Design Optimization and Development of Portable Vacuum Clamping (VacCLAMP) Based on Machining Performances

N. Ab Wahab, Shahazati binti Md. Rozali, Nabil Haikal Bin Abdul, Abd Khahar bin Nordin,Aliza binti Che Amran, S. Mohamad Saleh

Faculty of Engineering Technology
Universiti Teknikal Malaysia Melaka
norfariza@utem.edu.my

***Abstract*— Manufacturing and workshop practices have become important in the industrial environment to produce products for the service of mankind. Clamping in milling usually use tools and holding devices such as vise to clamp workpiece. The purpose of this project is to develop and optimize for portable vacuum clamping. The method is to develop and optimize of apply the vacuum clamping method on milling machine. Then, the design of the vacuum clamping is being optimized. After product is finished, a testing is done on the vacuum clamping to evaluate and experiment the result of product. The result shows that vacuum clamping has better surface roughness result which total of 1.696µm. As a conclusion, all the various result of analysis is taken and vacuum clamping can be able to be apply and used for teaching purpose.**

***Index Term*— Portable vacuum; vacuum; clamping; workpiece; milling; clamp; (key words)**

I. INTRODUCTION

Machining is manufacturing process of removing the undesired or unwanted material from the workpiece or job or component to produce a required shape using a cutting tool. This can be done by a manual process or by using a machine called machine tool (Singh, 2006)[1].

A clamping device holds the workpiece securely in a jig or fixture against the forces applied over it during on operation. Fixtures and jigs are used to locate and constrain a workpiece during a machining operation, minimizing workpiece and fixture tooling deflections due to clamping and cutting forces are critical to ensuring accuracy of the machining operation (Kaya, 2006)[2]. The clamping fundamentals to be used must equally neutralize the cutting forces (feed and speed) and grip down the workpiece through the machining process. Clamping force to ensure the dynamic stability of a fixture workpiece during machining(Vukelic et al., 2012)[3].

The advantage of vacuum clamping technology is the gentle non-damaging clamping action which it provides. Workpieces do not suffer any of the scratches or clamping marks associated with mechanical clamping. Demand for vacuum clamping systems is rising due to the increased use of thin-walled light metal workpieces, those made of composite materials and flat plastic workpieces, which cannot be clamped by magnetic means. Vacuum clamps develop a holding force which is spread across the entire workpiece area, making them ideal for flat thin-walled workpieces.

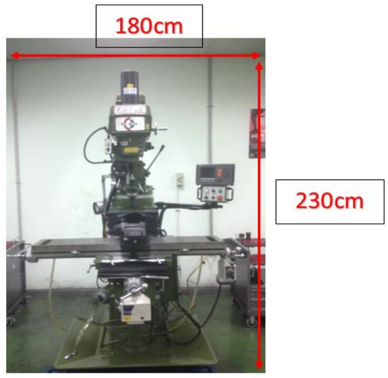

Fig. 1. Conventional milling machine

The fundamental standards vacuum clamping is the point at which a vacuum is made, a pressure differential is made between the vacuum areas plate and the workpiece. The vacuum causes an 'under-weight' underneath the workpiece which successfully presses the workpiece against the clamping plate. Along these lines, the workpiece isn't 'sucked' but instead squeezed against the vacuum table.

II. RESEARCH METHODOLOGY

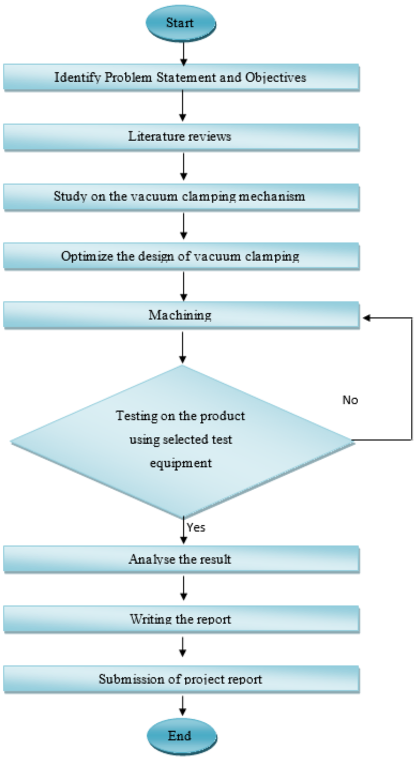

Fig. 2. Flow chart

A. Design of vacuum clamping

- In this stage, based on the limitation in conventional vises, a sketch is drawn for the design of the vacuum clamping
- Sketch then redrawn using Catia V5 software as shwon in Figure 3

