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COMPARISON OF MACHINING PERFORMANCE USING SELF-DEVELOPED PORTABLE VACUUM CLAMPING SYSTEM

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ABSTRACT

Usually instruments or holding equipment such as vise are used to clamp the piece of job. Due to the low stiffness of the workpiece during machining, thin wall components have always been a challenge to clamp. This study aims to compare the effect of machining performance using self-developed portable vacuum clamping system (SPVCS). SPVCS had been developed at laboratory. This study is to evaluate the work-ability of SPVCS; two process of machining process had been tested. Experiments were conducted on acrylic to end mill machining and engrave machining with parameters selected to cut. To analyses the result for end mill process, systematic measurement of process response parameters in terms of surface roughness had been conducted. The surface roughness was analyzed to observe the influence of process parameters on the suction vacuum clamp during machining. While for engrave process Coordinate Measurement Machine (CMM) had been used to check and verify the result of thickness at 13 points that been selected. For each machining process two condition of machining condition had been observed. Firstly, continuously vacuum pressure method and secondly, remain vacuum pressure method. The result showed that vacuum clamping contributed in better surface roughness with average value of 0.585μm for continuously pressure method and 0.663μm for remain pressure method for end mill process. On the other hand, the result also showed that vacuum clamping contributed in better dimension accuracy with average value of 14μm for continuously pressure method and 8μm for maintain pressure method for engrave process. As a conclusion, it was proofed that the vacuum clamping can improve the machining performances of acrylic plate in term of surface finishing and surface roughness quality.

Keywords: vacuum clamping, end mill process, engrave process.

1. INTRODUCTION

The clamp design plays an important role. Clamping design determine the developing product quality in good surface finish and accuracy. That is not possible to achieve a precise dimension by manual cutting [1]. The workpiece holder to give accurate dimension when manufacture when manufacture duplicate and interchangeable parts. Jigs and fixtures are specially designed so that large number of components can be machined or assembled identically, and to ensure interchange ability of components. A mass production process requires quick and easy workpiece lock methods in an exact position [2]. the most important could be effect of manufacturing process output is clamping machining [3]. Nowadays, it is a challenge in manufacturing to offer products of high quality at minimum times and costs [4]. The clamp is work holding device used to maintain position of workpiece for machining, inspection, assembly or other operation. When to be competitive it is necessary to increase continuously the economic effectiveness of the production process. Pneumatic-hydraulic multipliers are one of devices enabling automation of workpiece clamping [5]. The clamping is a device which sets workpiece in good position during manufacturing operation. This process is a balancing act between rigidly holding the workpiece and resisting deformation due to over application of clamping pressure. It also needs to resist vibrations generating during machining and avoid that the part does not lose its position, fly or sign of an incorrect location.

Smart clamping systems increase support and minimize deflections in machining [6]. The vacuum clamping system features a new design of the vacuum block that can be used as clamper on both sides of the vacuum block. An ideal vacuum clamping system where clamper done using a bottom surface that are flat and stable. On the dual side clamper, the vacuum block is clamped perfectly to any flat surface base without using additional mechanical clamping or attachment tabs.

Milling is an important process in production which extruded element on material by removing the unwanted material [7]. Pocket milling has been regarded as one of the most commonly performed machining. Pocketing is a usual process for mold and die making. The process begins on a particular tool path strategy from the surface of the component to the required depth of the mold. Compare to normal cutting, it depending on the shape of the design which the tool requires to travel in various straight then angle cutting [8].

The functional principle of the vacuum grippers is based on a pressure difference between ambient pressure and the inner volume of the suction cup which is placed airtight on the surface on the workpiece. Hence the workpiece is pressed against the sealing lip of the suction cup by the ambient pressure [9]. The vacuum clamping technology provided to ensure no damage when using this clamp system which any of the scratches or clamping marks on workpiece. Since the magnetic clamps cannot clamp composite materials and flat plastic workpieces and mechanical clamps cannot be use to clamp thin walled light metal workpiece, the demand for vacuum clamping systems is rise. Vacuum clamps develop a holding force which is spread across the entire workpiece area, making them ideal for flat thin-walled workpieces [10]. The workpiece or part machined can be replace after completed machining with a new one quickly. The vacuum clamping systems is main to ensure that the clamping forces generated are sufficient to support the parts while being machined [11].

