Development of a Cam shaker for threshing operations

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ABSTRACT

Proper selection of agricultural machine component can improve the productivity and efficiency of both conventional and prototype of a thresher. Out of four component (new concept CAM, vibrator, pitman and screen sorter) options, cam was chosen to aid the cleaning operation of a motorized cowpea thresher. The cam was designed and incorporated in between the blower and the discharge chute of the thresher. The calculated design parameters of the cam shaker are: Power to operate cam (0.75 kw), power to operate cam and spring (0.9 kw), spring allowable load / deflection (450 N) and weight of cam (215 N) respectively. The performance evaluation shows that the cam has an average cleaning efficiency of 97% while the thresher that does not have a cam shaker has an average cleaning efficiency of 49%. In this paper, issues on design process and selection criteria are discussed.

Key words: Design process, CAM, vibrator, pitman, screen sorter, conceptual, embodiment.

INTRODUCTION

Despite the increasing global need for design process, the ultimate approach to it is yet to be made. There is a continuous need for new, cost-effective and high quality products (Ullman, 1997; Oni, 2003). According to Nigel (1999), the ability to design is part of human intelligence and evidence from different cultures around the world suggests that everyone is capable of designing (John and Jacobs, 1998), but some people appear to be better designers than others (Pahl and Beitz, 1984). The principle of design is universal, but the techniques and technological processes of machines and their details differ, hence, there is an increasing interest in understanding how designers design (John and Tang, 2001). For instance, the designer of agricultural machines approaches the design process in three stages: First, the preliminary stage; that is, the development of specifications of crop product to meet the machine in question. Second, the analysis of conceptual design; that is, the detailed design stage which includes the embodiment of the design based on proper selection of parts and finally, fabrication of the prototype of the machine (Bosoi et al., 1990).

It is very important to design a machine component that is compatible with the machine and comfortable with its operator. It must be safe and with minimum level of 75 dB and maximum of 80 dB noise. Beyond this level of noise, an ear protector cover would be needed. The design of the cam under review derives its principles from similar principles on how the car cam in a gasoline engine works (Nice, 2001). In similar situation, if the cam is used in a motorized cowpea thresher, the spring serves as a self-reinforcing disturbance to the arrangement of the cam and the disc. This has an unstable behavior which is referred to as planned instability. Up to the limited pressure, the cam remains uniform under the preload of the spring. If this pressure is exceeded, then, the cam head (impact diameter) will lift up very slightly. In an intermediate pressure, the impact diameter throttles the shaker to intermittently oscillate instead of rapid oscillation like in the case of other options. This intermediate pressure acts on the additional surface area of the cam head and it produces a supplementary force that offsets the elastic force of the spring to such an extent that the cam head lifts rapidly. In
Table 1: Alternative solutions to cleaning operations for motorized cowpea thresher.

<table>
<thead>
<tr>
<th>Parameters considered</th>
<th>Concepts alternatives</th>
<th>Cam shaker</th>
<th>Cam shake</th>
<th>Vibrator</th>
<th>Screen sorter</th>
<th>Pitman</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selection criteria</td>
<td>Weighting (%)</td>
<td>Rating (%)</td>
<td>Weighted score</td>
<td>Rating</td>
<td>Weighted score</td>
<td>Rating</td>
</tr>
<tr>
<td>Compatibility</td>
<td>20</td>
<td>10</td>
<td>2.0</td>
<td>7</td>
<td>1.4</td>
<td>1</td>
</tr>
<tr>
<td>Cost</td>
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<td>6</td>
<td>1.2</td>
<td>9</td>
<td>1.8</td>
<td>1</td>
</tr>
<tr>
<td>Availability</td>
<td>20</td>
<td>10</td>
<td>2.0</td>
<td>5</td>
<td>1.0</td>
<td>1</td>
</tr>
<tr>
<td>Safety</td>
<td>15</td>
<td>7</td>
<td>1.05</td>
<td>5</td>
<td>0.75</td>
<td>1</td>
</tr>
<tr>
<td>Time taken</td>
<td>15</td>
<td>8</td>
<td>1.2</td>
<td>4</td>
<td>0.6</td>
<td>1</td>
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<tr>
<td>Reliability</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total score</td>
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<td></td>
<td></td>
<td>6.05</td>
<td></td>
</tr>
<tr>
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<td></td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Continue?</td>
<td>Yes</td>
<td>develop</td>
<td>No quit</td>
<td>No quit</td>
<td>No quit</td>
<td></td>
</tr>
</tbody>
</table>

