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Development of a power tiller operated safe grain cleaner

Abstract

Threshed grain contains impurities which should be removed as soon as possible after harvesting and certainly before storage. [12] Clean grain has a higher value than that is contaminated with straws, chaff, weed seeds, soil, rubbish, and other non-grain materials. Cleaning improves the storability of grain, reduces price penalties at the time of selling and improves milling output and quality. Traditionally farmers use wind or fan to remove foreign matter from the grain. In mechanical grain cleaner, a fan and several superimposed reciprocating sieves or screens are now used. These can be operated manually or by electric motor. Traditional cleaning methods are laborious and mechanical cleaners are costlier for a farmer. An attempt was made to develop power tiller operated grain cleaner incorporating safety protection. Power tiller operated (PTO) grain cleaner has been developed at BRRI research workshop and tested at BRRI threshing yard. Two flat bar of 68x10 cm size were taken and both ends of the bars were made curved in same direction. Those were fixed with a pulley as cross blade and fitted rigidly with the flywheel of a power tiller engine and a protection cage was made as safety measures to protect the operators/users from accident. The cage was made with mild steel (MS) wire (1/8th) and tightly attached with chassis and oil tank by nut bolts. Air flow rate was found 7 m/s at a linear distance of 1 m and decreased to 3 m/s at 5 m from center of flywheel. No foreign matter was observed in cleaned grain during operation. Fuel consumption was found about 700 ml/hr. About 1200-1600 kg paddy can be cleaned in an hour. Male or female can use it easily without any accidental risk i.e. clogging dress with flywheel. However, the developed safe cleaner can significantly contribute to improving product quality separating un-ambient materials especially foreign matter, insect bored and diseased grain.

Key words: Power tiller, Protection, Safe, Grain, Cage and Cleaner

Introduction

Three forth of total world population consumes rice as staple food as major constituent of their daily diet. Rice production is a crucial area of the agro-technical complex; it has the biggest impact on the supply of food to the population (Bilde, 2015; Matveev, Valieva, Kislov, &Trubetskaya, 2016). Harvesting, threshing, drying and bagging bears contaminants such as stones, sticks,chaff and dust (Usman et al., 2014) into grains, which needs to be cleaned. Materials separated through the concave and sieves are composed of grains, chaff and other small components of material other than grain (Miu, 2003). After manual threshing or by using hold on type threshers for threshing rice crop winnowing operation is necessary. Winnowing removes unwanted materials like straws, chaffs, weeds, soil particles and rubbish from grains. It improves grain storability, reduces dockage during milling, gives good quality milled rice and improves the milling output. It also reduces insects, pests and disease (Usman et al., 2017). Seed comes from the field, contains various contaminants like weed seeds, other crop seeds, and such inert material as stems, leaves, broken seed, and dirt. These contaminants must be removed, and the clean seed properly handled and stored to provide a high quality planting seed that will increase farm production and supply uniform raw material for industry.

Winnowing has greater importance as clean seed maintains the genetic purity of seed. One of the most labor-intensive and important operations in grain production is seed cleaning (Bilde, 2015; Sheidler et al., 2014; Stan & Linde, 2014). After manual threshing or mechanical threshing, winnowing operation is necessary (Hossain et al. 2023; BRKB, 2020). Winnowing is process of separating grain from a mixture of grain and chaff in an air stream created artificially or naturally. Separation is achieved by allowing the air stream to pass through the mixture falling vertically down. The grain being heavier material gets deposited almost at the place of dropping, whereas lighter material (chaff) is blown away to a greater distance. The winnowing operation which is very common in Bangladesh is done by kulaon threshing floor where all harvested crops are stacked in bundles. This is very simple method but output is very low, i.e., 40-45 kg/hr(Ali, 1997). For that, one has to wait

for wind currents. But this method is time consuming, uncomfortable and laborious and totally depends on wind conditions. Labor is required to stand at higher platform and pour grains from higher to lower elevation with unsuitable body conditions which increases drudgery of labor. Air is generated by natural or mechanical fan. However, the limitation of natural wind method for cleaning is its unpredictable direction, speed and continuity, high labor requirement and rather imprecise degree of separation (Aguirre and Garray, 1999). Considering these limitations in winnowing, now-a-days small fans are used but it also involves same drudgery, labor has to stand in front of fan and pour grains in prevailing direction of wind. This method has also one limitation that percentage of blown grain was high due to improper position of operator. Also these operations are carried out in open yard and subjected to inclement weather conditions. Hollatz and Quick (2003) reported that a combination of aerodynamic- mechanical process is used for grain cleaning and that it would be a simple mechanical sieving process without fan.

