Design and Fabrication of Jig and Fixture for Milling Operations in the Manufacturing Sector

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Abstract

Fixtures and jigs are work-holding devices used to position and support workpieces. Fixtures and jigs are important tools in production because their use determines the performance of the entire production process of a product. There are still situations in the manufacturing sector where products manufactured could be more precise. Work-holding devices that facilitate the machining process must be developed to ensure that the final products satisfy the required criteria. This study aimed to design, manufacture, and evaluate fixtures and jigs and then assess how well they worked with test specimens in rectangular shapes. The jigs and fixtures are planned based on a vacuum table that is adjusted to the machining position on the side of the material. The intention of employing a vacuum system is to simplify the process of setting up the workpiece. Fusion360 Design Software was utilized to design fixtures and jig models. Since aluminum is easy to form and has high wear resistance, it was chosen as the workpiece material. CNC machine was employed in the manufacturing process. Testing of jig and fixture tools is carried out on the side of the test specimen. According to the study's findings, jigs and fixtures accelerate the milling process on the material side. When jigs and fixtures are used, the milling process proceeds 17.47 minutes. Using this jig and fixture makes it possible to shorten the operating time, making the milling process run more quickly. Furthermore, the final product has remarkable dimensional accuracy.

Kata kunci: jig, fixture, milling, design, manufacturing

Abstrak

Fixture dan jig merupakan alat khusus yang digunakan untuk memposisikan, dan menyangga benda kerja. Fixture dan jig merupakan salah satu alat yang penting dalam produksi karena penggunaanya menentukan kinerja dari keseluruhan proses produksi suatu produk. Pada industri manufaktur masih terdapat kasus produk yang dihasilkan kurang presisi sehingga perlu adanya solusi dengan membuat alat bantu dalam proses machining agar produk yang dihasilkan sesuai spesifikasi yang ditentukan. Tujuan penelitian ini adalah untuk mendesain dan membuat jig dan fixture serta menganalisis kinerja pada spesimen uji berbentuk kotak. Jig dan fixture yang dibuat direncakan berbasis meja vakum yang disesuaikan dengan posisi machining pada sisi samping material. Tujuan penggunaan sistem vakum agar proses setup benda kerja lebih singkat. Desain jig dan fixture dibuat menggunakan perangkat lunak Fusion360. Proses fabrikasi menggunakan mesin CNC. Aluminium digunakan sebabagi material benda kerja mudah diproses dan memiliki ketahanan terhadap keausan. Pengujian alat jig dan fixture dilakukan pada sisi samping material uji. Hasil dari penelitian ini menunjukkan bahwa sisi material yang dimilling lebih cepat dikerjakan menggunakan jig dan fixture. Proses milling memerlukan waktu 17.47 menit. Keunggulan dari penerapan jig dan fixture ini adalah waktu operasi dapat dikurangi sehingga operasi yang cepat pada proses milling. Selain itu produk yang dihasilkan memiliki keakuratan dimensi yang baik.

Kata kunci: jig, fixture, milling, desain, manufaktur

1. Introduction

The demand from consumers for manufactured products has grown significantly during the last few years. As a result, manufacturers have created new techniques to create high-quality goods more quickly in order to fulfill the increasing demand [1]. Companies must invest in innovative developments and technology, simplify their manufacturing procedures, and prioritize customer satisfaction as long as they want to stay competitive [2]. Producing machinery has two vital roles in production optimization, namely ensuring efficient production at the desired product quality and potentially reducing production costs. Production equipment is essential to an efficient manufacturing procedure, which motivates companies to make appropriate investments to increase productivity and profitability [3].

Machining is one of the most important manufacturing processes. The invention of diverse machining procedures has played a major role in the Industrial Revolution and the expansion of manufacturing-based economies around the world. A variety of material

removal techniques are referred to as machining. Cutting tools eliminate undesirable material from raw materials to create a shape corresponding to the required geometry [4]. The part's raw material is often selected from a larger range of stock that comes in a range of standard shapes. These shapes consist of shaped blocks, hollow tubes, solid bars, and flat sheets. Furthermore, practically any material, including wood, composites, metals, and polymers, could be machined despite the fact that machined parts are generally made of metal. Numerous characteristics, such as holes, slots, pockets, smooth surfaces, and even complex surface contours, are possible to produce through machining [5].

In certain manufacturing industries, traditional methods are still employed in making products, leading to possible reasons for the final product being less precise. Maintaining the workpiece's alignment and proper interaction with the cutting tool or other instruments is necessary. A jig or fixture is employed to hold, support, and position every part to ensure that every machining operation is completed within the specified specifications [6]. In the production process, holding devices called jigs and fixtures are utilized to reproduce components precisely. Considering the manufacturing sector requires a lot of tooling procedures, fixtures all significantly impact the cost, cycle time, and production quality. Fixtures might have been used to clamp workpieces in conventional machining operations, eliminating the requirement for highly skilled workers and minimizing repetitive job setups [7].

