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Development of an Improved Circular Sawing Machine

Mogaji P. B.

Mechanical Engineering Department, The Federal University of Technology, Akure,

PMB 704, Akure, Ondo State, Nigeria

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A B S T R A C T

The increase use of wood for furniture design of various forms has called the need for an effective means of cutting wood of various types into required dimensions. An improved wood sawing machine was developed using locally available materials in this research. A detail material selection process was done to ensure that the proper materials were used for the production of the machine. Basically, two major areas of improvement were; introduction of guard system to the upper part of the blade that protrudes towards the end and hopper tray for the lower part. The performance evaluation of the developed machine was carried out with wood of various dimensions and types. The result revealed that the machine cut a hard wood of 50.8 mm thickness in 141.5 seconds and soft wood of 50.8 mm thickness in 128.5 seconds. The developed machine is safe to use, reduces the stress of cutting wood manually and has no environmental effect as a result of wood dust exposure. The estimated cost of production of the machine was ninety- thousand naira (#90,000) only which was approximately ($300).

1. Introduction

Plain Plank sawing is one of the plank or lumber sawing techniques. It is a method which require the simplest technique resulting in high production. Sometimes it involves cutting off the rounded bark sides of slabs to produce a cant and progressively sawing boards from the cant. The Table circular sawing machine used a toothed metal cutting blade. The blade is a tool used for cutting wood or other materials and may be hand-held or table-mounted. Circular saw are the most commonly used tool in the woodworking industry, though simple, it is a refined technology. Special attention must be given to detailed and quality of construction and fabrication processes because of the significant effect on performance of the circular sawing machine. This applies especially as the plate thickness and kerf are reduced. For achieving optimum performance, circular saws should be

considered as engineered tooling, not a commodity supply (John, 1973).

During wood working processes, dust and chips are the two by-products. Airborne sawdust presents hazardous effect on human health, safety and the environment. Wood dust when inhaled are known to be carcinogenic and may cause allergic respiratory, eye and headache symptoms in carpenter and saw mill workers. (Lange, 2008). Also, wood dust produced while processing woods containing substances such as lignins and fatty acids in large volume and large concentrations can leach into water and poison wildlife.

The act of using table circular saw without operation guarding system and delivery chute (Hopper Tray) causes many serious injuries and environmental pollution in our environment. These injuries are often a direct result of operating the unguarded machine in combination with other hazardous practices such as placing hands very close to the blade to guide stock (not using a push stick to guide stock through a cut), not firmly holding the stock which

may cause the hands to slip off, and divided attention (horse play) when operating. Kickback also is a significant hazard which occurs when the blade catches the stock and throws it back toward the operator. It's mostly caused when the sawing blade is not maintained and when the operator stops guiding the stock during the cut. (Alexander, 1985).

From the above statement, it is observed that the table circular sawing machine is very useful but still very dangerous as it can cause serious injuries if not handled with caution. Hence; the need to develop an improved circular sawing machine with guide system for the upper part of the saw blade and the hopper for the lower part of the saw blade. The guard system covers the saw blade and prevents any accident that might want to occur by touching the saw blade especially when it is not working. This paper aims at developing a circular sawing machine with guard system thereby preventing dust spread.

2.   Materials and Method

2.1   Materials

The components of the improved plank sawing machine are; the saw blade, work table, table guide, saw guide, power transmission systems, the hydraulic jack, wood dust delivery cute, and the machine frame. The power transmission system is located under the work table, to power the saw blade through the help of a rotating shaft receiving power from the motor and transmitting it to the blade. The saw blade is positioned in such a way that it protrudes out of the work table so that any wood placed on the table will be moved to pass through it as it rotates. The wood dust produce as a result of the cutting action is passed directly into the delivery cute positioned at the exit of the blade so as to ensure a clean sawing environment.

2.2   Methods

2.2.1 Design for Power Transmission System.

Power generated by the electric motor is transmitted to a rotating shaft that carries the sawing blade. The rotating shaft is designed to rotate faster than the speed of the electric motor so as to allow the saw blade to rotate faster and cut effectively.