Miu (2003) modeled vibratory cleaning sieve stochastically and divided overall movement of grain within chaff layer as segregation movement to the top of the sieve (diffusion created by the sieve vibration), transport movement along the sieve and passing through sieve openings. Transport of particles along an oscillating sieve influences the efficiency of the process and also affects metering of particulate substances along an oscillating pan (Elfverson and Regner, 2015) and particles caught in the opening reduce the sieving efficiency (Picket and West, 1988).No significant progress has been made in the design of new efficient grain cleaners of local manufacture or the development of improved grain cleaning techniques (Liang, Li, Xu & Zhao, 2016; Mingjie, Wei & Jianguo, 2012). One of the crucial problems facing manufacturers of competitive grain cleaners is the substantiation of rational designs and equipment for current technologies of cleaning and separation of grain seeds, which would achieve good results at minimum cost (Bischoff, 2015; Clearout, 2015). It needs to improve postharvest cleaning and separation of grain without implementing advanced technologies and creating next-generation

grain cleaners (Eskhozhin & Bayshugulova, 2015; Capov & Shepelev, 2010). These types of winnower use in Bangladesh are sophisticated and costly. Only 23% farmers are large and medium category in the country. Therefore, it is crucial to develop low cost and efficient grain cleaning mechanism.

In Bangladesh, Power tiller is a key agricultural element used in diverse operations i.e. tillage, planting, harvesting, milling and goods transportation. It would be better to design and develop effective grain cleaning mechanism useable in existing Power tiller at farmer's level. Thus, the study was undertaken to develop an effective cleaning mechanism and incorporate in available power tillers in Bangladesh.

Methodology

The study was conducted at BRRI research workshop; and tested at BRRI threshing yard and a farm house holder at Harinakundu, Jhenadah.

Components of PTO grain cleaner

Power tiller operated grain cleaner is consisted of the components: Power tiller, cleaning unit and safety cage. Fourteen horse power (hp), power tiller was used to develop the power tiller operated grain cleaner. SS flat bar, SS rod, Wheel plate, Nut, Bold were used to cleaning unit and safety cage.

Design Considerations

i. The machine should fulfill its basic task of cleaning the grain.

ii. It should be economical.

iii. There should not be a need for repeat of the process

iv. It should be portable to ease transportation.

v. The design should be optimized to reduce fatigue of farmers.

vi. The attachments should employ low cost materials, methods and standard parts that are locally available.

Determination of moisture content

Moisture content of grain and straw was determined by taking sample during each test. 100 g grains were taken and 10 g sample of straw was collected and filled in the moisture boxes.

Measurement of Speed

Digital Tachometer DT2234C+ was used which displaces the revolutions per minute on digital screen. MS6252A Digital Anemometer was used to measure the wind speed during the experiment.

Working procedure

1. The followings are the steps which were followed to evaluate the performance of a solar power operated paddy winnower:
2. At first, 50kg of paddy sample were taken.
3. After checking the winnower was started and then paddy was put into the hopper
4. Stopwatch was started at the beginning of winnowing and it was stopped at the time of winnowing finished completely.
5. The date of air speed rating was taken by using anemometer.
6. After finishing the winnowing, original paddy was weighted, chaff, immature paddy, dust weight was taken by a weight machine.

Performance evaluation of solar power operated paddy winnower

Measurement of performance was primary importance and was carried under controlled conditions to obtain reliable data on machine, such that work capacity, quality of work, adaptability to different kinds of crop in comparison with local methods. The feed rates on different parameters like cleaning efficiency, output capacity of winnower was also determined.

Determination of grain ratio

Weight of sample of paddy grain, weight of clean grain and impurities was measured and the grain ratio was calculated using the following equation (Kadam, 2016).

Grain ratio =

2 Percentage of blown grain

The sound grain carried away along with the straw and chaff was calculated (Kadam, 2016).

Percentage of blown grain =

Where,

F= Quantity of whole grain collected at chaff outlet per unit time, kg.

A= Total grain input per unit time by weight, kg.