The process of machining requires clamping and cutting force measurements [12]. The tool and workpiece interface generates energy as a result of plastic deformation of metal and friction. The work piece will absorbed large amount of heat product by high thermal conductivity material like aluminum alloys. It leads to an increase in working part temperature that can relate to dimensional inaccuracies, damage to the surface and distortions [13]. Therefore, while choosing the right an end mill, the tool material is an important factor. The carbide, high speed steel (HSS), ceramic and diamond are among the popular end mill cutting tool materials [14]. This study is to evaluate the work-ability of SPVCS with two different of machining process.

2. METHODOLOGY

2.1 Design of Self-Developed Portable Vacuum Clamping System

A vacuum is a state in a space that is free generally call it a vacuum when the air pressure in a space is less than that of the atmosphere. In vacuum clamping, an under pressure is generated under the workpiece being clamped, i.e. a pressure differential is created which presses the workpiece against the clamping plate. Thus the workpiece will be sucked, but is rather pressed against the vacuum table. The sliding force of the workpiece depends on its surface structure, the pressure differential and the area on which the vacuum acts. The larger the area, the better the holding force.

Figure-1 shows the SPVCS at laboratory. It consists of 6 components. They are air compressor, valve, pneumatic solenoid valve, vacuum generator, reservoir and vacuum block. While, Figure-2 shows the flow of air pressure on SPVCS.

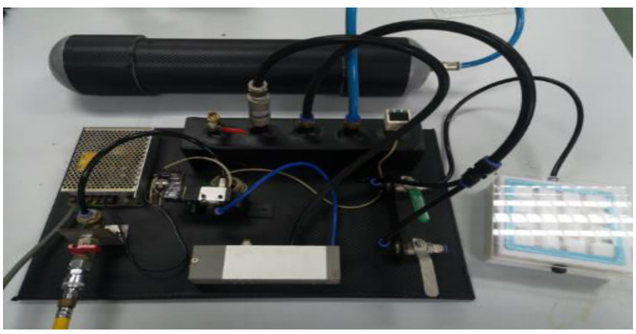

Figure-1. Self-developed Portable Vacuum Clamping System.

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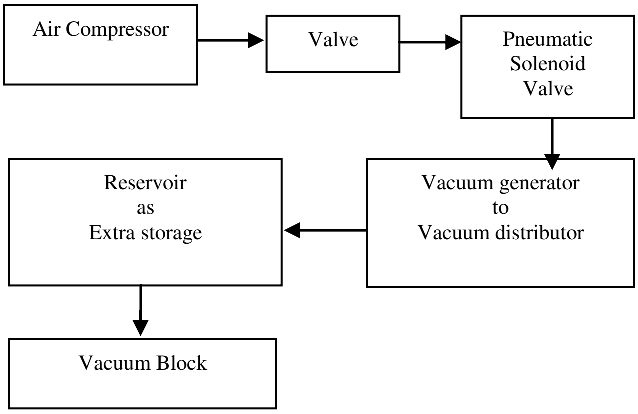

Figure-2. Block Diagram Self-developed Portable Vacuum Clamping System.

2.2 Experiment Setup for End Mill Process

On all surfaces of an object, there is an even pressure of approximately 70kPa that has been used in experiment testing consist of continuously pressure method and remain pressure method. Secondly, continuously pressure is always given air pressure in the system while remain pressure method will off the system from pressure flow to the vacuum clamper but it still can clamp and pressure drops every 5 minutes because of the surrounding atmosphere. Using air suction, the air underneath the component is sucked away so that the pressure load on these surfaces is partly removed; the clamping or holding force results from the difference in pressure between the upper and lower component surfaces. The amount of one-sided pressure is dependent on the amount of under pressure or vacuum generated. The clamping force on a component is proportional to the surface area; therefore, for a component size of 18.4cm x 18.4cm and a vacuum of 70kPa the clamping force can be calculated. Figure-3 shows the experiment setup on CNC router machine.

