand. In some other parts of the country still reaper or sickles are used during rice harvesting season. This was mainly due to the small size of the rice fields. Moreover, the heavy weight of the rice combine harvester destroys the soil structure as well. The soil compaction problem due to frequent use of these rice combine harvester is prevalent in many parts of rice growing areas of Thailand. It affects the land preparation cost as well as results in decreased yields. The farmers in the central region of Thailand can not use the 14 hp walking tractors for ploughing these compacted lands. They have to hire four wheel tractors for land preparation. All these practical limitations in use of big combines reveal that it is necessary to develop a small combine harvester suitable for Thai rice field conditions.

The design and development of small rice combine harvester suitable for small rice fields, with lower cost, light in weight and maneuverable in small

<sup>1</sup> Associate professor, Department of Agricultural Engineering, Faculty of Engineering, Rajamangala University of Technology Thanyaburi

<sup>2</sup> Professor, Agricultural System and Engineering, School of Environment, Resources and Development, Asian Institute of Technology

<sup>3</sup> Undergraduate students, Department of Agricultural Engineering, Faculty of Engineering, Rajamangala University of Technology Thanyaburi

fields is essential. This project is aimed at developing such machine for the use of Thai farmers.

## Materials and Methods

### Machine operation parameters

The operation parameters included the forward speed of the machine, effective working width, cutting height, fuel consumption, time elements (as used in computing field capacity and efficiency), quality of paddy, labor requirement and machine operation losses such as header loss, unthreshed grain loss and blower and screen losses.

Effective field capacity was calculated using the following formular:

$$FC = \frac{A}{T_p + T_i} \quad (1)$$

Where;

$FC$  = effective field capacity (ha/h)

$A$  = area covered (ha)

$T_p$  = productive time (actual time) (h)

$T_i$  = nonproductive time (turning, repair and adjustment time, other time losses) (h)

The field efficiency is calculated using the following equation

$$\text{Field efficiency, } \bar{E}_f = \frac{T_p \times 100}{T_p + T_i} \quad (2)$$

### Machine operation losses

Shattering loss: Shattering loss refers to the ears and grains that fall to the ground due to machine operation.

$$\text{Shattering loss, } C(\%) = \frac{W_s \times 100}{Y_i} \quad (3)$$

where;

$W_s$  = shattering grain loss (ton/ha)

$Y_i$  = estimated grain yield of crop (ton/ha)

Blower and screen loss (including unthreshed grain loss): The unthreshed grain losses and the blower and screen losses were measured from the straw discharged by the harvester.

$$\text{Blower and Screen loss, } B(\%) = \frac{W_v \times 100}{Y_i} \quad (4)$$

Where;

$W_v$  = blower and screen loss (ton/ha)

$Y_i$  = estimated grain yield of crop (ton/ha)

Total machine loss was the summation of shattering loss, blower and screen losses including unthreshed grain loss.

### A Small Rice Combine Harvester

A 72 hp, diesel engine is used as prime mover. The engine provide power to propel the machine to the field and to drive the harvesting components as well as to power the hydraulic system.

The axial piston pump with the volume displacement of 40 cm<sup>3</sup>/rev is selected for design of the hydrostatic drive system of the small rice combine harvester because of its higher pressure and higher volumetric efficiency than gear and vane pump. The working pressure of the piston pump is designed as 5000 psi. The swash plate is used to control the output of the piston. The hydraulic motor used in this design was piston type with a displacement of 40 cm<sup>3</sup>/rev.

The threshing mechanism consists of cylinder and concave. The cylinder used is peg tooth type which rotates inside a double section cylinder concave. The peg tooth cylinder consists of a number of steel teeth attached to metal bars which are mounted to the outer circumstance of a series of hubs. The upper concave has inclined louvers which move the threshing material axially between the threshing drum and the steel rod con cave. The diameter of threshing cylinder is designed as 360 mm. The threshing cylinder length is designed to be 1,000 mm. The steel rod diameter of upper concave is designed as 8 mm. The separating unit comprises of housing and blower. The blower is made of mild steel sheet and enclosed in spiral shaped housing. The blower is made of 5 vanes of 100 mm by 850 mm and is attached to a blower shaft mounted on two bearings on each side to allow free rotation.

