

Design of Innovative Pulse Thresher

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In manual pulse thresher, input rotary motion is converted into reciprocating motion of beaters. Due to indefinite swing angle of beaters usual four bar linkage cannot be used for this purpose. In this proposed investigation, a novel mechanism has been designed to overcome the problem of indefinite swing angle as is necessary for meaningful operation of manual pulse thresher. Here, Grashof mechanism has been modified to generate the desired kinematics. At first, particular four bar linkage satisfying Grashof's criteria has been designed considering definite swing angle of beaters, followed by a suitably designed slot has been incorporated into the coupler design to obtain indefinite swing angle. This modified linkage mechanism has been tested successfully to generate variable (may vary even on every cycle) swinging of beaters while taking rotary motion as input.

Keywords: Pulse, Thresher, Linkages, Mechanism, Coupler

Introduction

Pulse thresher is not new in agricultural field. But manual pulse thresher is new in term of principle of operation as well as ease of manual operation. India is very rich in agriculture. Various types of pulses are cropped in India¹. There are a number of processes for extracting seed from pulses. Studies were conducted with studied various agricultural tools used for agricultural operations by the farmers of Tamil Nadu, India². In the way of extracting seed, principle of threshing of the pulses is a very old process. A number of commercially available equipments use the same principle of threshing³. They are mainly useful for comparatively large quantities. But the nature of land holding in many parts of India is typically smaller. Therefore, small capacity pulse thresher is suitable in Indian context. A hand operated manual pulse thresher was developed by Gopalbhai Suratia⁴. But it is not suitable for continuous threshing operation. The proposed pulse thresher is pedal operated and as a consequence suitable for low capacity continuous threshing applications. Design of linkage mechanism of pedal operated pulse thresher needs a special attention. This is a four bar crank rocker mechanism. But a simple four bar mechanism of this kind does not serve the required purpose. In case of a four bar crank rocker mechanism; there is a

definite relationship between crank rotation and follower movement. For the proposed pulse thresher this definite relationship is not desirable at all. Schematic diagram of the proposed thresher is shown in Figure 1. From the figure it is seen that the beaters move according to the movement of follower. Now, during actual operation of threshing, pulses are loaded on the platform. Pulses on the platform looks like a heap. This heap has no specific height. Now, reciprocating motion of beaters is utilized for beating of pulses. But, the downward stroke of this reciprocating motion ends a little after actual contact between beaters and pulses takes place. So, the stroke of reciprocation of beaters varies depending upon the height of pulse heap. Therefore, variable stroke of reciprocation is required to take care of accumulation of pulses. Cam-follower mechanism could be employed for the above said problem. But it has some drawbacks. The problem associated with follower vibration in cam-follower mechanism has been described⁵. Here, a novel mechanism is employed for this stroke adjustment. Nearly 17 million tons of pulses are being produced every year in India at present. Almost all the pulses are harvested by traditional methods. It involves rooting out of the pulse plants bearing full grown pods with grains from the field, drying of the green crop under sun till moisture content is reduced to below 10%, then beating by a wood stick or stamping by the foot of heavy animals till most of the dry pods are broken and

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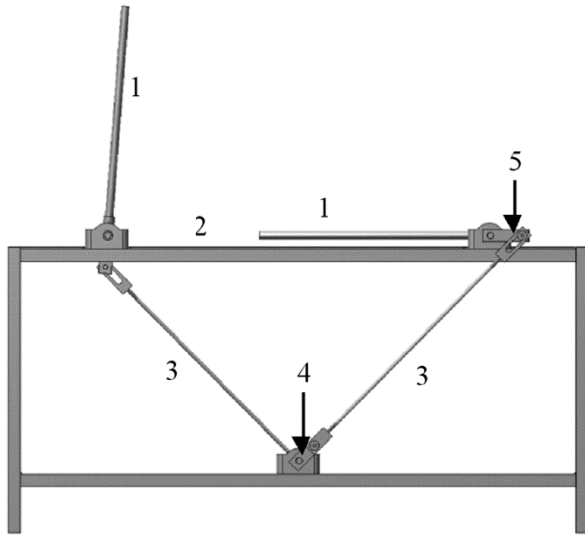


Fig.1 — Schematic diagram of a manual pulse thresher (1 Two sets of Beaters, 2 Threshing Platform, 3 Coupler, 4 Crank, 5 Follower)

grains are released from the crop. About 10-15% grains are lost with crop residues due to improper threshing in the traditional methods⁶. So there is a need to develop a manually operated machine to minimize the grain losses during threshing operation.

