Design And Fabrication Of Popcorn Machine, Using Local Raw Materials For Higher Productivity

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***Abstract*—The design and fabrication of a popcorn machine usingsquare pipes for the machine frame to ensure rigidity and to minimize vibration was carried out. An electric motor of 634Watt was used in the popping chamber to rotate the stirrer. A scissor jack was installed in the conveyor system to lower the ready popcorn into the cabinet. A rectangular framed wire mesh was used in the cabinet to separate the popped corn from the un-popped ones. The oven method of determining moisture content was adopted in the analysis and the following results for five different samples of zea maize were obtained: 10.00, 15.50, 20.00, 25.00, 25.70%, respectively. Lump system analysis was used to obtain the popping time for the different samples at their moisture levels and the following results were obtained; 5.00, 8.00, 8.50, 9.20 and 9.50sec, respectively. This machine is 72% efficient and is recommended for domestic application.**

Keywords—Design, fabrication, popcorn, popping, productivity.

Introduction

Popcorn vendorsoften complain of the cost of gas, the drudgeryin using manually operated popcorn machines and the resulting mechanical heat losses. However, this machine is designed and producedwith the sole aim of solving the above problems thereby improving efficiency during operation.

Popcorn is from a special type of maizeunlike other types of corn which pops when heated. The popcorn preparation has long been in practice in Nigeria. It usually required a heating source (stove, fire wood), a frying pan with spoon as the stirrer. It was first discovered and used by the early Americans. Popcorn was introduced to the Western world by Christopher Columbus in the 15th century. The kind of popcorn most people pop in their microwave is the *Zea mays*. *Zea mays everta* has a certain amount of moisture content, a strong pericarp that does not allow moisture to escape very fast as other corn when heated. Consequently, a popcorn machine, which is generically used for the purpose of making popcorn for human consumptionis essential. Most popcorn machines use gas, some use electricity, while some use the solar as sources of energy. The merits and demerits of these sources areobservable in the production rateof the various machines, which in turn depends on the intensity of heat as well as the power source.The objective of the project, therefore, is to design and produce an electric popcorn machine with a separator that will enhance popcorn production, using local raw materials.

Materials and Methods.

In the selection of materials for this machine different factors were considered, such as economic factor, mechanical and physical properties of the material used. In line with the concept of economy in manufacturing, every step taken was aimed at minimizing cost. As part of the economic consideration, feasibility studies were carried out to know the cost of these materials and availability. In the conveyor system the cost of producing a scissor jack was considered and compared with the cost of procuring a standard part. The cost implication showed that the cost of producing a scissor jack will be high compared to the cost of procuring a new one. However, going by this, standard parts were used in the production. Taking cognizance of the fact that the machine is a temperature-generating device, high temperature resistant materials for the different sub-systems were equally considered and used including among others stainless-steel, aluminum, refractory material and mild-steel.

The moisture content of maize was obtained using the oven drying methods. The frame of the system was joined by welding and also, the plate that covers the inner compartment to ensure firmness. The housing of the popcorn machine was constructed using square pipes and 4mm thickness plate to give the machine a shape and to ensure rigidity. At the cabinet, a glass of dimension, as specified in the design drawing, was installed for aesthetic purpose and then a housing was made for the scissor jack in the conveyor system. Also, seating was provided for the pot with a square geometry and a 300mm internal hole on it.

Fig. 1. Picture of the Popcorn Housing

The percentage of moisture was calculated as follows:

$$\%moisture = \frac{W_1 - W_3}{W_2 - W_1} \times 100 \ (1)$$

Where,

W_1 - Initial weight of empty dish.

W_2 - Weight of the dish + food before drying.

W_3 - Final weight of dish + food after drying (Onwuka, 2005)

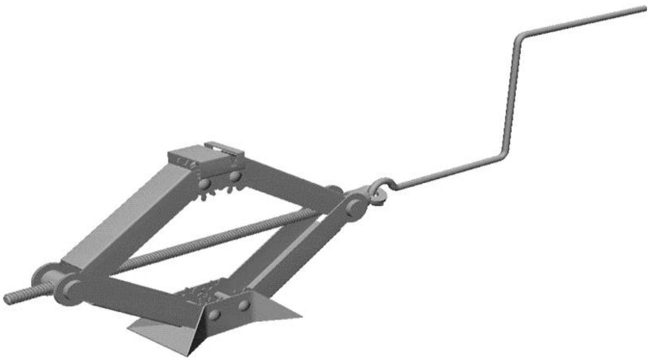

Fig. 2.Model drawing for the scissor jack.

