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Design and Development of Low-cost Rice Harvesting Machine

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Abstract

A Rice harvesting machine is designed and prototyped with a prime objective of making it affordable to small farmers. It is designed to reap two rows of rice crop at a time powered by an AC motor which in turn helps cutting and crop pushing away from the cutter. Three phase AC induction motor with the power of 0.5 HP is used. The time taken to reap one hectare area of paddy is around 6 hours. This is an alternative to the existing fully fledged rice harvester and is expected to be available in every farmer's house. The focus is on simplicity and low cost in machinery, and independent of manpower availability. This paper brings out the design, development and analysis of a rice harvesting product by making it affordable for poor and small time farmers.

Key Words— Rice harvester, Agriculture, cost reduction, design, small scale farmers.

I. INTRODUCTION

Agriculture sector in India contributes 13.7 % of GDP and 10 % of overall export earnings. In earlier days, agricultural workers had to harvest crops and carry out a series of various operations manually one after another. The primary operation is to cut down plants with a long handled cutting tool such as scythe or sickle. Next operation is to separate the edible grain from the chaff by beating the cut stalks called

threshing. Finally they had to clean the remaining debris from the seeds to make them suitable for use in a mill. This entire process consumes lots of man-power and time. The evolution of harvesting systems is as follows: *Manual harvesting and threshing* - This includes use of traditional tools for harvesting (sickles, knives) and threshing such as threshing racks, simple treadle threshers and animals for trampling; *Manual harvesting and mechanical threshing* - The use of portable thresher is usually the first step in mechanical threshing. Stationary threshing is generally done in the field, or near the field; *Mechanized cutting followed by machine threshing* - Cutting and laying the crop on a windrow is done using a reaper, threshing by a thresher and cleaning either manually or by machine; *Combine harvesting* - The combine harvester combines all operations: cutting the crop, feeding it into threshing mechanism, threshing, cleaning, and discharge of grain into a bulk wagon or directly into bags. But in modern days, all these processes have been automated with the help of combine harvesters. The crop is cut, threshed and cleaned by simply driving the harvester through the field. The crop is cut by the cutter and then conveyed out through the binder. As of November 1st, 2014, the inventory of rice is estimated to 13.7 million tons against the target of 7.2 million tons in India [1].Forecast shows that the production is to fall fractionally by 2014/15 while the demand is expected to increase to new heights. The trend of shifting towards machinery as observed in the above evolution is due to the drastic reduction in the availability of work force in agriculture sector over the years

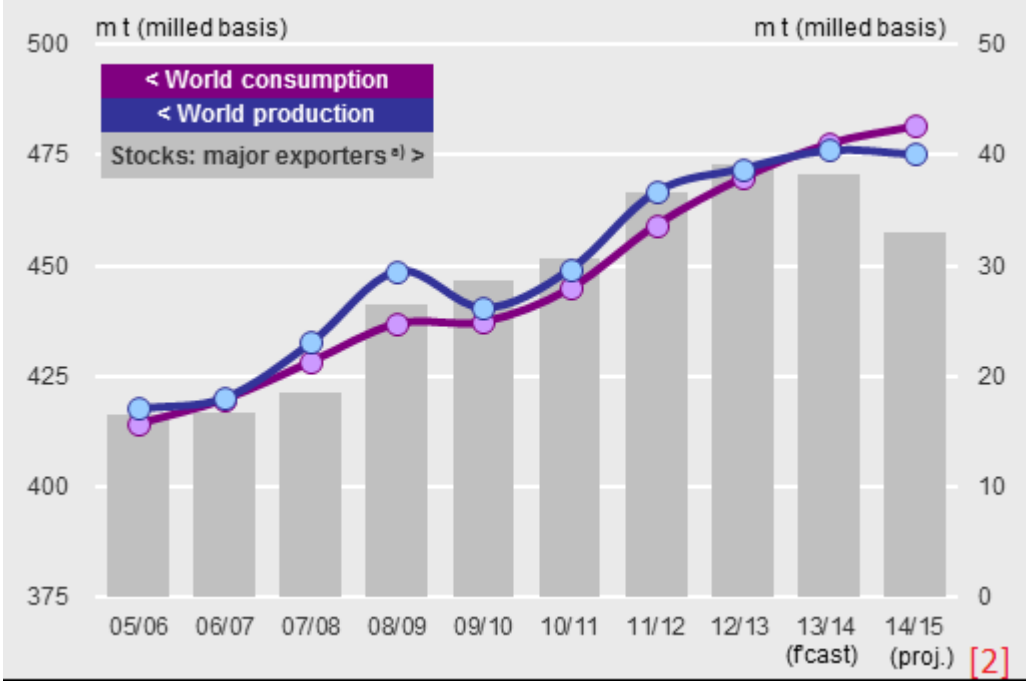


Fig 1.Graph representing world consumption and world production with respect to time[2]

Land Resources2011 [3]

Item Name	**Value**	**Measurement Unit**
Agricultural area	179,675.00	1000 Ha
Country area	328,726.00	1000 Ha
Forest area	68,579.00	1000 Ha

To meet the expected increase in demand either man-power in agricultural sector should be increased or the cost of machineries used by the farmers should be reasonably reduced. By doing this production increases.

