MODIFIED DESIGN OF A SELECTED DOMESTIC CHINCHIN CUTTING MACHINE

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Abstract - There exists various designs of well-developed chinchin cutting machines in the market today. The vast market for the product (especially in West Africa) necessitates every possible technological approach in ensuring optimal production (reducing overall production cost, lead time and the stress involved in its production). The existing chinchin cutting machines were all observed to have a common major set-back, which is the fact that their design only makes it possible for the chinchin pasta to be cut into strands; thus the operator would have to spend more time and expend greater energy in cutting these strands into smaller rectangular shapes with knife. This problem forms the basis for this research work, as its aim/objective is to improve on the existing design, such that the machine can cut the pasta into desired shape and length. The major innovation introduced is a system whereby the cutting shaft is designed such that it has small projected blades, machined along its circumference at specific and well calculated circumferential distances from each other, depending on the required length of the pasta to be cut. The design was done using Pro/Engineer Wildfire 5.0 software. It can be inferred from the developed model of the domestic chinchin cutting machine and from its design analysis as well as from the results obtained that the machine will serve its intended design purpose when fully developed and evaluated.

***Keywords*: Modified Design, selected, domestic, chinchin, cutting machine**

1. INTRODUCTION

Chinchin has been said to be a traditional Nigerian snack that is prepared from cereal flour, butter, milk and egg to form a stiff paste, which is then deep fried or baked until it turns golden-brown and crisp [1, 2]. It has been known to be a popular crunchy and delightful fried snack in West Africa, especially in Nigeria, amongst several age brackets [1, 3]. It is a sweet, hard, donut-like baked or fried dough and can be cut into different sizes and shapes [4]. It comes in handy at home, in the office, at parties, in reception halls, air-crafts and at schools among others.

Moreover, domestic chinchin production has been from time immemorial, and it is extremely stressful and time consuming; to a large extent, this has limited the domestic production capacity and quality of this snack. Considering the popular demand for this snack, the need arises for large scale domestic production [5]. The initial designs of domestic chinchin cutting machines that are available in Nigerian markets today can only cut rolled flour into strands as shown in Figure 1 and Figure 2. After the machine might have cut the rolled flour into strands, the manual means of cutting with a knife is usually employed by operators in order to achieve the desired shapes and sizes [6]. This method has been found to be time-consuming and onerous. There is a need to alleviate the human power expended, reduce production time and improve the quantity/quality of the chinchin. In order to address the challenge posed by the existing design of chinchin machines to domestic production of the snack, it has become necessary to improve on the design of a domestic chinchin cutting machine.

Figure 1: Ready to be cut rolled chinchin dough

Figure 2: Existing chinchin cutting machine in operation [7]

This study is aimed at modifying the initial design of a selected domestic chinchin cutting machine so that the machine will be able to cut rolled flour into strands and simultaneously slice them into smaller and desired rectangular shapes or sizes in a bid to reduce the drudgery involved in domestic chinchin production and enhance its production output. This study is targeted at domestic chinchin producers since they form the majority of producers of the product in Nigeria. Hence, a technological approach as this, aimed at alleviating the drudgery involved in the production process and simultaneously reducing the overall production time, will in the long run increase the overall production rate and inevitably make production easy for the domestic producers of the product. It is expected that the development of this modified domestic chinchin cutting machine will eliminate manual cutting of chinchin with knife, and will enhance domestic production of chinchin.

2. MATERIALS AND METHODS

A domestic chinchin cutting machine was bought, disassembled, studied carefully and its components were assessed. The component parts of the machine were gears, shafts, hand roller, connecting bolts and nuts, stainless steel shields, table clamp and detachable cutter.

2.1 Design Requirements for the Chinchin Cutting Machine

A number of factors were put into consideration during the design modification of the domestic chinchin cutting machine in order to avoid inefficiency in its operation and to achieve optimal production. These factors are as follows:

Weight: The materials selected for the component parts were such that the overall weight of the machine is relatively low so that the machine can easily be operated and moved from one place to another.

Stability: Apart from making the stand base flat and firm, another measure employed for the stability of the machine in order to ensure the safety of the operator is the incorporation of a table clamp. This also prevents unwanted haphazard movement of the machine while in use.

Procedure and Flexibility: Primarily, all the materials selected can be locally sourced and processed easily. The tolerances in the measurement of the various parts were made as large as possible so as to avoid assembly errors. The machine design also put flexibility into consideration as it makes it possible to easily change the cutting shaft with respect to the desired cutting length. The overall cost of the machine, which includes the design cost, the materials cost and the labor cost, was also kept as minimal as possible.

Performance: For excellent performance of the domestic chinchin cutting machine, the following performance criteria were taken into consideration during the design:

a. The design ensured a certain degree of freedom between component parts that must come in contact with each other, such as the gears, the cutting shafts and driving shafts.
b. The mechanical efficiency of the machine was also maintained as high as 90%.

Maintenance Procedure: The machine's modification was done to give room for easy maintenance at the barest minimal cost by taking the following factors into consideration:

(a. Lubrication of the machine parts is not necessary, since the pasta to be cut must have been initially mixed with margarine or vegetable oil which makes it move freely on the surface of the shaft.

