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Design and Fabrication of a Hybrid Paddy Thresher with Aspirator

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Threshing and winnowing are two different operations if we proceed through traditional method, which involves a lot of physical effort, cost, drudgery; makes human lives difficult, time consuming and yields very low level of output etc. In view of all the associated problems the hybrid thresher was designed and fabricated. In this machine, Threshing and winnowing of paddy are done simultaneously. This designed machine can be powered by both motor and or pedal. Power source during operation can be changed by adjustments. Fabrication of this machine was done at the workshop of "Department of Farm Machinery and Power Engineering". While research work was conducted on the farms of SHUATS, Prayagraj (U.P.). The threshing capacity obtained was found to be in the range of 70 - 90 kg/hr. Also, the average threshing efficiency, cleaning efficiency and threshing losses obtained were 98 %, 94 % and 5% respectively. Hence, the machine so designed was found to be economical, efficient, time saving, reducing labour charges with good quality grains and minimum damages etc. The machine was designed keeping in view of human engineering and Ergonomics so as to provide comfortable for any user be it male or female.

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Keywords: Motor; aspirator; threshing cylinder; fulcrum mechanism; autocad software.

1. INTRODUCTION

Rice (*Oryzasativa*) belongs to the grass family Oryzeae. Paddy is the most important Kharif crop of India. Rice is being a tropical plant; it flourishes comfortably in a hot and humid climate. Rice is a very flexible /adaptable plant that grows well under both flooded and rain-fed condition. The growing period of paddy is Kharif– June-July to October–November. More than 98% paddy (around 5.9 million ha) is cultivated during this season. Paddy is the basic food for two-thirds of the world population and is the most important cereal crop cultivated in the world as per the data, the total Rice production area in India during 2020-21 is 401.05 Ha (GOI), Traditional method of threshing and winnowing is very tedious, energy consuming process, insufficient and uneconomical. It reduces the quality and quantity of the grain (Broken, blown grain and damaged grain) is unsuitable for the seed purposes and also domestic as well as commercial purpose. “Conventional threshing practices of paddy is generally done by hand, bunches of panicles are beaten against its hard surface (table, wooden bar log or stones) or a flail. Through which output are obtained 10-30 kg of grain per man-hour according to varieties of paddy and method applied. The crop is threshed by being trodden underfoot (human and animal); the output is 30 -50 kg of grains per man- hour. The same method, but using a vehicle (tractor or lorry) is also a commonly applied. The total losses induced by traditional threshing methods are estimated 5 to 15%. In villages 53% of all workload done by women also she is devote 20% more as compared to men for farming operation” [1-5].

Hence, the Hybrid thresher with aspirator produces cleaner grain as compared to manual process. The application of this machine for threshing and winnowing of paddy will enhance the productivity and output as well as reduce drudgery. The objective of this work is to “Design and Fabrication of a Hybrid Paddy Thresher with Aspirator” through the analysis of the different properties of the local varieties of paddy such as Damini-Krishna, Damini-Gold, Dilkhush, Tata Mandsuri and Kanak Tata are selected as a sample for experiment. The basic components of hybrid thresher consists are wire-loop type threshing cylinder, power transmission system, motor, aspirator, mild steel sheet body and foot pedal, linkage mechanism etc. The threshing cylinder consists of wire-loops embedded in wooden bars. A shaft carries the threshing cylinder and is connected to the transmission system driven by motor or pedal. The torque required to operate the threshing cylinder and aspirator is derived by eighter motor or the force applied on a pedal through the leg of the operator. Pedal is attached on a linkage mechanism. In linkage mechanism crank, which is driver link, can make full rotation. Rotation of crank is transferred to the threshing cylinder through the pair of gear threshing. While machine is operated by motor; power is transmitted to the rotor shaft of the machine via a 1 HP electric motor. During motor connected to the threshing cylinder with the pulley and belt transmission system of 220 Volt. When, functioning the machine by operator lifts and holds a bundle of crop against the cylinder. He/she operate the pedal by one leg keeping the other leg on the ground in a standing posture. After threshing, the bundle is thrown away and new bundle is collected. At the end of work, the paddy grains over the ground are collected by sweeping the floor.

