VOL. 15, NO. 6, MARCH 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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EFFECT OF PORTABLE VACUUM CLAMPING ON ACRYLIC POCKET MACHINING PERFORMANCE

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ABSTRACT

This project provides a mechanical clamp limitation solution that should not leave marks on the clamped surface and is unable to handle small thickness of workpiece. Using a new method involving a new component that develops dual vacuum clamper to attach and detach the workpiece to the flat surface and is capable of clamping small and thin workpieces. In this project, which is reservoir will help it ability of pocket machining performance with two condition. The two conditions are air pressure from compressor through to vacuum system and one more is no air pressure from compressor. Experiments have been conducted using diameter 2mm HSS end mill and acrylic workpiece on pocket machining. The time required to run the experiment is about 30 minutes. So, the result of experiment had been taken for every 5 minutes. After the experiment, evaluation of thrust force and dimension accuracy also had been conducted. Dynamometer type 9257BAis used to evaluate the thrust force and Horizontal Optic Comparator and Coordinate Measurement Machine for analyze the diameter accuracy. As a result for thrust force, for Fx and Fy axis for both condition was stable however for Fz for both condition produced decline result as time increased. 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. The average dimension accuracy was produced by taken 13 points selected area on workpiece. For air pressure from compressor through to vacuum system condition, the vacuum capable of clamping the workpiece during the pocketing process which only dropped 1.7kPa from 70.3 kPa. As conclusion, this project had showed that the effectives in clamp during pocket machining using vacuum clamping method.

Keywords: clamping, pocket machining, thrust force, dimension accuracy.

1. INTRODUCTION

The clamp design plays an important role. Clamping design determinateness the developing product quality in 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 interchangeability 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 workholding 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-hydraul ic 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. Ideal vacuum clamping systems 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 mould. Compare to normal cutting, it depending on the shape of the design which the tool require 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 systems 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

VOL. 15, NO. 6, MARCH 2020 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

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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 ones 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].

2. METHOD/EXPERIMENTAL

There are two conditions that need to analysis for cutting force. First one is between inlets connected from compressor in open called Pressure in (PI) condition. The second one or the other one is the inlet connected from compressor is closed since the air pressure cannot enter to the system but the air in the vacuum state is sustain by the tank reservoir called Without Pressure In (WPI).

2.1 Vacuum clamping

The vacuum block made from material with high toughness called Delrin. The material provides lightweight advantages compare to stainless steel. That provides one opportunity to reduce weight and improve productivity. The important part of this experiment is a reservoir tank. The main purpose of reservoir tanks are to give the air storage capacity to machining operation that last for short periods of time or when suddenly no air inlet to system. This also will study of clamping durability in this condition.

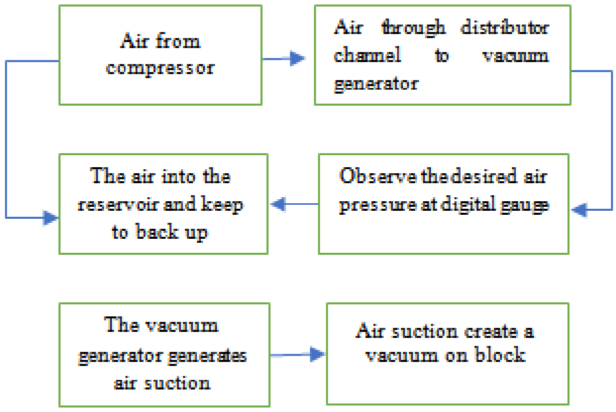

Figure-1. The air pressure flowchart on vacuum clamping system.

2.2 Machining 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. When it is machined properly, it has form 6 to 17 time's greater resistance to breakage than glass. To perform machining operation, High Speed Steel End Mill was used. The tool diameter was 2mm.

Figure-2. Shape of the pocket.

Dynamometer was attached to the workpiece to measure cutting forces. DynoWare software was connected to the dynamometer for recording data.

Calculation to find the necessary cutting parameter can be utmost in many situation, however, for the pocketing 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 minute machining process to ensure the vacuum clamping durability.

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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

2.3 Development and fabricate of the jig clamping

This experiment need a flat surface plate to attach between the vacuum block and the dynamometer because the vacuum block has no thread hole to make joined with the dynamometer. Having this jig able to the vacuum block suction flat surface area.

Figure-3. Thread hole on the top of the dynamometer.

Figure-4. The support plate (jig clamping).