II. DESIGN AND DEVELOPMENT

A. Theoretical Stage:

The main parameters for optimizing cutting elements in the harvester includes cutting internodes' position, cutting energy, cutting force etc., The cutting energy of rice stem at different internodes' position was examined and following data has been obtained.

Table 1. Data for selection of cutting height in the region of second internodes[4]

Variety	Tarom	Hybrid	Khazar	Dorfak	Net Average Height
Start Height(mm)	49.63	27.46	26.77	26.62	
End Height(mm)	84.12	48.8	51.28	44.7	
Average Cutting Height(mm)	66.875	38.13	39.025	35.66	44.9225
Major Diameter(mm)	3.65	6.84	7.49	6.17	6.0375

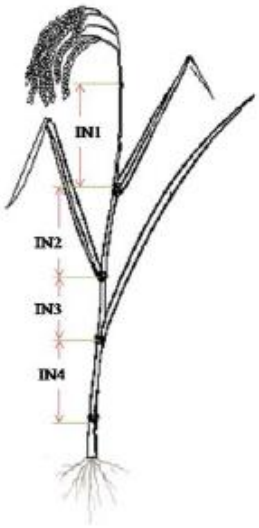


Fig 2.Schematic representation of Rice stem (IN1, IN2, IN3 and IN4 are the first, second, third and fourth internodes, respectively) [4]

Energy required for cutting the stem of various types of rice varieties such as Khazar, Fajr, Binam and Hashemi has been studied and the following data has been obtained.

Table 2.Maximum force and speed required for cutting single panicle of different varieties of paddy [5]

Variety	Maximum cutting force (N)	Maximum speed (ms^{-1})
Hashemi	1.15	23.87
Binam	1.253	24.19
Fajr	2.08	28.53
Khazar	2.82	31.98

B. Design Stage:

As the cutting force required for reaping one stem was found to be approximately 3 N [5]. Each hill comprises 3 panicles. At an instant the harvester is designed to reap two hills. Therefore the forces sums up to an approximation of 20 N. There is a pushing mechanism to push the crop on either side of the harvester. The drive for the cutting and pushing mechanisms is taken from a three phase ac induction motor whose power is taken from the ac power supply available nearby the field. The harvester is manually driven. The drive from the motor is conveyed to the cutting and pushing mechanisms with the help of belts and pulleys. When the harvester is moved forward the crop interacts with the cutting blade and gets reaped. Due to the weight of the rice grains, each crop tends to fall in random directions. In order to avoid that improper gathering of crops, the harvester has been installed with a pushing mechanism. The pushing mechanism has a rod attached with four claws that is capable of drawing the crops in unidirectional manner. The direction of claw rotation is controlled with the help of a modified three phase ac motor wired with an external switch providing the user to change the rotation on both clockwise and anti-clockwise directions.

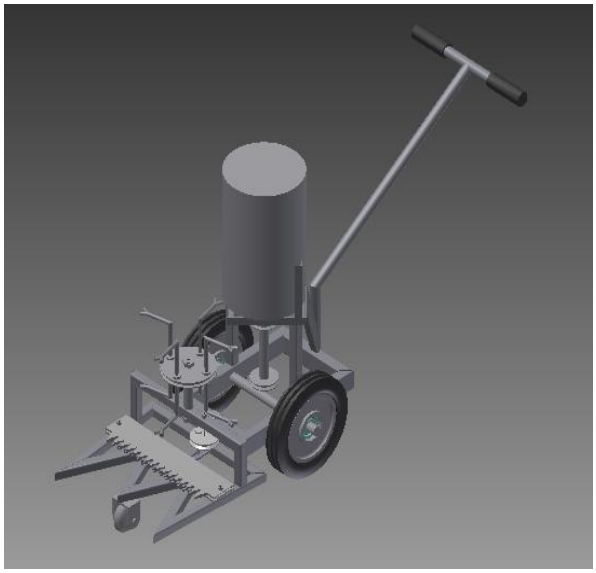
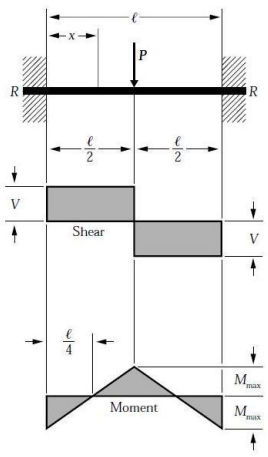