Centre of Excellence for Small and Medium Farm Implements Project has planned for Design and fabrication of affordable machine for marginal and small famers so as to increase their efficiency and productivity,. While reducing their expenses which would result in increased income of farming as per Government of India’s goal set to double farmers' income by 2022-23*. (Singh R.P., 2011).*

2. MATERIALS AND METHODS

This chapter consider the material, methods and procedure were used during the designing fabrication of this hybrid machine. We had designed; threshing unit, aspirator unit, power transmission unit (belt-pulley) with the power requirement to operate the machine etc.

2.1 The Design of Threshing Unit

The threshing cylinder as shown on Fig (1) consists of wire loop, wooden bars, bearing, circular rings, shaft etc. In wire loop type threshing cylinder consist of a number of wooden bars are fitted. On this wooden bar, number of wire loops is fixed for threshing purposes. The peripheral speed of at mid-point of loop of threshing cylinder for paddy is in the range of 15

to 17 m/s *(Sharma and Mukesh 2010).* The diameter of cylinder is 45cm [1].

Cylinder Length:-A length of 90 cm was chosen for this thresher. The length of drum of wire loop thresher is determined by using formula which is given by.

$$L = \frac{4}{\Pi D^2} \times V$$

Where,

V= the volume of drum (m),
D= diameter of cylinder (m),
L= length of cylinder (m)

Or

$$\frac{\text{legth of cylinder}}{\text{diameter of cylinder}} = \frac{Ls}{D} = 1.75$$

$$Ls = 1.75 \times D$$

Cylinder Diameter: - The speed of cylinder is also based upon the cylinder diameter. Therefore, the cylinder diameter without loop is 35 cm and with wire loop cylinder diameter is 45cm.

$$D = \sqrt{\frac{4 \times V}{\Pi L}}$$

Where,

V = the volume of the drum (m),
D = diameter of the cylinder (m),
L = length of cylinder (m)

Cylinder Speed: - Threshing drum speeds (rpm) is measured by using tachometer. The speed of cylinder obtained 340-390 rpm. Peripheral velocity is calculated as follows:

$$V = \pi ND/60$$

Where:

V = Rotational speed (rpm),
D = Threshing drum dia.,
N = speed of drum (rpm)

Wire loop on thresher: - Number of wire loop in each bar is 23. It is made of V shape -high tension steel. The Wire loop height is 10cm, spacing between loops 4.5 and total number of loops 276. No. of loop on threshing cylinder can be calculated by equation,

$$Z = N_p \times \left(\frac{I}{Ip} - 1\right)$$

Where,

Z = no. of loop,
N p = no. of rows,
l = length of threshing drum,
L p = distance between loop.

2.2 Design of Power Transmission Unit

The power transmission unit consist of motor, belt-pulley, pedal, fulcrum mechanism, spur gear assembly to produce rotary motion of threshing cylinder and aspirator shaft etc. The 2 experiment case was consider; Case 1- when machine is powered by motor, Case 2 - when machine is powered by human –

Case 1:- Motor operated - 1 HP single phase DC motor operating at 1440 rpm was used to transmit power to the thresher. In this machine, belt-pulley drive systems are used for operating threshing cylinder and aspirator. The motor was installed on the base of the main frame. One of the pulleys is mounted on the motor shaft and threshing cylinder and the other pulley was mounted on aspirator shaft. The threshing cylinder shaft was fitted with 70cm diameter pulley is connected to grooves of 10cm pulley on motor. Aspirator shaft is mounted on a 32cm pulley which is driven by a 70cm pulley located on left side of the threshing cylinder through a belt-pulley transmission system [6-8].