Formulation of the problem

In manual pulse thresher, reciprocating motion of beaters is utilized for threshing operation. The kinematic diagram of manual pulse thresher is shown in the Figure 2. Pulses to be thrashed are placed on the threshing platform, DE. The beating force comes from the set of reciprocating beaters, BC. The reciprocating motion of beaters is obtained from a four bar crank-rocker mechanism as shown in Figure 2(a). Crank, O_1A , rotates continuously and coupler, AB, transmits the motion to follower, O_2B . The pulses to be thrashed are placed on the threshing platform. Uploading and downloading of pulses to and from the platform are done with some unspecified time periods. Also, the amount of pulses as well as the height of accumulated pulses varies within certain ranges. As a result, when the thresher operates, beaters stop at different inclined position with respect to the threshing platform depending upon the height of accumulated pulses on the platform during the entire cycle of operation. In case of a normal crank-rocker mechanism, as crank rotates through 360° angle, follower also reciprocates through some fixed swing angle. If the swing angle of beaters is forcefully reduced, as required by above application, the

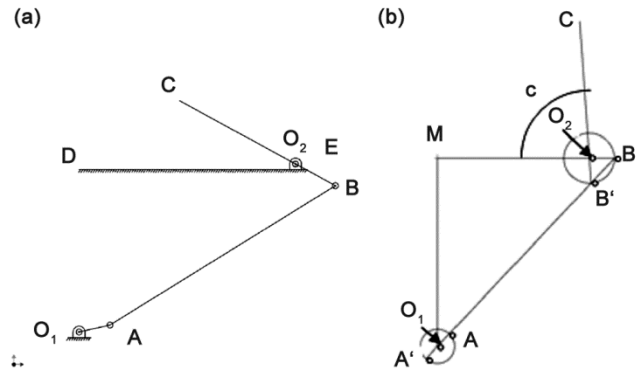


Fig. 2 — a) Kinematic diagram and b) Schematic diagram of kinematic mechanism

mechanism locks at that position and no further motion is possible. This change of swing angle takes place dynamically. So, designing of the linkage for manual pulse thresher needs some special attention.

Design

Determination of overall dimension

BMO_1 is a part of the manual pulse thresher. Four bar linkage to drive the beaters set consists of O_1O_2 as fixed link, O_1A as the crank, AB as the coupler and O_2B as the follower. O_1ABO_2 , one of the two extreme positions of the linkages, has been shown in the Figure 2(b).

Height

O_1M is the height of the thresher. This manual pulse thresher is built on an iron cot Gopalbhai Suratia (2011). So, the height is restricted by the convention of normal use of the cot. Also, the thresher mechanism is run by pedaling. Therefore, a height of 750 mm is selected from operational point of view.

Length

BM is half of the total length of the threshing platform. Now, half of the rotation of crank shaft is utilized to impart upward motion to one set of beaters whereas remaining half rotation is responsible for imparting upward motion to another set of beaters. So, four bar linkage must be designed without quick return mechanism. Now, the objective of the four bar linkage is to impart motion to the beaters. For proper threshing to take place, beaters are caused to oscillate starting from horizontal thresher platform up to a height by making certain angle (α) with respect to the platform. To maximize the beating force, the angle should be acute and also very close to 90 degree. This is because the beating force is obtained from the eccentric masses mounted on the beaters' shafts. For this particular design the value of α is assumed as 86

degree. From the geometry shown in the Figure 2(a), the length of the thresher can be obtained from the trigonometric relationship between O_1M , BM and α expressed in Eq. (1).

$$\frac{O_1M}{BM} = \cot\left(\frac{\alpha}{2}\right) \quad \dots (1)$$

From the relationship, we get length of the thresher platform as 1400 mm. Figure 4(a) shows the variation of thresher length with maximum angle of elevation of beaters.

Determination of linkages length

From the Figure 2(b), the following trigonometric relationship is obtained

$$\frac{BB'}{BO_2} = 2 \sin\left(\frac{\alpha}{2}\right) \quad \dots (2)$$

Crank length

Assuming the follower length, BO_2 , as 100 mm, BB' is obtained from Eq. (2). BB' is calculated as 136 mm. Now, BB' is exactly twice the crank length, O_1A . So, crank length comes out as 68 mm.