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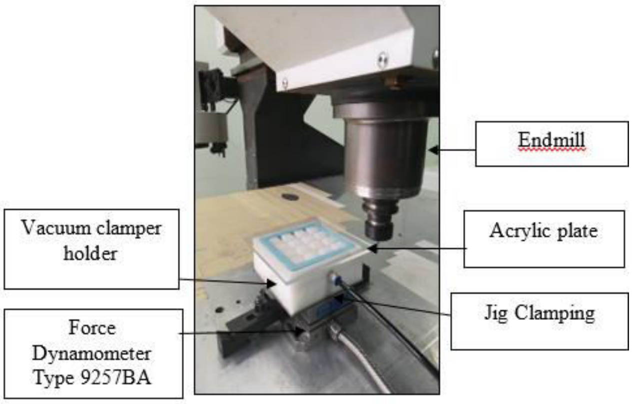


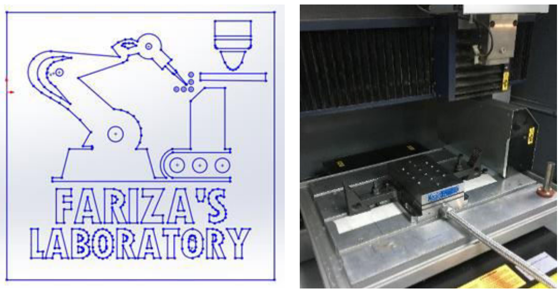
Figure-3. Experimental setup SPVCS on machining.

2.3 Experiment Setup for Engrave Process

Milling process was conducted using CNC Router Machine by HASS510. This machine can perform high speed machining operation with maximum spindle speed of 10,000 rpm. The routers are used for cutting and formed parts according the design.

The acrylic plate has been used as work material. Size of the acrylic sheet is 160mm x 160mm x 6mm. Acrylic is a tough and resilient plastic. To perform machining operation, High Speed

Steel End Mill was used. The tool diameter was 2mm. Dynamometer was attached to the workpiece to measure cutting forces. Figure-4 (a), 5 (b) shows the design of engrave process to evaluate machining performance of SPVCS and experiment setup.



(a) (b)

Figure-4. Design of engrave process and experiment setup.

Calculation to find the necessary cutting parameter can be utmost in many situation, however, for the engrave operations, desired cutting time which half an hour with approximate parameter can be determinations by using Master CAM software. This test was conducted above 30 minutes machining process to ensure the vacuum clamping durability. Table-1 shows the experiment parameters for engrave process.

Table-1. Experimental parameters.

Test	Cutting parameter value				
	Spindle Speed (RPM)	Feed rate (mm/min)	Depth of cut (mm)	Workpiece Material	Clamping Method
Pressure In	9500	1800	2.0	Acrylic	Vacuum Clamping
Without Pressure In	9500	1800	2.0	Acrylic	Vacuum Clamping

3. RESULT AND DISCUSSIONS

3.1 Result for End Mill Process on Surface Roughness

Once the machining has been completed, surface roughness has also been evaluated for objective assessment. It was measured along the feed direction using an Mitutoyo SJ-420 surface roughness testing. There are two different method of clamping which is using continuously pressure and remain pressure method. Both methods were measure ten point with 3-layer thickness consist of 1.5mm, 3mm and 4.5mm of surface roughness reading on acrylic panel. All the reading has been taken in average point. In this subtopic will be discuss the analysis of experimental result for surface roughness by effect single self-contained dual vacuum clamper on acrylic end mill performances. Table-2 shows comparison of surface roughness for both methods.

Table-2. Result of surface roughness.

