

Design Of A Manually Operated Egg Product Separating Machine Using Locally Sourced Materials

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-----ABSTRACT-----

An egg product separating machine is egg processing equipment that break eggs and separate their products (shell, yolk and albumen). In this study, the design of a manually operated egg product separating machine is presented. The egg product separating machine was designed to break nine eggs and separate their products (yolk, albumen and shell) at once. Geometrical drafting of the machine which includes parts design (machine frame, knives, albumen collector, separator, egg holder, actuating handle), assembly and exploded view of the machine was done using computer aided design (CAD) software (Solidworks, 2016). Design steps for each part designed was well outlined and The performance results based on the ratio of number of properly broken eggs to that of the total eggs broken was obtained as 90.7 % with separation time average of 20 seconds. The cost incurred in developing the machine was 71,000 Naira (₦) making it affordable for domestic use and for use by small scale food industries.

KEYWORDS: Design, Egg product, Machine, Manually operated, Solidworks

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I. INTRODUCTION

Eggs play an important role in the human diet and nutrition as an affordable nutrient-rich food commodity that contains highly digestible proteins, lipids, minerals and vitamins [1]. Eggs are composed of three main parts: eggshell (including the shell membranes between the albumen and the inner shell surface), egg white (albumen) and yolk, representing 9.5%, 63% and 27.5% respectively of the whole egg ([2] and [3]). According to Mittal et al., [4], eggshell and eggshell membrane has been used as absorbents for the removal of variety of organic as well as inorganic hazardous chemicals, particularly from waste water. According to Xu et al., [5], egg albumen (white) can be used in forming egg albumen adhesives which is reported to be fast and strong medical adhesive glue. An egg product separating machine (egg breaking and separating machine), is a processing equipment that break eggs and separate their contents. The basic egg breaking and separating machine is composed of a cracker (set of knives) and a yolk-albumen separator [6].

Patterson [7] invented an egg separator having an upper elongated slit to prevent the yolk of an egg from entering a collection device for egg whites. The device provides for a method that will allow multiple separations of egg whites from egg yolks upon cracking individual eggs. Kwapich [8] invented an intermediate bracing support and guide for use with an elongated egg cracker shaft and for preventing outward bowing deflection during egg delivery and breaking operations. Robinson [9] invented an advanced egg breaking system. The invention as described by the author is an egg transfer system for providing automated inspection and tracking of eggs prior to entering an egg breaker, as well as broken egg contents following breaking. Huang and Liu, [10] worked on design and test of automatic loading and unloading machine for egg tray. The automatic loading and unloading machine was designed for the high strength and low efficiency of egg tray loading and unloading in the egg candling process. So [11] invented an egg yolk separator. The device includes a strainer having a portion for retaining an egg yolk and aperture for straining egg white. A pair of arms extends in opposite directions from the strainer for resting on opposite sides of an opening vessel, locating the separator on the vessel.

Substantial progress has been made in the production of egg product separating machine howbeit, the cost of acquiring foreign egg product separating machines has made it difficult for local egg producers to fully utilize the economic value of eggs. Hence the need to design an egg product separating machine, that will be developed from locally sourced materials and require little technical skill to operate which will help small food industries break and separate egg products for various food applications.

II. METHODOLOGY

Design of Machine Components

The egg product separating machine was designed to break nine eggs at once. In designing the machine, a range of egg height and width was determined by measuring the height and width of eggs using a vernier caliper.

Table 1: Egg range

	Height (mm)	Width (mm)
Egg range	50-60	37-47

The specified egg range was used to determine the diameters of the egg holes on the egg holder with the larger egg hole having a diameter of 72 mm and the smaller egg hole in which the eggs sit has a diameter of 48 mm. In order to accommodate $\phi 72 \text{ mm} \times 9$ egg holes. The conceptual design of the equipment which include parts drawing, assembly and exploded drawings were carried out using Solidworks (version 2016) CAD software. The Solidworks interface is shown in Figure 1.