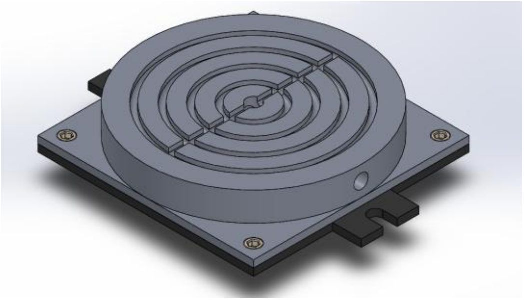

Fig. 3. Vacuum Clamping CAD model (isometric view)

B. Material solution of design

- A quotation was made to know material and tool that needed in develope the vacuum clamping.
- Mild steel choosen as the main material due to ease of machining and its toughness.

C. Developement of vacuum clamping for milling machine

- Machining process for each part completely using milling machine and CNC milling machine
- Process included are squaring, facing, milling and drilling

D. Evaluation of the product

- Surface roughness testing was conducted to evaluate the vacuum clamping
- Testing is done on mildsteel size 10mm x 10mm
- Experimental setup :
  1. Body and Base part is combine and fabricate by conventional and advance machining.

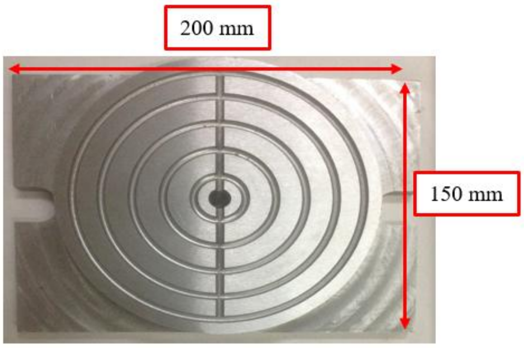

Fig. 4. Finish Product

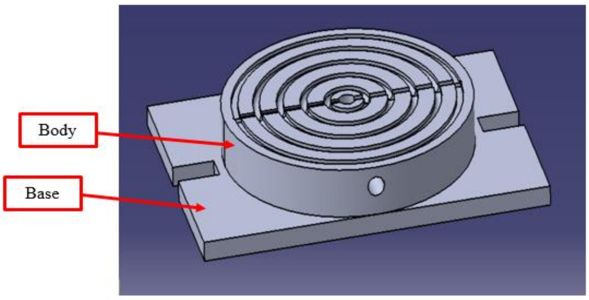

Fig. 5. Combination of body and base part

  2. The finish part then attach to the milling table using bolts and nuts as shown in figure 6.

Fig. 6. Device attached on milling table

3. The device than connected to vacuum pump using pneumatic hose as shown in figure 7.

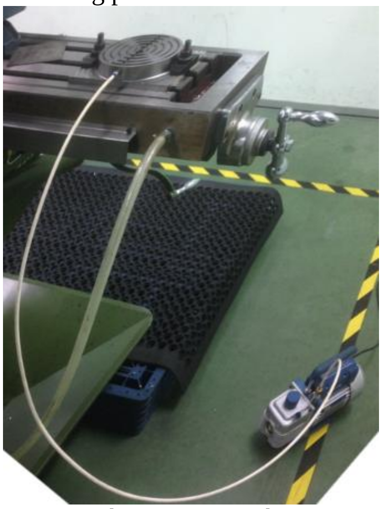

Fig. 7. Vacuum clamping connected to vacuum pump

4. A sealing cord is placed on the vacuum clamping according to the size of the workpiece as shown in figure 8.

Fig. 8. Sealing cord place on top of the vacuum clamping

5. The workpiece is placed on the vacuum clamping and vacuum pump is turned on to complete the clamping process as shown in figure 9.

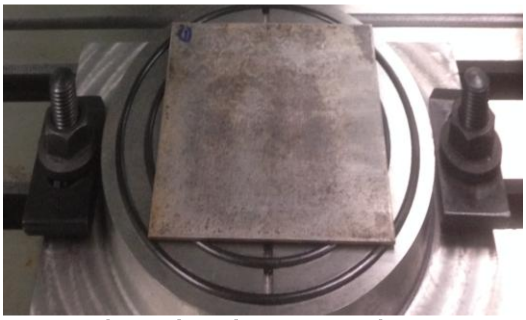

Fig. 9. Workpiece clamped using vacuum clamping

6. The workpiece cut using end mill. Workpiece then changed to next sample where it also cut using end mill.
7. There are three plates of workpiece use as sample.
8. The workpiece that have been cut is shown as in the figure 10, 11 and 12.