From Figure 1, let:
D_e and D_r are Diameter of the pulleys fitted to the electric motor and the rotating shaft.
shaft is $170\ mm$ and $90\ mm$.
T_1 and T_2 are Tensions in the tight and slack side of the belt.
C_{er} is the Center distance between the two pulleys.
α is the Angle of lap of the smaller pulley on the big pulley.
N_e and N_r are number of revolution of the pulley fitted to the electric motor and the rotating shaft
$N_e = 1450\ rpm$

According to (Khurmi and Gupta, 2009), the relationship between diameters of the pulley and the number of revolutions is given by equation (1).

$$\frac{N_e}{N_r} = \frac{D_r}{D_e}$$
(1)

From equation 1 we obtain;

$$N_r = \frac{N_e \times D_e}{D_r}$$
(2)

$$N_r = 2739\ rpm$$

According to (Joseph and Charles, 2001), the maximum and minimum center distance between the two pulleys are given as in equation (3) to (5)

$$C_{er_{max}} = 3(D_e + D_r)$$
(3)

$\therefore\ C_{er_{max}}$ was estimated to be $780\ mm$

$$C_{er_{min}} = 0.55(D_e + D_r) + D_r$$
(4)

$\therefore\ C_{er_{min}}$ was obtained to be $233\ mm$

The center distance can be determined from:

$$C_{er} = \frac{(C_{ea_{max}} + C_{ea_{min}})}{2}$$
(5)

Hence; the center distance between the two pulleys was $507\ mm$.

According to Khurmi and Gupta (2009), the angle of lap of the small pulley on the big pulley for an open belt is given by equation (6).

$$\sin \alpha = \frac{D_r - D_e}{2C_{er}}$$
(6)

From which;

$$\alpha = \sin^{-1}\left\{\frac{D_r - D_e}{2C_{er}}\right\}$$
(7)

α was estimated to be $0.09\ rads$

According to (Khurmi and Gupta, 2009), the angle of contact of the belt on the motor pulley (θ_e) and the rotating pulley (θ_r) can be obtained using equation (8).

$$\theta_e = 180° - 2\alpha$$
(8)

$$\theta_e = 180 - 2(4.53) = 170.9° = 170.9 \times \frac{\pi}{180} = 2.95\ rads\ \text{(smaller pulley)}$$

$$\theta_a = 180 + 2\alpha$$
(9)

$$\theta_r = 180 + 2(4.53°) = 189.1° = 189.1 \times \frac{\pi}{180} = 3.33\ rads\ \text{(Larger pulley)}$$

According to (Joseph and Charles, 2001), the length of the belt can be obtained using equation (10) to (12).

$$\text{length of belt }'L' = \sqrt{4C_{er}^2 - (D_r - D_e)} + \frac{1}{2}(D\theta_r - D\theta_e)$$
(10)

$$\text{Where}\quad D\theta_r = \frac{\theta_r}{360} \times \pi D_r$$
(11)

$$\text{And}\quad D\theta_e = \frac{\theta_e}{360} \times \pi D_e$$
(12)

$\therefore L = 0.7725\ m = 0.8\ m$

The dimensions of standard V- belts transmitting power between 2 to 15 kW are given as width 'w' = 17 mm and thickness't' = 11 mm. (Khurmi and Gupta, 2009)

Hence the area 'A' of the belt can be obtained from equation (13).

$$A = wt \quad\quad (13)$$

To determine the mass of the belt per meter length, equation (14) and (15) were used.

$Mass\ of\ belt = area\ of\ belt \times length\ of\ belt$
$\times density\ of\ belt\ material \quad (14)$

$\therefore mass\ of\ belt\ per\ meter\ lenght\ m_l$
$= \dfrac{area\ of\ belt \times density\ of\ belt\ material}{length\ of\ belt} \quad (15)$

$m_l = 0.104\ kg/m$

According to (Khurmi and Gupta, 2009), the speed of the belt is given by equation (16).

$$v = \frac{\pi D_e N_e}{60} \quad\quad (16)$$

The speed of the belt was estimated to be 13m/s

The centrifugal tension (T_c) in the belt can be obtained using equation (17).

$$T_c = m_l v^2 \quad\quad (17)$$

T_c was obtained to be 17.3 N

The maximum tension in the belt (T) can be obtained from;

$$T = \sigma A \quad\quad (18)$$

where;

σ is the allowable tensile stress in the belt.

