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FINITE ELEMENT MODELLING AND EVALUATION OF A SLIDING TABLE JIG FOR MITERING OPERATIONS IN CIRCULAR SAW MACHINE

Simon Ogbeche Odey and Asibong Asibong Icha,
Department of Wood Products Engineering, University of Cross River, Calabar, Nigeria.

Abstract
Table saw machine is readily utilized in carpentry and wood processing industry, but its operations are limited to ripping and crosscutting activities. This limitation can be mitigated by developing jigs the table saw machine. This research developed a Sliding Table Jig (STJ) used for producing miter cuts on the table saw machine. SOLIDWORKS software, 2021 was used in designing and modelling sliding table jig. Simulation of the components parts during operation was done to generate stress/strain analysis. Production of the jig was carried out. It consists of a Medium Density Fibreboard (MDF)with area 560 x 560 mm^2, having a 90º cut at one side of the square board for passage of the table saw blade. The jig designed was evaluated and results recorded. The simulation analysis shows Maximum Directional Deformation at 1.000e-30 mm, Equivalent Elastic Strain at 1.572e-05 N/m^2, Stress and Yield Strength at 5.237e+05 N/m^2 and 3.930e+07 N/m^2 respectively, with the factor of safety at 75. The produced jig performed optimally with the estimated cost of manufacturing at N15,740.00 (US$43,12) as at 2021.The developed STJ enhances the capacity of table saw machines. It is affordable, easy to use and enhances safety during operations.

Keywords: Sliding, Finite, Jig, Saw Machine, Evaluation, Modelling

1. Introduction

The need to reduce the amount of energy expended in the completion of activities while optimising the rate of carrying out those activities results in the development of machineries (Zielinska, 2004). Before the advent of machines, man's only way of carrying out activities was through physical strength which proved inefficient (Barger, 1963). Simple tools such as hammers and screwdrivers up to the most sophisticated machines are the result of men trying to reduce the amount of energy expounded in labour. Automated machines, with computerised systems powered by electricity, combustion engines and other mechanisms are available in developed countries (Zielinska, 2004). Machines with single-performing operation to those that perform countless operation have evolved. Access to such machine in developing countries is limited due to the high cost of importation (ITC/ITTO, 2002). Factories and industries make use of older versions of machines from countries which find it out-of-date, while those with little finical capacity locally fabricate them for use (Oteng-Amoako et. al., 2008).

Machines serve for every area of human endeavour including the wood industries. Several stationary machines such as table saws, ban saws and jointers have been produce locally to perform limited processes (Adewole, 2015, Adewole *et al*., 2017). The numerous types of woodworking machines available (both stationary and portable or moveable) are an attestation to their limited individual functionality. Other times, the need appears to seek simpler ways and perhaps more efficient ways of carrying operations (Capotosto, 1983). Jigs are designed to aid machines in functions and activities that such machines were not designed to carry out initially (DeCristoforo, 1988). They also ensure accuracy, accelerate work completion time and provide consistency in the fabrication of matching components (Capotosto, 1983). The table saw machine is among the basic wood working machines used for re-processing planks into dimension lumbers for several uses (Adewole, 2015). These machines are designed to carry out ripping and crosscutting operations on rectangular or square shaped surfaces of planks (Sahu *et al*., 2016). The table saw can also be used for special operations including cutting dadoes and rabbets and for re-sawing (EHSO, 2017).

The sliding table jig is a device designed to perform the special operation of mitercutting on a table saw. Mitercuttingis a cut made at an angle other than 90° to both the edge and the flat side of the wood (Capotosto, 1983). Mitering a good joint can be trying without applying adequate woodworking techniques to equipment. One of the challenges of cutting true miters is the stress of corresponding left- and right-hand cuts. This becomes extremely difficult if the work piece cannot be flipped due to its shape (DeCristoforo, 1988). This will mean having to work on both sides of the blade, which will requires changing the settings of the miter gauge (if using any) each time a corresponding side is required. This process consumes time and creates room for error. This research presents the Finite Element Modelling and Evaluation of a sliding table jig that performs the operations of miter cutting on a table saw with optimum safety.