(b. Easy assembly and disassembly when changing the cutting shafts.

(c. Damaged parts of the machine can easily be fabricated and replaced.

2.2 Material Selection for Component Parts of the Machine

According to [8], Table 1 presents the machine components, materials selected for each component and criteria/reasons for selecting the materials.

Table 1: Materials Selection for the Chinchin Cutting Machine

Machine Components	Material Selected	Selection Criteria/Reason
Gears	Cast iron	Good wear resistance properties, excellent machinability, tooth hardness
Cutting Shafts	Stainless Steel	Reliability, corrosion resistant, good wearing properties
Lock Pin	Alloyed Steel	Ductility, Good machinability, readily available
Machine Housing	Stainless Steel	Prevents rust, corrosion resistant
Connecting Rods	Stainless Steel	Corrosion resistant, High fatigue strength
Nuts and Cover Screw	Mild Steel	High fatigue strength, creep resistance, excellent machinability, readily available, cheap

2.3 Design Analysis of Component Parts of the Chinchin Machine

2.3.1 Modification of Cutting Shafts Assembly

The shafts in the machine are used to transmit power, which support both forward and reverse rolling.
In each cutting compartment of the machine, there are two cutting shafts:

(a. The first, known as the driving shaft, is designed with a splined opening at one end to accommodate the rotating lever which propels the motion in the entire machine.

(b. The second shaft, known as the driven shaft, is the one on which the modification was carried out. Its pattern of motion is rotational and inverse in direction to that of the driving shaft. This motion is achieved with the aid of the assembly of gears at one end of each shaft.

The initial cutting shaft dimensions were maintained with just a little addition by considering three lengths of chinchin dough: 60mm, 30mm and 20mm as shown in Figures 3 to 13. The modification made was on the cutting compartment with cutting shafts having larger cutting sections (6.45mm thickness), as well as that with cutting shafts having smaller cutting sections (2.08mm thickness). The thickness of the cutting sections was maintained from that of the existing chinchin cutting machine that was purchased. In order to determine the approximate length of each chinchin dough to be cut, the circumference of the external cutting sections was calculated using Equation (1).

$$C_{csh} = \pi d_{csh} \quad (1)$$

$$\therefore C_{csh} = 3.142 \times 19.5 = 61.27mm$$

Where: C_{csh} and d_{csh} are the cutting shaft circumference and diameter (which is 19.5mm) respectively.