Hence; tension in the tight side of the belt 'T_1' was derived from equation (19)

$$T_1 = T - T_c \quad\quad (19)$$

According to (Khurmi and Gupta, 2009), if T_2 is the tension in the slack side of the belt, then it can be derived using equation (20)

$$e^{\mu\theta_e} = \frac{T_1 - m_l v^2}{T_2 - m_l v^2} \quad\quad (20)$$

where;

μ is the coefficient of friction between the belt and the groove of the pulley fitted to the electric motor.

The coefficient of friction between an oak tanned leather material and a steel pulley operating under dry condition is 0.25 (Khurmi and Gupta, 2009)

From equation (20) the value of T_2 is obtained as;

$$T_2 = \frac{T_1 - m_l v^2}{e^{\mu\theta_e}} + m_l v^2 \quad\quad (21)$$

$\therefore T_2$ is estimated to be 187.1 N

According to (Khurmi and Gupta, 2009) the power transmitted by the electric motor is given by equation (22)

$$P = (T_1 - T_2) v \quad\quad (22)$$

$\therefore P$ was estimated to be 3 hp

2.2.2   *Design for Rotating Shaft*

The rotating shaft is located under the work table and supported in bearing to the frame of the machine. The shaft receives power from the electric motor that rotates the blade. For the ease of analysis, the positioning and loading of the rotating shaft is shown in Figure 2.
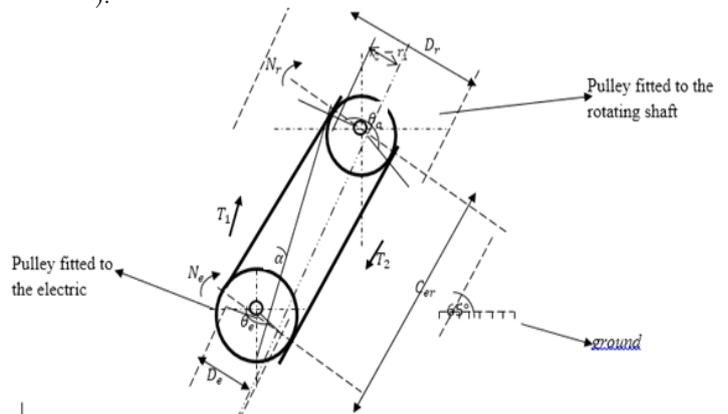

Figure 1: The Schematic Diagram of the Power Transmission System
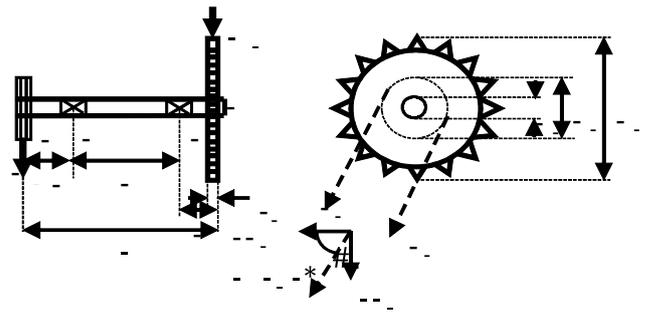

Figure 2: Schematic Diagram of the Rotating Shaft

From Figure 2 let:

L_{AB} be the Distance between the pulley and the bearing supporting the shaft

L_{BC} be the Distance between the two pulleys

L_{AC} be the Length of the rotating shaft

L_{CD} be the Length of the shaft between the bearing and blade

M_p be the Mass of the pulley fitted to the shaft.