High-performance cutting tools, modern machine tools, and advanced manufacturing techniques enable today's industries to produce some parts or components more quickly and effectively. Fixtures and jigs are essential components of equipment that significantly improve productivity [8]. Jigs and fixtures are made to make manufacturing easier, more efficient, and require less time for finished products [9]. In the machining process, jigs and fixtures are utilized for a variety of reasons, including lowering production costs, increasing productivity, guaranteeing that products are manufactured according to specifications, creating interchangeable parts, simplifying the machining of complex shapes, and decreasing quality control expenses [10].

Industrial manufacture, particularly that which involves procedures including milling, turning, grinding, and other related manufacturing processes, is made easier with the use of jigs and fixtures. A jig is a standalone piece of equipment that has clamped parts in place to carry out one or more tasks. A fixture is a unique holding equipment that holds the workpiece firmly and securely during the machining operation. In contrast, a jig is a tool with a mechanism for a guiding tool [11, 12]. In machining, a jig is equipment that holds, positions, and supports a workpiece while directing the motion of a cutting tool. This device's principal function is to regulate the tool's position and movement. Still, it also ensures that the finished output is consistently precise, interchangeable, and duplicative in the finished product [10]. A fixture is a tool utilized during machining that holds and positions a workpiece securely while maintaining consistent tool interactions [13]. A fixture is a device that holds and clamps a workpiece in position [8, 14]. Manufacturers utilize jigs and fixtures to mass create almost similar products. Perfect fixtures and jigs may function consistently and interchangeably to generate identical parts during manufacturing [15, 16].

Jigs and fixtures are specialized tools used to guarantee mass production and preserve accuracy when manufacturing any component. To ensure that every workpiece produced by a specific jig or fixture is the same, jigs and fixtures come with supplementary tools to guide, position, and support the tool. Furthermore, these tools may be used with a high degree of accuracy, which makes setup minimum and workpiece assembly possible. It is possible to design fixtures or jigs for specific applications. The geometry of the workpiece determines the needed shape and amount of machining [8].

The most common method for holding metal workpieces during machining is to use conventional fixtures, which include manually adjustable clamps and supports and hard contact locators. In most applications, the fixture is manually unloaded and loaded from the machining center. The operator’s time to unload and reload the workpiece is typically between one and two minutes. However, in the case of “hard-to-hold” workpieces, the setup time can be much longer, up to five minutes or more. Such workpieces typically have some combination of complex geometry, excessive flexure, and significant geometry variability, as well as difficult-to-machine locations [17].

Several technologies have been developed to simplify the clamping process of workpieces. In some cases, there is only one surface on the component available for clamping, such as one side of the component for clamping and the other side left unclamped for machining. Under these situations, a vacuum is a good solution for holding the component on one side [18]. The vacuum system can be applied to facilitate the gripping of the workpiece, especially if the location that needs to be worked on is on the side or top. Using a vacuum also shortens the process of removing and installing the workpiece [19].

As previously highlighted in the above description, the main goal of this paper is to demonstrate how to design and make jigs and fixtures to assist manufacturers and designers in cutting production time, which raises overall operational productivity and yields high-dimensionally accurate products. Additionally, it looks for ways to improve the dimensional accuracy and productivity of the products.

2. Materials and methods

The methodology is divided into two parts: the design concept and the preparation of the machining process. The design uses CAD software Fusion360 and an NC program using CAM software MasterCAM. The machining process uses a CNC machine.

The engineering design process is one of the steps required for product development. The tool design process must provide a clear solution to the problem according to the needs [15]. The design employed is modified in accordance with the necessary specifications and requirements [20].

Figure 1 presents the concept of fixture and jig design. The vacuum system used in the jig and fixture's clamping mechanism is appropriate for machining low-thickness products. The vacuum system is applied considering the position of the workpiece being machined on the side so that it does not use a clamping system on the edge of the material. The

workpiece is set up on an aluminum grid pattern and then pulled down using a vacuum pump so that the workpiece is firmly clamped in position. The object clamping system is below with a vacuum to hold the workpiece from shifting from the predetermined location.

Figure 1. 3D model

Following the completion of the design phase, the machining and fabrication processes begin. In the component fabrication process, a milling machine is used. The workpiece material, in the shape of a block, is milled to create fixtures and jigs that fulfill the requirements.

Material selection for fixtures and jigs needs to be completed carefully. Hardness and wear resistance are the two most important properties of materials for jigs and fixtures. The intention of materials resistant to stress and wear is to keep the components being made from getting damaged [1, 7]. The material used for jigs and fixtures is aluminum. Considering that aluminum is easily formed during the machining process, it has strong wear resistance [21].

A CNC machine is employed to complete the machining procedure. The milling process uses cutting fluid to enhance the machining process's performance. Contours are made on the surface of the fixture to create a grid as a path that functions as a path to channel air when clamping the workpiece. Figure 2 shows the cutting groove on the top or surface to create a grid. The next phase of the milling procedure for clamping requirements on the machine table is depicted in Figure 3. For vacuum path or vacuum inlet purposes, make a hole on the side of the product.

