



Development of Chicken De-feathering Machine

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A B S T R A C T

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This paper presents the design and fabrication of an electrically-operated chicken de-feathering machine using stainless steel, mild steel, elastomer feather pluckers and electric motor as major materials. The electric motor drives the feather plate (to which the feather pluckers are attached) on which the chicken carcass is placed hence spinning the carcass as it rotates. The feathers are removed as the carcass spins against the rotating feather pluckers and stationary pluckers on the drum by friction effect of the feathers and pluckers. The fabricated machine was tested and took 10 seconds and 6 seconds for chicken carcass scalded at temperatures 80°C and 90°C respectively; removing all the feathers without any damage to its skin at both instances. It is therefore concluded that the performance of a chicken de-feathering machine depends on scalding temperature, and the duration of de-feathering.

1. Introduction

De-feathering is the process of removing feathers so as to prepare poultry, like chicken, for further processing. Processing and plucking feathers of a chicken at home provides complete control over the meat and butchering conditions, but can be messy, unpleasant, and hard to do (Brown, 2010). Chicken plucking becomes a simpler process if the bird is brought to the correct temperature before any feathers are removed. Young chickens tend to be easier to pluck than the old ones. For large batches, mechanical plucker can make the process easier, but some hand plucking is usually required. Poultry is a family name for various birds that have been domesticated by man (Bilgili, 2002). It also includes all feathered animals both wild and the domesticated ones. It includes chicken, duck, geese, turkey among others. It varies in size, types, colour and breeds in each available species.

De-feathering started in pre-history age when man discovered the use of chicken for food. For several centuries, de-feathering of poultry was done in the manual and traditional way and this continued till the nineteenth century.

Traditionally, the process of de-feathering involves immersing the chicken in a bucket of hot water, a process known as scalding. Roger and Don (1995) reported that the temperature for scalding varies between 50°C and 80°C; the lower temperatures in the range are used more frequently to lessen injuries sustained while

plucking the feathers manually. Broiler for fresh trade are usually scalded at temperature of about 53oC and 54oC whereas the broiler to be frozen are scalded at a temperature of about 56oC turkey and duck are usually scalded at higher temperatures. After scalding, the feathers of the chicken are hand-pulled in bit until all the feathers are removed. According to Brown (2010), six women pluck 250 chickens in 8 hours a day. This limited the number of chicken that could be processed within a given space of time.

The first patented chicken de-feathering machine was invented by Graves in United States (Patent Number: 1881, United States Patent, 1999). Several innovations have been brought into chicken de-feathering processes resulting into several versions of chicken de-feathering machine invented and patented by different researchers some of whom are Berg in 1917, Bingham in 1933, Slayton in 1935, Schlicksupp in 1940, Barker in 1945 and so on (Roger and Don, 1995)

The need to locally develop the machine arose as a result of the rate of consumption of the poultry birds of all kinds. Only few farms have the imported machine, none is having locally developed one. The scarcity of the imported and non-availability of the locally developed ones informed this design.

2.0 Materials and Methods

A number of components were assembled such as drum, pluckers, frame, pulley and shaft to make the machine.

The Drum

The drum is of diameter 438 mm and height 505 mm. The material used is stainless steel 304 (S30400) of thickness 1.5 mm

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which contains Chromium-nickel-iron alloy with 20% chromium, 18% nickel (Ni), and low carbon content, with non-magnetic properties

The Pluckers

Flexibility is required during operation; elastomer was used in fabricating the pluckers. The ease with which rubber can stretch elastically to as much as 80% of their original length is unique, and it is this elasticity that constitutes the hallmark of an important class of polymers called elastomers yet when heated say 200oC they behave like viscous or visco-elastic bodies.

The Frame

The Frame holds the drum and prime mover (electric motor). Being the main support for the machine, it must have good welding properties, good compressive strength and ability to withstand loads. Having considered all the properties needed, mild steel in form of angle bar and mild steel sheet were used.

Pulleys

The size of the pulley used was selected from the available standards using manufacturers catalog, and the material is mild steel.