% (parameters weighing out of 100%), ^ (for example, of compatibility for all the 4 alternatives: 20/100 x 10 = 2.0, 20/100 x 7 = 1.4, 20/100 x 1 = 0.2, 20/100 x 1 = 0.2 & 20/100 x 5 = 1.0 (Maunde, 2010).

Cam about up: $F_s = s . d > p . A_v . h = 0$

Cam about down: $F_s = s . d \leq p_1 . A_v . h = 0$

Cam fully down: $F_s = s (d + h) < P . A_v + P_i . A_a, h h_i = P_o$

Cam fully up $F_s = s (d + h_i) = P' (A_v + A_a), h = h$ (new equilibrium position)

MATERIALS AND METHODS

The development of the cam was as a result of previous research (Maunde, 2014, 2010, 2008; Maunde et al., 2009, 2007). Out of four component (new concept cam shaker, vibrator, pitman and screen sorter) options as shown in Table 1, the cam shaker was found appropriate for aiding the cleaning process of motorized cowpea thresher. Only the development of a cam shaker is reported. The cam head has to accommodate the drum concave of the motorized cowpea thresher, hence, some assumptions made were:

If $d =$ pre-compression of spring; $s =$ stiffness of spring; $F_s =$ spring force; $h_i =$ lift of cam head up; $h_1 =$ lift of cam head down; $P =$ pressure on the cam head; $p_1 =$ limiting pressure just sufficient to push the spring downward; $p_i =$ intermediate pressure on opening valve; $p' =$ pressure after the opening of the valve; $P_o =$ atmospheric pressure; $A_v =$ cam head surface area; $A_a =$ additional surface area.

For the spring to perform the function as earlier stated, the following criteria must be fulfilled:

Cam about up: $F_s = s . d > p . A_v . h = 0$

Cam about down: $F_s = s . d \leq p_1 . A_v . h = 0$

Cam fully down: $F_s = s (d + h) < P . A_v + P_i . A_a, h h_i = P_o$

Cam fully up $F_s = s (d + h_i) = P' (A_v + A_a), h = h$ (new equilibrium position)

Design of cam parts

The diameter of the cam is determined by adopting velocity at midpoint of the drum and specifying the interval between the successive strikes of the cam head on the curve disc (which is equal to the number of beaters calculated earlier (Maunde, 2010; Adamu, 2014).

Cam main (D) and impact diameter (Di)

$D = \frac{V t N s}{\pi}$

Where:

$D =$ Diameter of cam (m);

$V =$ Velocity of threshing cylinder (m/ s);

$T =$Time between successive beater strikes (s);

$N s =$ Number of spring to be used (2)

$D_i = D + 0.03$

Where: $D$ is the main diameter; 0.03 is an assumed thickness to differentiate the actual value from the impact values. $D = 0.1$ and $D_i = 0.13$ m.
**Design and selection of spring for cam**

Catalogue specification for the spring from (Association Spring, 2006):

- Deflection angle (Ø) = 450
- Torque rating (T) = 4.73 kg·mm
- Coefficient of stiffness (€) = 0.7
- Minimum axial space (s) = 125 mm
- Force (F) = 225 N
- Spring index (j) = 8
- Shear modulus of elasticity (E) = 78 GN/m²
- Shearing stress (St) = 400 MN/m²
- Diameter of wire (d) = 3.4 mm
- Mean coil diameter (dm) = 29.5 mm
- Number of coil (n) = 27.5

\[ \text{Spring length (SL)} = s - dm / \epsilon \]

\[ \text{SL} = 0.136 \text{ m}. \]

Calculating the allowable load (Ps):

\[ \text{Ps} = \frac{F_i}{g} \]

(7)

Where:

i: number of spring to be used (Equation 2) substituting the values earlier given:

Spring deflection (∆) = 2 SL2 StK / dE

(8)

Where:

K = linear damping coefficient (0.35).