2.4 Experiment set up

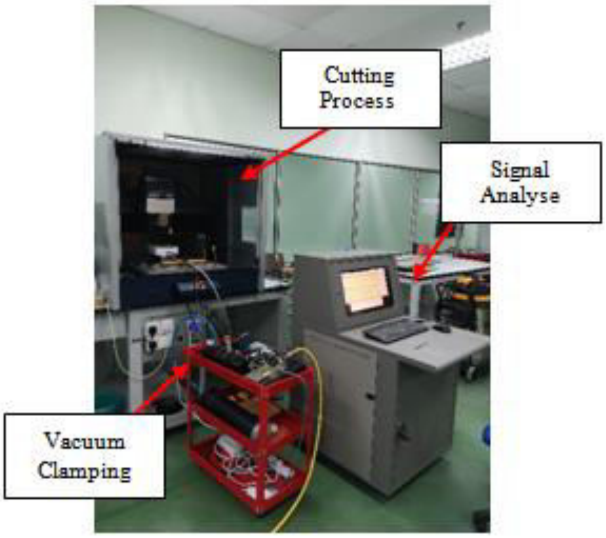

Figure-5. Experimental set up.

3. RESULTS AND DISCUSSIONS

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.

3.1 Thrust force

Cutting was carried out on CNC Gantry Router Machine. Acrylic plates were cut as per required dimension. As shown in figure shown the acrylic cut at 9500 rpm and 1800 mm/min.

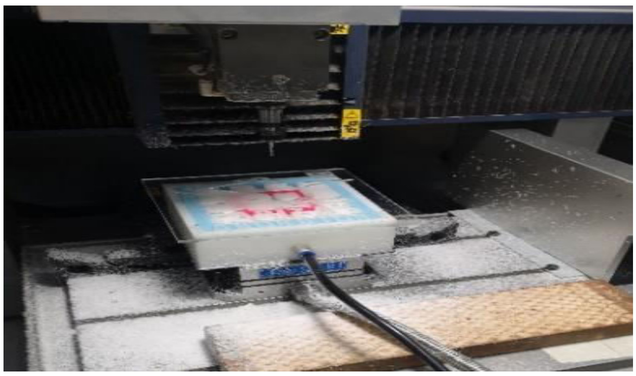

Figure-6. Cutting process of acrylic plate.

VOL. 15, NO. 6, MARCH 2020 ISSN 1819-6608
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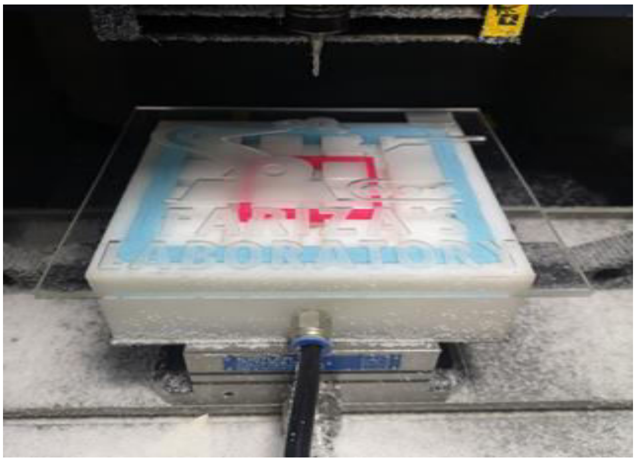

Figure-7. Pocketing design on the acrylic plate.

Table-2. Thrust force data for Pressure in Method.

Time taken (min)	Average time (s)	Fx (N)	Fy (N)	Fz (N)
5min	300	4.0725	3.0164	9.6861
10min	600	3.9950	2.8896	9.5243
15min	900	4.1038	2.8827	9.1448
20min	1200	3.9646	2.413	8.9789
25min	1500	4.2102	2.5732	8.5673
30min	1800	4.2046	2.3365	8.0717
35min	2100	4.2003	2.3056	7.4916
38.18min	2291	4.249	2.0081	6.8453
	Average	4.1250	2.5531	8.5388
	Tolerance			

Table-3. Thrust force data for without pressure in Method.

Time taken (min)	Average time (s)	Fx (N)	Fy (N)	Fz (N)
5min	300	4.7158	3.0231	8.3476
10min	600	4.6653	2.8550	8.3771
15min	900	4.7853	2.8678	8.1742
20min	1200	4.7405	2.4079	8.2011
25min	1500	4.9755	2.5606	8.0047
30min	1800	4.9409	2.3399	7.8517
35min	2100	4.9488	2.3276	7.6976
38.85min	2291	5.0408	2.1795	7.5081
	Average	4.8516	2.5702	8.0203
	Tolerance			

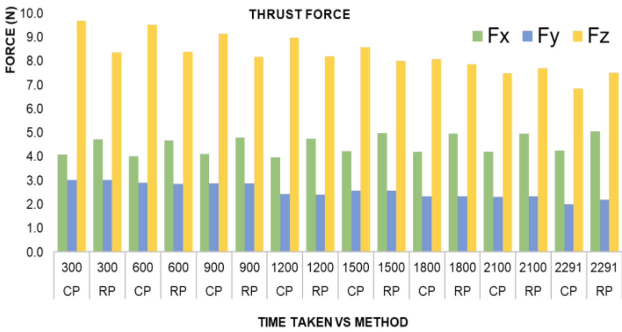

Figure-8. Thrust Force.