Capacity analysis for the Scissor Jack in the Conveyor system

At first, the core diameter of the screw on the basis of compression and tension was found.

$$D_c = D_o - P \ (2)$$

Where,

$D_c - core\ diameter$

$D_o - outer\ diameter = 25mm(\ standard).$

$L -\ Lead\ of\ the\ screw.$

$P -\ pitch\ of\ the\ thread$

A standard outer diameter, core diameter and pitch of the threaded were selected.

$$P\ =\ L\ = 2.544mm \ (3)$$

Also, torsional moment to be transmitted to the nut and screw was calculated

$$Torsional\ moment\ (M_t) = \frac{f_s \times 0.7 \times \pi d^2 t}{2} \ (4)$$

Where,

$f_s - torsional\ shear\ stress$

The direct stress and the torsional shear stress and check on the screw for combined principal stress was found from computation.

$$Direct\ stress\ (f_c) = \frac{4F}{\pi D_C^2} \ (5)$$

Where:

$D_C = core\ diameter$

$$Torsional\ shear\ stress\ (f_s) = \frac{16Mt}{\pi D_C^3} \ (6)$$

The turning moment required to lift and bring down the load was calculated.

$$Torque\ (T) = F \times \frac{D_{mean}}{2} \ (7)$$

Where:

$D_{mean} = mean\ diameter$

$F\ =\ force$

More so, the reactions at different joints in the scissor jack was

Computed (Sharmaand Aggarwal, 2012).

Design of Circumferential Lap Joint for the Popping Chamber

The circumferential joint is a lap joint with the hollow plate overlapping at the wall of the pot.

The thickness of the pot was measured and the dimension obtained,

$$t = 2mm \ (8)$$

The diameter of the rivet hole was determined practically using the Unwin's empirical formula;

$$d = 6.05\sqrt{t} \ (9)$$

The pitch of the rivets was calculated considering tension and shear, in other words, to make the joint secure against fracture by tearing.

$$(p-d)t \times f_t = \frac{\pi}{4} d^2 f_s \ (10)$$

The number of rivets in one row of a circumferential lap joint (z) was calculated with the formula;

$$z = \frac{\pi(D+t)}{p} \ (11)$$

Where,

D - Diameter of the pot.

P - Pitch of the rivet.

The plate resistance to tension was calculated using the formula:

$$(p-d)t \times f_t \ (12)$$

Resistance to crushing of one rivet was obtained:

$$d \times t \times f_c \ (13)$$

The efficiency of the joint was computed with the formula: $\eta = \frac{p-d}{p}$ (14)

(Sharma and Aggarwal 2012).

Design of Rivet Joint in the Popping Chamber

The thickness of the two plates was measured to be 2mm.

Assumption: The resistance of rivet in shear $(f_s) = 28N/mm^2$

Resistance of plate in tension $(f_t) = 35N/mm^2$

Crushing stress $(f_c) = 52.50N/mm^2$

Using Unwin's formula from (9)

$$d = 6.05\sqrt{2} = 8.5mm\ let's\ say\ 8.4mm$$

Using standard size of rivet for a rivet hole size of 8.4mm. The rivet diameter was chosen to be 8mm.

Equating tearing of the plate to shearing of the rivet (10), is adopted

$$(p - 8.4)2 \times 35 = \frac{\pi(8.4)^2 \times 28}{4}$$

$$p = 30mm$$

Circumferential joint

Shearing resistance of one rivet using (11), we have

$$Z = \frac{3.142 \times 8.4^2 \times 28}{4} = 1.55KN$$

Resistance in crushing of one rivet from (11),gives

$$8.4 \times 2 \times 52.50 = 0.882KN$$

Strength of un-punched plate

30 × 2 × 35 = 2.1KN

Number of rivets in a pitch length is computed using (12)

$$z = \frac{3.142(30 + 2)}{30} = 3.35nos.(let's\ say\ 4nos.)$$

Efficiency of the joint is computed using (13)

$$\eta = \frac{30 - 8.4}{30} = 72\%$$

Fig. 3. Picture of the popcorn machine

Results and Discssion

From Table 1, the dimension of the zea mays samples was measured and the moisture content for these samples was obtained. It was observed that the moisture content increased with increase in dimension of the zea mays samples.

