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Development of pedal operated thresher for finger millets

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ABSTRACT : This paper deals with the development of a pedal operated millet thresher. Millet is one of the oldest human foods and believed to be the first domesticated cereal grain. Millets are important food for sustaining tribal population in Bastar region of Chhattisgarh. Available evidence suggests that the mode of threshing finger millet is by traditional method like beating with sticks, rubbing and trampling finger-heads under bullocks feet or men feet. Traditional method is time wasting, energy sapping and often the grains are broken. Pedal operation is the most efficient way of utilizing power from human muscles. Keeping this thing in mind, pedal operated thresher for minor millets with spike-tooth type threshing cylinder was designed, fabricated and tested. This machine basically consists of four major components: feeding, threshing (consisting of threshing cylinder, concave and cylinder casing), cleaning and power transmission mechanism. The developed millet thresher has the ability to winnow the premature grains and leaves, which are often lighter, thus, leaving aside the massy grains that, will be collected. It is beneficial for farmers with reduced time of operation, reduction in breakage of the grains and separation of the stalk from the grains. The machine is economically viable can be used by farmers easily.

KEY WORDS : Finger millet thresher, Spike-tooth type threshing cylinder, Pedal operated thresher

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Millet is one of the oldest human foods and believed to be the first domesticated cereal grain. Millets are the principal food sources in arid and semi-arid regions of the world. India is the top one millet producing country in the world. Millets are important food grains in the diets of a large section of population in India. Millets are important food for sustaining tribal population in Bastar region of Chhattisgarh. The important small cereals among tribes of Bastar region after rice are kodo millet (*Paspalum scrobiculatum* L.) and finger millet [*Eleusine coracana* (L.) Craertn] (Verma and Mishra, 2010). Chhattisgarh facing problems of power storage due to rapid industrialization, like non-availability of power in interior areas and large scale unemployment of semi-skilled worker.

The present design of threshers available in the market are mostly for threshing of cereal and legume crops for rather than minor millets like finger millet (Ragi) hence, only conventional method is used by the farmers. Threshing process of the millet is a major constraint in this regard. The traditional method for threshing of finger millet is generally done by hand. Bunches of panicles are beaten against hard elements (e.g. a wooden bar log, bamboo table or stone). In many areas, the crop is threshed by being trodden underfoot by humans or animals (Kumar *et al.*, 2013). This method often results in some losses due to the grain being broken or buried in the earth. Often this local method of processing the crop leads to low quality product due to the presence of impurities like stones, dust and chaff.

In the view of socio-economic conditions of farmers living in villages of developing countries including India, human muscles power can be good alternative to fulfill the energy requirements for performing many activities like threshing. Pedaling is the most efficient way of utilizing power from human muscles. The power levels that can be produced by an average healthy athlete is 75 W maximum (Modak and Bapat, 1987). A person can generate more or same amount of power for longer time if they pedal at certain rate. A simple rule is that most people engaged in delivering power continuously for an hour or will be more efficient when pedaling rate is in the range of 50-70 rpm (Tiwari *et al.*, 2011). Keeping these things in mind, the study was planned to develop a pedal operated millet thresher to utilize human muscle power for threshing of finger millet.

■ METHODOLOGY

Determination of the threshing drum diameter :

Threshing drum diameter is needed in order to determine the capacity of the threshing drum. Therefore, the diameter of the threshing drum was determined using the standard formula for calculating the volume of a cylinder and is given as follows :

$$V = \frac{\pi d^2}{4} \times L$$ (Gbado *et al.*, 2013) **(1)**

where,

V = the volume of the drum (m^3)

d = the diameter of the cylinder (m)

L = the length of the cylinder (m)

Evaluation of weight of threshing drum :

$W = M \times g$ (Khurmi and Gupta, 2005) **(2)**

M = ° × v

where,

W = the weight of threshing drum (N)

M = mass of threshing drum (kg)

g = acceleration due to gravity (m/s^2)

ρ = the density of the drum (kg/m^3)

V = the volume of the cylinder (m^3)

Mass density of steel (ρ) = 7850 kg/m^3

Power required to combing off grains from stalk :