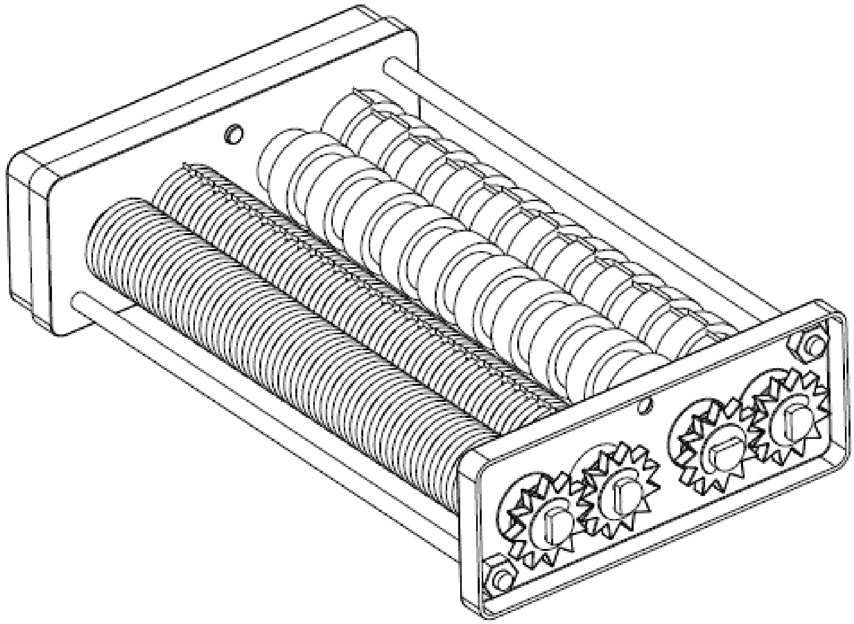

Figure 3: Isometric view showing the assembly of gears and cutting shafts

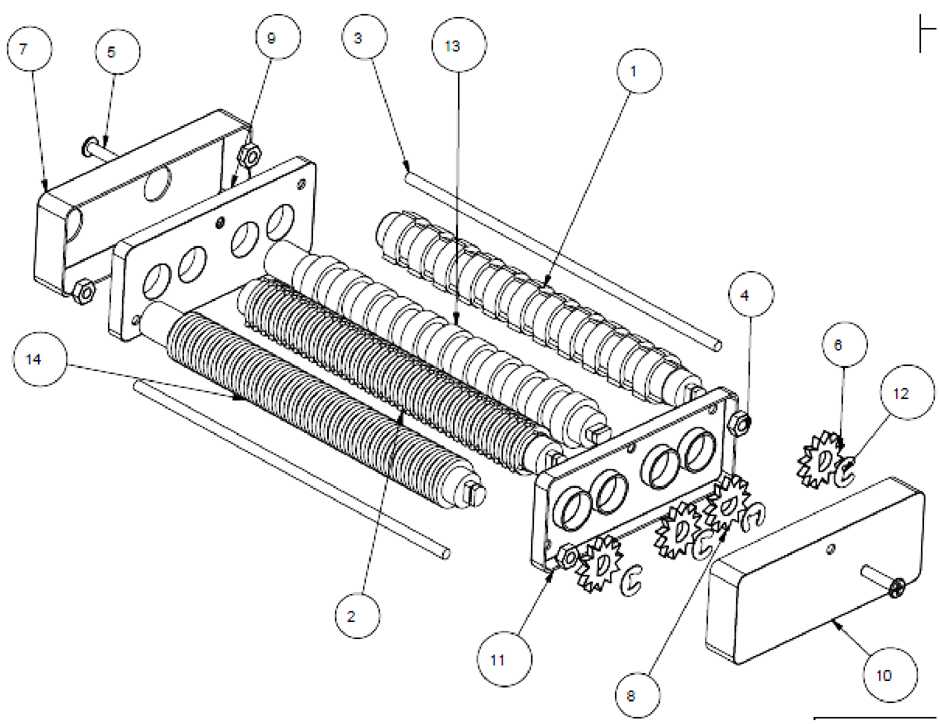

Figure 4: Exploded view of the modified chinchin cutting compartment; (1) Main cutting shaft with protruded blades; (2) Mini-cutting shaft with protruded blades; (3) Connecting rod; (4) Connecting nut; (5) Cover screw; (6) Driven gear; (7) Shaft cover; (8) Driving gear; (9) Inner shaft cover; (10) Gear assembly cover; (11) Inner cover for gear assembly; (12) Lock pin; (13) Main driving shaft; and (14) Mini driving shaft.

As shown in Figures 3 to 6, the cutting shafts were re-designed by incorporating protruding cutting blades on each cutting section. The cutting blades protrude perpendicularly up to a length of 1.3mm to an imaginary line that is tangential to the circumference of the cutting section and are relaxed at an angle of 30° backwards along the circumference of the cutting section for proper cutting force application. The blades are repeated linearly on each cutting section along the length of the entire 60mm chinchin cutting shaft as shown in Figures 5 and 6. The sectional view of the 60mm cutting shaft is as also shown in Figure 7.