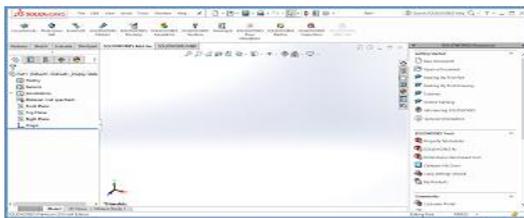


Figure 1: Solidworks interface

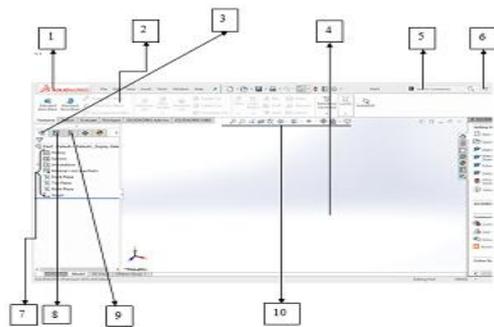


Figure 2: Parts drawing interface

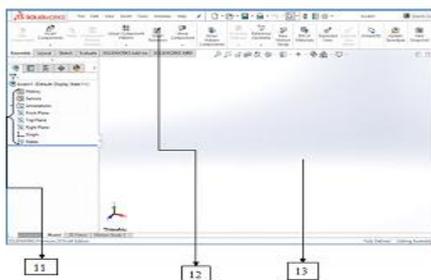


Figure 3: A assembly drawing interface

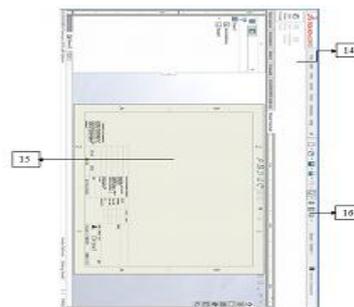


Figure 4: 2D drawing environment

1. Menu bar
2. Parts drawing interface command manager/toolbar
3. Feature manager filter
4. Graphics area (part drawing)
5. Solidworks search
6. Help fly-out menu
7. Feature manager design tree for parts drawing interface
8. Property manager
9. Configuration manager
10. Heads-up view toolbar
11. Feature manager design tree for assembly drawing interface
12. Command manager (Assembly drawing interface)
13. Assembly drawing graphics area
14. Command manager / toolbar for presentation (2D drawing) interface
15. Drawing sheet
16. Standard toolbar

Egg holder

The egg holder provides sits for eggs to be broken and it also prevents shell from already broken eggs to fall into the separator. The design steps are outlined as follows:

- I. Launch the solidworks application software, on the standard tool bar, click file, select new and parts drawing then click ok. On the features tool bar, click extruded boss/base and select a plane (front plane) and on the sketch tool bar select corner rectangle. Move the pointer to the sketch origin in the graphics area and drag the pointer upward to complete the sketched rectangle then click on exit sketch on the sketch tool bar and select the extrude parameters in the property manager that is, select 'blind' in end condition and set the extrude length or depth then click ok
- II. Draw holes on the extruded profile. Select the top of the profile and on the sketch tool bar, click on the circle tool and on the selected plane of the extruded profile sketch a circle. Use the smart dimension tool on the sketch tool bar to dimension the circle and also set the distance from the center of the circle to the edge of the extruded profile
- III. Create the hole by clicking the cut extrude tool on the features tool bar and set the depth of cut in the property manager also setting end conditions to 'through all' then click ok.
- IV. Select center line tool on the sketch tool bar and select the bottom plane of the drawn rectangle. Click on the circle tool and sketch the first circle equal to the diameter of the cut hole on the extruded rectangular profile. Using the same center line. sketch the second circle to the specified diameter and set the distance between the two circles using the smart dimension tool
- V. Join the two sketched circles by using the lofted boss/base tool on the features tool bar. This is done by selecting the two circles and the path through which the loft will pass on the property manager. Select the loft profile and select the shell tool on the features tool bar. On the property manager, set the specified thickness and click ok. Cut the hole using cut extrude tool.
- VI. Complete the egg holes by clicking on linear pattern on the features tool bar. Click the direction where the pattern will follow that is any line parallel to the x and y axis. Set the distance between the egg holes and select the number of patterns in the property manager then click ok.