W_p be the Weight of the pulley fitted to the shaft

d_p be the Diameter of the pulley fitted to the shaft.

d_r be the Diameter of the rotating shaft

d_b be the Diameter of the saw blade

t_b bes the Thickness of the saw blade

To determine the diameter of the rotating shaft, the vertical and horizontal loading of the shaft will be considered for analysis to determine the bending moment of the shaft. The weight of the pulley and blade will be considered in the vertical loading of the shaft. The blade is made from high speed steel of density 7850 kg/m^3, (Harrison and Nettleton, 1994)

The volume of the saw blade V_b can be obtained from;

$$V_b = \frac{\pi d_b^2}{4} t_b \quad\quad (23)$$

$$W_b = m_b g \qquad (24)$$

2.2.3. Design for Frame

The frame supports the work table, blade guide, hopper, rotating shaft, and the electric motor. The frame of the machine is designed using an angle bar mild steel. There are different types of end connections used in holding frames together. The type of end connection used will affect the performance of the frame. The type of end connection used is the fixed type, because the members are welded together at the ends to give the required rigidity.

According to Khurmi and Gupta (2009), the Euler's theory for crippling and buckling load 'W$_{cr}$' under various end conditions is represented by a general equation given by equation (25)

$$W_{cr} = \frac{C \pi^2 E A}{(l/k)^2} \qquad (25)$$

where :

C is the constant representing the end conditions of the column or end fixity coefficient = 4 for welded and bolted joints

E is the modulus of elasticity or young's modulus for the material of the column

A is the area of cross section

l is the length of column

k is the least radius of gyration of the cross section.

where:

$$k = \sqrt{\frac{I}{A}} \quad \text{where } I \text{ is called polar moment of area.}$$

The column supporting the peeling shaft and auger shaft have an L- shaped cross section as shown in Figure 3
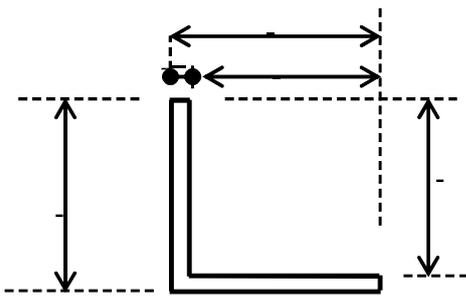

Figure 3: Cross Section of the frame used in the washing machine

where,

B is 30 mm, D is 30 mm, d is 27 mm, t is 3 mm and b is 27 mm
According to (Ogaga and Sule, 2000) the polar moment of area of the section shown in Figure 3 can be obtained using equation (26) and (27)

$$I_{XX} = \frac{1}{12}(BD^3 - bd^3) \qquad (26)$$

$$I_{YY} = \frac{1}{12}(B^3D - db^3) \qquad (27)$$

Since $I_{YY} = I_{XX}$ therefore the section will tend to buckle along the $Y - Y$ axis and $X - X$ axis. Thus we shall take $I = I_{YY} = I_{XX}$ which is $23213.25 \ mm^4$ (Khurmi and Gupta, 2009)

The frame carrying the electric motor was supported by two columns at the edge. Figure4. shows the schematic diagram of the electric motor and its support.
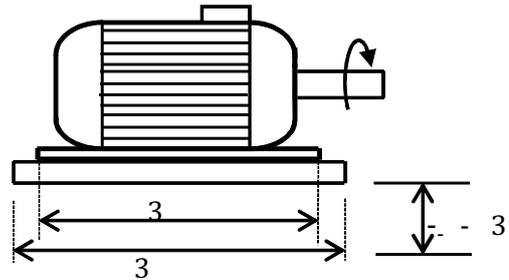

Figure 4: The Schematic Diagram of the Electric Motor and its Supporting

The weight of the electric motor on the support will be a uniformly distributed load which will be equivalent to a single load acting at the center of the vertical supports as shown in Figure 5. If the mass of the electric motor (M$_{em}$) is 21kg then the weight of the electric motor (W$_{em}$) is obtained from equation (31)
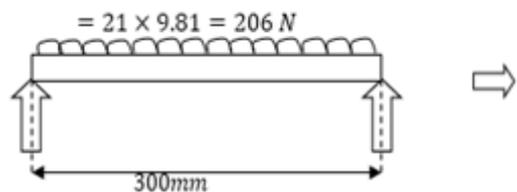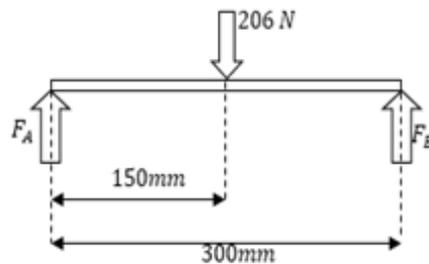
$$W_{em} = M_{em} \times g \qquad (31)$$

