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A Review on Compact Agricultural Harvester and Its Cutting Blade Geometries

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Abstract- Harvesting is the process of gathering a ripe crop from the fields. The automatic combine harvesters are used in most part of the world for harvesting grains. These automatic harvesters are not suitable for the farmers who have small land typically less than 2-3 acres. Thus, it is important to develop the small harvester which is considerably cheaper and more accessible to the farmers who have small land. The objective of this paper is to review the efforts made by various researchers to develop the small and compact harvester for the farmers and modify the geometry of the cutting blade of harvester.

Keywords- Crop cutter, harvester, cutting mechanism, blade.

I. INTRODUCTION

In ruler area, labor shortage for agricultural work is a common problem now days. This is mainly due to job opportunities available in nonfarm sectors which offers high wages, migration of workers from villages to cities and low status of agricultural work [1].

In India, the agricultural work can be broadly classified in two categories; conventional farming, mechanized farming. The crop cutting is one of the most important stages in farming. In most of the parts of India the farmers are using conventional methods of crop cutting. In conventional crop cutting, the crops were cut by the labor which requires lot of effort and time [2].

Due to these problems the farmers are shifting towards mechanized farming which includes the usage of harvesters. The harvesters which are available in the markets are costly to buy. However, the farmers can rent these harvesters on an hourly basis. The automatic harvesters are widely used in the developed countries and its usage results in improved production of agricultural output.

These modern machines are suitable for the farmers who have large acre of cultivation area. But; the farmers who have small land cannot afford this harvester with full features. In addition to this, the harvesters are difficult to transport in ruler part of the country. Thus, it is important to develop the small harvester which is considerably cheaper and more accessible to the farmers who have small land.

Broadly the process of crop cutting can be classified into two categories; manual harvesting, and harvesting with machineries[3]. The manual harvesting is done with the help of sickle which is a tedious task and takes lot of time. The second method involves the usage of modern harvesters which cuts the plants. Sometimes the harvesting operation is combining with threshing and winnowing. Such harvester is called as combine harvester or combine. Figure 1 shows the manual harvesting and combine harvester respectively.

Fig 1. (a) Manual harvesting (b) Combine harvester.

Table 1 shows the top 10 mini combine harvester available in India with their manufacturer, specifications and affordability.

Table 1. List of model, manufacturer and speciation's of mini combine harvester (Ref. [4])

SN	Model	Manufacturer	Specification	Cost
1	Dasmesh (3100)	Dasmesh	76hp engine 2200 rpm, four cylinders, dry type heavy duty clutch, Cutting capacity 2 acre/hr, NSW: 4, CW: 9 feet	Low
2	Preet 849	Preet	4 Cylinder engine, dry clutch, tank capacity 160 liters, small turning radius	Reasonable
3	New Hind 499	New Hind	76 hp engine 2200 rpm, tank capacity 180 liters, CBW: 2744 mm	Low
4	Preet 749	Preet	70 hp engine 2200 rpm, 32 blade, 125-	Affordable

			litre, CBW: 9 feet, 5 Speed gear box	
5	Dashmesh 7100	Dashmesh	76 hp engine, CBW: 9 feet, self-propelled	Low
6	Shaktiman 3776	Shaktiman	76 hp engine, CBW: 2185 mm, 1250 liters fuel tank capacity, self-propelled	Effective
7	Balkar B 546	Balkar	76 hp engine, NSW: 4, forced air cleaning	Fair
8	Vikas Turmeric	Vikas Turmeric	80 hp engine, high rpm, NSW: 5, CBW: 14 feet, cutting capacity: 500 mm/hr	Budget
9	Supreme mini	Supreme	2 hp petrol engine, 1 liter capacity	Perfect
10	Osaka full feed	Osaka	14 hp engine, machine size 3250 x 1340 x 1220 mm. Weight: 580 kg	Affordable

NSW: Number of straw walker, CBW: Cutter bar width

The objective of this paper is to review the efforts made by various researchers to develop the small harvester and modify the geometry of the cutting blade of harvester.

