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Design and Fabrication of Jig and Fixture for Drilling Machine in the Manufacturing Industry to Improve Time Productivity

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ABSTRACT

Jigs and fixtures were brought to the world of machining, bringing a variety of practical purposes. The concept enables rapid mass production of the same product. Thus, the company will streamline the manufacturing process for each component and boost productivity. At times, the machining operation was carried out entirely by the machine, without jigs and fixtures. As a result, jigs and fixtures were created to expedite the drilling process. The project's objectives are to design a jig and fixture, fabricate it, and analyze the performance on a square block of wood. The structural model for drilling jigs and fixtures was created using the Inventor Professional 2019 Computer-Aided Design Software. The fabrication process used were milling, surface grinding, CNC wire-cut, and drilling machines. Aluminium 1065 was utilized because it is less expensive, lighter than other materials, and easy to process. The result demonstrates that a hole can be drilled quickly using the jigs and fixtures. Preparing the hole with a jig and fixture takes only 1.28 minutes, compared to 3.45 minutes with a table drill. The advantages of this product are the time operation can be reduced and quickly operations on the drilling process.

1. Introduction

As the world evolved as time flowed, humanity also invented and innovated various technologies to help humankind develop a better life. One of the best inventions is the machining concept which involves any machine. Machining is a term used to describe a variety of material removal processes. A cutting tool removes unwanted material from a piece of raw material to produce the desired shape of the machining part. The part's raw material is typically cut from a more extensive stock selection, available in various standard forms. Those are flat sheets, solid bars, hollow tubes, and shaped beams. Machining can be used to create a variety of features, including holes, slots, pockets, flat surfaces, and even complex surface contours. Also, while machined parts are typically metal, almost all materials can be machined, including metals, plastics, composites, and wood [1,2]. Hole-making is

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a class of machining operations specifically used to cut a hole into a workpiece. Hole-making can be performed on various machines, including general machining equipment such as CNC milling machines or CNC turning machines. Specialized equipment also exists for hole-making, such as drill presses or tapping machines.

A jig is a work-holding or support device in the manufacturing business. It is used to securely locate and position the workpiece and are not attached to the machine table. It is typically made of light materials. Jigs are also classified according to their primary structure [3]. Additionally, it ensures the conformance and interchangeability of all goods manufactured using the jig. There are numerous jigs, and each is specifically designed to do a particular task. Multiple jigs are developing to meet the merchants' needs. Certain types are designed to boost productivity through consistency, perform repetitive tasks, or perform a task more precisely. Additionally, it decreases the need for expert labour by streamlining the mounting of workpieces. As a result, manufacturing time is reduced [4-6]. Fixtures are devices that securely hold and locate the workpiece when machining and ensure a consistent relationship between the tools [7]. A fixture is a device that physically support and clamp a workpiece [8,9].

Jigs and fixtures are cost-effective methods of mass-producing a component. Jigs and fixtures are employed and are a critical component of mass production systems. These are one-of-a-kind work-holding tool guidance devices. Jigs and fixtures are devices that facilitate manufacturing operations by enabling interchangeable pieces of work to reduce production costs [10-12]. These devices include attachments for guiding, positioning and supporting the tools, ensuring that all workpieces produced by a particular jig or fixture are identical. Additionally, the employment of these devices can result in a high degree of accuracy, allowing for the assembly of wok pieces with minimal fitting. A jig or fixture can be customised for a specific application. The shape of the workpiece determines the forms to use and the amount of machine work required. Jigs and Fixtures are associated with the references considered during the design process. After designing a Jig or Fixture, we can make identical components of a particular product without additional setup. Additionally, the precision is maintained throughout the sections [13].

Today's industries can produce parts faster and better due to the new machine tools, high-performance cutting tools, and sophisticated manufacturing procedures. Jigs and fixtures are critical types of equipment that contribute significantly to productivity [14]. While metal cutting techniques have advanced in the manufacturing business, the classic drilling procedure remains one of the most prevalent. Drilling is removing metal from the revolving edge of a cutting tool called a drill to create a cylindrical hole. Machine holes can be bored fast and economically. The hole is formed by the rotating edge of a cutting instrument called a drill, which exerts a considerable force on the work secured to the table. Drilling can be used on a variety of different types of workpiece materials. Cutting speed and feed rate are the most apparent elements affecting the precision of drilled holes. Cutting speed and feed rate will substantially affect the roughness of the machined surface, with a higher cutting speed and a lower feed rate resulting in a more finished surface [15]. Referring to [21], the feed rate and cutting speed combination significantly affect the drilling process.