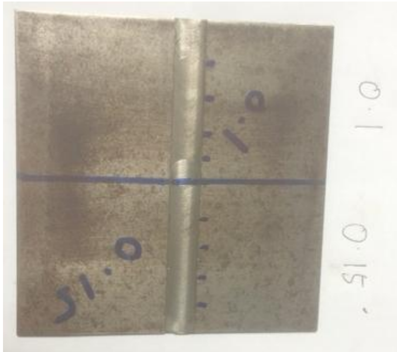

Fig. 10. Sample with 0.10 and 0.15 depth of cut

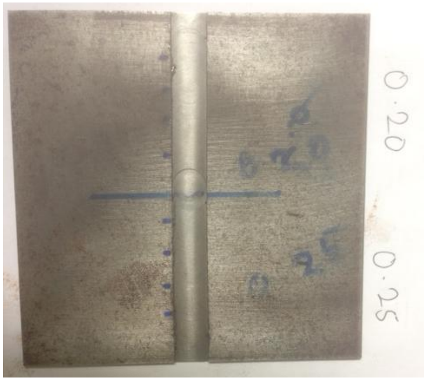

Fig. 12. Sample with 0.20 and 0.25 depth of cut

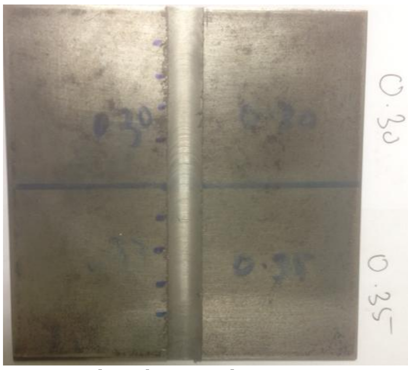

Fig. 12. Sample with 0.30 and 0.35 depth of cut

The workpieces then tested on its surface roughness using using Portable Surface Roughness Tester, SJ-401 as shown in figure 14.

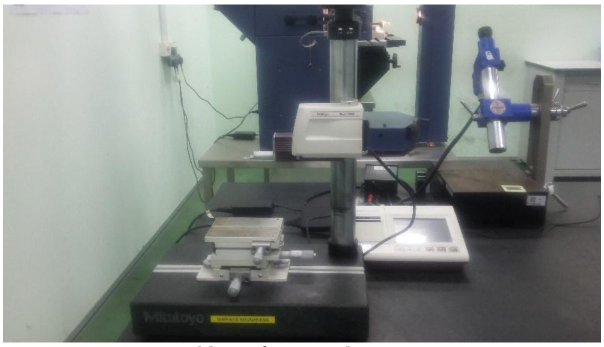

Fig. 14. Portable Surface Roughness Tester, SJ-401

III. RESULT AND DISCUSSION

Fig. 15. Finish product

After undergo all the machining process to fabricate, the vacuum clamping finally completed. There are some changes and limitation that need to be change to ensure the finishing of the product. Figure below show the dimension using CATIA V5 :

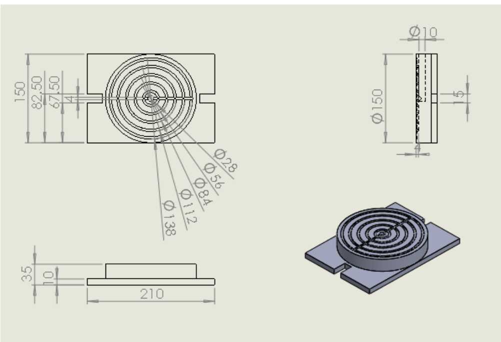

Fig. 16. Dimension design of vacuum clamping

a) Comparison on clamping method

There are two different method of clamping which is using conventional vise and vacuum clamping. For each method, four point of surface roughness reading is taken from workpiece. The obtained arithmetic mean value, Ra are as shown in the Figure 17.

Reading number	Arithmetic mean value, Ra	
	Conventional vise	Vacuum clamping
1	2.731	1.418
2	2.523	1.498
3	2.308	1.948
4	2.122	1.923
Average	**2.421**	**1.696**