The power required to thresh grains from the millet panicles is expressed as:

$P = T \times \mu$ (Khurmi and Gupta, 2005) **(3)**

$$\omega = \frac{2\pi N}{60}$$

where,

P = is the power required (watts)

T = torque of the drum (Nm)

ω = angular velocity (rad/s)

N = speed of the threshing drum (rpm)

F = the impact force required to thresh millet

r = the distance of point of force application from axis of rotation (m)

The torque resulting from individual force is given by :

$T = F_i \times r_i$

where, F_i and r_i force and radius, respectively

Total torque (T) on the drum was calculated as follows:

$T = T_R \times K_b$

where, K_b is the number of beaters on the drum

Torque, $T = F_r$ **(4)**

Assuming that force acts per unit length of tong, taking force per 10 mm segment of length.

= FN Ĝ FN/10 mm

= 0.1 FN/mm **(5)**

Considering Fig. A

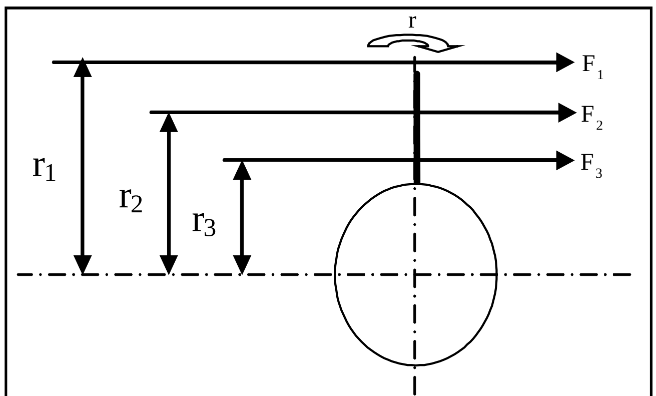


Fig. A : Cross section of tongs on rotating drum

The torque resulting from individual force is given by,

$T = F_i \times r_i$ **(6)**

where, F_i and r_i and i_{th} force and i_{th} radius, respectively.

Resultant torque,

$$T = F_1r_1 + F_2r_2 + \ldots\ldots\ldots\ldots F_ir_i = \sum_{i=1}^{i=n} F_ir_i$$

where n = number of length segments given by,

Torque required to combin off grains from stalk :

This is given by,

$P = T_t\mu$ ETF

where ω = angular velocity in rad s^{-1}

Belt analysis :

Considering Fig. B

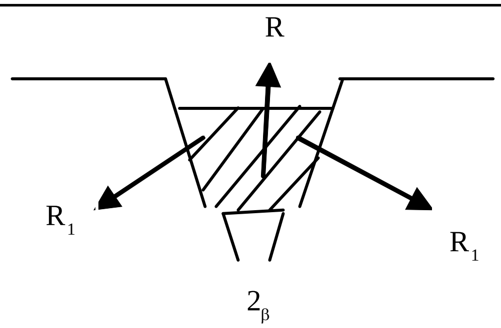


Fig. B : Cross-section of vee-belt

where,

R_1 = normal reactions between belts and sides of the groove,

R = total reaction in the plane of the groove.

μ = co-efficient of friction between the belt and the sides of the groove

Resolving the reactions vertically to the groove, we have :

$R = R_1 \sin \quad + R_1 \sin \quad = 2\ R_1 \sin$ **(8)**

$R_1 = R/(2 \sin \beta)$

Frictional force = 2μ R, = $2\mu \times R/(2 \sin\beta)$

$= \mu\ R/\sin$

$= \mu\ R\ \text{cosec}$ **(9)**

For vee-belt, the relation between T_1 and T_2 is given by,

$\log(T_1/T_2) = {}^{a-}\ \text{cosec}$ ENMF

where,

θ = Angle subtended by the arc along which the belt touches the pulley, at the center.