2. Materials and Methods

This study was conducted in four phases: The first phase entailed the design, calculations and structural analysis of the sliding table jig using CAD and SOLIDWORKS software, 2021. In the second phase, the material cost of fabricating the jig was estimated and jig fabricated using materials locally found within the environs of Cross River University of Technology, Calabar in the third phase. In the final phase, the jig was evaluated.

2.1 Design and Considerations

The sliding table jig was designed using SOLIDWORKS software with 3D rendering interface. All parts were carefully considered during the design process. Figure 1 shows the pictorial view of the designed sliding table jig. A detailed drawing and an exploded view of the sliding table jig is shown in Figure 2 and 3 respectively. Further details and dimensions of individual component are also presented.

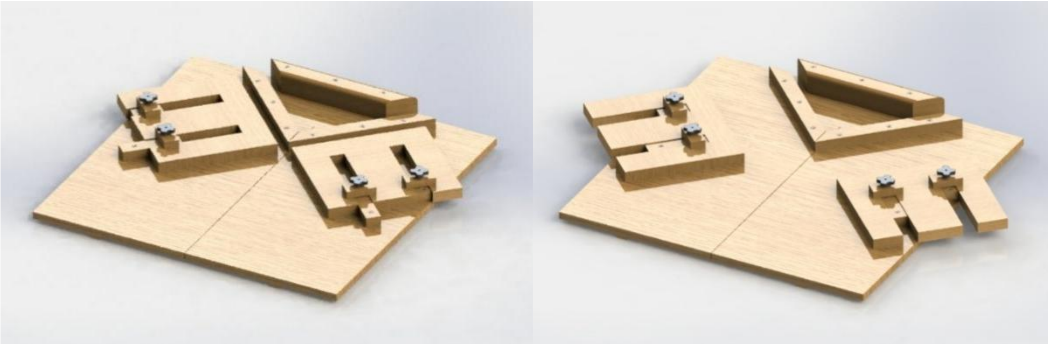


Figure 1. Pictorial View of the Designed Sliding Table Jig