Figure 5: Schematic Diagram Showing the Load on the Electric Motor Frame

Considering vertical forces in Figure 5 (b) we obtain

$$F_A + F_B = 206 \ N \tag{32}$$

Taking moment about F_A we obtain

$(206 \times 0.15) - 0.3F_B = 0$

$\therefore F_B = 103 \ N$

Hence ; $F_A = 103 \ N$

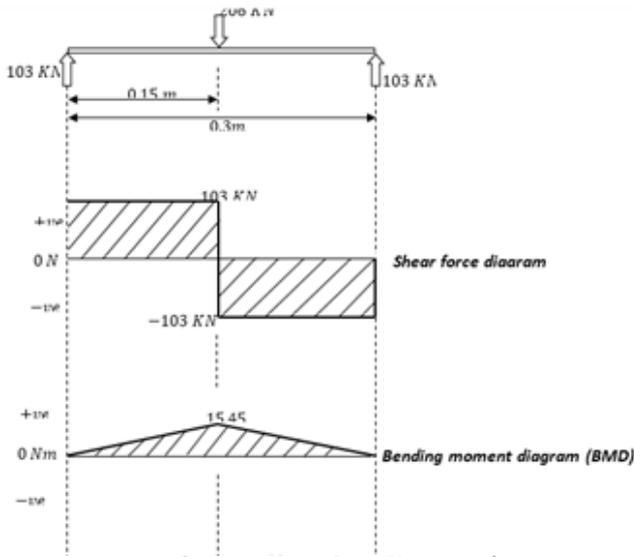The shear force and bending moment diagram is shown in Figure 6

Figure 6: Shear Force and Bending Moment Diagram of The Electric Motor

From Figure 6 the maximum shear force $'F'$ and bending moment occurs at midway of the beam hence the maximum deflection $'\delta_{max}'$ of the beam is obtained using equation (33)

$$\delta_{max} = \frac{F L^3}{48EI} \tag{33}$$

where:

L is the length of the beam *and is* 300 *mm*

E and I are as defined in equation 3.34 and 3.35 respectively

$\therefore \delta_{max} = 1.2 \times 10^{-11} \ m$

The buckling load on the vertical beam supporting the electric motor can also be obtained using equation (31);

$$W_{cr_{em}} = \frac{C \pi^2 E A}{(l_v/k)^2}$$

Where,

$l_v = 200 \ mm$

$\therefore W_{cr_{em}} = 4786742 \ N = 4.8 \ MN$

In Figure 7 and 8, the *Pictorial and orthographic View of the Improved Design Plank Sawing Machine with dimensions are shown respectively.*
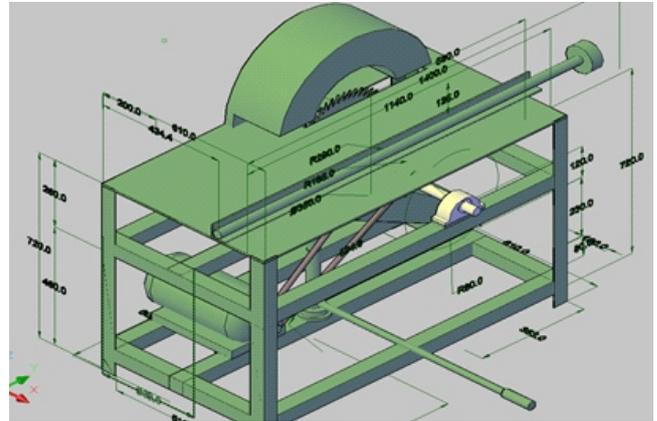