Coupler length

The trigonometric relation for calculation of coupler length, AB , may be obtained as Eq. (3). So, from Eq. (3) the length of the coupler link comes out as 958 mm.

$$AB = \sqrt{BM^2 + MO_1^2} - O_1A \quad \dots (3)$$

Length of fixed link

From the geometry shown in Figure 2(b) the trigonometric relation for the fixed link, O_1O_2 , is expressed as Eq. (4). The fixed link length is obtained as 961 mm.

$$O_1O_2 = \sqrt{MO_1^2 + (BM - BO_2)^2} \quad \dots (4)$$

Grashof's criteria

In the above calculation, the length of the linkages can be arranged as below. $l_{\min} = 68$, $l_{\max} = 961$, $l' = 100$, $l'' = 958$ Now, $l_{\min} + l_{\max} = 1029$ and $l' + l'' = 1058$. Therefore, it is obvious from the above calculation that and $(l_{\min} + l_{\max}) < (l' + l'')$ Hence, the linkages satisfy the Grashof's criteria. With this Grashof mechanism, we can generate swinging motion of beater through angle, α , varying from 0° to 86° , assuming $\alpha=0^\circ$ when beater touches the threshing platform. But the accumulation of pulses on the threshing platform changes the starting value of α dynamically. So, modification in the mechanism is necessary to cope up with this difficulty.

Slotted-link mechanism

The above said mechanism along with a slot, positioned suitably in one of the linkages, is used in this application. Basic objective of the pulse thresher must be considered for converting the mechanism, as designed above, to a useful one. The energy stored in the beaters along with the eccentric masses is utilized for threshing of pulses. Now, the beater's downward stroke may end up anywhere depending upon the pulse accumulation. In order to avoid system complexity beaters must be allowed to fall freely in this downward stroke. During the free falling of beaters power from the driving shaft, here it is the crank shaft, does not get transmitted directly to the beater shaft at the moment of actual contact of beaters with the pulses. So, eccentric masses are mounted on the beater shaft to increase the beating force. Now, the main objective of the mechanism design is to generate the upward stroke of the beaters. The conventional cam mechanism can serve this purpose but only to increase the equipment overall cost. A slotted link mechanism reduces the cost by reducing the number of components as well as eliminating costly manufacturing process.

Design of slotted-link mechanism

Starting point of designing slotted-link mechanism is the Grashof mechanism which has been designed above. Characteristics of the slot also depend on the minimum and maximum swing angle. Maximum value of swing angle of the follower, as obtained from the basic mechanism designed above, is $\alpha_{\max} = 86^\circ$. Minimum swing angle depends on the type of application. Two important activities of threshing operation are uploading and downloading of pulses to and from the threshing platform. During both of these activities, beaters should remain idle at their highest inclined position from horizontal plane. With this consideration minimum swing angle is taken as $\alpha_{\min} = 0^\circ$. The slot should be so provided that when the beaters get struck or remain idle then the pin connecting the follower and the coupler moves in this slot allowing the coupler to move without transferring any motion to the follower. From the Figure 2(b) it is evident that the length of the slot must be equal to BB' so that crank shaft can rotate continuously even when the beaters remain idle at the highest elevation. Width of the slot depends on the diameter of the pin connecting coupler and the follower.

Calculation of torque and power

Sufficient torque is required for threshing the pulse. This torque comes from series of beaters made from steel and placed on the beater shaft. Beater angle with respect to threshing platform varies with crank rotation. Variation of beater angle for two sets of beaters is shown in Figure 3(a). Now, crank shaft torque and power are calculated as follows.

Number of beaters on each shaft = 3

Beater diameter = 25 mm

Beater length = 750 mm

Density of Beater material = 7850 kg/m³

Therefore, force due to weight of one set of beaters is $\frac{\pi \times (0.025)^2}{4} \times 0.75 \times 7850 \text{ N} = 85.1 \text{ N}$

Now, torque exerted by one set of beaters depends on beater position. Beater position changes with the crank rotation. Torque contributed by each set of beaters and also the total torque are shown in Figure 3(b) as a function of crank rotation. Maximum total torque is obtained from Figure 3(b) as 45.5 N-m. Now, assuming crank speed of 20 RPM power required to drive the crank is calculated as follow.