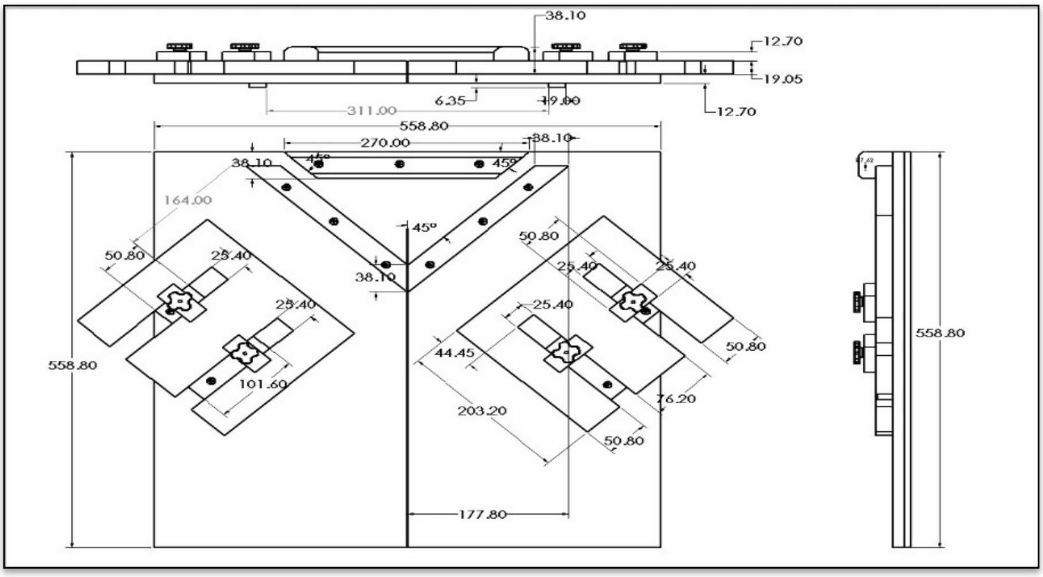
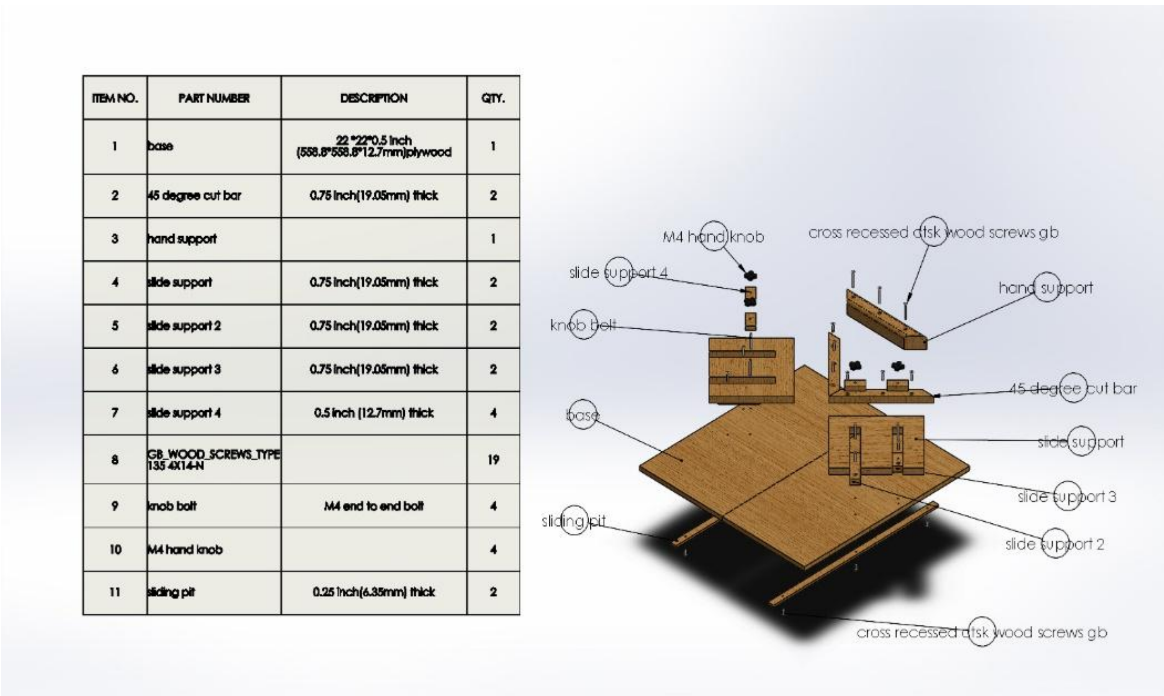


Figure 2. Detailed Drawing of the Designed Sliding Table Jig



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	base	22 *22*0.5 inch (558.8*558.8*12.7mm)plywood	1
2	45 degree cut bar	0.75 inch(19.05mm) thick	2
3	hand support		1
4	slide support	0.75 inch(19.05mm) thick	2
5	slide support 2	0.75 inch(19.05mm) thick	2
6	slide support 3	0.75 inch(19.05mm) thick	2
7	slide support 4	0.5 inch (12.7mm) thick	4
8	GB_WOOD_SCREWS_TYPE 135 4X14-N		19
9	knob bolt	M4 end to end bolt	4
10	M4 hand knob		4
11	sliding pit	0.25 inch(6.35mm) thick	2

Figure 3. Exploded View of the Designed Sliding Table Jig

2.2 Design Calculations

The sliding table jig design considered calculations for the nut and bolt fasteners, screw holding capacity and loading capacity and resistance. The procedures for the design of fasteners stated in Forest Products Laboratory (2010) General Technical Report were followed.

