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Development of a Master Jig for Circular Saw Machine

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ABSTRACT

This paper presents the detailed development of a master jig (MJ) and the construction processes. The master jig aids the circular saw machine to perform intricate, multifaceted functions that the Circular saw machine cannot perform on its own. SOLIDWORKS software 2021 was applied in designing the MJ. The master jig is divided into three sections – the Master jig body (MJB), The master jig accessories (MJA) and the master jig guide (MJG). The MJB consist of the sliding table, the vertical work support, vertical mitre guides and the right-angle guides. The MJA consist of the mitre guides, the adjustable stop, the circle cutting guide, the taper guide, the hold-down, and the notching jig. The MJG consist of the rigid plastic placed between two solid woods. The designed master jig was fabricated and evaluated. Materials used in the production of the MJ include MDF (1220 x 2440 x 18mm) and full-lengths of solid wood with dimensions of 50 x 300 x 3600mm. The produced master jig performed efficiently with the estimated cost of materials at N106,400.00 (US$66.84) as of 2024. The master jig increases safety when working with the circular saw, minimizing hazard and improving the general woodworking process. it is affordable and easy to use.

Keywords: Circular Saw Machine, Master Jig, Fabrication, Woodworking operations, 3D Design.

I. INTRODUCTION

Woodworking and wood products manufacturing sector has undergone dynamic transformation in the developed countries of the world. This transformation is underscored by a shared aspiration - reducing energy expenditure in labour-intensive tasks while enhancing precision and safety - an enduring challenge that has shaped the evolution of machines (Sharma and Singh, 2020; Khan and Turowski, 2016; Zhou, et al., 2015; Brynjolfsson, and McAfee, 2011; Zielinska, 2004). Historically, human endeavours in woodworking were marked by the constraints of physical labour, a method fraught with inefficiencies (Brynjolfsson, and McAfee, 2011; Barger, 1963). The quest for innovation and optimization drove the development of increasingly sophisticated tools and machinery, from rudimentary implements like hammers and screwdrivers to contemporary marvels driven by electricity and combustion engines (Xu et al., 2018; Brynjolfsson and McAfee, 2014; Zielinska, 2004). However, the transition to advanced machinery has not been universal (Schmitz, 2010; Teravaninthorn and Raballand, 2009; ITC/ITTO, 2002). In underprivileged regions, the economic burden of importing cutting-edge equipment often limits access, compelling local industries to rely on antiquated machinery or devise makeshift solutions with limited financial resources (Ogechukwu, 2010; Oteng-Amoako et al., 2008).

Central to the woodworking industry's modern landscape are a diverse array of machines (Bajpai and Bajpai, 2018), both stationary and portable, encompassing circular saws, band saws, jointers, and more (Adewole, 2015; Adewole et al., 2017). These mechanical workhorses have revolutionized wood processing, yet the boundaries of their capabilities sometimes necessitate inventive solutions (Capotosto, 1983). In this context, the innovation of jigs emerges as a pivotal mechanism for augmenting machine functionality (Icha and Odey, 2024; Odey and Icha, 2022; Okpala and Okechukwu, 2015; DeCristoforo, 1988). These purpose-built accessories not only enhance precision and speed but also guarantee uniformity in producing matching components (Grosu, et al., 2019; Capotosto, 1983).

The circular saw is the fundamental piece of equipment used in woodworking, serving as the industry's cornerstone and enabling the conversion of unfinished wood into dimension lumber for a variety of uses (Kováč, et al., 2021; Adewole, 2015; Vasques and Cardoso, 2011). Circular saw machines are renowned for their ability to perform fundamental cutting with precision and efficiency. These machines are precisely designed to handle a variety of materials, including wood for various woodworking activities (Nasir and Cool, 2019; Kminiak and Kubš, 2016; Sahu et al., 2016). Beyond these foundational functions, circular saws undertake specialized roles, including re-sawing and the precision crafting of dadoes and rabbets (EHSO, 2017). Within this intricate milieu, the performance of other specialized operations and a variety of joints, such as tenons, box joints, and dovetails emerges as a defining challenge in woodworking—a critical component in cabinetry and furniture construction (Icha and Odey, 2024; Capotosto, 1983; Icha et al., 2022). The attainment of these operations accurately on circular saw machines has historically presented a formidable task. Hence, the need for the Master Jig—a specialized accessory meticulously engineered to aid and ensure accurate and safe crosscutting, mitring, feathering, splining, tenoning, and slotting, amongst other standard operations (DeCristoforo, 1988). This sophisticated device securely clamps work pieces and expertly guides them through the circular saw, delivering operations with precision (DeCristoforo, 1988). Beyond precision, the Master Jig elevates efficiency by delivering consistent results, allowing woodworkers to craft uniform operations with ease (Fleming, 2020).