Feather Plate

The feather plate is 1.5 mm thick and 530 mm diameter. It has 16 finger holes (19 mm diameter). The back side of each finger hole was chamfered so the finger pulls in easily. The feather plate was braced by angle bars (three in number) at an angle of 120oC to each other to give the feather plate the strength to support three chickens at once. Stainless steel sheet was also used for this.

Shaft

Medium carbon steel rod was used for the shaft. The shaft is of 25 mm in diameter and 380 mm long.

2.1 Design Considerations

The power required to operate the machine will be determined as follows:

Speed of driving motor, W_1 (Khurmi and Gupta, 2008);

$$W_1 = \frac{2\pi N_1}{60} \tag{1}$$

where N_2 is the angular speed of electrical motor in rev/min.

Angular speed of driven pulley, W_2 ;

$$W_2 = \frac{2\pi N_2}{60} \tag{2}$$

where N_2 is speed of the driven pulley in rev/min

Angular speed of flat disc , W_3 ;

$$W_3 = \frac{2\pi N_3}{60} \tag{3}$$

where N_3 =flat disc speed in rev/min.

Force F is determined using the equation (Groover, 2007),

$$F = MrW_3^2 \tag{4}$$

where M is mass of chicken in kg and r is radius of feather plate (m)

The velocity of the disc, v (Groover, 2007);

$$v = \frac{\pi d N_3}{60} \tag{5}$$

where d is the diameter of the disc.

The power P (watt) required to operate the machine (Groover, 2007);

$$P = Fv \tag{6}$$

Transmission of power from output shaft to flat disc shaft can be obtained as follow.

Power obtained from electric motor, $P_1 = 1500$ watt

Motor speed $N_1 = 1410$ rpm (speed from manufacture)

Angular speed of motor (W_1) = 147.7 rad/sec

Motor Pulley diameter (d_1) = 50 mm

Flat disc speed (W_3) = 49.22 rad/sec

Efficiency of the flat disc shaft $\eta_1 = 0.96$

Power at the disc shaft P_2

$$P_2 = P_1 \eta_1 \tag{7}$$

The Pulleys

The diameter of the flat disc pulley, d_2 , can be determined from the equation below (Dixon and Poli, 1995).

$$d_2 = \frac{W_1 d_1}{W_2} \tag{8}$$

The angular speed of the driven shaft, W , is calculated using the equation;

$$W = \frac{W_1 d_1 (1-E)}{d_3} \tag{9}$$

where E is the speed loss factor.

Belt Length

The belt length, L , is determined from the equation:

$$L = 2a + \frac{x}{2} (d_1 + d_2) + \left(\frac{280.55 - 165}{4 \times 891.1} \right) \tag{10}$$

By using rubberized fabric belt, the thickness must meet its requirement.

The dimension for a ply of a rubberized belt including the inter layer is 1.5mm and should not exceed 7 plies. The number of plies is determined from the equation;

$$N_{ply} = \frac{\text{thickness of belt}}{\text{dimension for the ply including interlayer}} \tag{11}$$

Design of Shaft

It was to determine the correct shaft diameter to ensure strength and rigidity when the shaft would be transmitting power under various operations and loading conditions. The ASME code equations for a solid shaft combined torsion: bending and axial loads by applying the maximum shear equation modified by introducing shock, fatigue and column factor is as follows (Dixon and Poli 1995).

$$d^3 = \frac{16}{\pi S_s} \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

Where,

M_t = Torsion Moment

M_b = Bending Moment

S_s = shear Stress

K_t, K_b = shock and fatigue factors applied to torsion and bending moment respectively

The forces exerted at each end of the shaft are not only due to the weight of the pulley and flat disc, but also forces acting due to pre-tension in the belt are also considered.

In Figure I, force acting on the left side end of the shaft is: 222.24 N (belt pre-tension).

Force acting on the right side end of the shaft is: 261.79 N (tangential driving force).