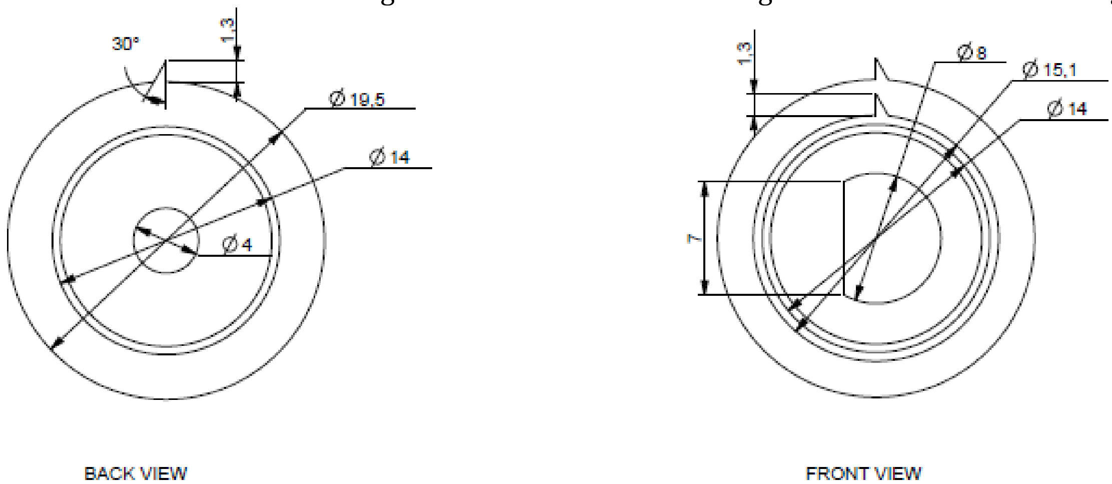

Figure 5: Back and front view of the 60mm chinchin cutting shaft

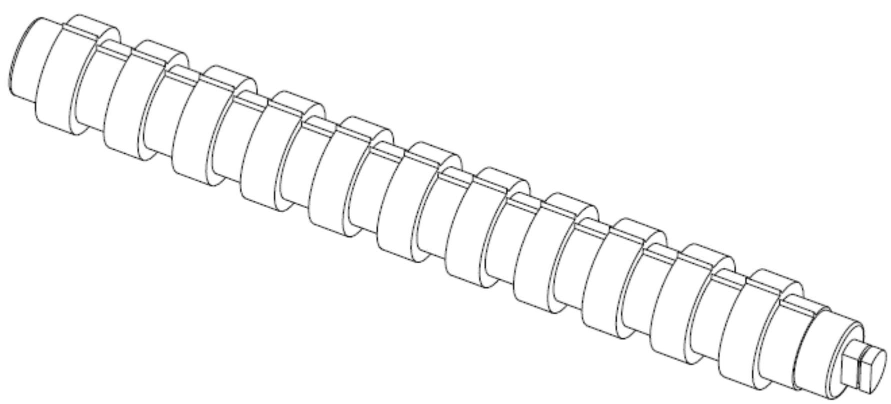

Figure 6: Isometric view of the 60mm chinchin cutting shaft

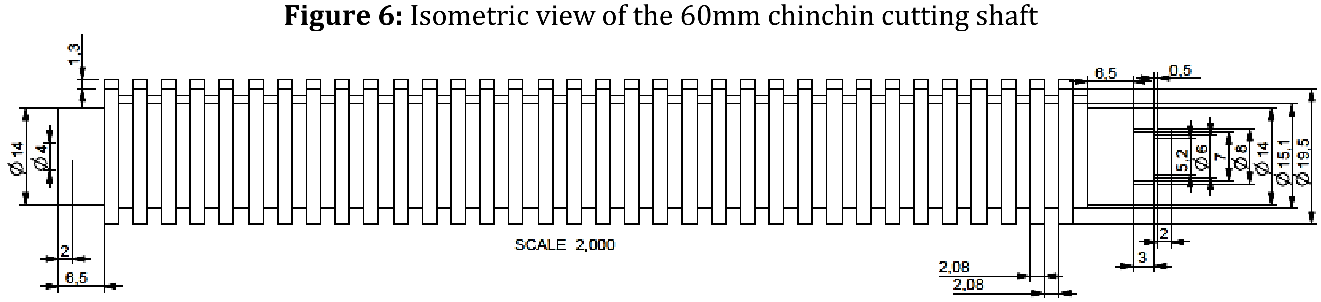

Figure 7: Sectional view of the 60mm chinchin cutting shaft

For the 30mm chinchin cutting shaft, the design involved two (2) cutting blades of uniform dimensions, positioned at 180° to each other along the circumference of each cutting section, thereby implying a cutting length of approximately 60/2, which is 30 mm between the blades on either side as shown in Figures 8 and 9. This implies that the shaft is able to cut chinchin doughs of 30 mm long. The sectional view of the 30mm cutting shaft is as shown in Figure 10.