Cleaning efficiency

Cleaning efficiency of the winnower can be defined as the ability to separate the sound grains from a mixture of dust, straw and chaff (Kadam, 2016).

Cleaning efficiency (ɳ)=

9 Where,

I =Weight of whole grain per unit time at main grain outlet, kg.

J= Weight of whole material per unit time at the main outlet, kg.

Theoretical Considerations

The following theories and equations were considered in this study

Optimal fan wind speed and corresponding required rpm

It was found that the optimal wind speed for this application was 900-1400ft/min, or 4.57-7.11 m/s. In order to achieve this wind velocity, a specific rotational speed (rpm) would be required of the shaft of 8 the centrifugal fan. This was calculated using the fan affinity law (Ngadi, 2013).

where,

Q1 = first air flow rate (m3 /min)

n1 = rotational speed corresponding to Q1 (rpm)

Q2 = second air flow rate (m3/min)

n2 = rotational speed corresponding to Q2 (rpm)

Due to the equal diameter of two pulleys, the optimal fan wind speed and corresponding required rpm is the same.

Pulley diameter

To size the correct dimensions of the pulley, a ratio between RPMs and pulley diameter was used (Ngadi, 2013).

where, d1 = diameter of driver pulley, cm

n1 = rotational speed corresponding to d1, rpm

d2 = diameter of driven pulley, cm

n2 = rotational speed corresponding to d2, rpm

Belt length

After sizing the 2 pulleys, the length of the V-belts between the motor and fan shaft is calculated by finding 14 the angle of contact between each pulley. The Angle of contact was found using the following equations (Ngadi, 2013)

Angle of contact of small pulley =

Angle of contact of large pulley = θD = π + sin

where:

D = diameter of blower pulley (cm, in) = 7 in

d=diameter of motor pulley (cm, in) = 7 in

θD= Angle of contact of large diameter pulley (rad)

θd = Angle of contact of small diameter pulley (rad)

C = Length between the pulley centers = 18 in

θd =

θD=

When the angle of contact was found between the two pulleys, the total outer 8 length of the belt was calculated using the following equation:

Length of belt =

Performance Evaluation

The performance evaluation involves collecting samples from the grain outlet and the non-grain or unwanted outlet. The weight of grains and other materials in each sample was recorded. The procedure was replicated for each throughput.

The following equations were used to determine the percentage cleaning efficiency and percentage grain loss.

Where,

Ec = 7 Cleaning Efficiency (%)

GL = Grain Loss (%)

W1= Initial Weight of Sample (kg)

W2= Final Weight of Sample (Kg)

Wtg = Weight of Total Material in Clean Grain Sample (Kg)

Wgn = Weight of Grain Material in Non Grain Sample (Kg)

Cost economics of winnowing

Fixed cost:

Interest (Tk./hr)= Principal×Interest Rate×Time

Insurance and taxes (Tk./hr) = 2 per cent of initial cost

Housing (Tk./hr)= 1.5 per cent of initial cost

Total fixed cost = Sum of all cost

Variable cost:

Electricity cost= Electricity consumed (KWh) X Electricity charge (Tk. /kWh).

Operators cost= Wage of operator/ working hours

Repair and maintenance = 10 per cent of initial cost.

Total variable cost = Electricity cost+ Operators cost+ Repair and maintenance

Operating cost= Fixed cost + Variable cost

where,

C = Initial cost of machine, Tk.

H = Annual use of machine, hr.

I = Interest rate, per cent.

L = Total life of machine, yr.

S = Salvage value, Tk.

Results and discussion

PT operated safe grain cleaner was developed using locally available material at WMMD research wokshop.

Single Blade

Two flat bar of each was taken 6800X100 mm and 1/8th thickness. End of each blade was made curve 45 degree angle in inner direction to zero degree angle at center of the blade. It was bended at inner side by 45 degree angle . Each single blade thickness was 100 mm. This airflow helps separate lighter impurities like chaff and dust from the grains. The single blade was shown in the Fig. 1.

Cross blade

Cross blade of a power tiller engine was fixed with the engine flywheel before to use. Two curved and inner bended blade was perpendicularly fixed as cross sign as shown in Fig.2. A linear distance of 1 m from the flywheel revealed the air flow rate, which fell at a rate of 3 m/s at that distance.