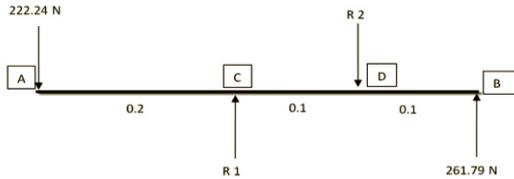


Figure I: Forces acting on the shaft

Taking the moment about the right side end; 261.79 N

$$-0.1R_2 + 0.2R_1 - 222.24 \times 0.4 = 0$$

$$-0.1R_2 + 0.2R_1 - 88.896 = 0$$

$$0.1R_2 + 0.2R_1 = 88.896 \quad (I)$$

Sum of upward forces = sum of downward forces

$$R_1 + 261.79 = 222.24 + R_2$$

$$R_2 - R_1 = 261.79 - 222.24$$

$$R_2 - R_1 = 39.55 \quad (II)$$

Solving equation (I) and (II)

$$x1 - 0.1R_2 + 0.2R_2 - 88.896 \quad (III)$$

$$x0.2 \quad R_2 - R_1 - 39.55 \quad (IV)$$

$$-0.1R_2 + 0.2R_1 = 88.896$$

$$0.2R_2 - 0.2R_1 = 7.910$$

$$0.1R_2 = 80.986$$

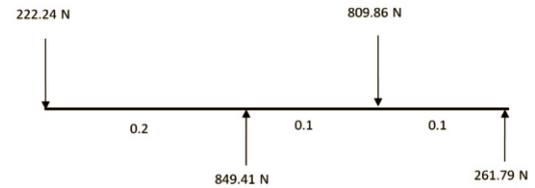
$$R_2 = 809.86 \text{ N}$$

Substituting the value of R_2 into equation (II)

$$R_2 - R_1 = 39.55$$

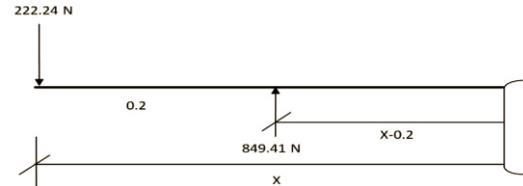
$$809.86 - R_1 = 39.55$$

$$R_1 = 849.41$$



Bending moment at A – 0 (fixed ends) $SF = -222.24 \text{ N}$

Section 1 is considered at the Left Hand Side of C



$$M_b = -222.24x + 849.41(X - 0.2)$$

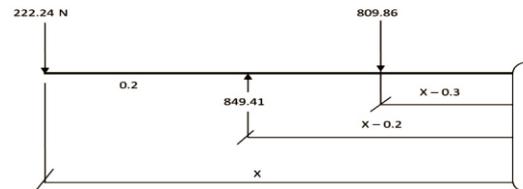
$$M_b = -222.24x + 849.41x - 169.882$$

$$M_b = 627017x - 169.882 \quad SF = dm/dx = 627.17 \text{ N}$$

$$\text{At } x = 0.2 \quad M_b = 627.17(0.2) - 169.882$$

$$M_b = 125.434 - 169.882 = -44.448 \text{ N}$$

Consider section 2 at the LHS of C



$$M_c = -222.24x + 849.41(x - 0.2) - 809.86(x - 0.3)$$

$$M_c = 627.17x - 169.882 - 809.86x + 242.958$$

$$M_c = -182.69x + 73.076$$

$$SF = dm/dx = -182.69 \text{ N}$$

$$\text{At } x = 0.3 \quad M_c = -182.69(0.3) + 73.076$$

$$M_c = 18.269 \text{ Nm}$$

At $x = 0.4$ on the left hand side of D

$$M_D = -182.69(0.4) + 73.076$$

$$M_D = 0 \text{ (fixed end)}$$

The Load Diagram is presented in Figure 2.