2.2.1 Bolts

The bearing stress under a bolt is computed by dividing the load on a bolt by the product LD, where L is the length of a bolt in the main member and D is the bolt diameter (Khurmi and Gupta, 2005).

Bearing stress = L/D (1)

2.2.2 Screws

Tapping screws are commonly used in particleboard where withdrawal strength is important. Care must be taken when tightening screws in particleboard to avoid stripping the threads. The maximum amount of torque that can be applied to a screw before the threads in the particleboard are stripped is given by

$$T = 3.16+0.0069X \qquad (2)$$

Where: T is torque (Nm) and X is density of the board (kg m^{-3}).

Equation (2) is for 8-gauge screws with a depth of penetration of 15.9 mm. The maximum torque is fairly constant for lead holes of 0% to 90% of the root diameter of the screw.

Ultimate withdrawal loads P (N) of screws from particleboard will be predicted by the equation given in Wood (FPL, 2010).

$$P = KD^{1/2} (L-D/3)^{3/4} G^2 \qquad (3)$$

Where: D = shank diameter of the screw (mm, in.), L = depth of embedment of the threaded portion of the screw (mm), and G = specific gravity of the board based on oven-dry weight and volume at current moisture content. K = 41.1 for withdrawal from the face of the board and K = 31.8 for withdrawal from the edge.

2.3 Material Costing Analysis

The materials used for the fabrication of the jig were estimated from the list produced from the design software (Figure 3). Table 1 shows the cost of fabricating the sliding table jig. The sliding table jig cost a total of fifteen thousand, seven hundred and forty naira (N15,740.00) an equivalent of US$35as at 2021. This shows that the sliding table jig can be afforded by local workshops owners within the locality with interest of fabricating the circular saw machine.

Table 1: Material Cost Analysis of Sliding Table Jig

Description of Item	Qty	Unit	Rate	Amount (N)
Plywood	0.5	Half board	17,500	8,750
Screws	2	pieces	25	50
Medium size top bond glue	1		800	800
Bolt and nut	4	Pieces	100	400
Washer	8	Pieces	30	240
Transportation				500
Workmanship				5,000
TOTAL				**15,740.00**

2.4 Fabrication of Sliding Table Jig

Materials for the fabrication of the jig was sourced from the local wood market within the research location and taken to the Wood Products Engineering Department workshop, while the fabrication process of the metal components were fabricated at the Mechanical Engineering Department Workshop, Cross River University of Technology, Calabar. Using the detailed drawings of the jig, the parts were processed to specification and assembled piece by piece using methods detailed in DeCristoforo (1988).

2.5 Model Performance Analysis and Evaluation

The CAD interface for the experimentation was activated and setup based on the type of experimentation to be carried out. The wizard interface was opened and the name of the project, unit system, analysis type and the coordinate system were set. This setup opens up the previous interface where the rotating regions, boundary conditions and the goals to be experimented were setup. A force of 500N was applied to analyse its impact on the design. An analysis was conducted using CAD and SOLIDWORKS software, 2021 to evaluate the stress, strain, displacement and factor of safety of the design. Other design parameters were extracted from the appropriate section corresponding to the strength data of the wood species used in NCP (1973).The sliding table jig after completion was attached to the table saw machine in the Wood Products Engineering Workshop and tested for efficiency. Observations were recorded.

3. Results and Discussion

3.1 Analysis of the Sliding Table Jig

Table 2 presents data of structural analysis carried out on the model sliding table jig when a force of 500N was applied. The static stress, strain and deformation are presented at minimum and maximum levels. The yield strength and factor of safety are also presented on the table. The maximum and minimum stress values are recorded at 5.237 x 10^5 and 0 N/m^2 respectively. Static strain at maximum and minimum levels were registered at 1.572 x 10^{-5} and 0 N/m^2 respectively. Displacement at maximum and minimum levels were observed at 5.237 x $10^{-3}$and 1.000 x 10^{-30}mmrespectively and Yield Strength at 3.930 x 10^7 N/m^2. The factor of safety which represents the strength capacity of the sliding table jig is 75.