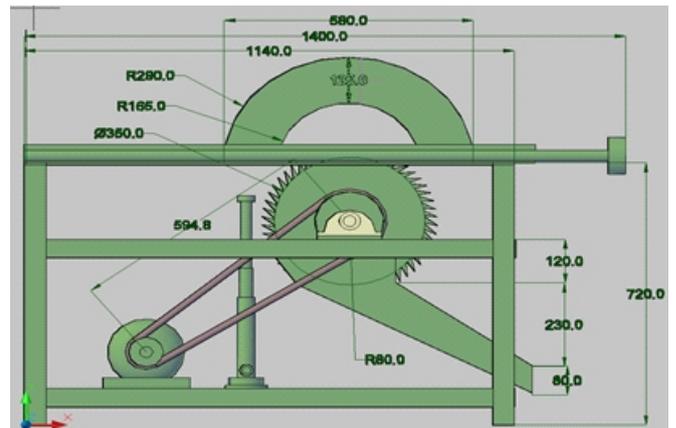Figure 7: *Pictorial View of the Improved Design Plank Sawing Machine*

Figure 8: Orthographic View of the Improved Design Plank Sawing Machine

3.1 MATERIAL SELECTION FOR THE IMPROVED PLANK SAWING MACHINE

Material selection is important in machine design; it involves the selection of material from which the respective components of the improved plank sawing machine will be fabricated. To analyze these components, some design factors were taken into consideration for selecting the materials for the machine:

1. **Cost**: The materials to be used for the fabrication of the component parts must be relatively cheap. They must meet up with the standard required for efficient workability and performance of the machine.

2. **Availability of Material**: The materials to be used for the fabrication of the components parts must be readily available in other to reduce the overall cost of fabricating the machine and the cost of maintaining it during operation.

3. **Rigidity and Strength**: The frames of the machine used must be

rigid enough to withstand the load of various components been supported. This will help to reduce vibration effect during operation and improve efficiency of the machine.

4. **Overall Weight**: The weight of the components that are used in the fabrication of each component in the machine should not be too heavy so as to reduce the stress involve in moving the components for maintenance.

5. **Corrosion Resistance and Rust**: The components of the machine especially those in direct contact with the atmosphere must be made from materials that are less vulnerable to oxidation so as to prevent rust and corrosion.

3.2. COST ANALYSIS OF PRODUCING THE IMPROVED CIRCULAR SAWING MACHINE

The cost estimate of producing the plank sawing machine can be obtained by summing the material cost, the cost of components, machining and non-machining jobs. This is as shown in Tables 1- 4

Table 1: Material Cost (A_1)

S/N	NAME OF COMPONENTS	MATERIAL	SPECIFICATION	QTY REQUIRED	UNIT COST (₦)	TOTAL COST (₦)
1	Frame	Angle iron	2 inch	3	5200	15600
2	Rotating shaft	Mild steel	(50 × 500)mm	1	4000	4000
3	Plugs	Standard	15 amps	3	100	300
4	Soldering lead	Soldering lead	2mm	10	500	5000
5	Electrodes	Electrodes	Guage 10	1 pack	1800	1800
6	conductor	Cable wire	3 core × 1.5mm	1 row		1800
7	Sheet metal	Mild steel	½ inch	1	2800	2800
8	Metal plate	Mild steel	2 inch	1	5200	7200
					Subtotal	51 600

Table 2: Cost of Bought Out Components (B_1)

S/N	MATERIAL	SPECIFICATION	QTY	RATE (₦)	TOTAL (₦)
1	wood	50.8mm thick	1	2000	2000
2	Blade	350mm × 3mm	1	6500	6500
3	Pillow bearing	206	2	1200	2400
4	Bolt and nut	M 10	12	50	600
5	Bolt and nut	M 17	2	60	120
6	Electric motor	1hp /300rpm	1	8500	8500
7	Pulley	170mm	1	600	600
8	Pulley	90mm	1	250	250
9	Paint	Oil paint	1 tin	750	750
				Subtotal	19 220

Table 3   Machining Job (C_1)