Maximum bending moment occur when $dm/dx = 0$ or $f = 0$

Point of inflexion

$$627.17x - 169.882 = 0$$

$$627.17x = 169.882$$

$$X = \frac{169.882}{627.17} = 0.27 \text{ m}$$

Point of inflexion is a point on a beam from bending moment diagram where the bending changes from sagging to hogging. This point is common in loaded beam with overhang. Point of inflexion $X = 0.27 \text{ m}$

$$M_b = ((M_b)^2 + (M_c)^2)$$

$$= \sqrt{((-44.448)^2 + (18.269)^2)}$$

$$= \sqrt{(1975.62 + 333.76)}$$

$$= \sqrt{(2309.38)}$$

$M_b = 48.06 \text{ Nm}$

Power from motor $P = 822.01 \text{ watt}$

$W = \text{angular speed of disc} = 11.83 \text{ rad/sec}$

$M_t = 822.01 / 11.93 = 69.49 \text{ Nm}$

$K_b = 2, K_t = 1.5$

$$d^3 = \frac{16}{\pi S_s} \sqrt{(K_b M_b)^2 + (K_t M_t)^2}$$

$$d^3 = \frac{16}{\pi \times 56 \times 10} \sqrt{(2 \times 48.06)^2 + (1.5 \times 69.49)^2}$$

$$d^3 = \frac{16}{\pi \times 56 \times 10} \sqrt{(9239.05) + (10864.94)}$$

$$d = \sqrt[3]{0.000012895}$$

$d = 0.02345 \text{ m}$

$d = 23.45 \text{ mm}$

Diameter of shaft (d) = 23.45 mm

The components were put together in a model design presented in Figure 3.

The design is 505 mm long, 380 mm wide and 1100 mm high. It consists of:

- i. Stainless steel drum which is 438mm in diameter and 505mm high. It has 21 holes drilled into it to hold feather pluckers.
- ii. Stainless steel feather plate of 400 mm diameter. It has 16 holes drilled into it to hold the pluckers. Each of the holes is 19 mm.

- iii. Mild steel frame (505 mm x 505 mm x 380 mm).
- iv. A 2 horsepower electric motor with speed 1410 rpm connected by a belt and pulley drive to the machine.