Figure 5a: Egg holder

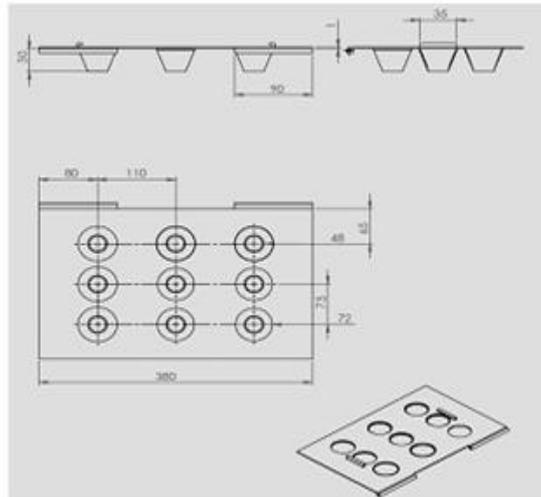


Figure 5b: Orthogonal view of the egg holder

Machine housing

The machine frame is the main body of the machine and it serves as a protective cover for the separator and the knives. The design steps are outlined as follows:

- I. Open a parts drawing graphics environment by clicking file on the standard too bar, select new, click parts drawing and click ok. Draw the main housing by first sketching a rectangle using corner rectangle tool in the sketch tool bar. Dimension the sides of the rectangle using the smart dimension tool in the sketch tool bar.
- II. Exit sketch and extrude the rectangle using the extrude boss/base tool in the features tool bar and in the property manager, set the extrude parameters then click ok to have a solid drawing. Sketch the rack housing on the extruded rectangular profile by selecting an edge on the right plane of the extruded rectangle and use line tool to sketch the profile.
- III. Use smart dimension tool to dimension the sketch then exit sketch and extrude the sketch. Set the extrude parameters (basically specifying the length) then click ok.
- IV. Shell the extruded rectangular profile using the shell tool (shell tool helps to create a thin walled feature) on the main housing. Set the shell parameter(s) in the property manager
- V. Select a face on the main casing (face width) and sketch a rectangle at the base of the face. Dimension the height and width of the sketch using the smart dimension tool the click extrude cut tool in the features tool bar. under the property manager,, adjust the extrude parameters to specification and click ok
- VI. To make holes on the frame, select a plane showing the face having the longer length and use the circle tool from the sketch tool bar to sketch a circle on the selected face of the housing. Set the distance from the center of sketched circle to the edge of the face selected and set the diameter of the circle using the smart dimension tool.
- VII. Click on the cut extrude tool on the features tool bar and set the cut distance to the thickness of the shelled wall then click ok.
- VIII. Click on linear pattern on the features tool bar, click on the pattern to be reproduced and select the axis, set the distance between the circles and click ok.
- IX. Repeat the same step on the opposite face having same length
- X. To draw the rack stopper, select the horizontal edge of one of the faces with shorter length and sketch the profile using line tool. Extrude the sketched profile to the specified dimensions.
- XI. In order to draw the 2D drawing, click file on the standard tool bar and select new. Click on 2D drawing option to access the 2D engineering drawing environment then click ok. Set the drawing sheet and under property manager select the drawn machine housing by double clicking on it. Adjust the orientation under the orientation subsection of the property manager. Adjust the scale under the scale subsection of the property manager. The display can also be changed as desired under the property manager.

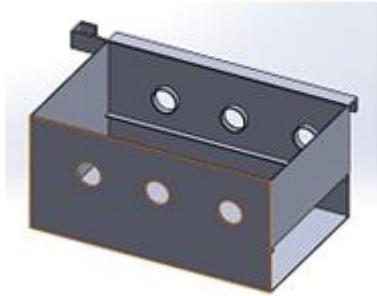


Figure 6a: Machine housing

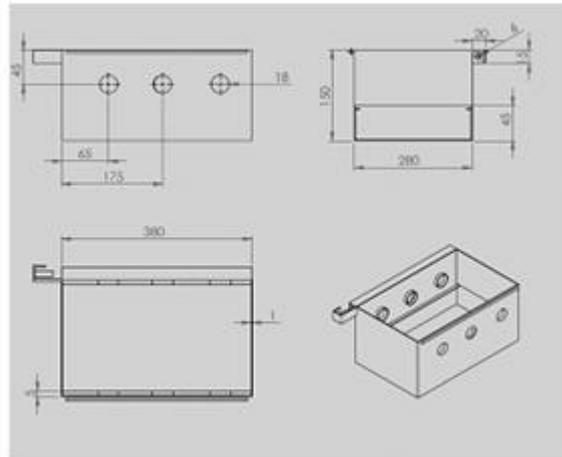


Figure 6b: Orthogonal view of the machine housing

Hollow pipe

The hollow pipes carry the knives and are attached to the pinions on one end and fastened to the machine housing at the other end with bolt × nuts to prevent it from removing during breaking operations. The design steps are outlined as follows:

- I. Click file on the standard tool bar, select new, click on parts drawing option and click ok. Select circle tool in the sketch tool bar and sketch a circle in the graphics area by placing the pointer on the origin, holding down the left mouse and dragging the pointer upward.
- II. Set the hole diameter using the smart dimension tool and click on the exit sketch icon to exit sketch and extrude the sketched circle by clicking on extrude boss/base icon in the features tool bar
- III. Select the face of one end of the extruded circle (solid pipe) and sketch a smaller diameter circle using the same center as the bigger circle earlier sketched
- IV. Set the diameter of the sketched circle using the smart dimension tool then exit sketch
- V. Select the small circle and click on the extrude cut tool in the features toolbar to obtain a hollow pipe. In the property manager, set the extrude conditions to 'through all' and click ok.

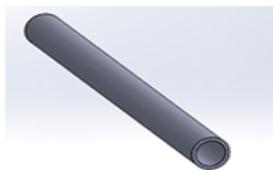


Figure 7a: Hollow pipe

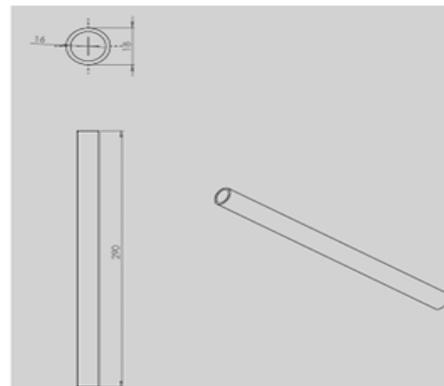


Figure 7b: Orthogonal view of the hollow pipe

Knives

The design steps are outlined as follows:

- I. Open a new part drawing interface by clicking file on the standard toolbar, select new and parts drawing then click ok.
- II. To draw the ring base of the knife, select the circle tool and sketch two concentric circles. Set the diameter of each sketched circle using the smart dimension tool then click on extruded boss/base icon on the features tool bar to extrude the sketch. Set the extrude length in the property manager and click ok.
- III. To draw the knife, click on reference geometry icon on the features toolbar and select plane to create a new plane. Select the faces to define the plane and in the property manager, choose mid-plane then click ok.

- IV. Use line tool to sketch the sides of the rectangle and use spline tool to draw an arc to join the lines on the circumference of the extruded ring. Exit sketch and extrude. Set the extrude parameters in the property manager to blind, input the extrude length, select mid-plane extrusion and click ok
- V. Click the top of the extruded rectangular profile and with line tool; sketch a triangle on one end of the selected area. Extrude the triangle to the required thickness and click ok. Sketch another triangle (a smaller one) opposite the first triangle using the line tool
- VI. Click on lofted boss/base icon in the features toolbar and select the sides of the two triangles to create the loft path then click ok
- VII. Cut extrude and chamfer the base sides of the lofted triangles using the cut extrude and chamfer tool in the features toolbar



Figure 8a: Knife

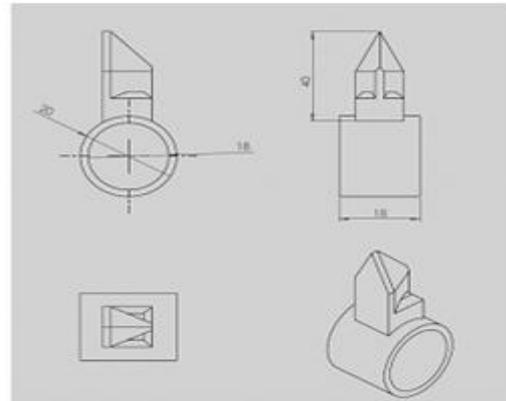


Figure 8b: Orthogonal view of the knife

Separator

Slit-cup separators were used so that yolk can settle at the base of the cup pushing the albumen up thereby allowing the albumen escape through the slits on the cup into the albumen collector. The design steps are outlined as follows:

- I. Open a new parts drawing interface and on the features tool bar, click on revolved boss/base icon and in the graphics area, sketch the profile of the separator using line and arc tools in the sketch toolbar and dimension it using the smart dimension tool in the sketch toolbar then exit sketch to automatically return to the features tool bar.
- II. In the property manager, under direction 1, select angle 360° to complete the cup shape
- III. Click on the fillet tool in the features tool bar and set the fillet radius in the property manager then click ok. This creates fillets at the selected edges
- IV. To create slits in the drawn cup, select corner rectangle tool in the sketch toolbar and sketch a rectangular profile on any selected side of the cup
- V. In the features toolbar, click on cut extrude and set direction to blind and depth to cut through the selected cup side. Click exit sketch on the sketch tool bar and the slit is created
- VI. To draw other slits, click on circular pattern tool under the features toolbar and in the property manager, set the angle parameter to 360° and tick the equal spacing box and set the number of slits to the required number
- VII. To draw the separator frame, open a new parts drawing interface, click on the sketch icon in the sketch toolbar, select corner triangle tool and from the origin drag the pointer upward holding down the left mouse then release to get the sketched triangle. Exit sketch and click on Extrude boss/base icon to extrude the sketched triangle. Sketch the thickness of the extruded drawing under direction 1 of the property manager and click ok
- VIII. Select the top plane and in the sketch tool bar, click on the circle tool and at the specified distance from the edge of the rectangular frame, sketch the circle on the frame. Click on extruded cut tool in the features tool bar and set the depth of the cut under the property manager then click exit sketch. This will create hole on the egg frame to which the separators will be fitted
- IX. Click on any side of the frame (x and y axis) and select linear pattern on the features tool bar to cut other holes on the frame. Set the distance between the center of the holes and the number of holes to be created along the selected axis in the property manager and click Ok. Repeat the step for other axis until the required holes have been cut on the frame

- X. To assemble the parts together, open an assembly drawing interface by clicking file, select new and choose assembly drawing to access the assembly environment
- XI. Select the insert component icon in the assembly command manger/ tool bar and click on the parts to be assembled. Select the separator and its frame and the edges where they will mate then click the mate icon also in the assembly command bar and select coincident in the property manager then click ok. The separator will automatically fit itself to the hole on the frame
- XII. Click on linear component pattern and select the direction, that is, the axis along which the pattern is to be drawn and click on the pattern (separator) to be reproduced along the selected axis in the property manager under direction 1, set the distance between the patterns and number of pattern to be drawn in each chosen direction then click ok



Figure 9a: Slit-cup separator

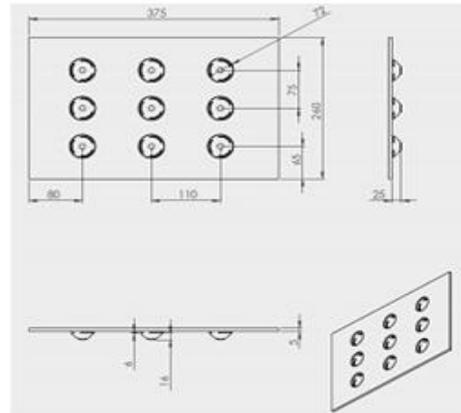


Figure 9b: Orthogonal view of the egg separator

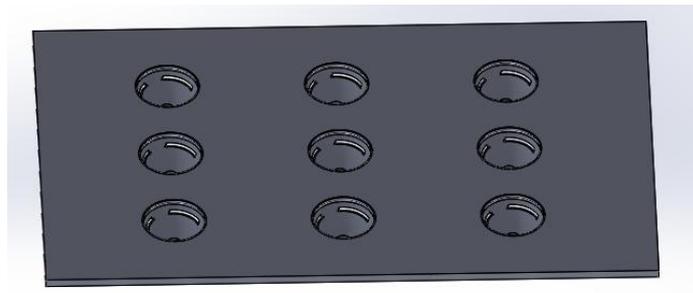


Figure 9c: Separators

Albumen collector

The design steps are outlined as follows:

- I. Open a new parts drawing interface and on the sketch toolbar, click on corner rectangle tool and drag the pointer up in the graphics area to draw the rectangle. Dimension the sides of the rectangle using the smart dimension tool then exit sketch
- II. On the features toolbar, click on extrude boss/base to extrude the rectangle and in the property manager, set the extrude length
- III. Select the top of the extruded rectangle and click on shell tool in the features tool bar. Set the shell thickness in the property manager then click ok.
- IV. To draw the handle, sketch the profile using the line tool on one end of the sketched rectangle, exit sketch and extrude. Set the extrude parameters in the property manager section
- V. Create fillets on the edges of the handle using the fillet tool in the features tool bar.
- VI. Sketch the inner profile of the handle using line and tangent arc tool and click on cut extrude icon/tool in the features toolbar then exit sketch and click ok