Power transmitted by belt :

Considering Fig.C

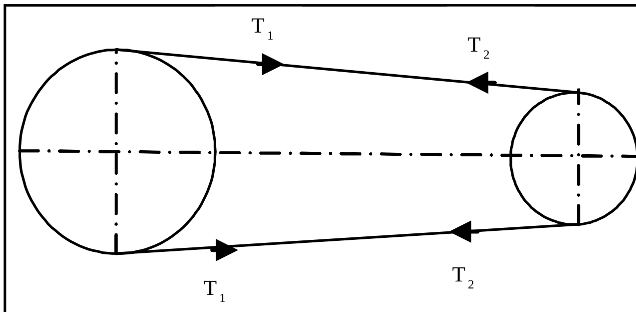


Fig. C : Power transmitted by belt

Effective driving (turning) force, is given by,

$T_1 - T_2$ **(11)**

Power transmitted, is given by,

$P = (T_1 - T_2)\ v$ **(12)**

where,

T_1 = Tension in the tight side in N

T_2 = Tension in the slack side in N

V = Velocity of belt in m/s

Torque exerted on driving pulley, is given by,

$(T_1 - T_2)\ xr_2$ **(13)**

$(T_1 - T_2)\ xr_2$ **(14)**

Centrifugal tension, Tc, is given by,

$T_c = mv^2$ **(15)**

where,

m = mass of belt per met length,

v = velocity of belt,

Tension on tight side of belt, T_1 is given by,

$T_1 = T - T_c$

but,

$T = f \times a$

where,

T = maximum tension in the belt

f = allowable tensile stress in N/mm^2

a = cross sectional area of belt.

Pulley analysis :

Centrifugal stress induced in the run of pulleys,

$f_c = {}^{\circ}v^2$ **(16)**

where,

ρ = density of the rim material,

v = velocity of rim, given by, $v = \frac{\pi DN}{60}$

where,

N = speed of pulley in rpm,

D = diameter of pulley.

RESULTS AND DISCUSSION

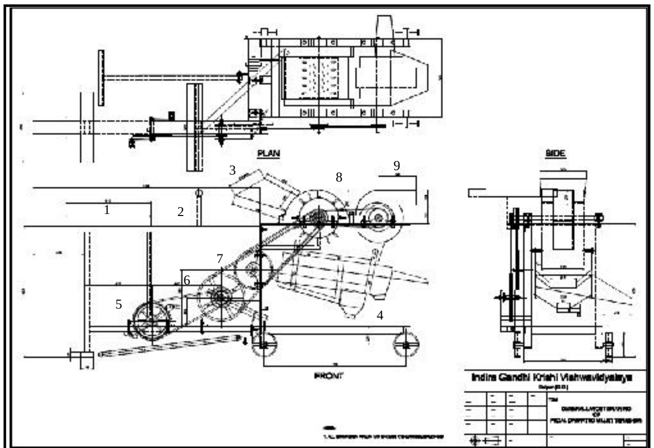
In construction the pedal operated millet thresher basically consists of these major components: drive unit, frame assembly, feeding mechanism, threshing mechanism (consisting of threshing cylinder, concave and cylinder casing), separating and cleaning mechanism.

Drive unit :

The seat is adjustable in height to fix the height according the operators posture and comfort. Pedal were transmitted human power to all the units of threshers by using chain drive and v-belt drive as power transmission device. The pedals, in turn, are fixed to a chain ring (sprocket) with teeth that engages the bicycle's continuous chain. The chain then transmits the pedaling action to a cog on the hub of the front wheel causing the front sprocket to rotate and then drive the shaft on which pulley is mounted. A sprocket of 250 mm diameter (60 teeth) is fitted on pedal operated shaft. The pedal power is transmitted to the main pulley of 300 mm diameter fitted with smaller sprocket having diameter of 70 mm (18 teeth). The main pulley transmitted power to the threshing unit (50 mm diameter pulley) by a V-belt. The threshing unit sep up pulley (100 mm) transmit power to the blower pulley (140 mm). Step-up pulley (130 mm) transmits power to the sieve shaker pulley (225 mm).