Numerous studies have been conducted on the jig and fixture; however, some of them have limitations because the jig and fixture are not intended to be utilised for all sorts of items. Machining can be performed on either a conventional or a CNC machine. Drilling can be performed precisely and accurately with these machines due to their superior machine characteristics and smooth machine axis motions. However, it is superfluous to use that machine for drilling using coordinate systems for holes with low tolerance dimensions. People frequently employ machines that require numerous preparations before drilling a hole [16]. According to [17], the drill jig developed was only available in specified sizes and unsuitable for big dimensions. For pieces with low precision

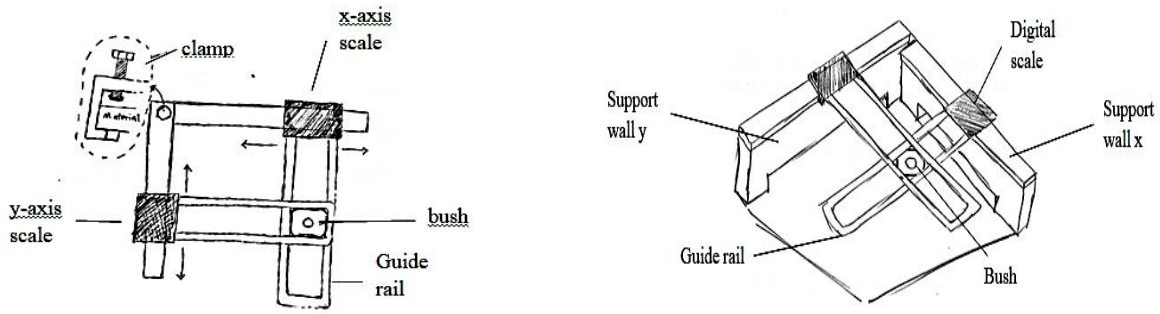
dimensions, finishing them on a CNC machine is a waste of time due to the lengthy setup time and machining expense. A drill jig is a tool that is used to ensure that a hole is drilled, tapped, or reamed in the appropriate location on a workpiece [18]. A jig contributes to production efficiency by facilitating smooth transitions and rapid operation [19]. It is designed so that the workpiece may be swiftly entered and removed after the machining operation is completed [20].

2. Methodology

The methodology is divided into two parts: the design concept and machining process preparation. The modelling is carried out via the Inventor Professional 2019 software. Milling, surface grinding, CNC wire-cutting, and drilling machines are used in this process.

2.1 Design Concept

Figure 1 (a) illustrates design concept 1, in which jigs and fixtures are clamped directly to the materials. The clamp system secures the jig to the material's edge, automatically giving a datum for drilling coordination. There was no base or other support provided. Figure 1 (b) depicts the base of the second design concept, which is where the material will be placed (b). The base will be attached to the support wall, which serves as a datum for the drilling procedure. The base will alleviate some of the operational support burdens. Figure 2 shows the completed design concept, which incorporates aspects from the first and second design concepts. This final design is optimal and best, considering its functions, form, size, and mobility.



(a) Design Concept 1 (b) Design Concept 2

Fig. 1. Design concept 1 and 2 (Sketching)

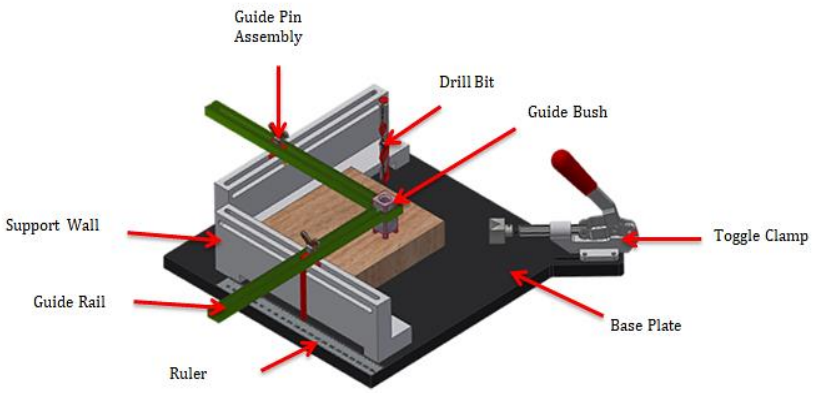


Fig. 2. Jig and fixture for drilling (Inventor Professional 2019)