Reading number	Continuously Pressure (CP)	Remain Pressure (RP)
1	0.597	0.657
2	0.582	0.714
3	0.562	0.615
4	0.599	0.665
Average	0.585	0.663

Waviness may effect on surface texture due to single self-contained dual vacuum clamper such factor as workpiece deflection, vibration, heat treatment nozzle and vacuum suction. Vacuum clamp pressure flow has controlled vacuum suction on the panel when pressure is given. The vacuum pressure flow will flow through each other through two holes located in the centre of the vacuum depth as seen in figure below. Additionally, the

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panel is sucked heavily according to silicon rubber on the vacuum clamp. When the pressure is removed, the vacuum clamping was release pressure slowly.

However, influence on acrylic surface texture when clamp on dual vacuum clamper workpiece deflection. This is because nozzle laser cut that cut panel size measurement measuring 183mmx183mm is not accurate. Nozzle laser cut used indoor light on work piece cutting. So, heat treatment from nozzle light was produced and will influence material cutting measure size and expand material properties if cut without distance between nozzle and material. It proves by [16] heat treatment generated by the concentrated light energy causes melting, vaporization, and decomposition on workpiece. Although, laser cutting in principle meets the requirements, it is often not used for component trimming and contour cutting, due to insufficient knowledge about the influences of thermal machining on the material behavior was prove [17]. Indirectly, sheet acrylic that clamped uses dual vacuum clamper not accurate. In process machinery carried out on the other hand will happen cutting that is irregular.

Secondly, an inaccurate setting device is also one of the factors affect in surface texture on acrylic panel because of the friction force between the cutting tool and the panel is not accurate when the machining process is executed in the experiment. That problem can prove by [18] is no machine device showed any significant advantage over the expert system's accuracy in any setup process when the same problem was treated as classification. Meanwhile, vibration was produced between the cutting tool and panel when machining due to the vacuum suction on the panel releasing a little bit of pressure from the vacuum clamper.

Apart from that, suction force vacuum clamper also became influence on panel surface. This is because suction point was inhale panel with strength of pressure force set is 70kPa. This problem had given bending effect on panel because vacuum suction.

In this experiment, analysis thrust forces and surface quality obtained by using vacuum clamper during machining operations was carried out to present the experimental set-up and measurement methodology.

3.2 Result for Engrave Process on Dimension Accuracy

According to the experiment result, the cutting depth has a critical effect on the dimensional accuracy. Air dropped in the vacuum clamping testing is capable to holding right the workpiece and operate the clamping effectively.

Table-3. Dimension accuracy for CP.

Bil.	Actual Dimension (mm)	Checked by Optic Comparator (mm)			Average (mm)	Difference (mm)
		1	2	3		
1	10.299	10.277	10.277	10.285	10.280	0.019
2	24.587	24.556	24.567	24.571	24.565	0.022
3	23.538	23.529	23.353	23.537	23.473	0.065
4	5.104	5.102	5.101	5.101	5.101	0.003
5	23.368	23.364	23.364	23.365	23.364	0.004
6	5.391	5.386	5.384	5.388	5.386	0.005
7	23.368	23.362	23.363	23.356	23.360	0.008
8	3.546	3.524	3.522	3.521	3.522	0.024
9	4.6	4.611	4.589	4.588	4.596	0.004
10	10.4	10.393	10.399	10.397	10.396	0.004
11	4.575	4.563	4.563	4.573	4.566	0.009
12	2.544	2.539	2.538	2.54	2.539	0.005
13	22.205	22.189	22.187	22.198	22.191	0.014
Average						0.014

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Table-4. Dimension accuracy for RP.

Bil.	Actual Dimension (mm)	Checked by Optic Comparator (mm)			Average (mm)	Difference (mm)
		1	2	3		
1	10.299	10.281	10.28	10.281	10.281	0.018
2	24.587	24.57	24.571	24.567	24.569	0.018
3	23.538	23.539	23.537	23.54	23.539	-0.001
4	5.104	5.122	5.104	5.101	5.109	-0.005
5	23.368	23.368	23.367	23.363	23.366	0.002
6	5.391	5.387	5.386	5.388	5.387	0.004
7	23.368	23.366	23.359	23.363	23.363	0.005
8	3.546	3.524	3.52	3.504	3.516	0.030
9	4.6	4.59	4.587	4.598	4.592	0.008
10	10.4	10.4	10.396	10.398	10.398	0.002
11	4.575	4.576	4.584	4.575	4.578	-0.003
12	2.544	2.539	2.532	2.54	2.537	0.007
13	22.205	22.201	22.202	22.199	22.201	0.004
Average						0.007

The higher the spindle speed over 9500 rpm improve both the pocket dimensional accuracy. The mean of CP and RP values are 14µm and 7µm. There could be acceptable for a huge component or part processes. Any increasing in the cutting speed in order to improve the machining accuracy of materials sample. So it can be said this parameter of cut improves the pocket accuracy.