Electric motor - An electric DC motor (1-HP) connected to power source transmits the torque to the threshing cylinder and aspirator shaft with help of a belt pulley drive arrangement.

Design of Belt-pulley:-Pulleys diameter - For the selected 1-HP motor with 1440 rpm, the diameter of pulley chosen is 10cm for the motor pulley and 70cm for the driven pulley. For the selected motor speeds of 1440rpm, the speed on shaft or driven pulley can be obtained. By using equation as follow,

$$D_1 N_1 = D_2 N_2$$

Where,

D 1 = diameter of the driver pulley (mm),
N_1 = speed of motor pulley (rpm),
D_2 = diameter of the driven pulley (mm),
N_2 = speed of driven or shaft pulley (rpm)

Belt size - The centre distance between motor pulleys to driven pulley was obtained to be 20 cm for best performance. For proper installing of the motor on the frame to avoid unnecessary vibrations. Through the formula we defined length of belt,

$$L = \Pi/2 (D_1 + D_2) + 2C + 1/4C (D_1 + D_2)$$

Where,

D_1 = diameter of the driver pulley (mm),
L = Length of belt (m),
D_2 = diameter of the driven pulley (mm),
C = Centre distance between driver and driven pulley.

Contact angle of belt - Firstly, we define the angle of contact (Ɵ) for both driver and driven pulley. Through the equation from pulley geometric we can determine,

$$\text{Sin } \alpha = (D_2 - D_1) / 2C$$

For, the value $\alpha = 64^0$, angle of contact for the driver pulley will be,

$$Ɵ = 180^0 - 2\alpha$$

For find out, angle of contact for the driven pulley will be,

$$Ɵ = 180^0 + 2\alpha$$

Belt tension - If belt is too tight in a system, it can add stress to bearings due to which over amperage of motor or motor failure .when belt is too loose: the belt can slip while in motion and cause extra friction. Mass of belt/metre length –

$$\text{Belt speed} = \frac{\Pi d1N1}{60}$$

When,

power of the motor is 1 hp,

$$P = (T_1 – T_2) \times V_S$$

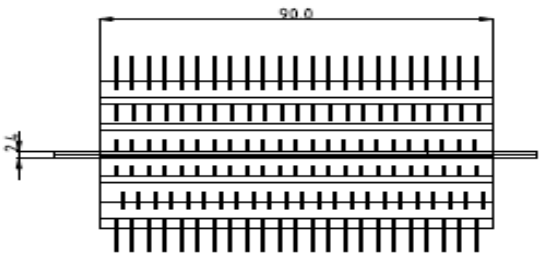
Where,

P = power of the motor (hp),
V_S= belt speed (m/sec),
T_1= tension in tight side of the belt,
T_2= tension in slack side of the belt

Case 2:- Pedal operated – "In pedal operated version of machine, the drive shall be of eccentric type. The drive consists of a crank , one end of which is connected to the spur gear and other is connected suitably to the pedal frame fulcrum which is welded to the pedal frame shall carry the pedal board. The thresher is normally operated with a speed of 400 rpm/min. Pedal transmits human power to all the unit of threshers by using spur gear and chain drive as a power transmission device. A shaft carries the threshing cylinder and is connected to the transmission system. The transmission system consists of meshed gears. The larger gear is connected to foot pedal/bar with links. The foot pedal/bar is always in raised position. On pressing the pedal, threshing cylinder starts rotating. For continuous rotation of the cylinder, the pedal is lowered and raised repeatedly"[1].

While operating the machine by operator lifts and holds a bundle of crop, ear head portion of the crop is placed on the rotating cylinder. The wire-loops hit the ear heads and grains get detached from the rest of the plant. Operator operates the pedal by one leg keeping the other leg on the ground in a standing posture. At the end of work, scattered grains to be collected from the floor [9-11].