2.2 Machining Process

2.2.1 Raw material (cutting process)

After the design phase is complete, the machining process will start with the process of fabrication. The parts fabrication method involves using a bend saw machine for the first step shown in Figure 3. The aluminium raw material in the block obtained and being cut on bend saw machine. This process was to split the material in half to be used for both support walls machining. The material is placed on the machine after creating a mark for half size of the material. Coolant is used for a better cutting process without damaging the saw blade.

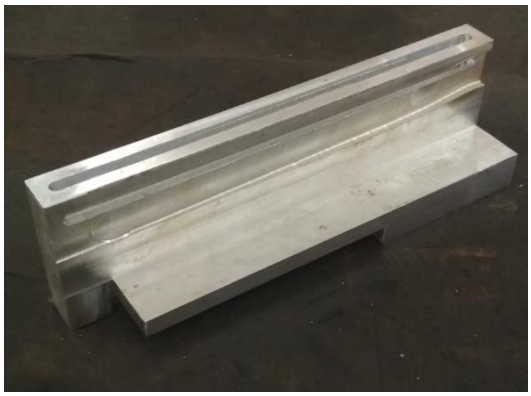
Fig. 3. Cutting material with bend saw machine

2.2.2 Support wall parts

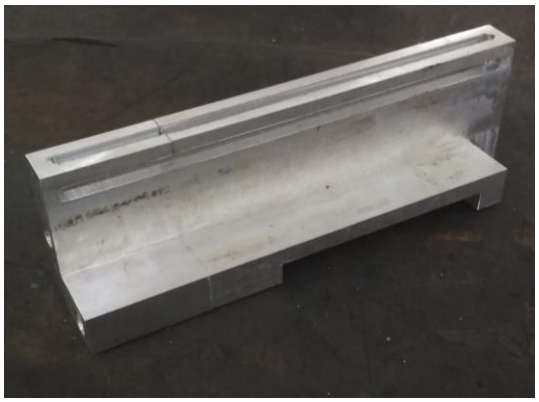
Support walls were used to set the datum or origin of the workpiece at the edge as soon as the workpiece was clamped on the jig and fixture. This part will help the clamping process quickly obtain the machining coordinate's origin, as illustrated in Figure 4. The machining process was done by using a conventional milling machine. The slot was created for the guide pin assembly to move along the slot. It acts as the path and guides the guide pin to move accurately with fewer errors occurring. The slot needs to be smooth, with no burr at the edges and free from any dented or scratches. Figure 5 shows the cutting slot at the top and side surface, while Figure 6 show the finishing support wall for X-axis and Y-axis.

Fig. 4. Removing material to form L shape

Fig. 5. Cutting slot at top and side surface



(a) Support wall for X-axis (Finished)



(b) Support wall for Y-axis (Finished)

Fig. 6. Support wall for X-axis and Y-axis (Finished)

2.2.3 Base plate and guide rail

Base plate and guide rail fabrications involve CNC Wirecut Machine, which operates as the thin wire runs through the workpiece, as illustrated in Figure 7. The cutting process occurs once the spark hits the material surface and cuts the material with no force required.

Fig. 7. Cutting outer shape of base plate

Figure 8 shows the base plate, and Figure 9 shows the guide rail. Outside shapes and slots on the base plate and guide rail were cut using a CNC Wirecut, while all holes were drilled using a manual drill machine. The holes drilled are precise and according to the specification.

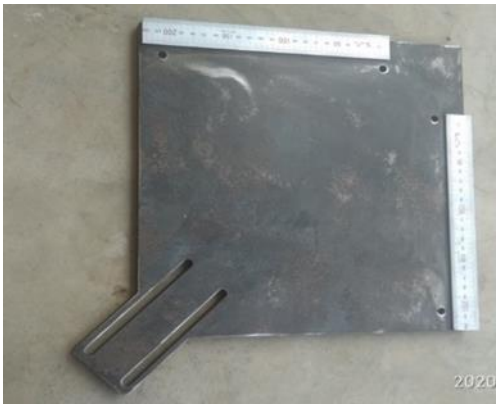


Fig. 8. Base plate (Finished)