II. STAGES INVOLVED IN THE DEVELOPMENT OF MINI HARVESTER\

1. Interaction with local farmer:
As the harvester is used by the local farmers, so it is very important to know their demands and expectations from the harvester. On common method to identify the demands of the local farmer is to have interaction with them. The purpose of interaction is to identify; what machines they are using for harvesting, what is the cost of machine, is it feasible for small scale harvesting, what other traditional harvesting techniques were used by them, what labor cost incurred etc. These questions will present the picture of small scale farming and the requirement and needs of farmers.

2. Consultation with local machine manufacturer:
It is important to have a consultation with the local harvester manufacturer to get the basic behind the manufacturing of harvester. They must be interrogated with the questions like; what difficulties they are facing while designing and fabricating compact harvester, how many products they manufacture for small scale farmers, Do the firm consult local farmers while designing a new products.

3. Internet search:
With this search it is possible to know how much work has been reported earlier on the same issues. The past data like google patents, publications in national and international journals and conferences can be used. Table 2 shows the efforts made by various researchers to design and develop the compact harvester for various crops and their findings.

Table 2. List of papers on design and fabrication of compact harvester and its findings.

SN	Title of paper	Type of crop	Remarks	Ref.
1	Design and evaluation of self-propelled reaperfor harvesting multi crops	wheat, rice and forage crops	Self-propelled reaper, 5kW gasoline engine is used, can harvest a hectare in 2.5hour	[5]
2	Design and Fabrication of Agricultural Reaper Machine	Rice	5HP petrol engine, V Belt and pulley, Collecting mechanism	[6]
3	Design and Modeling of Cereal Crop Reaper Machine	Cereal	Scissoring action between cutting blades, 2.2 kW 3000 rpm diesel engine, 600 rpm cutting speed	[7]
4	Design and fabrication of small scale sugarcane harvesting and multi crop cutting machine	Sugarcane	3 BHP petrol engine, bevel gear box is used for power transmission	[8]
5	Development of Working Prototype for Ragi Harvesting and Threshing	Ragi	1.2 kW petrol engine, bevel gear arrangement, threshing mechanism is included	[9]
6	Design and analysis of arm of reaper and binder machine		7.5 KW diesel engine, 400 kg weight, cutting of crop and biding straw	[10]
7	Development of power tiller operated rice combine harvester for smallholder farmers in Tanzania	Rice	Harvesting capacity 0.42 acre/h, grain loss 28.86%,	[11]
8	Modification of a grass cutter into a small rice	rice, maize, grass,	2 HP/6,000 rpm gasoline engine, working capacity	[12]

	harvester	and other cereals	19 hours/ha, efficiency 90%,	
9	Design, Development and Fabrication of a Compact Harvester	Soybean	3HP diesel engine, collecting mechanism, Rs 900 per day per acre can be saved,	[13]
10	Design And Development Of Manually Operated Reaper Machine	Rice	5HP petrol engine, bevel gear box, V belt,	[14]
11	Design and Fabrication of Automatic Potato Harvester	Potato	Efficiency improved by 4% as compared to conventional lifters	[15]

III. PARAMETERS TO BE CONSIDERED WHILE DESIGNING HARVESTER

1. Reduce human effort:
The harvesters are designed to reduce human efforts. The machine can be operated with a single operator while not more than two labors are required to handle the machine.

2. Time and cost reduction:
The time and cost required to harvest the crops like jawar, wheat, cereals etc. should be drastically reduced.

3. Easy to handle:
The machine should be easy to handle, even a semi-skilled person can operate the machine.

4. Safer to use:
The safety is prime importance. Lot many accidents are reported and farmers have lose their life while working with the harvester.

5. Adjustable cutting mechanism:
The same machine can be used for different crops. The machine should be easy to maintain.