II. Materials and Methods

The materials used for the master jig include solid wood (Balsa equivalent), medium-density fibreboard (MDF), bolts and knobs.

A. *Description of Parts*

The master jig has been divided into three section to ease the description of process. Master jig body (MJB) - the sliding table, the vertical work support, vertical mitre guides, Right angle guides, (Figure 1 and 2), the Master jig accessories (MJA) – the mitre guides, adjustable stop, circle cutting guide, taper guide, Hold-down, and Notching jig (Figure 3 and 4). The Master jig guard (MJG) – Rigid plastic placed between two solid woods (Figure 5 and 6). An exploded view of the master jig is shown in Figures 7.

Figure 1. Pictorial View of the Master Jig Body

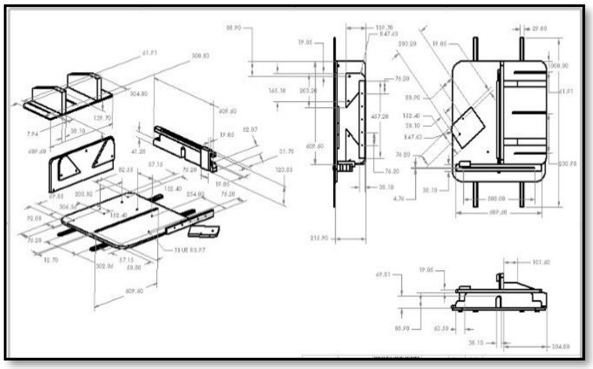


Figure 2. Detailed Drawing of the Master Jig Body

Figure 3. Pictorial View of the Master Jig Add-on

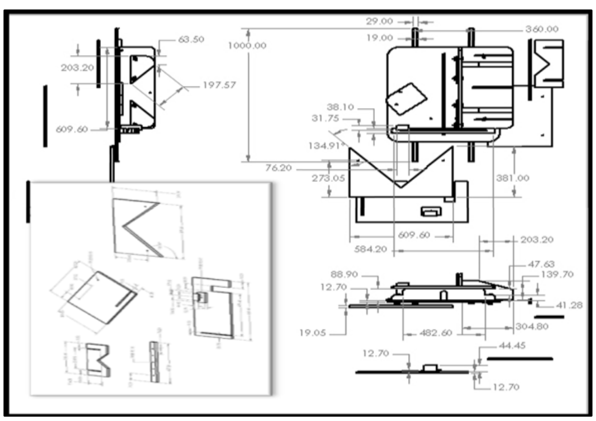


Figure 4. Detailed Drawing of the Master Jig Add-on

Figure 5. Pictorial View of the Designed Master jig

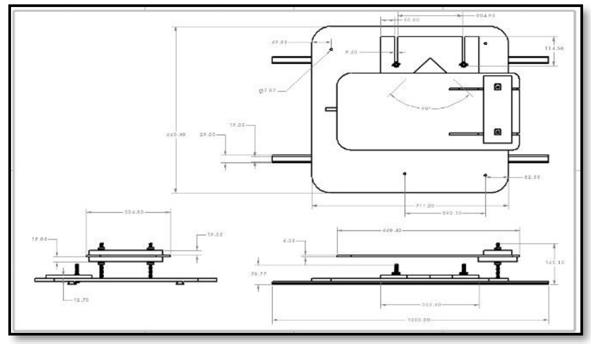


Figure 6. Detailed Drawing of the Master Jig Guard

B. Design Considerations

The master jig design took into account estimates for the fasteners' resistance, screw-holding ability, and loading capacity. The fastener design processes outlined in Forest Products Laboratory's General Technical Report from 2021 were adhered to.

Bolts. The shear and bearing capacity under the bolt were computed using the formula of Seward (2014).

Shear capacity, $F_{v,\,Rd} = \frac{0.6\, f_{ub} A}{\gamma_{M2}}$ …… (Seward, 2014)

Bearing capacity, $F_{b,\,Rd} = \frac{f_{ub} d t}{\gamma_{M2}}$ …. (Seward, 2014)

Where. f_{ub} = ultimate tensile strength of bolt, A = bolt tension area/full area, γ_{M2} = partial safety factor = 1.25, d = nominal bolt diameter, t = plate thickness

Screws. Screws were commonly used in areas where withdrawal strength was important (Hu et al., 2022). Care was taken when tightening screws in the wood to avoid stripping the threads. The maximum amount of torque that was applied to a screw before the threads in the wood were stripped is given by

$T = 3.16+0.0069X$ .. (Khurmi and Gupta, 2005)

Were T is torque (N–m) and X is the density of the board (kg m–3).