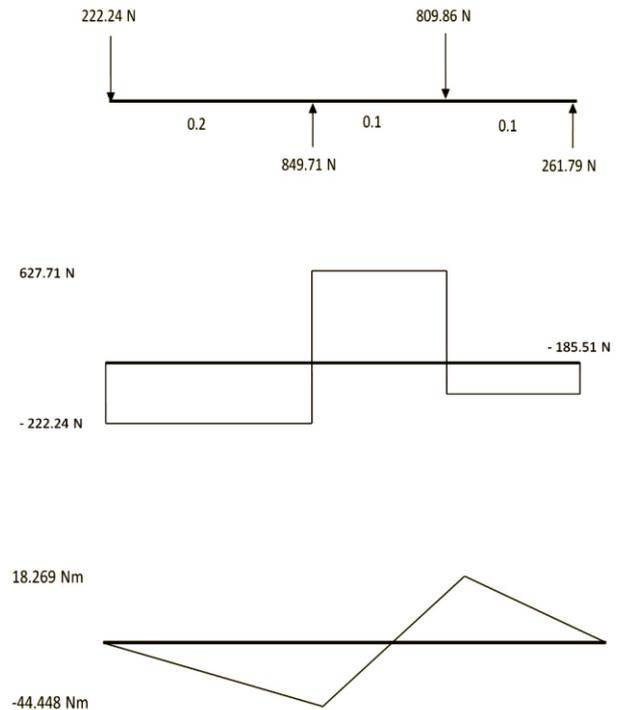


Figure 2: Load Diagram

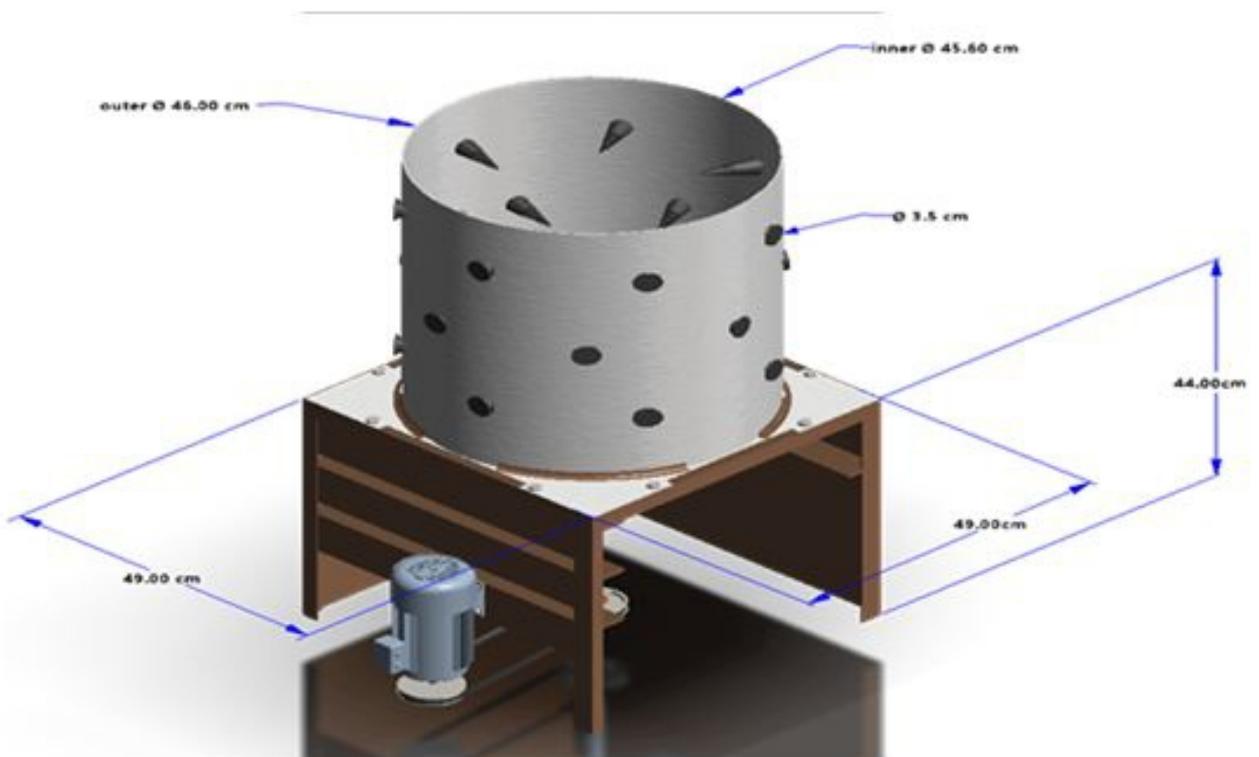


Figure 3: Model design of the Chicken de-feathering machine



Plate I: Assembled Machine



Plate II: Drum with pluckers



Plate III: De-feathered Chicken

Table I: De-feathering durations and Physical appearance of de-feathered chickens

S/N	Test	Scalding Temperature ($^{\circ}$ C)	De-feathering Duration (s)	Quality of De-feathering (Appearance after De-feathering)
1	Test 1	80	10	No feather left and no damage to skin
2	Test 2	80	10	No feather left and no damage to skin
3	Test 3	90	6	No feather left and no damage to skin

3.0 Results and Discussions

The assembled machine is presented in Plate I. The drum with the feather pluckers is shown in Plate II. Tests were carried out to evaluate the performance of the machine. The machine was tested for chicken scalded at temperatures 80oC and 90oC. The results are presented in Table I while the de-feathered chicken is shown in Plate III. From the results obtained from the performance evaluation of the machine, it was observed that scalding temperature played a significant role in that at the temperature of 90oC, the de-feathering time was 6 seconds, while at the temperature of 80oC, it took the machine a total time of 10 seconds to remove the feathers. The role of high temperature could be attributed to the effect of heat on the

feathers and the skin of the chicken. The heat might have softened the them beyond what could be experience at the temperature of 80oC, thereby taking less effort for the pluckers to get rid of the feathers.

4.0 Conclusion

The machine designed and fabricated has been found to remove all the feathers on the chickens used for the tests carried out. It can be concluded that the performance of a chicken de-feathering machine depends on the speed of the machine and the Scalding temperature.

It was observed that during performance evaluation of the

machine, the higher the scalding temperatures, the neater the chicken de-feathered and the lesser the time spent to de-feather the chicken.

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