Gear Housing - The gear housing consists of spur gear which shall engage the pinion. The bigger gear has 105 numbers of teeth and small gear has 24 numbers of teeth. The speed ratio of gear is 1: 4.3. The cast iron material is used for the working condition when power, speed and torque to be transmitted.



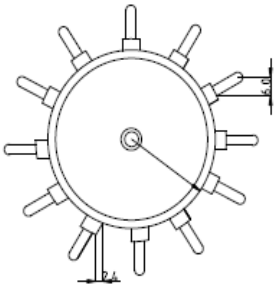


Fig. 1. Front and side view of threshing cylinder

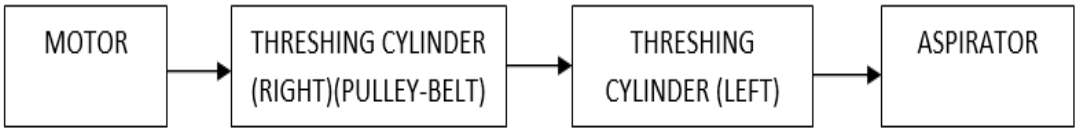


Fig. 2. Block diagram of the power transmission system in hybrid thresher (Case-1)

Fig. (3). Right side and left side view of pedal cum power operated hybrid thresher (Case-1)

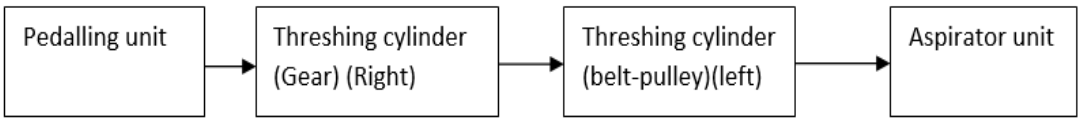


Fig. 4. Block diagram of the power transmission system in hybrid thresher (case-2)

Crank - The crank shall be mace of bar of not less than 0.9cm in diameter, this shall be preferably be 'U' shaped.

Pedal – "Pedal is used in the thresher to get power through human pedalling and with the drive mechanism, convert pedalling motion to rotary motion of the thresher cylinder. In this machine the pedal is made by wood and its length is 102 cm, width 10 cm and thickness is 3.5 cm. Its length shall be depend on the size of the cylinder" [1].

Pedal frame and Pedal frame fulcrum - The pedal frame shall be of mild steel flat of at least 0.3×0.05 cm size. The fulcrum shall be made of

mild steel bar. In case bar is used, it shall be round and square with 3 cm diameter and side respectively.

The design of Frame: - The frame is the skeleton of machine.

Side frame - The side frame shall be of mild steel angle section of nominal size of at least 0.3×0.3×0.03cm and parts shall be welded or bolted.

2.3 The Design of Aspirator Unit

An aspiratory or blower is provided on a separate shaft below the threshing cylinder. The terminal velocity and drag coefficient is important properties for designing of aspirator. The blower diameter is 32cm. The blower fan consisted of three blades of the size of 62 x 14 cm made of 2 mm thick mild steel plates. The discharge of air required for blowing the impurities from the grains. The area and velocity can be calculated as below-

$$Q_A = A \times V \ldots\ldots\ldots \quad (i)$$

Where,

Q_A = Actual air flow (m3/s),
A = Area of blower (m^2),
V = Air velocity (m/s)

The efficiency of aspirator can be considered as 30%. The theoretical discharge (QT) can be estimated as.

$$Qt = Q_A / 0.3$$

The theoretical discharge of a blower can be also obtained as,

$$Qt = \pi \times d1 \times b1 \times V_1$$

$$= \pi \times d2 \times b2 \times V_2 \ldots\ldots\ldots \quad (ii)$$

Where, b1 and b2 are the width of blades at diameter d1 and d2 of impeller $V_1$and and V_2 are tangential components of absolute velocities. V_2 can be approximate as 20% of the peripheral velocity of impeller tip for the design. Therefore

$$V_2 = 0.2 \times \pi \times d_2 \times N \ldots\ldots\ldots\ldots\ldots\ldots \quad (iii)$$

Where

N = speed of impeller (rpm).