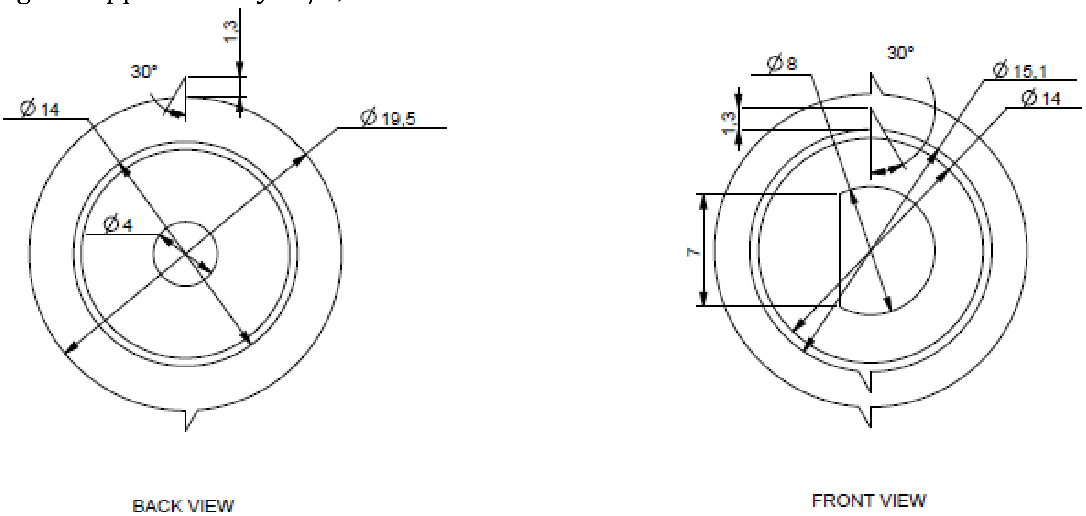

Figure 8: Back and front view of the 30mm chinchin cutting shaft

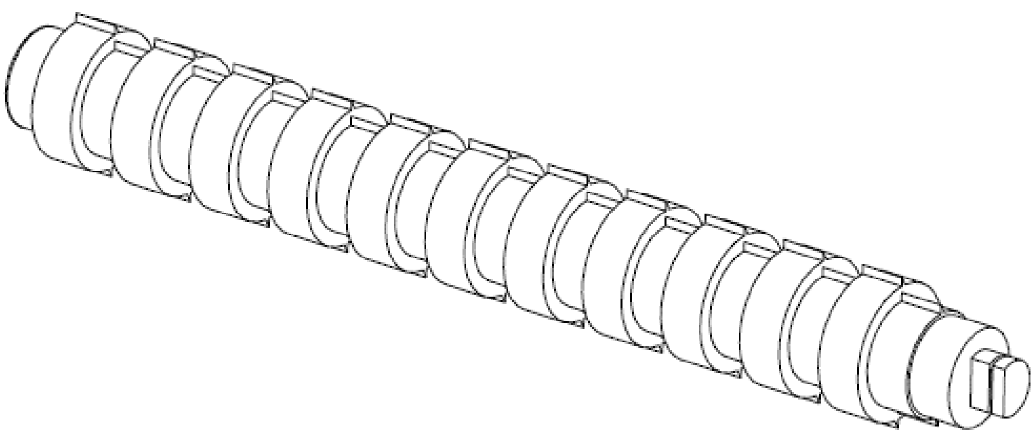

Figure 9: Isometric view of the 30mm chinchin cutting shaft

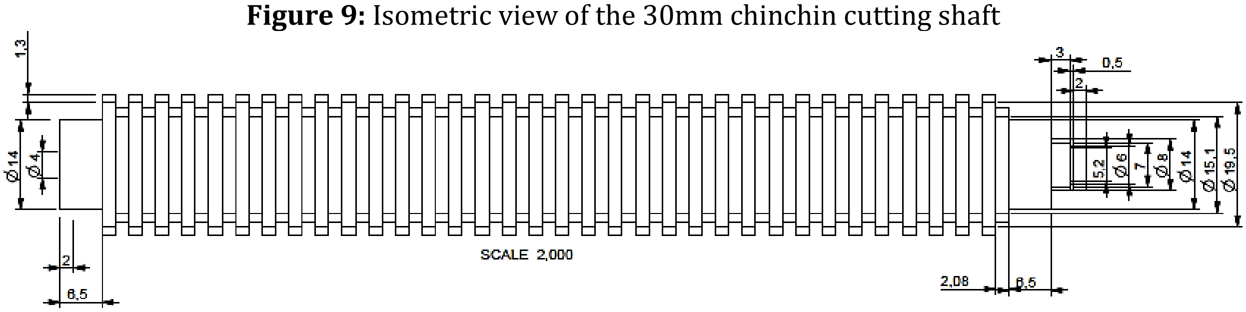

Figure 10: Sectional view of the 30mm chinchin cutting shaft

In the case of the 20mm cutting shaft, three (3) cutting blades were incorporated along the circumference of each cutting section at an angle of 120° to each other, thus the length of dough cut in-between any two blades is approximately 60/3, which is 20mm as shown in Figures 11 and 12. This implies that the shaft is capable of cutting chinchin doughs of 20 mm long. The sectional view of the 20mm cutting shaft is also shown in Figure 13.