Frame assembly :

The frame was made of mild steel angle, which gives sufficient strength to the thresher. The frame was fabricated from 35 × 75 × 2 mm channel section. Four iron angle of 35 × 35 × 5 mm size were welded vertically on it to support the side plates. Four angles were bolted on the support in bearing and roller shaft. The provision was made on the frame for fixing. The main frame is shown in Fig. 1 and 2. The bottom of the frame was above 160 mm from the ground surface. The main frame was 2500 mm long, 1130 mm wide and 1140 mm in height. Four wheels were provided for easy transportation of thresher.



(1. Saddle, 2. Handle, 3. Fedding chute, 4. Sieve mechanism, 5. Chain wheel, 6. Main pulley, 7. Sieve shaker pulley, 8. Threshing unit, 9. Blower unit)

Fig. 1 : Design layout of pedal operated finger millet thresher

Fig. 2 : Pedal operated millet thresher in operation

Feeding mechanism :

The feeding chute was fabricated according to specifications using mild steel sheet. The feeding hopper is welded to the top cover of the threshing unit, which is hinged on mainframe of the thresher it can be lifted up for visual observations and clearing of the space between roller and belts. The dimensions of the feed hopper are 320 × 220 × 340 mm (L×W×H) with thickness of 2 mm.

Threshing unit :

The threshing unit of the pedal operated finger millet thresher consists of driving pulley is fitted on chain and sprockets belts are mounted for threshing the ear-head samples. Threshing mechanism consists of threshing cylinder, concave and cylinder casing.

Threshing cylinder :

The millet thresher fitted with a closed type spiked tooth threshing cylinder of 250 mm diameter. Round shaped 10 mm diameter spikes (36 Nos) are bolted in 4-paired rows and rectangular plate of 55 x 25 x 3 mm was welded (16 Nos), in staggered manner on the cylinder. Spike length can be adjusted to change the cylinder concave clearance. The cylinder top cover is semicircular in shape and is made of mild steel sheet. Angle iron pieces (25 x 25 x 3 mm size) are welded on the inner side of cover parallel to axis to act as rubbing base for threshing of the crop.

Concave :

The concave made of 6 mm square bar with 7 or 9 mm gap, is fixed beneath the cylinder. The square bars are welded to two semicircular mild steel side plates at 7 mm or 9 mm gap. The concave adjusting the length of spikes the width and length is 250 mm and 450 mm, respectively.

Separating and cleaning mechanism :

The separating and cleaning unit consisted of blower and sieve shaker.

Blower :

An aspiratory blower is provided on a separate shaft behind the threshing cylinder. The blower diameter was 290 mm. The blower fan consisted of four blades of the size of 140 x 115 mm made of 2 mm thick mild steel plates. Straw and chaff from the top sieve are sucked by the blower and blown away to one side. Blown material can be collected, if required, by attaching a bag at the outlet.

Sieve shaker :

Sieve shaker consisted of three sieves with separate outlet and is suspended below the cylinder concave assembly on the main frame, through hangers. It is oscillated by an eccentric drive with provision for altering the amplitude of oscillations. The top sieve separates the heavier pieces of straw from grain and can be changed as per crop. The grains; passes through the top sieve to middle sieve, which separates the grain from fine material (dust, grass, seeds, etc.) and clean grain flows out from middle sieve outlet. Fine material passing through the middle sieve is collected at the bottom outlet.

Conclusion :

The development of a pedal operated thresher for finger millet has been successfully carried out by this work at the farm of FAE, IGKV Raipur during 2014. The machine was capable of threshing, separation of stalk from grains and reduction in number of broken grains, thereby, giving better method of threshing than the traditional methods. All the materials used were locally sourced. The performance of pedal operated millet thresher was evaluated at three different pedaling speeds were taken as 35, 45 and 55 revolution per minute. The experiment was conducted with VR-708 of variety of finger millet. The speed ratio of pedal to the threshing cylinder is 1:20. Feeding rate was found 39.13 to 43.37 kg/h whereas the output capacity was found to vary from 6.39 to 7.17 kg/h for finger millet crop at 11 per cent (wb) grain moisture content. The threshing efficiency and were 66.92 to 69.25 per cent and cleaning efficiency were 87.77 to 88.44 per cent at pedaling speeds 35, 45 and 55 rpm, respectively. The total grain loss was 44.45 per cent.

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