Equation (T) 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 wood was predicted by the equation given in Forest

Products Laboratory's General Technical Report from 2010.

P = KD1/2 (L-D/3)3/4 G2 …… (FPL, 2010)

Were 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. Other screw withdrawal load resistance considerations were following Hu et al., (2022).

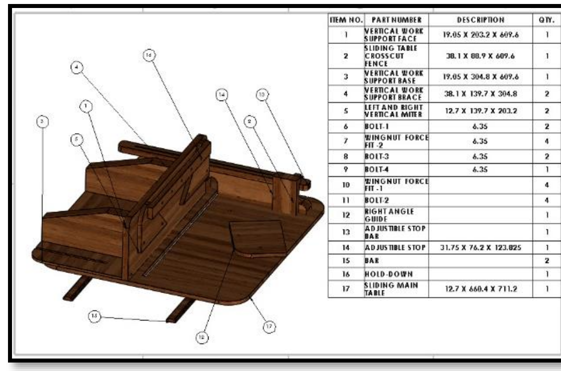
C. Costing of Materials

TABLE I

Material Cost Analysis of Master jig

Description of Item	**Qty**	**Rate**	**Amount (N)**
Full length of 19mm MDF	1	18,000	18,000
Full length of 12mm MDF	1	18,000	18,000
Full length of 9mm MDF	1	16,000	16,000
Full length of 38 x 45 mm Hardwood	2	4,500	4,500
Aluminium sheet	1	3,000	3,000
Pronged Tee-Nuts	18	10,000	10,000
Wood screws	12	21,400	21,400
Bolts	4	4,000	4,000
Panhead sheet metal screws	5	1,500	1,500
Washers	16	2,000	2,000
Wing nuts	10	3,000	3,000
Threaded steel rod	10	5,000	5,000
TOTAL			**106,400**

The materials for the construction of the master jig were assessed from the list generated by the design software (Figure 7). Table I presents the cost of materials purchased to fabricate the master jig. The materials cost a total of one hundred and six thousand, four hundred naira (N106,400) an equivalent of US$66.84 as of 2024. This shows that workshops within the town can afford the master jig with the interest of fabricating the table saw machine.



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	VERTICAL WORK SUPPORT FACE	19.05 X 203.2 X 609.6	1
2	SLIDING TABLE CROSSCUT FENCE	38.1 X 88.9 X 609.6	1
3	VERTICAL WORK SUPPORT BASE	19.05 X 304.8 X 609.6	1
4	VERTICAL WORK SUPPORT BRACE	38.1 X 139.7 X 304.8	2
5	LEFT AND RIGHT VERTICAL MITER	12.7 X 139.7 X 203.2	2
6	BOLT-1	6.35	2
7	WINGNUT FORCE FIT -2	6.35	4
8	BOLT-3	6.35	2
9	BOLT-4	6.35	1
10	WINGNUT FORCE FIT -1		4
11	BOLT-2		4
12	RIGHT ANGLE GUIDE		1
13	ADJUSTIBLE STOP BAR		1
14	ADJUSTIBLE STOP	31.75 X 76.2 X 123.825	1
15	BAR		2
16	HOLD-DOWN		1
17	SLIDING MAIN TABLE	12.7 X 660.4 X 711.2	1

Figure 7. Exploded view of the Master Jig Guard

D. Fabrication of Master jig

Materials for construction of master jig were obtained from the local wood market within the study area and taken to the University Wood Products Engineering workshop for the fabrication process. MDF (1220 x 2440mm) and full-lengths of solid wood with dimensions of 50 x 300 x 3600mm were first processed and cut into dimensions as specified in the design (Figure 2). Holes for bolts and knobs were drilled as detailed. Finally, the master jig was assembled using an electric driver. Screws were driven into the blocks perpendicular to the face to ensure the screw threads were fully inserted into samples (Figure 8).

Figure 8. Fabrication Process of the Master Jig

D. Operational Evaluation

Different wood species were used to test the precision of the master jig on the circular saw machine using visual observations and measurement tape. The jig was also observed for signs of possible failures. All observations were recorded.

III. RESULTS AND DISCUSSION

Fabrication of Master jig

The master jig as shown in Figure 8 was easy to fabricate using simple and portable tools. It is observed that using fabrication methods according to DeCristoforo (1988) and Capototos, (1983) produced satisfactory results.