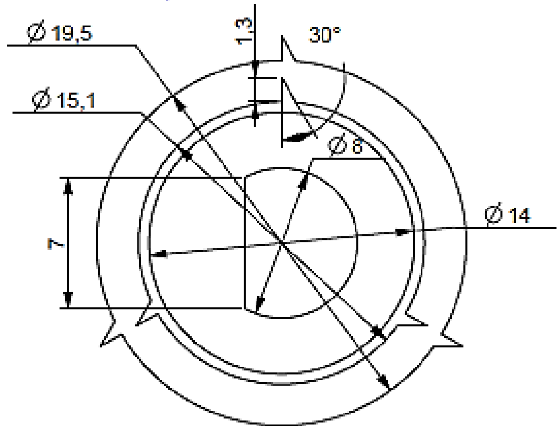

Figure 11: Front view of the 20mm chinchin cutting shaft

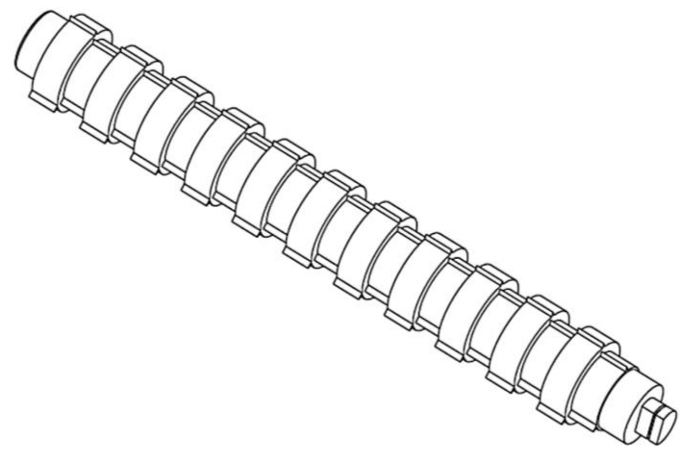

Figure 12: Isometric view of the 20mm chinchin cutting shaft

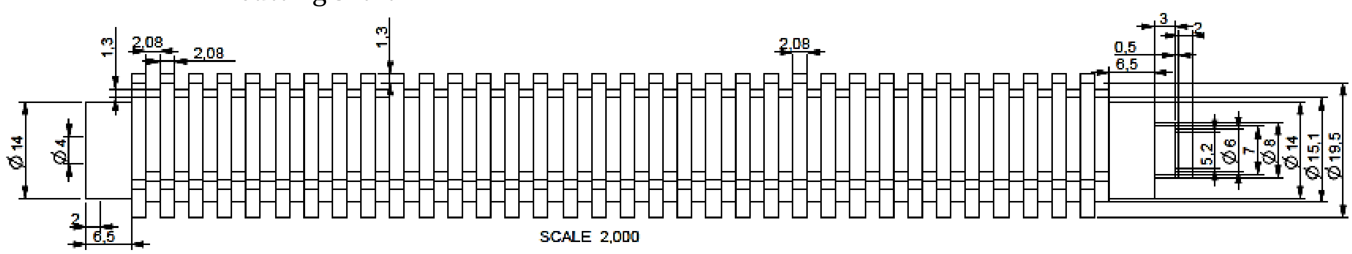

Figure 13: Sectional view of the 20mm chinchin cutting shaft

2.3.2 Torque Transmitted by the Shaft

The torque transmitted by the driving shaft (T_{ds}) can be defined as the product of the forces (F_{ro}) required by the operator to roll the machine through the handle of the roller and the perpendicular distance from the gear to the arm (L_{pdg}).

$T_{ds} = F_{ro} \times L_{pdg}$ (2)

$F_{ro} = m_b \times g$ (3)

Where: m_b is the mass of the operator's body and g is the acceleration due to gravity of the body.

Assume the average weight of the operator to be 65 kg,

$\therefore F_{ro} = 65 \times 9.81 = 637.65\ N$

Also, the perpendicular distance from the gear to the arm is taken as 200 mm.

Hence, from Equation (2)

$\therefore T_{ds}$ = 637.65 x 200 = 127530 N-mm

2.3.3 Tangential Force of the Gear on the Shaft

$F_t = \frac{2T_{ds}}{D_G}$ (4)

Where: F_t is the tangential force on the gear and D_G is the diameter of the gear.

The diameter of the gear was measured from the existing chinchin cutting machine gear, which is 20.5mm.

From Equation (4),

$F_t = \frac{2 \times 127530}{20.5} = 12441.95\ N$

2.3.4 Normal Load Acting on the Tooth of the Gear Attached to the Shaft

W $= \frac{F_t}{\cos\alpha} == \frac{12441.95}{\cos 20°} = 13240.45\ N$ (5)

Where: α is the pressure angle of the gear.

The Machine Housing

An entirely new machine housing was designed to accommodate the newly modified cutting shafts and to prevent unwanted friction between the cutting shafts and the driving shafts.

The machine housing is made from aluminum materials in order to prevent corrosion and to maintain optimal hygienic production conditions. It performs several functions, among which are:

a. housing the major functional components of the machine;
b. fitting each component at accurately pre-determined distances to each other;
c. incorporating the stand for clamping the machine to the worktable; and
d. preventing accidental contact between components while the machine is in operation.

Measures to Be Taken Prior to Assembly

The modified machine was designed in such a way that a single housing can serve the purpose of cutting into any of the three specified lengths of chinchin doughs. Only the cutting shafts need to be changed in any case necessary. In changing the shafts, some important Steps need to be taken:

a. The work area where the assembly is to be carried out must be kept clean, dry and spotless.
b. All the component parts (the shafts, gears, connecting bolts and nuts, lock rings and the housing itself) must be cleaned carefully.
c. The gear compartment must be properly and carefully greased with the recommended grease.

The Gears

The major reasons why gear drives are used in the machine, as compared to other drives like belt, rope and chain drives are:

a. It is capable of transmitting large power.
b. It has reliable service.
c. It can be used for small center distances of shafts.
d. It has high efficiency.
e. It transmits exact velocity ratio, and
f. It has compact layout [9].

There are two gear trains in the design since there are two separate cutting compartments (for 6.45mm thickness and 2.08mm thickness). The power is transmitted from the first (driving) shaft through the first gear; the first gear meshes the second gear and the power is transmitted to the second (driven) shaft. The material selected for the fabrication of the gears is cast iron. This is because it has good wear resistance properties as well as tooth hardness and excellent machinability.

Speed Ratio of the Gears

Speed Ratio, $N_R = \frac{N1}{N2} = \frac{T2}{T1}$ (6)

Where: N_1 is the speed of the driving gear in revolutions per minute; N_2 is the speed of driven gear in revolutions per minute; T_1 is the number of teeth on driving gear, which is 12; and T_2 is the number of teeth on driven gear, which is 12.

Since both the driving and the driven gears are of the same diameter and have equal number of teeth, the speed ratio can easily be determined by using Equation (7):

Train Value

Train value = $\frac{1}{speed\ ratio} = \frac{1}{1} = \mathbf{1}$ (7)

Tangential Tooth Load

$$W_T = \frac{P}{V} \times C_s \quad (8)$$

$$V = \frac{\pi DN}{60}$$

Where: W_T is the tangential tooth load; P is the power transmitted in watts; V is the Pitch line velocity in m/s; D is the Pitch circle diameter; and C_s is the service factor, which is 1.00 for light load.