Table 2. Model Structural Analysis Results on Sliding Table Jig

Object Name	Equivalent Stress	Equivalent Elastic Strain	Directional Deformation	Yield Strength	Factor of Safety
Minimum	0.000e+00 N/m^2	0.000e+00 N/m^2	1.000e-30 mm	3.930e+07 N/m^2	75
Maximum	5.237e+05 N/m^2	1.572e-05 N/m^2	5.237e-03 mm		

3.2

Stress Analysis

Figure 4a and 4b show the stress distribution around the design sliding table jig when a force of 500N acts on it. The stress distribution can be read by matching each colour on the design to a corresponding value on the rectangular legend. Stress distribution is observed to be highest at the 45º angle bar area with the sliding support sharing the stress distribution. Other areas were observed to be in the minimal levels of stress (Figure 4a). To observe a physical deformation on the sliding table, the diagram was scaled to 13,920.6 (Figure 4b). However, the true scale represents the possible stress deformation that can occur on the sliding table jig (Figure 4a).

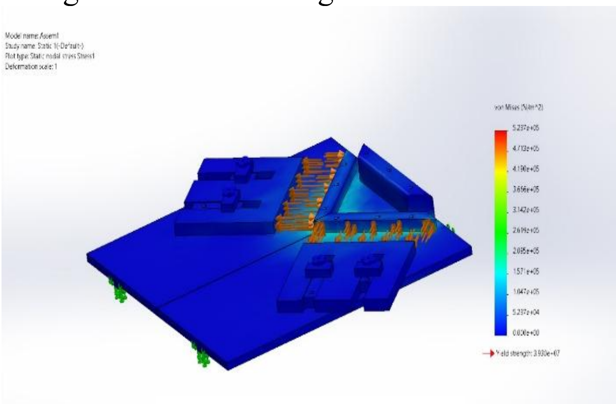


Figure 4 (a). Scale 1

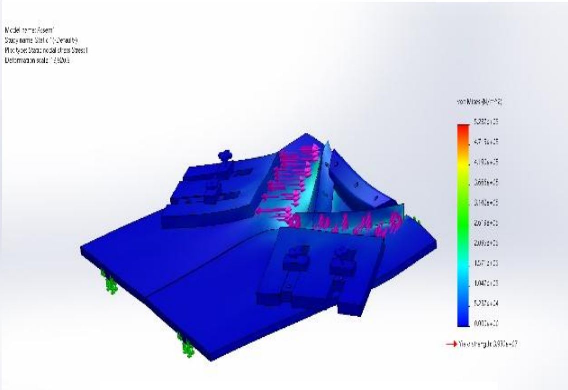


Figure 4 (b). Scale 13,920.6

Figure 4(a & b). Stress Distribution on Sliding Table Jig Presented at Scale1(a) and 13,920.6(b).

3.3

Strain Analysis

Figure 5a and 5b. show the strain distribution around the design sliding table jig when a force of 500N acts on it. The strain distribution is observed to be highest at the 45º angle bar area, spreading along the surface of the platform with the sliding support sharing the distribution. The sliding pit is observed to absolve average strain of about 7.860 x $10^{-}6$. Other areas were observed to be in the minimal levels of strains (Figure 5a). To observe a visible destruction in strain on the sliding table, the diagram was scaled to 13,920.6 (Figure 5b). And the 45ºagle bar is observed to displace towards the handle with the platform folding. However, the true scale represents the possible strain deformation and distortion that can occur on the sliding table jig (Figure 5a).