OPERATION	MACHINE USED	TIME SPENT(hrs)	LABOUR COST/hr	TOTAL COST (₦)
Marking out	Scriber	2	800	1600
Cutting	Power hacksaw	2	900	1800
Drilling	Drilling machine	$1\frac{1}{2}$	1000	500
Filing	Grinding machine	1	200	200
			Subtotal	4 100

Table 4: Non Machining Job (D_1)

S/N	JOB	TIME SPENT (hr)	LABOUR COST/hr	TOTAL (₦)
1	Painting	$3/4$	1000	750
2	Welding	8	1600	12800
3	Assembling	1.5	1000	1500
			Subtotal	15 050

$$Total\ cost\ of\ the\ sawing\ machine$$
$$= A_1 + B_1 + C_1 + D_1$$
$$= 51\ 600 + 19\ 220 + 4\ 100 + 15\ 050$$
$$= ₦89,970$$

4. RESULTS AND DISCUSSION

The performance evaluation of the developed machine was carried out using two types of wood having different thickness. The length of the wood was measured to be the same to ensure uniformity, and the thickness of the wood was also recorded before feeding it into the machine. The rate of feeding the wood was also monitored to ensure that the blade was not destroyed and to prevent accident. Figure 9 shows the developed machine under test. The result obtained is shown in Table 5.

Figure 9: Developed machine under test.

From the results of the test carried out, it is evident that as the thickness of the wood increases, the time required by the machine to saw the wood also increases. Also, the nature of the wood also affects the time required by the machine to cut the wood. A graph of

the wood thickness was plotted against the time spent by the machine as shown in Figures 10 and 11 for hard wood and softwood respectively.

Table 5. Table of Results for Performance Evaluation

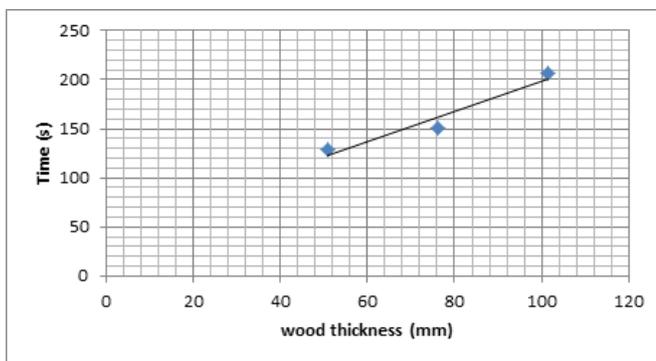| S/N	SOFT WOOD			HARD WOOD		
	50.8mm	76.2mm	101.6mm	50.8mm	76.2mm	101.6mm
	t (s)	t (s)	t (s)	t (s)	t (s)	t (s)
1	130	188	203	142	220	252
2	127	213	210	144	215	246
Total	257	301	413	283	435	498
Avg	128.5	150.5	206.5	141.5	217.5	249.0

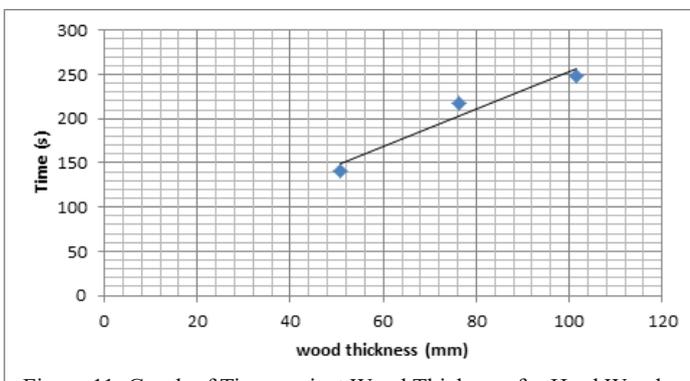Figure 10: Graph of Time against Wood Thickness for Soft Wood

Figure 11: Graph of Time against Wood Thickness for Hard Wood

5. CONCLUSION

Improved circular sawing machine was developed. The Guard system is designed such that it cannot obstruct the operation of the sawing blade. The Hopper tray is mainly for easy passage of the saw dust which will aid easy removal without hand mistakenly touching the lower part of the sawing blade. It also guard against accident that might want to occur with the rotating belt.

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