We can obtain the impeller diameter (d2) by using equation (ii) & (iii), while the width of the impeller can be decided on the basis of the width over which air flow is required.

2.4 The Design of Power Requirement for Threshing and Aspirator Unit

The power supplied to the threshing unit by motor or by pedal N_s, is utilized to overcome idle resistance N_j and the total useful resistance due to the process of threshing N_u.

$$N_s = N_j + N_u$$

Total power requirement for the aspirator is given by the formula-

$$P = 2 \pi N T / 60$$

$$T = mg \times D/2$$

Where,

T = Torque (N-m),
P = power requirement (Watt),
N = speed of shaft (rpm),
m = mass of material (kg),
g = gravitational acceleration (N/m^2),
D = diameter (m).

From the psychometric chart, the density of air at 30^0 to35^0 is 0.88kg / m^3
Therefore, weight of air blown / min. So, HP required operating aspirator,

$$HP = \frac{\text{weight of air lifted/ min} \times \text{height tobe lifted}}{4500}$$

Let us use, 1 P motor for operating this unit.

3. RESULTS AND DISCUSSION

Initial sketch was made before the actual design and fabrication of machine to work out the plan.

Principle of operation:-The machine operates on the principle of rubbing action and impact force. When paddy bundle is placed upon rotating threshing cylinder, the grains get detached from the panicles by rubbing against loops on the threshing cylinder, loops attached on the surface of threshing cylinder produces impact force when in motion. The grains striking the loops are detached from the panicles by impact force. In this way threshing operation completed.

The separation of impurities from the grains is carried out through aspirator by blowing air.

Winnowing depends upon the aerodynamic property of grains/paddy like: terminal velocity and drag co-efficient.

Threshing cylinder:-Threshing cylinder is the basic component of threshing unit. Its main function is to detach the grains from panicles.

Transmission system:-When machine is operated by motor, the belt-pulley arrangement is used for the transmission of power. Gear and belt-pulley is used when machine is powered by human source.

Specification of hybrid thresher:- The developed thresher as shown on Fig.(6) is designed to be powered by both motor or pedal (human force).

Properties of paddy:- All the properties of grains play an important role in designing of particular equipment or machine as well as determining the behavior of the product for it handling or particular operation. Some important properties of paddy such as grain dimensions (length ,width and thickness),shape ,weight of 100 grains ,density, sphericity and the mechanical properties including angle of repose ,coefficient of friction some other aerodynamic properties consideration like terminal velocity and drag coefficient, for Damini Krishna(V_1), Damini Gold (V_2), Dilkhush (V_3), Tata Mandsuri (V_4) and Kanak Tata (V_5) were determined. (Ghadge, P. N. and Prasad, K. 2012).

Experiment results: - Hybrid Paddy thresher with aspirator was tested by using different paddy variety. The results are described and discussed as follows. For each experimental run bundles of harvested crop were manually fed in to threshing unit at uniform rate and the time requirement for threshing was recorded. Testing of machine was based on impact action. The threshing drum speed and aspirator air flow rate was recorded or experimentally find out. these type thresher have adjustment for changing power source eighter motor or pedal.

- Feed - 5kg
- Threshed grains (average) - 2.16kg
- Time taken for threshing 5 kg sample - 92.02 sec.
- Threshing efficiency- 95.5%

Performance evaluation of machine:-Time consumed for threshing of 5 kg bundle (average) - 92.02 sec.Time consumed for threshing 1 kg of paddy sample – 18.35sec.The average weight of grains obtained from outlet in 92.02 sec. (average) – 2.16kg**.** Therefore, Machine capacity – 84.70 kg/hr.