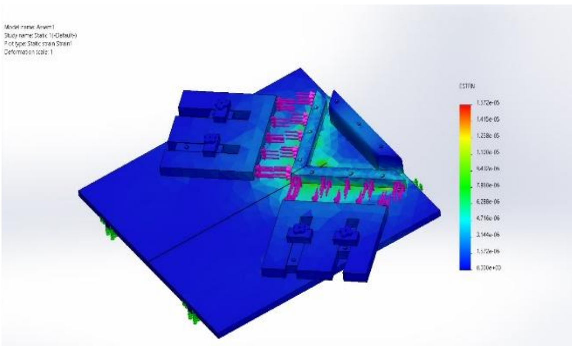


Figure 5 (a). Scale 1

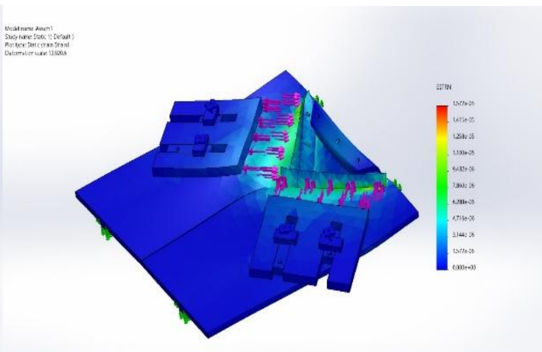


Figure 5 (b). Scale 13,920.6

Figure 5(a&b). Strain Distribution on Sliding Table Jig presented at Scale 1(a) and 13,920.6(b).

3.4 Displacement Analysis

Figure 6a and 6b. shows the displacement distribution on the design sliding table jig when a force of 500N acts on it. The deformation is observed to be highest towards the end of the platform kerf just past 45º angle bar area, spreading along the surface of the platform within the 45º angle bar. Other areas where observed to be at the minimal levels of displacement (Figure 6a) and no visual distortion is observed on the platform. To observe a visible deformation on the sliding table jig, the diagram was scaled to 13,920.6 (Figure 6b) and the 45º angle bar within the areas of the cutting kerf is observed to displace towards the handle with the platform folding. However, the true scale represents the possible strain deformation and distortion that can occur on the sliding table jig (Figure 5a).

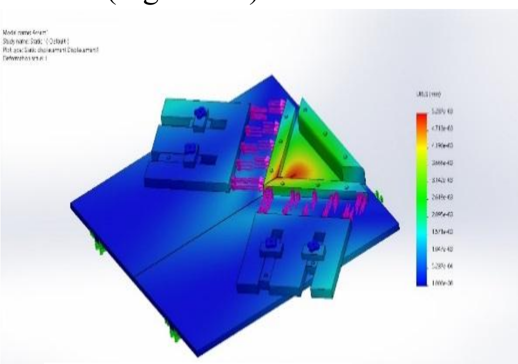


Figure 6 (a). Scale 1

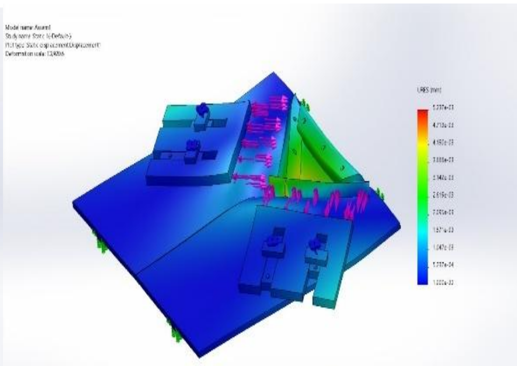


Figure 6 (b). Scale 13,920.6

Figure 6(a & b). Displacement Distributions of Sliding Table Jig Presented at Scale1(a)to 13,920.6(b).

3.5 Factor of Safety

Figure 7 shows the factor of safety value across the design. The design when subjected to a force of 500N has a minimum factor of safety of 75. This means the design is 75 times stronger than the force acting on it.