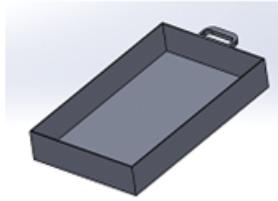


Figure 10a: Albumen collector

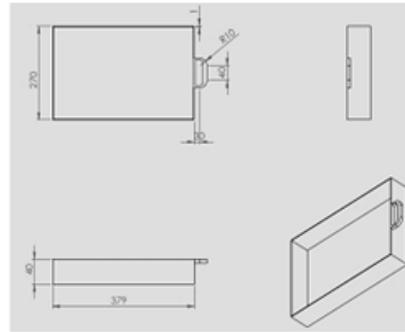


Figure 10b: Orthogonal view of the albumen collector

Actuating handle

The design steps are outlined as follows:

- I. Open a new parts drawing interface, draw the lower rod that connects the actuating handle to the driver pinion by selecting the circle tool in the sketch toolbar then sketch a circle in the graphics area by placing the pointer on the origin and holding down the left mouse drag it up from the origin
- II. Once the sketch is completed and the circle diameter has been set, exit sketch and on the features tool bar, click on extruded boss/base to extrude the drawn sketch
- III. Click on the right end face of the extruded rod and using the center point arc tool, draw an arc using the same center as that of the earlier extruded circle and draw an arc to the specified radius
- IV. Sketch another arc using the center arc tool, having its center on the same axis as the first arc drawn.
- V. Join the two arcs together using line tool then exit sketch and click on the extruded boss/base icon to extrude the sketch. Set the extrude parameter in the property manager and click ok to get the connector
- VI. On the right face of the smaller arc, sketch another circle on the selected face of the small arc having the same center using the circle tool in the sketch toolbar
- VII. Exit sketch after drawing and extrude using the extruded base/boss to the specified extrude length
- VIII. To draw the last part where the force is applied directly, sketch a circle using the same center as the extruded boss on the small arc. Set the required diameter using the 'smart dimension' tool
- IX. Once sketch is done, click 'exit sketch' and on the features toolbar, click 'extruded base/boss'. In the property manager, input the length of the extruded circle and click ok.

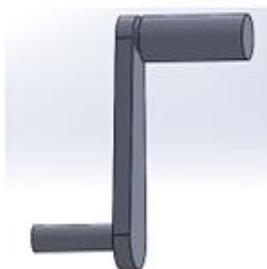


Figure 11a: Actuating handle

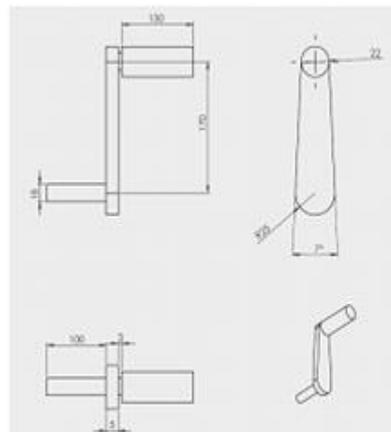


Figure 11b: Orthogonal view of the actuating handle

Assembly and Exploded Drawing

Assembly and exploded drawings was done after parts' drawing was completed and the assembly drawing and exploded drawing of the egg product separating machine is shown in figures 12a and 12b.

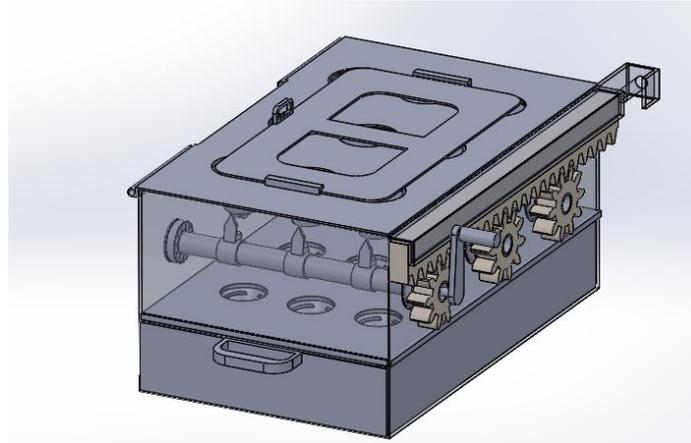


Figure 12a: Isometric view of the egg product separating machine

S/N	PART DESCRIPTION	QUANTITY
1	CRACKER	9
2	HOLLOW PIPE	3
3	BEARING	6
4	SLIDING COVER	1
5	EGG HOLDER	1
6	SEPARATOR	1
7	PINION	3
8	ACTUATING HANDLE	1
9	HOUSING	1
10	RACK	1
11	ALBUMEN COLLECTOR	1