Fig 3.Final design of the Rice Harvesting machine model (Software used: Autodesk Inventor 2014)

C. Material Selection and Design for Light weighting:

In order to withstand the overall weight which is around 18 kilograms the frame has to be strong enough. Considering weight reduction and strength, mild steel is selected. The force is split among two beams in the frame. In each beam there acts a force of 90 N.



Formulae used:

R= $\frac{P}{2}$= $\frac{90}{2}$= 45 N

M_{max}= $\frac{Pl}{8}$= 19.68 Nm

$\Delta_{max} = \frac{Pl^3}{192EI}$

=3.06× 10^{-11}m

Fig 4.Moment diagram for a beam fixed at both ends [6]

The cutting blade should withstand a force of 20 N while reaping and it should be corrosion resistant. Reciprocating cutting blade is used instead of rotating cutting

blade because in rotating blade adequate cutting force required for the reaping cannot be obtained and there is a chance of crop being escaped without being cut between the two consecutive blades. The working mass reduces when a linear reciprocating cutting blade is used. Cost of manufacturing and complication increases in case of making a rotating cutting blade.

Table 3.Comparison between currently available rice harvesters in market and newly designed harvester:

Available rice harvesters in market	Newly designed Rice harvester
More complex and bulk	Simple and efficient
High energy consumption	Low energy consumption
Heavier and complicated	Less weight and compact
Uses engine as power source for all activities	3 phase AC Motor is used to run the cutting blade and pushing claw mechanism
Fuel used to run the engine causes pollution	Electricity is used to run the motor which reduces pollution because of no emission
High machine cost	Low machine cost
Used mainly for increasing production in big farmlands	Used to harvest a small piece of farmland
High maintenance	Less maintenance
High running cost	Low running cost
Integrated design	Modular design

D. Fabrication of prototype:

Cutter frame was initially fabricated according to the designed 25x25 mm cross sectioned 2mm thick hollow square frame. The frame was cut using a disc cutter according to the designed dimensions after precise markings and allowances. Then the cut frames were ensured to be free from unnecessary burrs that were formed during cutting. Then they were arranged on a flat surface checked for correct orientations using L-angles.After ensuring the correctness of dimensions and orientations, welding of the frames were done using standard arc welding techniques. Proper welding techniques were incorporated to ensure proper heat distribution and unwanted bending of frame, due to selective heating, was avoided. The welded cutter frame was then given final finish using hand grinding and holes were drilled to attach the cutting blade assembly as shown in Fig 5.

Fig 5.Cutter frame

The cutting blade was taken for milling according to design. The cutting blade consists of thirteen cutting teeth and the reciprocating length of the blade according to the design is around 20mm. Small sockets were drilled in the stationary cover surfaces inside which ball ruses were kept accordingly enhancing sliding action, reducing the friction between blade and cover. Two slots of 40 mm length with the thickness of 8mm were milled and correspondingly two 8mm pins were welded to the top supporting plate.

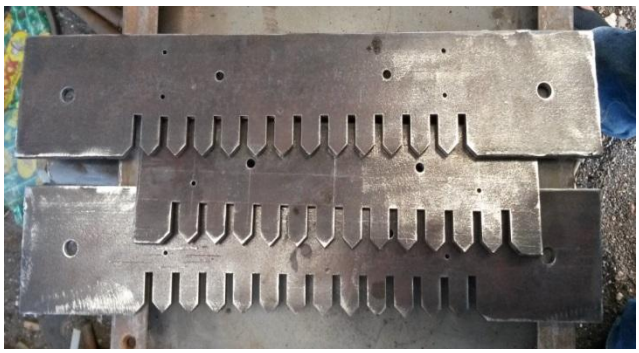


Fig 6.Cutting blade (middle) and its supporting cover plates

Fig 7.Cutter assembly fixed on the base cutter frame

The two supporting plates sandwiching the blade were attached to the base cutter frame with bolts and nuts as shown in Fig 7. Washers of appropriate sizes were placed between the supporting plates to ensure precise clearance for the blade to reciprocate freely.