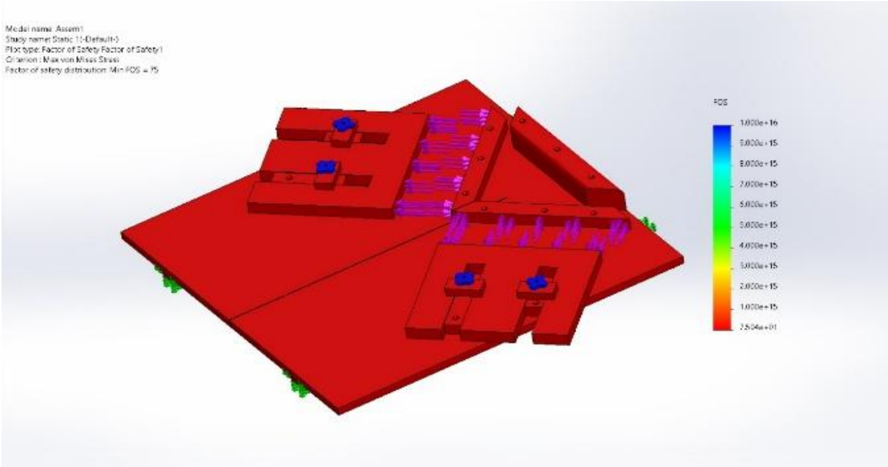


Figure 7. Factor of Safety

3.6
Fabrication and Evaluation of STJ

The sliding table jig as shown in Plate 1 was fabricated using simple and portable tools. It was observed that using accurate markings and firm handling yielded fabrication results. For easy screwing an improvised method was used to fabricate the nuts for the bolts. The evaluation process was done in the Departmental workshop of Wood Products Engineering using the Table saw machine examined during the design process. The sliding table jig was tested with a 50 x 75 mm (2 x 3 inch) wood (Plate 1). The jig was observed to function adequately and satisfactorily after the evaluation.

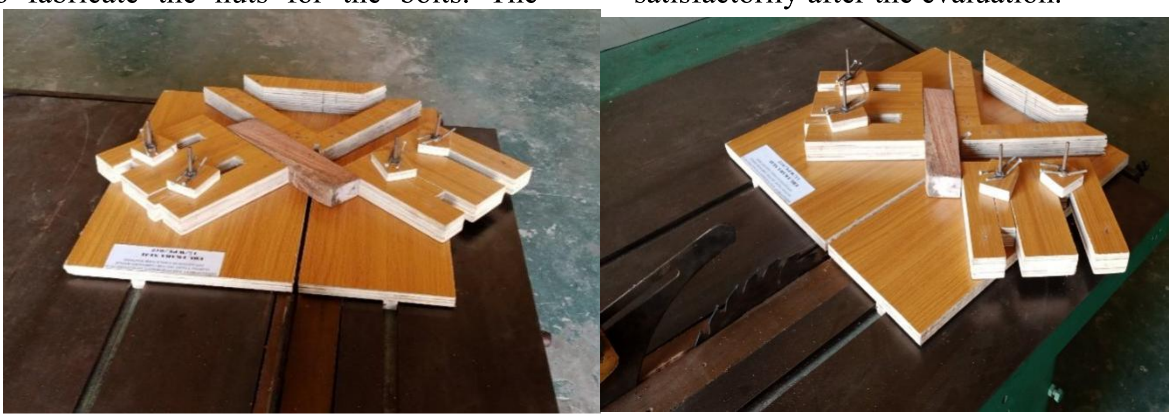


Plate 1. Sliding Table Jig Evaluation on Table saw Machine.

4. Conclusions

This study was able to development a sliding Table Jig (STJ) which improves the use and safety of the table saw machine thereby encouraging the development of locally made table saw equipment. Future works should focus on machine jigs capable of performing different wood processing operations as desired. The STJ is affordable, easy and safe to use, and adaptable for teaching and research enhancing economic development.

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