Figure 2. Milling Process

Figure 3. Side Milling Process

Figure 4 shows the finished result of the machining operation. Next, the completed product is attached to the side grid using a vacuum gasket. During the clamping procedure, the vacuum gasket ensures that the isolated surface area stays airtight.

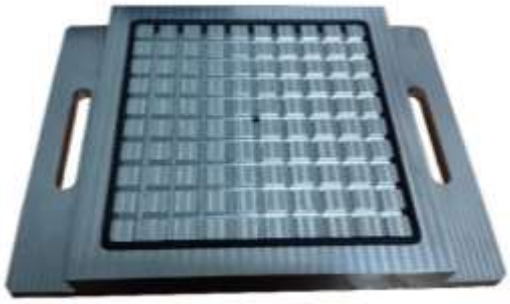

Figure 4. Final Product

3. Result and Discussion

The fabricated jigs and fixtures are then evaluated through experiments to assess their performance. Jigs and fixtures were tested by side milling the test specimens. The test was run twice; jigs and fixtures were used for the first run. The following test was conducted without the use of fixtures and jigs. The precision of the side milling results and the setup loading and unloading time (minutes) were the aspects under consideration. The measure of the final product's dimensional accuracy is the differences between the dimensions that correspond to the design requirements and the machining process outputs. Figure 5 shows the placement of jigs and fixtures on the conventional milling machine. A vacuum inlet connects the vacuum hose, the work-holding device, and a vacuum gasket to keep the surface airtight. The workpiece for testing is placed on the work-holding device. Testing is carried out on the side with a workpiece thickness of 5 mm. Using jigs and fixtures makes it easier to hold the workpiece without having to load and unload.

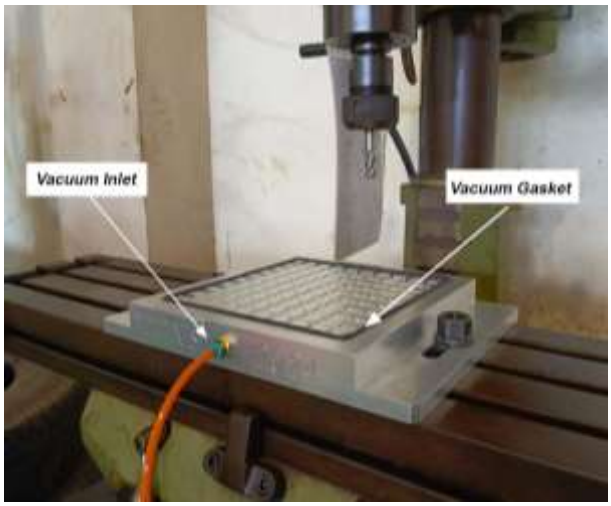

Figure 5. Jig and Fixture

Tables 1 and 2 demonstrate the way jigs and fixtures may accelerate the side milling operation. Table 1 shows that the machining process is able to decrease by using jigs and fixtures, taking a total of 17.47 minutes. Table 2 indicates that using other tools takes 24.37 minutes. The time required shows that by using jigs and fixtures, the side milling process is carried out quickly. The advantages of jigs and fixtures are reducing operating time and increasing productivity [8, 19] [8], [19].

Table 1. Total time for jig and fixture

Position	Time (minutes)		
	Loading-Unloading	Machining	Total time
Side 1	1.7	3.35	17.47
Side 2		4.47	
Side 3		3.83	
Side 4		4.12	

Table 2. Total time for other tools

Position	Time (minutes)		
	Loading-Unloading	Machining	Total time
Side 1	2.5	3.35	5.85
Side 2	1.6	4.47	6.07
Side 3	2.2	3.83	6.03
Side 4	2.3	4.12	6.42
			24.37

Testing of jig and fixture tools is applied to the machining process on the side of the workpiece. The use of jigs and fixtures results in a shorter time compared to using the tools currently used. The jigs and fixtures used do not require repeated loading and unloading processes because the clamping process is not on the side of the workpiece, where in this case the side of the workpiece is the part to be machined. Because of this, the machining process could be completed in a single step, but with other tools, the clamping process is required on the side of the workpiece so that the loading-unloading process is needed to position the side of the workpiece to be machined.

The evaluation of the dimensions obtained with the use of jig and fixture devices is provided in Table 3. In this case, the tolerance value is set at ±0.5. The final product dimensions still meet the minimum and maximum limits of the specified tolerance.

Table 3. Dimensional accuracy for jig and fixture

Location	Design	Experiment	Differences
Length (x)	40 mm	40.3 mm	0.3 mm
Wide (y)	40 mm	39.8 mm	0.2 mm

4. Conclusion

This project presents the design and fabrication of jigs and fixtures for milling machines in the manufacturing industry to improve dimensional accuracy and time productivity. The resulting product helps minimize setup time for the milling process, and less time is required to complete the machining process, thereby increasing production rates. This product will facilitate setup operations for cutting workpieces without the need to load and unload materials. Furthermore, dimensional accuracy that corresponds with the given tolerance limits is produced by using this work-holding device.

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