The result of the performance evaluation of the developed hybrid thresher which includes: weight of material feed, Time taken to thresh the fed material (sec.), Time for threshing (sec.), Weight of broken grain (kg), Weight of Un-threshed grain (kg) is represent on Table (3). While, through put capacity (kg/hr), Threshing capacity (kg/hr.), Threshing efficiency (%), Loss (%) is represented on Table (4)-

Threshing capacity of the hybrid thresher was obtained 70-90 kg/hr. An average threshing efficiency obtained in the range of 95-98%. The average losses of grains obtained to be 2.9-3.3%.

Fig. (5). Right side and left side view of pedal cum power operated hybrid thresher (case- 2)

Table 1. Technical specification of hybrid thresher

S. NO.	Item	Description
1	L× B ×H	110×98×89
2	Type of thresher	Hold on type
3	Type of threshing drum	Loops tooth
4	Drum diameter	114cm
5	Drum length	90cm
6	Number of loops	276
7	Power source	Human/ motor(1hp)
8	Weight	75kg

Fig. 6. Developed pedal cum power operated hybrid thresher

Table 2. Result of laboratory calculation of different properties of paddy

Variety	Length (mm) (grain)	Width (mm) (grain)	Thicknss (mm) (grain)	Sphericity	Aspect ratio	Bulk density (kg/m^3)	Weight of grains/panicle (gram)
V1	6.18	1.52	1.36	35.3	24.5	440	1.75
V2	7.54	2.34	1.5	39.1	31.1	439	3.05
V3	7.55	1.53	1.128	31.4	20.8	436	1.35
V4	7.55	2.54	1.35	38.5	33.1	439	2.1
V5	8.04	2.32	1.32	35.8	28.9	435	2.45

Table 3. Measured experimental result of the hybrid paddy thresher

Variety	Feed (kg)	Weight of paddy collected(kg)	Time for threshing (sec.)	Weight of broken grain(kg)	Weight of Un-threshed grain(kg)
V1	5kg	2.16	1834.9	0.31	0.46
V2	5kg	2.5	2164.2	0.70	0.82
V3	5kg	2.13	1972.4	0.19	0.34
V4	5kg	2.6	2000.2	0.46	0.61
V5	5kg	2.2	1890.6	0.40	0.55