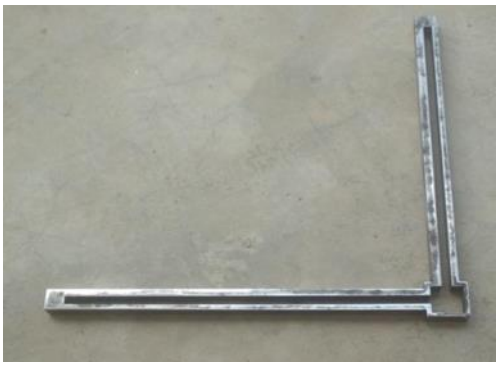


Fig. 9. Guide rail (Finished)

2.2.4 Clamping

The toggle clamp selected is due to the direction of clamping for this product, and the clamping direction required is the horizontal direction. This type of toggle clamp was selected to push the workpiece to the surface of the support walls shown in Figure 10.

Fig. 10. Toggle clamp (Purchased)

2.2.5 Final product assembly

The assembly includes all parts of the product, such as guide pins, guide rail, support walls, base plate and toggle clamp, as illustrated in Figure 11. Some of the features were connected by mechanical fastenings, like bolts and nuts. There are also socket head cap screws to fasten the guide pins to the slot at the support walls.

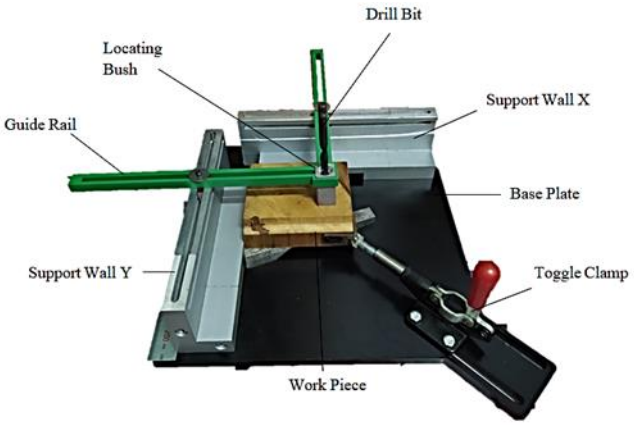


Fig. 11. Jig and fixture for drilling (Assembled)

3. Results and Discussion

The jig and fixture are then evaluated to determine their performance through experiments. The product was tested by drilling a hole in a block of wood. First, the test was done by first using the jig and fixture. Then, using a table drill, three holes were then drilled in three different spots using the table drill shown in Figure 12. The variable studied was the setup time (minutes) and the accuracy of drilling the hole. The difference between the position in the drawing and the actual position of the hole after drilling with the jig and fixture was taken as an indicator of accuracy.

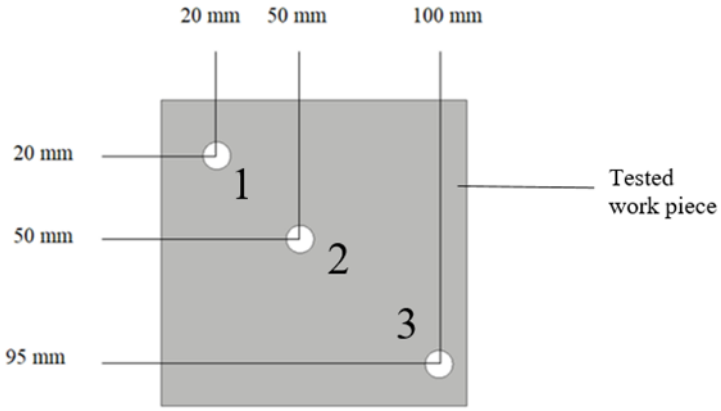


Fig. 12. Positions for test drill for performance analysis

Table 1 shows the jig and fixture can drill the hole faster than a table drill. At position 1, jig and fixture assembly took 1.28 minutes, while drilling a hole with a table drill took 3.97 minutes. At position 2, drilling the hole takes 1.63 minutes with the jig and fixture and 4.05 minutes with the table drill. At position 3, the jig and fixture drill the hole in 2.18 minutes, whereas the table drill drills the hole in 3.45 minutes. The time taken shows that using a table drill will take a lot of time to drill a simple hole. With the help of this jig and fixture, the hole will be made quickly. The advantage of jigs and fixtures is reducing operation time and increasing productivity. In interchangeability terms, jigs and fixtures facilitate uniform quality in the manufacture [3].