**Weight of the cam (Wtc)**

The case of small vibration of the shaker about the centre of the cam at the eccentricity and attitude angle of additional weight at one side of the cam was considered.

Weight of the cam (Wtc) (Meriam and Kraige, 1993):

\[ \text{Wtc} = \frac{S_f}{g} (j \cos \theta) D + 1 - (dr \tan \theta). \]

(9)

Where:

Sf = Spring force (N)

\[ g = \text{Acceleration due to gravity (m/s}^2) \]

\[ j = \text{Component of linear damping coefficient (0.5)} \]

\[ \theta = \text{Suspended angle between cam and disc (180°)} \]

\[ D = \text{Diameter of cam (0.1 m)} \]

\[ dr = \text{Rotational damping coefficient (0.3)} \]

**Area of disc curve to accommodate cam**

Area a circle (As) = \( \pi r^2 / 4 \)

(10)

Where:

\[ As = \text{Area of a curve disc (m}^2) \]

\[ r = \text{radius of cam (m)} \]

Design of shaker

Width of shaker (Ws) = Width 2 of the concave;

Length of shaker (Lsh) = Ws + \( \frac{1}{2} \beta \)

(11)

Where:

\[ \beta = \text{from equation (0.08)} = (0.04 \text{ m}) \]

Ws = width of shaker (0.51 m)

Lsh = 0.51 + 0.04 = 0.55 m.

**Power requirement to operate the cam through the spring and the shaker**

Figure 1 shows illustration of cam arrangement with the disc curve for motorized cowpea thresher, while Figure 2 shows projected view of motorized cowpea thresher showing cam shaker (Maunde, 2014) and Figure 3 shows constructed, assembled and tested motorized cowpea thresher incorporated with the cam shaker (Maunde, 2014).

\[ P = (Wtc + Ps)Svfm \] (Smith and Wikes, 1990)

(12)

Where:

Wtc = Weight of cam (N)

Ps = Spring allowable load (N)

\[ Sv = \text{Spring velocity (m/s)} \]

\[ fm = \text{Rotational damping coefficient (0.2)} \]

P = 0.9 kW.

**RESULTS AND DISCUSSION**

Table 2 shows the results of designed cam parameters. The result shows that the cam weight and impact diameter (215 N and 0.13 m) respectively provided a mechanical advantage to produce the needed time frame between the primary threshing and secondary threshing of the cowpea before the blower separates the seeds from the chaffs, this agrees with the report of Maunde (2010, 2008). The unit and bulk density of cowpea seeds and chaff informed the designed blower (Maunde, 2007). The incorporation of physics mechanical properties of cowpea thresher into it
Figure 1: Illustration of cam arrangement with the disc curve for motorized cowpea thresher. Legend: A = Cam, B = Concave to accommodate cam movement, C = Two horizontal spring space at distance L, R = Cam head, X – Y = Direction of cam movement.


becomes imperative (Bosoi et al., 1990; Smith and Wilkes, 1990). The disparity between powers to operate cam through spring is 15 kW, hence, the recommended spring from Associated spring, 2006 is justified. Cleaning efficiency of the motorized cowpea with the cam was 97% (Adamu, 2014), while cleaning efficiency of Alvan Blanch Aspra master without the cam was 49%. Thus, the selection of cam which was incorporated in the design of motorized
cowpea thresher has significantly improved its cleaning efficiency. This will reduce the drudgery and labour of re–
winnowing or cleaning cowpea seeds after threshing.

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