Normal Load Acting on the Two Gears

$$W_N = W_T \cos\varphi \quad (9)$$

$$W_T = W_{T1} + W_{T2}$$

Where: W_N is the normal load acting on the gear; W_T is the sum of tangential loads on both gears; and φ is the pressure angle, which is 20°.

The Connecting Rod

The material selected for this component is stainless steel and its primary function is to hold the two sections of the machine housing (gear section and driving section) together. Its overall length is 160mm with a diameter of 4mm. Each end of the rod is to be tapped to a length of 10mm so as to accommodate connecting nut.

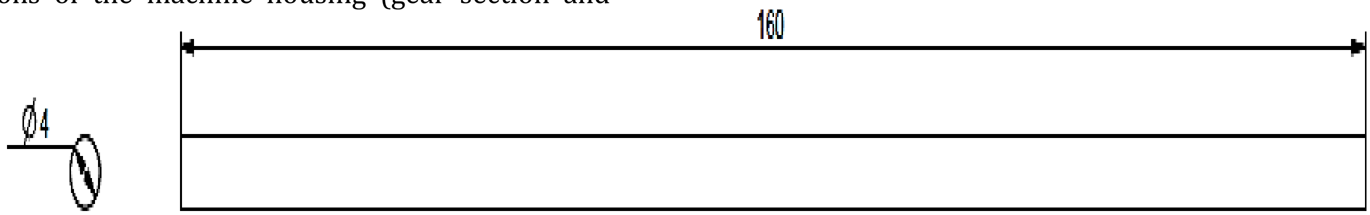

Figure 14: The Connecting Rod

The Connecting Nut

The nut is designed to hold each connecting rod firmly against the body of the inner housing on both sides. Mild steel was selected as the suitable material for the connecting nut. The dimensions for the nut are shown in Figure 15.

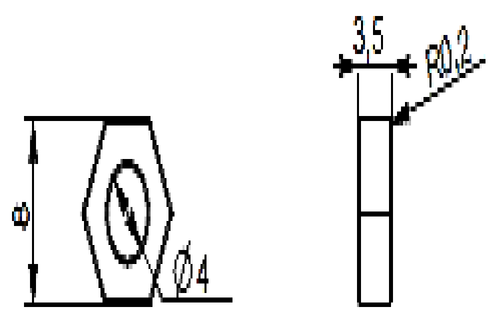

Figure 15: The Connecting Nut

The Lock-Pin

The lock-pin is a specially designed component whose function is to secure each gear in position on the shafts. The material selected was alloyed steel. Its dimensions are as shown in the Figure 16.

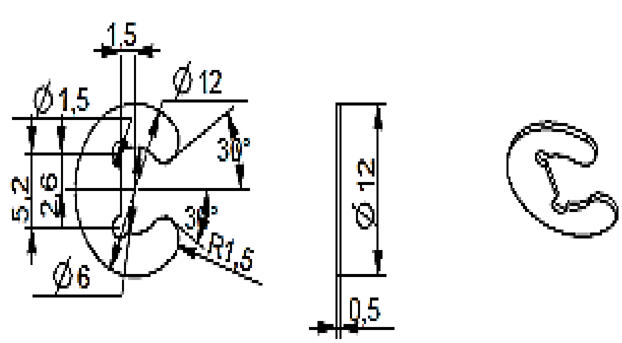

Figure 16: Lock-Pin

The Computer Aided Design of the Machine

The Computer Aided Design (CAD) of the machine was carried out using Pro/Engineer Wildfire 5.0 software. The individual part drawings were made, after which they were assembled appropriately. The final phase was the drawing phase, where all the parts, the whole assembly and the exploded view were presented with their respective dimensions for easy interpretation. Screenshots from the software interface during design are as shown in Figures 17 to 20.

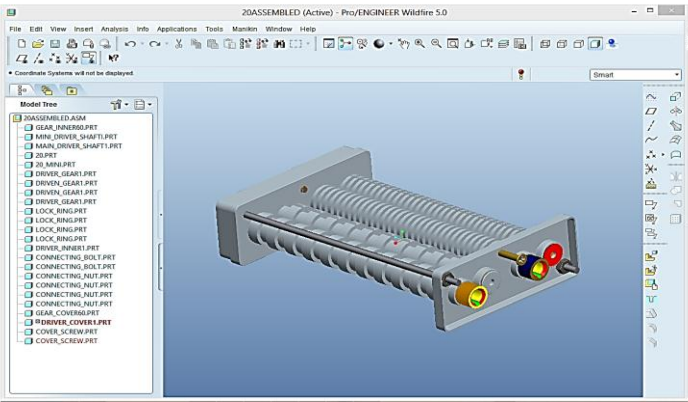

Figure 17: Screenshot showing the inner section of the Machine driving side during assembly