The vacuum clamping in pressure in condition is under force which 4.0725 N and the acrylic plate are stable during machining compared with the without pressure in conditions which is supported by the reservoir as back up supply air pressure. The Fx thrust force is decreased by 5 minutes to 10 minutes for both condition by constant cutting speed and other parameters. The interface friction between cutting tool and acrylic plate decreases at the first 10 minutes. The ratio between fx and fy for both axis is 1.17 N and 1.01 N.

3.2 Dimensional accuracy

The focus on objective is dimension accuracy through new design of vacuum clamping when applying 70.3kPa during machining.

3.2.1 Diameter

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Table-4. Dimension accuracy for PI.

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

Table-5. Dimension accuracy for WPI.

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 PI and WPI 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.

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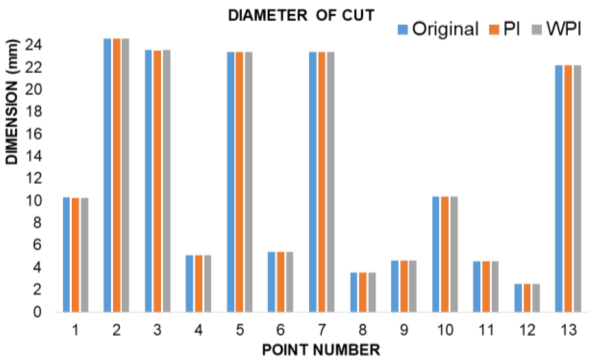

Figure-9. Diameter accuracy.

The highest dimensional accuracy would be produced at the lowest level of the nose radius. As increasing the nose radius, there is increased vibration. The increasing the nose radius has potential for tool wear is exacerbated but dimensional precision is improved by the lowest vibration generated [15].

The higher dimensional accuracy at the small nose radius can be related to the lower feed force (fx) and vibration, which enhance because of the depth of cut was set at 0.1mm per cycle and inaccurate contact area between the cutting tool and the workpiece surface.

3.2.2 Depth cut

Table-6. 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

Table-7. 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

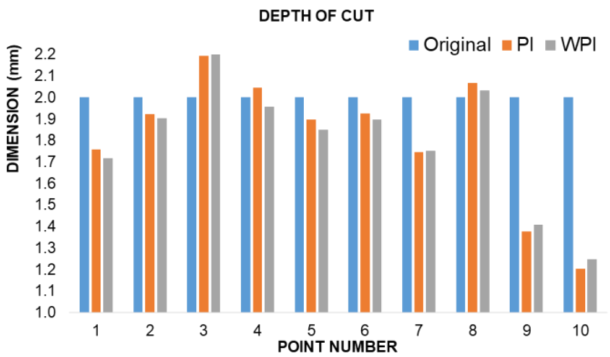

Figure-10. Line graph of overall cut depth average between 10 difference marks.

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.

3.2.3 Air dropped for WPI condition

Start pressure: 70.3 kPa
Last pressure remain: 68.6 kPa

Table-8. The value of air pressure dropped during machining process.

Air dropped for every 5 mins;	
5 min	7.00 kPa
10 min	69.8 kPa
15 min	69.5 kPa
20 min	69.3 kPa
25 min	69.1 kPa
30 min	68.9 kPa
35 min	68.7 kPa
38.11 min	68.6 kPa

The most important thing on the vacuum clamping is durability. Durability here is the how much air pressure required to machining process through the cycle to a finish the process. A longer lead time and a little bit air dropped increase in efficiency and productivity and reduced cost.

The clamping test is passed which only dropped 1.7kPa from 70.3 kPa to 68.6 kPa within 38.11 minutes. However, the vacuum is capable of clamping the workpiece during the pocketing process without supply air pressure into the system. The factor could be air leaks coming from vibration working table during machining but other factor could possible mean that there is something more serious. The factor air dropped is the hose pipes. A leaky hose might be as simple as a loose connection at the faucet valve. The hose (blue) connected from distribution channel to air reservoir to supply back up air pressure and a reservoir is always keep connected without removing the hose connection. There is no fixed place to place it. So that, it have a problem with the hose fitting and hose end. Thus, the way hose performs need to give attention. This is due to air from any air vent at hoses will escape.

4. CONCLUSIONS

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

There method was applied to predict thrust force for pocket milling process. An FxFy defined as the rate of force to vibration was accepted through experiment work. It was established that for the machining of acrylic plate using HSS cutting tool this force average is 1.17 N and 1.01N.

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.

ACKNOWLEDGMENTS

This work is partially supported by Universiti Teknikal Malaysia Melaka (UTeM) and the Malaysia Ministry of Higher Education for the financial funding under Grant No. FRGS/2018/FTKMP-AMC/F00387.

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