Table 1. Dimensions and Moisture Content of *Zea Mays* indurate sample

S/N	diameter	Thickness	length	Width	Moisture content (%)
1.	7.00	4.00	10.00	8.30	10.00
2.	7.30	4.20	10.20	8.50	15.50
3.	7.40	4.30	10.40	8.60	20.00
4.	7.50	4.50	10.10	9.00	25.00
5.	7.60	4.60	10.20	9.10	25.70

Table 2, the popping time for each of the zea mays sample at variant moisture level was obtained from lump system analysis. This was done considering the capacity of the heat generator and the result as obtained showed that the popping time depended on the level of moisture content and dimension. In other word, the zea mays sample at different moisture level popped at different time interval.

Table. 2.Reactions at the Joint of the Scissor Jack Model

HORIZONTAL FORCES	REACTIONS (KN)	VERTICAL FORCES	REACTIONS (KN)
F_X	0	F_Y	0
C_X	36→	C_Y	98↑
B_X	36←	B_Y	98↑
E_X	36→	E_Y	98↓
D_X	36←	D_Y	98↓

Table 3, presents the reactions at the joints of the scissor jack in the conveyor system. At the fixedend of the jack, the reaction was equal to zero whichshowed that there was no reaction at the fixed end of the jack. The axial forces (horizontal) balanced each other thereby obeying the law of stability which states that for a body to be in equilibrium the sum of forces on both axes and moment must be equal to zero

Table 3.Weights and Popping Times for The Samples

Samples	W_b (g)	W_1(g)	W_2(g)	W_a(g)	W_3(g)	Moisture content (%)	Popping Time (min)
A	0.102	16	16.102	0.010	16.010	10.00	5.00
B	0.107	16	16.107	0.017	16.020	15.50	5.72
C	0.113	16	16.113	0.023	16.023	20.00	5.82
D	0.126	16	16.126	0.032	16.032	25.00	5.92
E	0.131	16	16.131	0.034	16.034	25.70	6.00

In the analysis it was observed that the moisture content varied in the five differentmaize samples. This formed the basis for using a 2KW heating coil to generate heat at the rate of $0.387\times 10^{8} w$ at every meter radius. Consequently, the heating coil that was installed produced 600KJ in 5minutes and was capable of producing popcorn snack within 20 minutes. The graph in Fig. 4 shows that at different moisture level, the time interval for the sample of corn at different moisture content to pop is different.

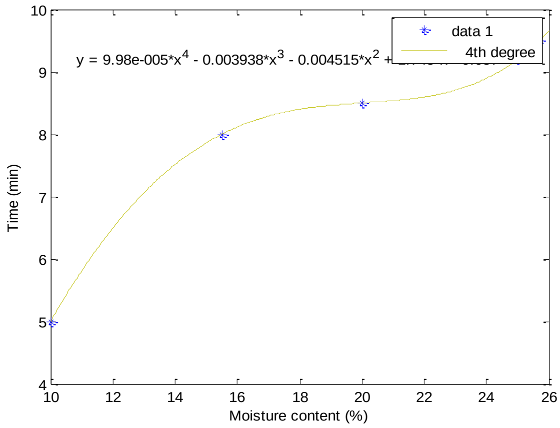

Fig. 4.Moisture content and popping time

A particular moisture level can exist in more than one sample of corn during production and varies likewise. This is clearly seen in Fig. 4 in the crocket nature of the curve. The popping temperature was at 177℃ and for that reason the design made provision for a regulator that would be used by the operator to maintain a steady temperature rate.

Analysis showed that the scissor jack required a maximum torque of 0.2226KN/m to lift a full load of popcorn. The maximum height the scissor jack could attain was determined to be 99mm. Also from the result, the torque required in raising the load was greater than the torque required to bring it down. Following from the results that involved the reaction at the joint in the scissor jack, it was noted from the analysis that the reaction at the fixed end of the scissor jack was zero. This shows that at the fixed joint there was no force effect since it was static. More so, the result showed that the forces balanced each other; thereby obeying the concept of equilibrium. For rigidity, the welded joint was welded according to design thickness of 16 mm which created a torsional effect of 880 N.m.

Conclusion

The design and production of an electric popcorn machine was meticulously carried out successfully with very minor modifications. The machine part was designed in such a way that it could be easily assembled and disassembled. The design process used in production was simple, considering the cost of working tools. The product was tested in real time and was 72% efficient. However, further improvements are recommended to enhance portability and aesthetics.

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