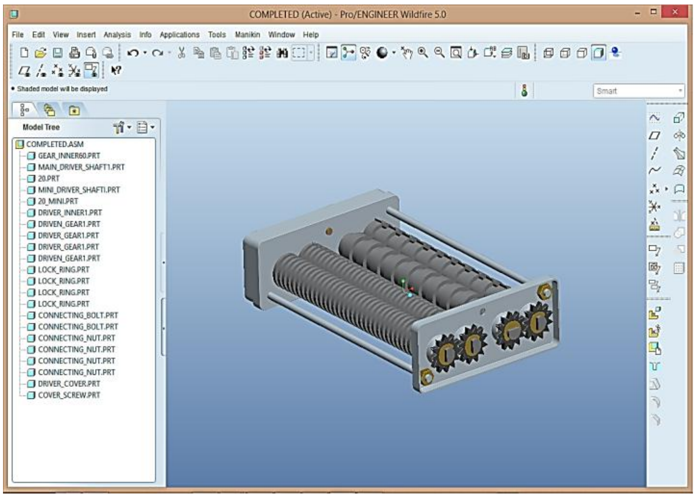

Figure 18: Gear compartment during assembling of the machine parts

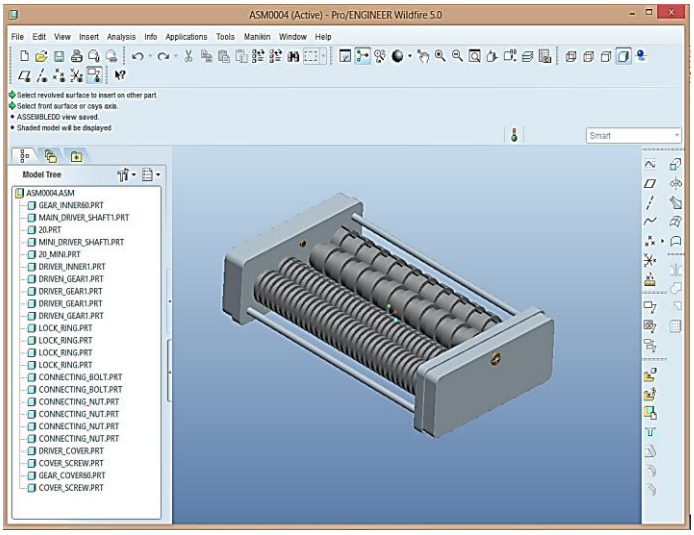

Figure 19: Cutting shaft assembly of the machine as viewed from the gear compartment side

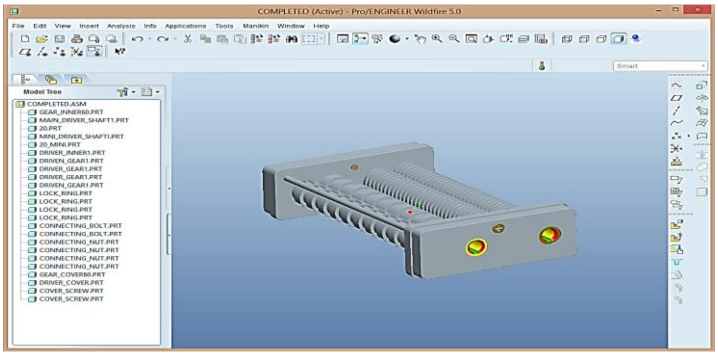

Figure 20: Cutting shaft assembly of the machine as viewed from the driving side

3. RESULTS AND DISCUSSION

A prototype of the domestic chinchin cutting machine was fabricated and tested to determine its performance efficiency on the flour pasta being fed into it when fully developed as shown in Figure 21. It was observed that all the parts of the machine functioned effectively.

Figure 21: The fabricated prototype of the domestic chinchin cutting machine in operation

It was also noted that the cutting accuracy of the machine blades along the shaft circumference was quite remarkable as the cut out product for each of the specified sizes (20mm, 30mm and 60mm) were measured and they were found to be relatively accurate as shown in Figures 22, 23 and 24 respectively.

Figure 22: The pasta cut out by the 20mm chinchin cutting shaft

Figure 23: The pasta cut out by the 30mm chinchin cutting shaft

Figure 24: The pasta cut out by the 60 mm chinchin cutting shaft

4. CONCLUSION

It can be inferred from the developed model of the domestic chinchin cutting machine and from its design analysis as well as from the results obtained in Figures 22, 23 and 24 that the machine will serve its intended design purpose when fully developed and evaluated. The machine will absolutely require no skill or professionalism to be operated effectively when fully developed. The machine is relatively light in weight and it has the required strength and capacity to operate without vibration. It is also noteworthy to say that the machine will be highly cost-effective and will require cheap maintenance since all the materials used for the fabrication of the machine's prototype were sourced locally.

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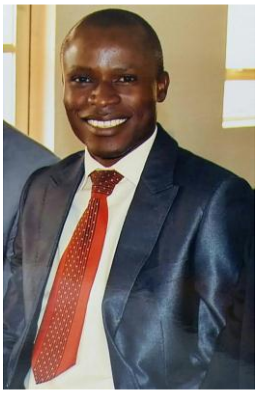
BIOGRAPHY



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