TABLE II

Material Specification for Production of Master Jig Body

Parts	Component	Qty	Specs. (mm)	Material
Sliding Table	Main table	1	12 x 660 x 711	MDF
	Bars	2	9 x 19 x 914	Hardwood
	Crosscut fence	1	38 x 88 x 609	Hardwood
Vertical Work Support	Base	1	19 x 304 x 609	MDF
	Face	1	19 x 203 x 609	MDF
	Brace	2	38 x 140 x 305	Hardwood
Vertical Mitre Guide	Guides	2	13 x 140 x 203	MDF
Right Angle Guide	Guides	1	13 x 152 x 203	MDF

Table 1 presents the material specification for the production MJB. The parts, specific components, quantity, specification and material used are presented. The sliding table thickness reduces the maximum hight of the sawblade by 0.5 mm but no significant effect was recorded due to the fact that maximum blade projections were within 70mm to 90mm in hight depending on the type of sawblade installed on the machine and the kind of task performed. It was necessary to take into consideration the dimensions of the bars with respect to their positioning on the main table to align with the slots on the table for easy slide (Figure 9). The full set-up of the MJB after construction is shown in Figure 10.

Figure 9. Master Jig Main Table Slot Alignment

Figure 10. MJB Ready For Use with Circular Saw Machine

TABLE III

Materials Specification for Production of Master Jig Accessories

Parts	Compt.	Qty	Specs (mm)	Material
Mitre Guide	Guides	2	19 x 304 x 406	wood
Adjustable Stop	Bar	1	19 x 38 x 863	MDF
	Stop	1	32 x 76 x 124	wood
Circle Cutting Guide	Platform	1	13 x 381 x 457	wood
Taper Guide	Platform	1	13 x 305 x 660	wood
	Stop	1	38 x 44 x 76	wood
	Clamp Pad	1	13 x 57 x 114	wood
Hold-Down	Bar	1	16 x 38 x 457	wood
Notching Jig	Guide	1	13 x 165 x 355	MDF

Table 3 presents the material specification for production of MJAs. The parts, specific components, quantity, specification and material used are presented. The mitre guides are made as two pieces rather than a one-piece V-block to enable the two pieces to be used when mitring parts that have been pre-cut to length, either as the left- or right-hand guide when making successive mitre cuts on a single length of stock. It was ensured that the crosscut fence was removed when using the mitre guide (Figure 11). Use a triangle to ascertain their alignment with the saw kerf.

Figure 11. Mitre Guide installed on the CSM without crosscut fence

TABLE IV

Hardware Specification for Production of Master Jig

Component	**Qty**	**Specification**
Sliding Table	9	6mm Pronged Tee-Nuts
	10	#8 x 19mm fh Wood screws
	2	6 x 50mm Bolts
	2	6mm Flat washers
Vertical Work Support	6	6mm Pronged Tee-Nuts
	13	#10 x 38mm fh Wood screws
Adjustable Stop	3	#10 x 38mm Panhead sheet metal screws
	3	6mm Flat washers
Circle Cutting Guide	2	6 x 19mm fh Bolts
Hold-Down	1	6 x 101mm fh Bolts
	1	6mm Flat washers
Locking Hardware	8	6mm Wing nuts
	8	6mm flat washers
	8	6 x 50mm lengths of threaded steel rod
Table Mitre Guides	2	8mm Tee-Nuts
	6	8mm flat washers
	6	8mm nuts
	2	8 x 152mm lengths of threaded steel rod

Table 4 present the different hardware used for the MJB, MJA and the MJG. Details presented include the parts where the hardware is located, the quantity and the specification. Where hardware could not be gotten, or ordered, they were fabricated.

Operational Evaluation

Figures 12, 13 and 14 shows different applicational method for the Master jig. Guard is used when MJAs are utilized and not used with the MJBs. For illustrative purposes, the guard was removed to allow for clear view. The vertical right-angle guide was applied to end cuts including slots and tenons. When utilising the vertical work support for narrow slots, the width was set to the required position and a pass made. The stock was then reverse and another pass performed.

To ensure the vertical mitre guides is properly set, one piece of the mitre is locked in place, then the second piece is set with a triangle to obtain a 45º edge. The table mitre guide was used for slotting of round and square stock. This implies that the table mitre guide not only performs mitre cuts. Care was taken to ensure that the wood piece used was not too big or small to be held safely. All parts of the jig functioned optimally.

Figure 12. Evaluation Process of the MJB on Circular Saw Machine.

Figure 13. The Crosscut Table During Evaluation

Figure 14. The Notching Jig and Table Mitre Guide During Evaluation with the circular Saw Machine

IV. CONCLUSIONS

Developing a master jig for the circular saw machines using the SOLIDWORKS software for the design was presented in this study. The master jig improves the usage, and safety of the circular saw machine thereby encouraging the development of locally made circular saw machine. Future work should focus on modelling the behaviour of the jig to investigate the stress distributions on the MJ and possibly predicts the failure mode. Thus optimize the design where necessary. The master jig is affordable, easy, safe to use, and adaptable for teaching and research enhancing economic development. Woodworkers can improve their efficiency and precision, and create high-quality wood products.

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