Table-5. Depth cut accuracy for PI.

Bil.	Actual Dimension (mm)	Checked by CMM (mm)			Average (mm)	Difference (mm)
		1	2	3		
1	2.000	1.778	1.761	1.736	1.758	0.242
2	2.000	1.937	1.926	1.902	1.922	0.078
3	2.000	2.185	2.190	2.205	2.193	-0.193
4	2.000	2.073	2.035	2.030	2.046	-0.046
5	2.000	1.867	1.894	1.928	1.896	0.104
6	2.000	1.924	1.934	1.915	1.924	0.076
7	2.000	1.796	1.747	1.696	1.746	0.254
8	2.000	2.061	2.069	2.067	2.066	-0.066
9	2.000	1.409	1.375	1.344	1.376	0.624
10	2.000	1.234	1.210	1.166	1.203	0.797
Average						0.187

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Table-6. Depth cut accuracy for WPI.

Bil.	Actual Dimension (mm)	Checked by CMM (mm)			Average (mm)	Difference (mm)
		1	2	3		
1	2.000	1.735	1.720	1.701	1.719	0.281
2	2.000	1.915	1.902	1.888	1.902	0.098
3	2.000	2.182	2.201	2.216	2.200	-0.200
4	2.000	1.983	1.973	1.916	1.957	0.043
5	2.000	1.816	1.848	1.882	1.849	0.151
6	2.000	1.907	1.902	1.884	1.898	0.102
7	2.000	1.807	1.752	1.700	1.753	0.247
8	2.000	2.028	2.030	2.039	2.033	-0.033
9	2.000	1.439	1.406	1.378	1.407	0.593
10	2.000	1.283	1.253	1.203	1.246	0.754
Average						0.204

The average cut depth for PI is 1.81 mm While for WPI, the average value is 1.796mm. The cutting depth has the critical effect on the dimensional accuracy. The experiment reveal that the constant depth is not achieved by all point marked for both pressure condition. This is related to the higher vibration which leads to the depth accuracy is worse. Thus, higher the pressure through the inlet valve appears to increase bending area of the acrylic plate during machining. The problem due impact at certain area of acrylic plate can be that worsen by the decreases of the depth of cut to adhere to the bending condition.

4. CONCLUSIONS

Variable in surface roughness and thrust force was noted to be directly proportional in experiment to achieve the objectives experiment. In terms of factors such as wall deflection on the panel can be found by influencing the surface roughness through the suction forces and devices setting. Besides that, the thrust force is also influenced by the setting not accurately and all at once deflection between tool and work surface during machining performances not uniform. The deflection led in irregular contact between the wear of the instrument and the workpiece, resulting in variable thrust force and roughness of the surface.

However, the result of the surface roughness indicates workpiece using vacuum clamping has the lowest Arithmetic mean value, Ra compared to previous literature review. It proved by using vacuum clamping is more dynamic stability, capable and functionable as one of the clamping methods while doing machining.

In this experiment, force and accuracy for pocket machining were method clamping development and approved. The acrylic plate were tested at same parameter between two difference conditions strategies.

A desired cutting time which half an hour with approximate parameter can be determinations by using MasterCAM software for milling of pocket. A setting air pressure was developed to establish optimal cutting time of milling of a pocket. With a given set of cutting time, the situation of the vacuum clamping hold the acrylic plate during machining could be predicted which only dropped 1.7kPa from 70.3 kPa. The experiment was found to be effective in ensuring the vacuum is good enough clamp during milling.

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