Safety Cage

Safety cage was prepared using stain less steel (SS wire) as shown in Fig. 4. The cage length and width were 747 mm and 723 mm respectively. As a safety precaution, a cover was created to shield the users or operators from any mishaps. The cover was composed of stainless steel wire and was firmly fastened to the chassis and oil tank with nut bolts. Farmers are safe in using PTO safe grain cleaner due to the safety cage. The safety cage can protect the user to avoid cloth cling to the PTO safe grain cleaner. PTO grain cleaner is safe for both men and women to use and won't cause any accidents among farmers.

Cleaning unit

Cross blade with safety cage was fixed with a wheel plate. The diameter of the wheel plate was 180 mm. Then it was fixed with flywheel of the power tiller. That is termed as cleaning unit as shown in Fig.5. The cleaning unit is the core of the grain cleaner and composed of cross blade, fly wheel and cage.

Fig.1 Single Blade

Fig. 2 Cross Blade

Fig. 3 Wheel Plate Attached with Flywheel

Fig. 4 Safety Cage

Fig. 5 Cleaning Unit Attached with Flywheel

Fig.6 Power tiller operated safe grain cleaner side view

Those were fixed with a pulley as cross blade and fitted rigidly with the flywheel of a power tiller engine (Fig. 1&2). Before operation, it should be fixed with the engine flywheel well. Then a cover was made as safety measures to protect the operators/users from any accident. The cover was made with SS wire and it was tightly attached with chassis and oil tank by nut bolts.

Performance evaluation

In this system the grain is cleaned removing unexpected materials. The air flow rate was found 7m/s at a linear distance of 1 m and it is decreased at 3m/s at the distance of 5m from the flywheel. Threshed paddy was fallen from man height and linear distance 5m from the flywheel. When grain was fallen at this height, the forein materilas are gone away for air flow and no foreign materials are observed in the cleaned grain (Fig.7).

Capacity of PT operated grain cleaner

About 1200-1600 kg paddy can be cleaned in an hour. Male or female can use this easily. Fuel consumption of it is 700-800 ml/hr. Safety cage gave safe guard for the user. Farmers can use this cleaner as safe one without accident.

Fig.7 PT operated grain cleaner without safety cover tested in farmer's yard

Cost of cleaning per kg in PT operated grain cleaner and manual is Tk. 0.07 and 0.31, respectively. This finding coincides with Kadam, 2011 and Manisha, 2017.Cost of cleaning can be saved by 77% using PT operated grain cleaner over manual method. The system was found economically feasible on the basis of the cost of operation of solar photo voltaic (SPV) operated paddy winnower 0.30 Tk./kg for the feed rate 120 kg/hr. which is less

than power operated paddy winnower 0.40 Tk./kg (Kadam,2011), power operated fan 0.80 Tk./kg (M/s. Benson Agro Engineering), manual operated fan 1.1 Tk./kg (M/s. Benson Agro Engineering) and manual winnowing operation 2 Tk./kg.

The economic parameters of power tiller operated safe grain cleaner for the feed rate of 120 kg/hr was carried out. The result obtained is summarized in Table 1. The economics of different paddy winnowing machine like power operated paddy winnower, power operated fan, manual operated fan and manually winnowing operation was calculated.

Table 1. Economics of power tiller operated safe grain cleaner

Sr.No

Economical parameters

Particulars

1

Cost of the grain cleaner (Tk.)

10973

2

Total fixed cost (Tk./hr)

7.9

3

Total variable cost (Tk./hr)

31.9

4

Capacity of winnower (kg/hr)

120

5

Operational cost (Tk./kg)

0.30

Conclusion

PTO grain cleaner is found satisfactory in paddy cleaning. It decreased time required to clean the rice grain, while cost is also saved. Its' materials could be sourced locally, while the machine will be suitable and needful for farmers. PTO grain 1 cleaner is much faster than manual cleaners. The cleaner can also be used any time of harvest. This can be a great advantage in hotter climates. The design of this machine is such that a single operator can do the cleaning operation with ease. This machine has a limited number of moving parts and hence requires less maintenance. The machine is cheap and easily affordable by the farmers. About 1200-1600 kg paddy can be cleaned in an hour. Male or female can use it easily without any accidental risk i.e. clogging dress with flywheel. However, the developed safe cleaner can significantly contribute to improving product quality separating un-ambient materials especially foreign matter, insect bored and diseased grain.

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