IV. STEPS INVOLVED IN DESIGN AND FABRICATION OF COMPACT HARVESTER

1. Selection of cutting blade:
Presently, two types of blades (Figure 1) are used in the harvester namely reciprocating and rotary type. In the rotary type of blade the more focus was given on the motion parameters and structural design of the blade, while two important factors namely; shear stresses between two parallel blades and arrangement of blades are mainly consider while designing reciprocating blades for the harvester.

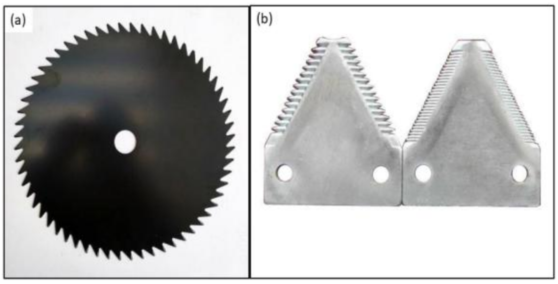

Fig 2. (a) Rotary blade (b) Reciprocating blade.

2. Diesel Engine:
LaukikRaut et al. [13], [16]–[19] designed and fabricated a compact harvester which is suitable for the farmers who have very small land typically in 2-3 acres. The machine developed by the authors was compact in nature and useful to cut two rows of soybean. The machine was powered with 3HP diesel engine and cut the plants with scissoring action of the blade. It was also provided with the collecting mechanism to collect the plants at one side of the machine after cutting. It was found that the cost harvesting using developed harvester was considerably less than the manual harvesting.

Charwak et al.[1] used reciprocating cutter blade to cut the plants and crank and slotted lever mechanism was used to convert rotary motion into linear motion. In addition to this the authors have used chain and sprocket mechanism for collecting the plants at one side of the machine. A two stroke petrol engine with 7.5 BHP rpm was used for powering the harvester.

3. Collecting Mechanism:
One of the major problems associated with the harvesting of small plants like lentils is damaging of cutting blades due to stones. To overcome this problem Gharakhani et al. [20]designed and fabricated a new safety mechanism for each blades. The authors found that forward speed, carousel speed and knife speed (independent variables) impacted on the cutting height and product losses. It was concluded that forward speed of 2 kmh−1, knife speed of 476 rpm and carousel speed of 34.83 rpm were the optimum parameters for the harvester.

Sidahmed et al. [21] designed and tested a cutter mechanism for the harvesting of lentils. The authors have developed a self-propelled harvester which could cut and collect the shoots without threshing. The machine was tested on lentils with 22% moisture, with 5 km/h speed and cutting height of 59 mm above ground. It was found that the shattering losses was not that much different from than which was occurred by hand harvesting.
Khayrallahet al. [21]quoted different problems such as shattering of leaves and seeds, uneven ripening and pods growing close to the grounds require low cutting height.

The low cutting height is also necessary to avoid leaf shattering and recover the straw. Sometimes the uneven land and presence of stones also affects the harvesting operations [22].

During working on harvester, the operator have to apply force over the pedal and control, at the same time he has to bend and twist so many times [23]. This may results in pain in body parts such as thighs, legs, buttocks and back [24]. Edris Ghaderi et al. [25] proposed a seat dimensions based on the anthropometric principles, as the authors found the mismatch between seat dimensions and anthropometric characteristics of the operator. It was observed that the seat height was too high and the seats were too narrow and shallow. The seats were not provided with proper armrest and backrest height was also not proper.

Amponsah et al. [26] pointed out that the harvesters like self-propelled, pull type and riding-tractor are not suitable for the farmers who have small land and limited knowledge about the operating the machine. Jawalekar et al. [27]developed the combined harvester for rice and wheat and evaluated its performance with manual harvesting. The authors found that the forward speed of the harvester is the crucial factor which influences performance of the harvester. Also they noted that with the decrease in the forward speed the grain damage is also decreased.