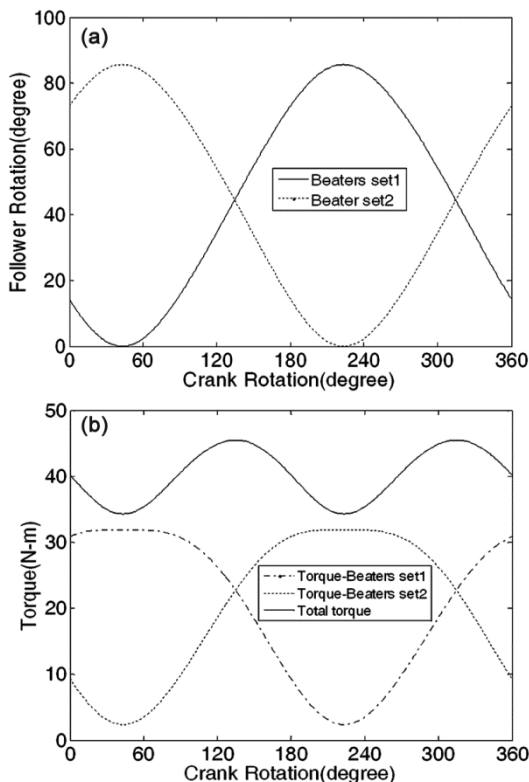


Fig. 3 —a) Variation of beater/follower position with crank angle and b) Variation of torque coming from beater set with crank angle

$$\text{Power} = 45.5 \times \frac{2\pi \times 20}{60} \text{ W} = 95.3 \text{ W} = 0.128 \text{ hp}$$

Therefore, for 20 strikes of beaters per minute, power requirement will be 0.128 hp. One human being is capable of delivering this power. Therefore design is suitable for human operation. In the original prototype, beating operation was done by hand. Here continuous operation cause a problem. Also threshing output was comparatively low. Here in the present thresher kinematic design has been changed to generate beater motion by paddling. In this case human being can run it continuously while seating comfortably.

Results and Discussion

A prototype of pedal operated manual pulse thresher has been developed based on the above design parameters. It has been tested successfully. The developed prototype manual pulse thresher has shown in Figure 4(b). It is seen from the figure that almost as soon as the actual contact between beaters and pulses takes place the slot incorporated into the coupler starts playing its role. During experiment, it has been observed that the impulse from the beaters is sufficient for threshing the pulse. The use of additional elastic element such as torsion or tension spring would definitely enhance the beater impulse and thereby improve the pulse threshing. But from operational point of view, it would become very difficult for a human being to operate the thresher

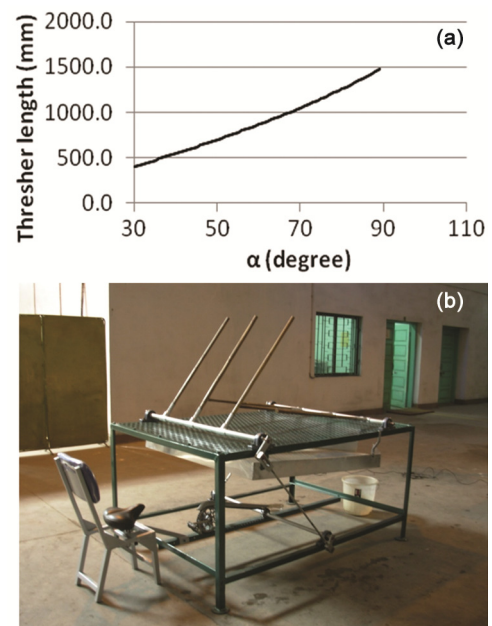


Fig. 4 — a) Variation of Thresher length with maximum elevation of beaters angle b) Prototype of Manual Pulse of Thresher

continuously. The pin connecting the coupler and follower is in the middle of the slot which was designed. This happens because no further movement of the beaters is possible. In fact, during the upward movement of beaters, this pin touches the top end of the slot. Now, during the downward movement of the Beaters, a little after the moment the beaters come into contact with the pulses the pin starts moving with respect to the top end of the slot. Exactly at this point, the mechanism without the slot would get locked and no further operation would be possible. This relative movement of the pin in the prototype allows the mechanism to run continuously. This machine is used for efficient threshing of matured crop of different pulses, irrespective of different shape and size of plants or grains. It can be applied for green gram, black gram, arhar, horse gram, lentil etc., with minimum power consumption and labour input. The crop residue can be used as animal feed. About 50% harvesting cost is reduced and 10% yield is increased over the traditional threshing methods as grain loss in crop residue is reduced to almost nil and the rate of operation is 2 to 3 times faster with a threshing capacity of 400 kg/hr of the dry crops.

Conclusions

Conversion of rotating motion to reciprocating motion using four bar linkage is a well known

method. In four bar linkage, stroke of reciprocation is fixed. If angular stroke of reciprocation depends on some uncertainties then cam is incorporated in the mechanism to bring flexibility into the system. Design of cam surfaces is, in general, complex in nature. Also, the incorporation of cam mechanism increases the number of components. The novel linkage mechanism, described here, is an easy to incorporate mechanism to replace cam and which will, necessarily, reduce the system complexity as well as the manufacturing cost.

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