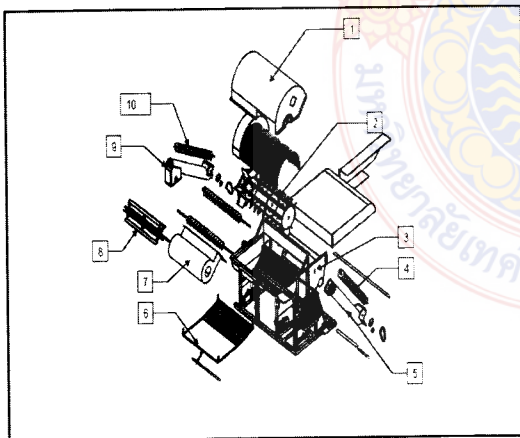
The harvesting unit consists of three main parts, namely: a reel, a front auger and a cutter bar. The hexagonal reel with reel fingers feed the paddy crop on the cutter bar for cutting. The hydraulic lever is provided at the operator's seat to change the

position of the reel by lifting it up or down. This unit consists of 25 knives and guard and has a width of 1.8 meters. The speed of the knife is designed as 420 strokes per min. The guards are spaced at 80 mm center distance.

The front auger is 1,800 mm long and is made by mounting a helical coil to a 280 mm outside diameter pipe. The optimum width of the slit depends on the volume of the material drawn at the platform or the density of the crops and the working speed of the machine. The retractable fingers, positioned in the center of the header auger, guarantee even crop flow into the chain conveyor. These fingers, mounted in the center, keep the header clear for the following crop. The feeder house uses a chain and slat design to transport the cut crop from the header to the threshing cylinder (Fig.1-3).

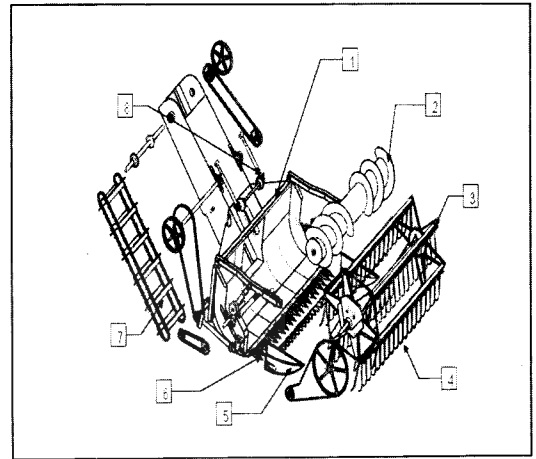
## Results and Discussion

The performance of the small combine was evaluated in terms of field capacity, field efficiency, fuel consumption, harvesting losses. Table 1 gives the results of the performance tests of the small rice combine harvester. Table 2 gives the performance of existing combine [1].



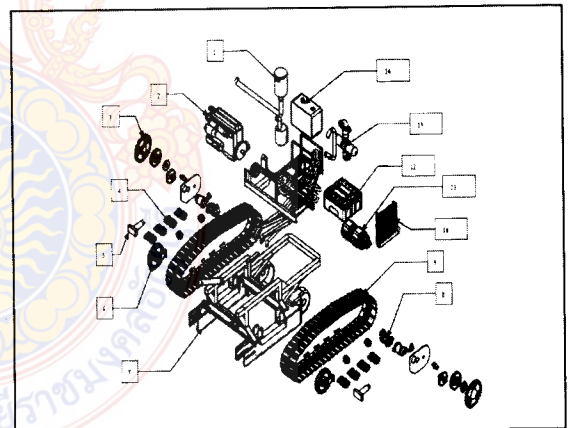
1. Threshing cover
2. Threshing cylinder
3. Threshing frame
4. Rethreshed grain auger
5. Rethreshed grain pipe
6. Oscillating screen
7. Blower case
8. Fan blade
9. Clean grain pipe
10. Clean grain auger

Fig. 1 Threshing unit



1. Header platform
2. Front auger
3. Pick-up reel
4. Finger
5. Divider
6. Cutter bar
7. Chain conveyor
8. Chain tightening

Fig. 2 Header unit



1. Air filter
2. Engine
3. Sprocket wheel
4. Roller
5. Track chain tightening
6. Idler
7. Undercarriage frame
8. Hydraulic motor
9. Track chain
10. Hydraulic oil cooler
11. Hydraulic pump
12. Battery
13. Strainer
14. Hydraulic oil tank