Torres et al. [28] presented a brief overview about the autonomous navigation system used in agricultural harvester. The authors pointed out that the harvester with multi sensor combination can provide more accurate positioning, mapping and navigation than the GPS system. The sensors like camera and laser range scanner (primary sensor), odometer, gyroscope and digital compass (secondary sensors) along with FL controller can be the promising alternative to control and navigate the harvester.

There are few problems associated with engine operated crop harvester namely; exhaust from an engine, vibration of engine, excess weight of and engine etc. In order to overcome these limitations, Prakash Gautam et al. [29] developed a solar energy operated compact harvester for the farmers with small land. The solar panel is mounted over the harvester and delivers power to 1 HP 1440 rpm motor. The motor transmit power to gear box through V belt arrangement and the cutter assembly reciprocates with 200rpm.

The aim of fabricating harvester is not only reducing the efforts of farmers but also improving the economics of the farmer. Aravind et al. [30] manufactured the paddy harvester which can harvest two rows simultaneously. The authors have tested the harvester and compare the cost of traditional harvesting with newly developed harvester. The newly developed harvester made the harvesting process faster and reduced the cost of harvesting by 53%. Similarly Laukik Raut et al. [13] stated that amount saved by newly developed compact harvester was Rs. 900/- per day per acre when compared to manual harvesting.

V. DESIGN OF BLADE OF HARVESTER

The degree of mechanization in agricultural process is increasing day by day hence it is important to reduce the energy consumption of the equipment's so as to reduce the carbon emission [13], [31], [32]. The cutting blade is one of the major components in the harvester which needs to be carefully designed so as to reduce total energy consumption of the cutting process. Presently two types of blades are used in the harvester namely reciprocating and rotary type. In the rotary type of blade the more focus was given on the motion parameters and structural design of the blade [33].

While designing the reciprocating blades more focus reported on motion parameter matching and blade arrangement. Most of the harvester have rotary blade as less cost is involve in its manufacturing and does not require any separate mechanism to provide motion to the blade. However, this blade is suitable for the crops like ragi and pady as it is thin in nature. This problem can be overcome by using reciprocating blades which are more effective for thick and strong straw.

Two important factors namely; shear stresses between two parallel blades and arrangement of blades are mainly considered while designing reciprocating blades for the harvester. Vishal Ullegaddi et al. [34] designed a cutting blade using finite element analysis and found that maximum shear stress on the blade was 4.87MPa when applied a cutting force of 85N. Figure 3 shows the design of the harvester cutting blade.

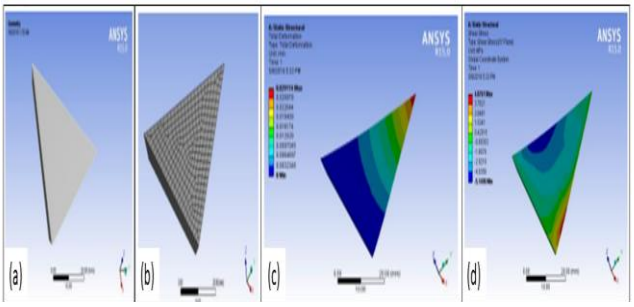

Fig 3. (a) Geometry of cutting blade (b) Mesh model of cutting blade(c) Total deformation of cutting blade (d) Shear stress distribution of cutting blade.

The authors[35] reported that the manufacturers are using same cutting blades which is used to cut wheat and rice for cutting corns. This resulted in poor quality of stubble, large cutting resistance and energy consumption. Therefore, it is very important to develop the reciprocating blades to cut corn stalk. Tian et al. [36]designed a cutting

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blade based on bionic principle and inspired from the design of tooth profile of horsfieldi palate.The authors reported that there was a reduction by 10.73% and 12.89% in cutting energy consumption and cutting forces respectively when used bionic design for the blade (Figure 4).