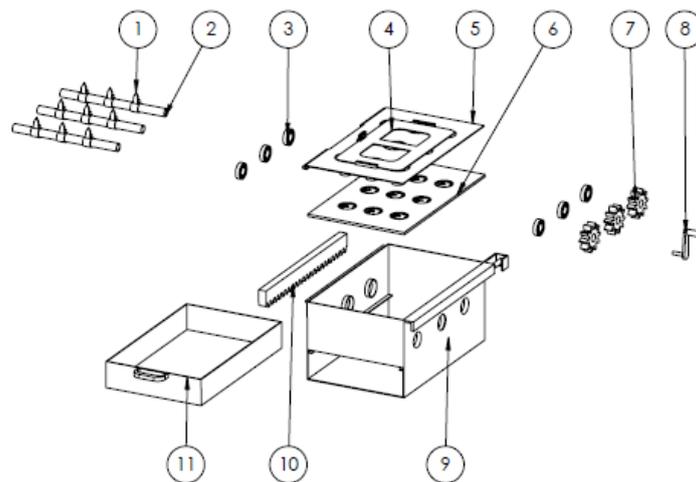


Figure 12b: Exploded view of the machine showing labeled parts

III. BILL OF ENGINEERING MEASUREMENTS AND EVALUATION

The cost expended in the design and fabrication of the equipment is direct cost (material cost and labour cost) as shown in Tables 2 and 3 respectively and overhead cost shown in Table 4.

Table 2: Material cost

Item	Quantity	Cost per unit (Naira)	Cost (Naira)
Stainless steel sheet (4 by 4)	1	18000	18000
Rack and pinion	1 rack and 3 pinions		7500
Stainless Electrode	10	500	5000
Hollow stainless pipe	1 m	6000	6000
Bearing	6		2000
Bolt and nut	10	50	500
Spray	2	1000	2000
Plastic spoon	10	100	1000
Total			42000

Table 3: Labour cost

Job Description	Cost (Naira)
Marking out and cutting	3000
Welding	2000
Assembly	3000
Surface finish	1500
Painting	1500
Design	10000
Total	21000

Table 4: Overhead cost

Description	Cost (Naira)
Printing	2000
Transportation	3000
Miscellaneous	3000
Total	8000

Total cost incurred

The total cost incurred in the cause of the work is the sum of these three highlighted costs and it is shown below mathematically as;

$$\begin{aligned} \text{Total cost (Naira (₦))} &= \text{materialcost} + \text{labourcost} + \text{overheadcost} && (1) \\ &= 42000 + 21000 + 8000 \\ &= \mathbf{₦ 71000} \end{aligned}$$

The total cost incurred in producing a unit of the machine is ₦ 71000 (\$203) compared to imported machines which cost about \$500-\$600000 depending on its capacity and mode of operation, (<https://goo.gl/Vu3BsE>).

IV. RESULT AND DISCUSSION

Fabrication and assembly of the machine was successful and a breaking efficiency of 90.7 % was obtained with separation time average of 20 seconds and a setup time of 25 seconds. The cost of the machine is less than the cost of egg breaking and separating machines purchased abroad.

V. CONCLUSION

The egg product separating was designed using solidworks CAD software (2016 version). The CAD software was used for the parts drawing, assembly drawing and 2D drawing of the machine. The parts drawing interface, assembly interface and 2D drawing interface were shown as figures. Design steps for each machine part designed was outlined and the parts drawing for each machine parts, assembly drawing, exploded view and 2D drawing were shown in this study. The performance results based on the ratio of number of properly broken eggs to that of the total eggs broken was obtained as 90.7 % with separation time average of 20 seconds. The cost incurred in developing the machine was 71,000 Naira making it affordable for domestic use and for use by small scale food industries.

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