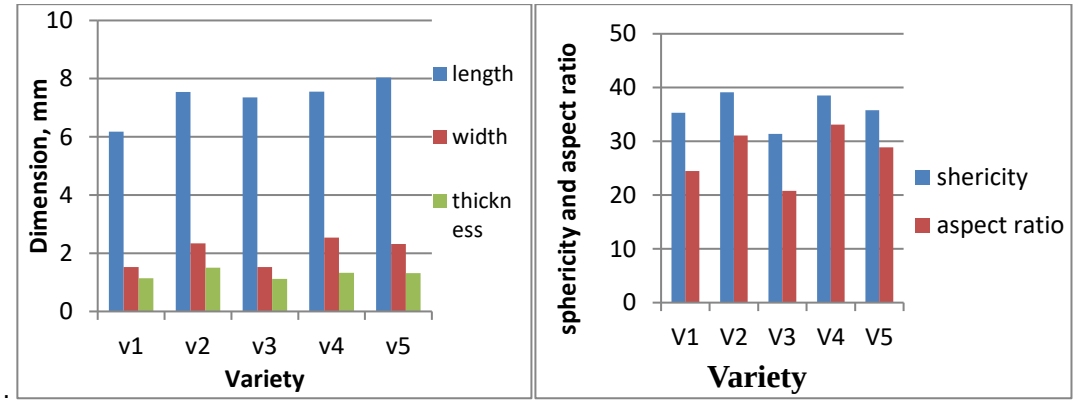


Fig. 7. Size and Shape parameters of paddy grains

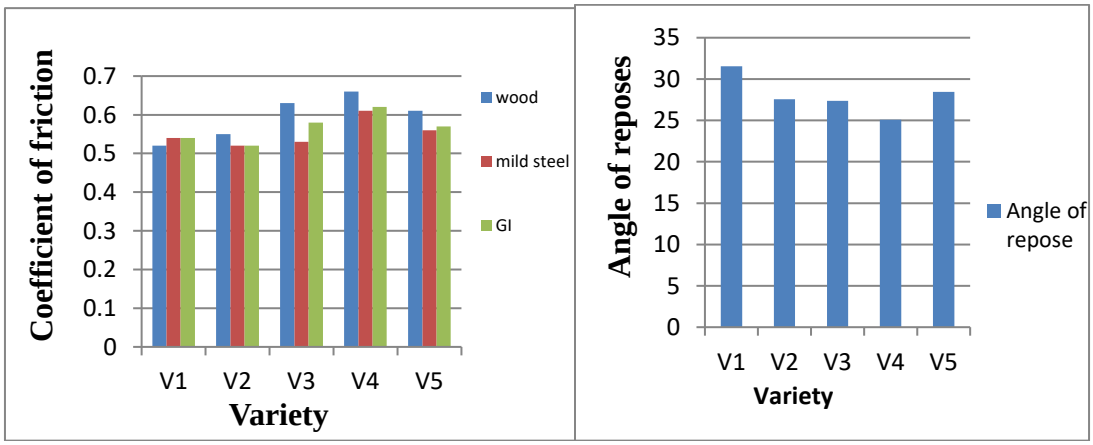


Fig. 8. Coefficient of friction and Angle of repose of paddy grains

Table 4. Calculated Performance result of the hybrid paddy thresher

Variety	Through put capacity (kg/hr)	Threshing capacity (kg/hr.)	Threshing efficiency (%)	Loss (%)
V1	120	71.92	95.5	3.2
V2	140	80.1	96.1	3.3
V3	110	90.27	95.72	3.1
V4	150	69.21	98.45	2.9
V5	130	87.65	97.1	3.1

4. CONCLUSION

Traditional method of threshing and winnowing of paddy was very tedious, causing pain in the arms. The workers had to do the job in squatting position for long time which causes pain in thighs, legs and feet, energy expenditure is very much, requires more labours etc. Hence, there was a need for appropriate thresher with aspirator that could perform both threshing as well as winnowing operation in the same time. So this hybrid thresher was designed and developed.

From the above study undertaken following conclusions are drawn.

- The performance of pedal cum power operated hybrid thresher was satisfactory.
- The cost of the machine is less so the farmers can buy this machine; they recover the invested money back in less time.
- This traditional method of threshing and winnowing is highly tedious, inefficient and time consuming with low productivity, hence to remove all these associated problems this hybrid machine was designed.
- By using this machine the threshing and winnowing operation of paddy could be done faster with reduced labor cost and threshing time.
- The machine is made especially for marginal and small farmers.
- For optimum threshing and winnowing of paddy the average speed of threshing shaft was kept 390 rpm and the average speed of the aspirator was kept 880 rpm.
- The air that was coming out from the aspirator was 2.4 to 3.5 m/sec after reading from the anemometer for winnowing.
- The threshing capacity for both pedal cum power operated are respectively 70-90 kg/hr with 98% threshing efficiency.
- Power requirement for operating threshing cylinder is 1 hp motor with 1440 rpm is used.
- Human engineering and Ergonomics so as to provide comfortable operation for male or female.

CONFERENCE DISCLAIMER

Some part of this manuscript was previously presented in the conference: 6th International Conference on Strategies and Challenges in Agricultural and Life Science for Food Security and Sustainable Environment (SCALFE-2023) on April 28-30, 2023 in Himachal Pradesh University, Summer Hill, Shimla, HP, India. Web Link of the proceeding: https://www.shobhituniversity.ac.in/pdf/Souvenir-Abstract%20Book-Shimla-HPU-SCALFE-2023.pdf

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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