Table 1
Setup time testing between table drill and jig and fixture

Test Product	Time, t (min)		
	Position 1 (20 x 20) mm	Position 2 (50 x 50) mm	Position 3 (100 x 90) mm
Table Drill	3.97	4.05	3.45
Jig and Fixture	1.28	1.63	2.18

According to Table 1, the jig and fixture only require a short setup time because the product will already set its datum right after clamping the workpiece. Finding datum in the drilling process is a step that requires a lot of time to be done. If the table drill does the drilling process, the centre fix is needed to find the datum for the x-axis and y-axis. So, it will result in a long setup time.

Figure 13 shows that the setup time for drilling a hole using the jig and fixture requires very minimal setup time compared to using a table drill for drilling a hole. It proved that the jig and fixture created had successfully minimized the setup time for drilling a hole. The blue bar indicates the time for drilling a hole using a table drill, while the red bar indicates the time to drill a hole using a jig and fixture.

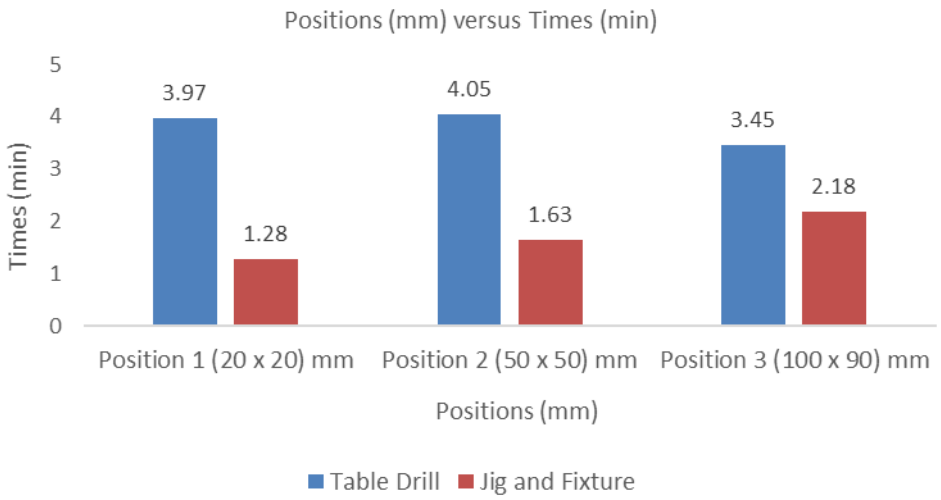


Fig. 13. Comparison between positions (mm) versus times (min)

By referring to Table 2, the result shows the tolerance for drilled holes compared to the actual distance (theory) are minimum of 0.2 mm and a maximum of 1.4 mm. The jig and fixture employed can drill a hole with near-perfect positional accuracy. The table summarises all of the drilling process testing findings. It demonstrates how jigs and fixtures prevent the need for individual marking, positioning, and frequent inspection. Jigs and fixtures simplify locating and clamping workpieces, hence reducing skill requirements. Tool guiding elements ensure that tools are correctly positioned relative to their workpieces, and there is no requirement for skilful positioning of tool workpieces. Any amateur can be taught to use jigs and fixtures instead of a skilled worker. Unskilled labourers can significantly reduce labour expenses [3].

Table 2
Evaluation accuracy between actual position (theory) and machined position for jig and fixture

Test Product	Time, t (min)								
	Position 1			Position 2			Position 3		
Jigs and Fixture	Actual Distance (Theory)	Experiment Distance	Tolerance	Actual Distance (Theory)	Experiment Distance	Tolerance	Actual Distance (Theory)	Experiment Distance	Tolerance
X-axis	20	20.5	± 0.5	50	48	± 2.0	95	95.4	± 0.6
Y-axis	20	19.8	± 0.5	50	51	± 1.0	100	101.4	± 1.4

4. Conclusions

This project presents the results of the design and fabrication of the jig and fixture for drilling machines in the manufacturing industry to improve time productivity. As this product is finished, it should help minimize the setup time for the drilling process, and less time required for completing certain functions will gain more rate of production. This product will ease the setup operation for drilling a hole or reworking any hole with specified dimensions.

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