Fig. 3 Traction unit

Table 1 Field performance of small combine in Thanyaburi district, Pathumthani province

Parameter	Field no.			
	1	2	3	4
1. Crop variety	PI*	P1	P1	P1
2. Grain moisture content (%wb)	21	22	21	22
3. Average plant inclination angle (deg)	8	8	8	8
4. Average crop height (cm)	68	68	68	68
5. Fuel consumption (l/ha)	14.7	14.7	14.7	15.5
6. Effective width of cut (m)	1.7	1.7	1.7	1.7
7. Avg. speed of combine (km/h)	1.5	1.5	1.8	3.3
8. Grain yield (tons/ha)	5	5	5	5
9. Shattering loss (%grain yield)	3.5	2	2.6	2.9
10. Blower & screen loss (%grain yield)	6.9	1.4	0.9	2.5
11. Total grain loss (%grain yield)	10.4	3.4	3.5	5.4
12. Effective field capacity (ha/h)	0.1	0.1	0.18	0.37
13. Field efficiency (%)	60	60	70	78
14. Percent purity (%)	91	91	91	95
15. Engine speed (rpm)	1,500	1,500	1,500	1,700

\* Pathumthani 1 rice variety

Table. 2 Field performance of existing combine harvester [1]

Parameter	Value
1. Crop variety	PT*
2. Grain moisture content (%wb)	19
3. Average plant inclination angle (deg)	5
4. Average crop height (cm)	96
5. Fuel consumption (l/ha)	18
6. Effective width of cut (m)	2.8
7. Avg. speed of combine (km/h)	3.4
8. Grain yield (tons/ha)	2
9. Shattering loss (%grain yield)	1.1
10. Blower & screen loss (%grain yield)	1.4
11. Total grain loss (%grain yield)	2.5
12. Effective field capacity (ha/h)	0.65
13. Field efficiency (%)	83

\* Puangtong rice variety

At the engine speed of 1,500 rpm, the effective field capacity of small rice combine harvester varied from 0.1 to 0.18 ha/h with an average of 0.13 ha/h as shown in Table 1. In term of materials handled, the machine's field capacity varied from 0.5 to 0.9 tons of paddy per hour with an average of 0.63 tons of paddy per hour. The average field efficiency was observed to be 63%. At the engine speed of 1,700 rpm, the effective field capacity was found to be 0.37 ha/h and the field efficiency was found as 78%. In term of materials handled, the machine's field capacity was observed to be 1.85 tons of paddy per hour. The lower field capacity of the machine in fields no. 1 to 3 during field operation mainly due to low travelling speed of the machine. Because of the blocking of the crop at the threshing cylinder, the operator had to move the machine as low as possible to minimize clogging problem in the threshing unit resulting in lower speed of the machine during field operation in fields number 1 to fields no. 3. The engine speed of the machine in fields no. 4 was maintained at 1,700 rpm resulting in higher working speed of the machine (Fig. 4).



Fig 4. The machine in operation

The total machine losses of the machine in fields no. 1 to 3 varied from 3.4 to 10.4% with an average of 5.77% of grain yield as shown in Table 1. The total machine losses of the machine in fields no. 4 was found to be 5.4% of grain yield. The harvesting cost was calculated as Baht 1,328/ha. Considering the weight distribution of the small rice combine harvester over the ground during field operation, the machine weight was 2,800 kg and area



of the track was 10,800 cm<sup>2</sup>. The ground pressure was calculated as 0.26 kgf/cm<sup>2</sup>, which was about 10% less than the existing combine pressure on ground. The weight of existing combine (3-m cutting width) was 5,800 kg and area of track was 20,007 cm<sup>2</sup>. The ground pressure of existing combine was calculated as 0.29 kgf/cm<sup>2</sup> [2]. Therefore, the problem of soil compaction in the paddy field and failure of the soil structure during field operation will be reduce with the use of the small rice combine.

## Conclusions

The effective field capacity was 0.37 ha/h at the engine speed of 1,700 rpm. The corresponding field efficiency was 78%. The total grain losses was 5.4% of grain yield at the engine speed of 1,700 rpm. The average percent grain purity was 95%. The fuel consumption of the small combine harvester at the engine speed of 1,700 rpm was 15.5 liter/ha. The total cost of using the machine was calculated as Baht 1,328/ha.

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