The main frame consisting of handle and motor holder structure was fabricated according to design specifications. The motor is oriented in such a way that the shaft of the motor extends towards the ground. The location of the motor varies in the vertical direction according to the driven pulley location in the cutter frame or any other pulley in the further upgrades. So, a slotted vertical frame as shown was made to make adjustment to the vertical position of the pulley. Then the main frame was properly cut, welded and then surface finished. The motor holder frame was then properly welded in the main frame and then the motor was mounted onto the frame using nuts and bolts in the slots of the motor holder frame. The handle pipes were cut and welded to the main frame according to the design and handle grips were added to the holder.

The motor of 0.5 HP is used based on the design calculations shown below:

Average human walking speed = 5km/hr

= 83 cm/sec ~ 90cm/sec

Space between two crop cluster = 15 cm

Time taken to cut a cluster = $\frac{1\text{sec}}{90\ cm}$ x $\frac{15\ cm}{1\ cluster}$

= 0.167 $\frac{sec}{cluster}$ ~ 0.15 $\frac{sec}{cluster}$

One stroke = $\frac{1}{2}$ revolution of the pinned pulley

= $\frac{1}{2w}$ = 0.15 $\frac{sec}{cluster}$

Therefore, angular frequency turns out to be 200 rpm.

Angular frequency obtained in the final fabricated model is 288 rpm which is greater than 200 rpm. Therefore rice crops can be cut efficiently.

Three phase motor was used in order to change the direction of the rotating claw accordingly while moving through the field. An extra switch was placed near the handle to change the motor shaft rotation direction. The claw rotation must be changed because all crops should fall on the same side when the direction of reaping is reversed.

Fig 8.Belt drive between two pulleys

The speed reduction was achieved by fixing a 20mm diameter pulley in the motor output shaft which rotates at 1440 rpm and 120mm diameter pulley which was placed at a centre distance of 300mm rotates at 288 rpm. A35 V belt was used to connect the driving and the driven pulley. A pin of 5mm diameter was welded to the crank pulley which moves precisely inside the slot provided in the cutting blade extension as shown in Fig 8. In the initial design two belt drives were provided but during fabrication the speed reduction achieved was more than sufficient for the pushing mechanism also. Ultimately the purpose was achieved by using a single belt drive itself. Four claws were updated with a single claw to match the new speed.

The wheel shafts were welded directly below the main base frame in a location where the entire weight of the machine was balanced properly as shown in Fig 9.

Fig 9.Wheel mounting

The claw assembly and cutter pinned pulley were hence coupled to same shaft as shown in Fig 10. The shaft, pinned pulley and claw assembly are held to the cutter frame with the help of square block containing 6204 bearing in it. The pin is also fitted to the cutter pulley with the help of a small bearing to allow free reciprocation motion. The pin is surface finished in order to reduce friction during the motion.

Fig 10.Claw mechanism

Table 4.Specifications of components used in the Rice harvester machine

Part	Specification
Motor	3 phase, 0.5 HP, 1 ampere AC motor
Cutting Blade	No of teeth - 13 Material - Hardened Steel Included angle - 90 degrees Blade length - 470 mm Blade thickness - 6 mm Groove width - 6 mm Teeth length - 25mm
Frame	25x25mm^2 - 5 metre
	50x25 mm^2 - 1 metre
	25mm diameter - 0.5 metre
Wheels	250mm diameter - 2 no's
Bearing	6205ZZ - 4 no's
	6204 - 1 no.
Pulley	120mm diameter – 1 no. 20mm diameter – 1 no.
Belts	A35 V belt
Electricals	3 Phase direction change Switch – 1 no
	Three phase wire – 150 metres
Bolts, nuts and washers	As required

The cutter base frame which holds the cutting blade was welded to the main rectangular base frame which holds the motor. All components were assembled to the main frame and final finishing processes were done. The final prototype was painted using spray paint to avoid corrosion making it ready for harvesting shown in Fig 11.

Fig 11.Final prototype of Rice harvesting machine

E. Testing and future scope:

The rice harvester machine prototype was tested in the paddy field and the rice crop was reaped competently. Assuming an average human walking speed along with the machine at 5 km per hour it takes approximately 6 hours to reap one hectare area of paddy field. Overall weight of the prototype is around 20 kilograms. A further attachment such as binder, thresher etc., can be added to harvester in future updates. The production cost of the rice harvester can be drastically reduced when accounted for mass production. The rice harvester can be estimated to be completed around rupees twelve thousand only on mass production.

F. Conclusion:

Low cost rice harvesting machine was successfully designed and fabricated with low weight making it more compact and simple. The objective to provide a low cost and dependable tool for a small time farmer was demonstrated in this paper. The design is rugged and materials used are selected considering the cost and strength factors. It has low running and the maintenance cost. All parts of this harvester machine such as cutting blade are modular and can be easily altered to accommodate further improvements in future.

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