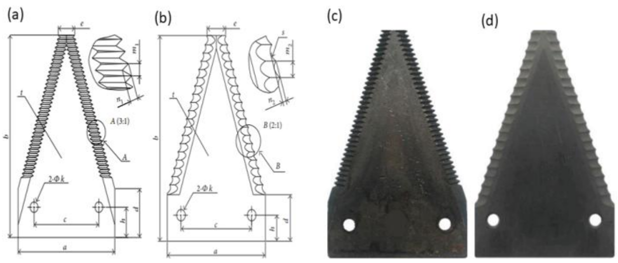

Fig 4. (a) Sketch of Ordinary blade (b) sketch of Bionic blade (c) fabricated ordinary blade (d) fabricated bionic blade.

Abdallah et al. [37] concluded that the cutting force required for the sugarcane ranges between 1272 to 2698 N, lifting moment ranges between 30.62 to 129.11 Nm while maximum lift force varies between 105 to 300 N. Patil et al. [38][39] observed that rotating blade system is commonly used for thick stalks than cutter bar cutting system as it offers more cutting resistance. In on the experiments carried out by Mello et al. [40]reported that forward blade with a 3 mm pitch showed higher energy efficiency as it has more projection thus easily penetrated and makes the cutting process easier. Figure 5 shows the schematic of backward and forward curved serrated edge blade.

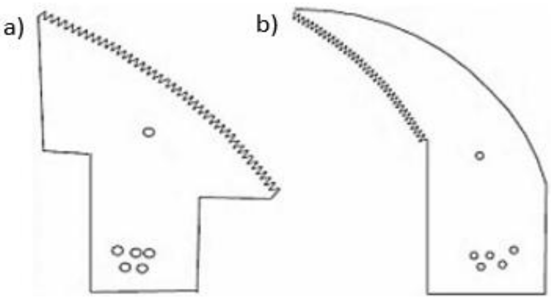

Fig 5. (a) Backward-curved serrated-edge blade, (b) forward-curved serrated-edge blade.

Frazzetta et al. [41] quoted that the shape of cutting blade plays an important role because it is directly related with power requirement and amount of cutting force. Figure 6 shows cutting blades with smooth edge and serrated profile. The authors further stated that the serrated-edge blades required less cutting forces, power and produced better cutting quality. One of the drawbacks of serrated profile blade was material loss while cutting which was significantly greater than smooth edged blade.

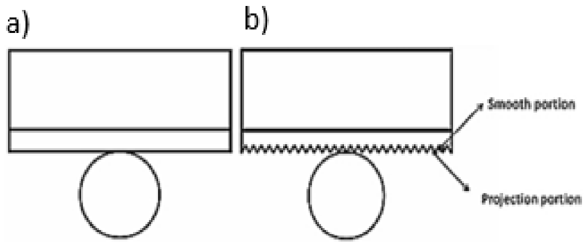

Fig 6. (a) Cutting by the smooth-edged blade; (b) cutting by the serrated blade.

VI. CONCLUSION

This paper presented an in depth review of the efforts made by various researcher to fabricate compact harvester and design the cutting blade. The following conclusions and future research directions can be drawn from this work

- It is observed that the harvesters developed by various researchers are comparatively large in size so there is still scope to manufacture the harvester which is compact and light in weight.
- The shape of cutting blade plays an important role because it is directly related with power requirement and amount of cutting force. The serrated-edge blades requires less cutting forces, power and produced better cutting quality. One of the drawbacks of serrated profile blade was material loss while cutting which is significantly greater than smooth edged blade.
- The bionics principle can be used to design the profile of the blade which significantly reduces the cutting forces and power requirement.
- In the rotary type of blade the more focus should be given on the motion parameters and structural design of the blade, while two important factors namely; shear stresses between two parallel blades and arrangement of blades should be consider while designing reciprocating blades for the harvester.

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