Fig. 17. Surface roughness result for comparison method

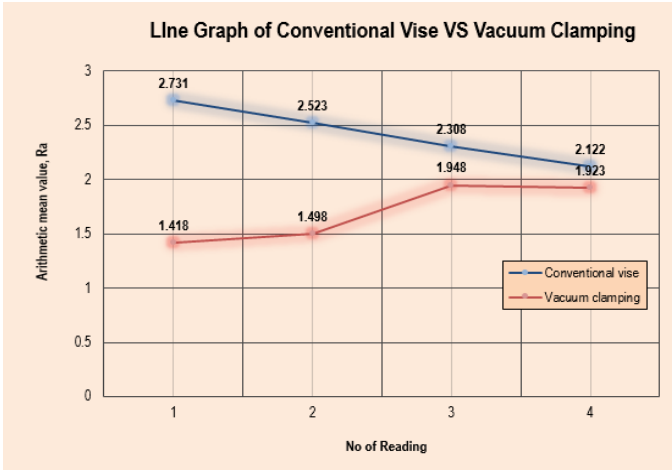

Fig. 18. Line graph of conventional vise and vacuum clamping

From the line graph above show the line comparison for 4 reading point with arithmetic mean value, Ra between conventional vise and vacuum clamping. The average RA value for conventional vise is 2.421 µm while the average RA value for vacuum clamping is 1.696 µm. These comparison between both average RA value show that the value for vacuum clamping is much lower than the RA value for conventional vise. These relationship prove that the dynamic of stability by using vacuum clamping is more stable and less vibration while doing machining at conventional milling machine.

b) Comparison on depth of cut

For the next comparison of this experiment is about the suitable depth of cut for machining using conventional milling machining. The selected depth of cut for this experiment is 0.10, 0.15, 0.20, 0.25, 0.30, 0.35 mm. The cutting parameter for spindle speed and feedrate is remain the same which is 600 RPM and 0.15 mm/min. Table below show the obtained arithmetic mean value, Ra for each reading.

Depth of cut (mm) / Reading	Arithmetic mean value, Ra, (µm)					
	0.10	0.15	0.20	0.25	0.30	0.35
1	1.418	2.398	0.873	1.912	1.776	1.728
2	1.498	1.142	1.044	1.429	2.508	1.804
3	1.948	1.146	1.858	1.191	1.667	2.053
4	2.122	1.932	1.783	1.652	1.785	1.511
Average	**1.745**	**1.654**	**1.389**	**1.546**	**1.934**	**1.774**

Fig. 20. Surface roughness result different depth of cut

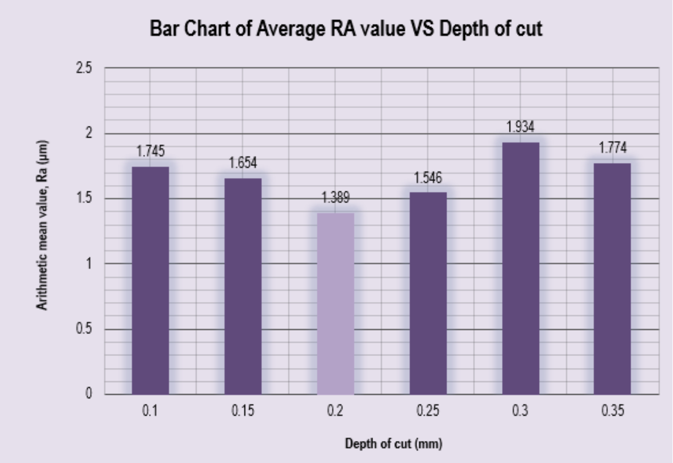

Fig. 21. Bar chart of comparison between depth of cut

From the bar graph above shows the comparison of average between arithmetic mean value, Ra and depth of cut. The highest RA value is 1.934 µm at 0.30mm depth of cut however the lowest RA value is 1.389 µm at 0.20mm depth of cut. This comparison between depth of cut proved that 0.20mm is the suitable depth of cut because of the surface roughness on this depth is smooth and the lowest. So for machining process on conventional milling machine using vacuum clamping jig, the maximum depth of cut for each level are recommended to set for 0.20mm.

The clamping force on a component is proportional to the surface area. The formula for vacuum clamping force are:

$$F\ (N) = P(bar) \times A\ (m^2)$$

where F is the force, P bar is the suction pressure and A is the surface area effected for the workpiece. So the clamping force that able to generate from the vacuum clamping is depend on the vacuum suction force and also surface area of the workpiece. The vacuum pump that used in this project is single-staged vacuum pump VE115N with 0.47 bar suction. The vacuum pump suction force is fixed so the clamping force generate is depend on the area of the workpiece.

Due to surface area for this project is circe, so the formula area for surface area that will be use is $A=\pi r^2$. The minimum surface area of the workpiece that the vacuum clamping can clamp is 0.049 m². Using the formula for minimum clamping force generate will be 0.023 kN. For the maximum surface area of the workpiece that vacuum clamping can clamp is 1.431 m². Therefore, fot the maximum clamping that generate will be 0.6725 kN.

Fig. 22. Vacuum pump VE115N

IV. CONCLUSIONS

This research was develop to optimized of the design and analyze for vacuum clamping on milling machine. The aim of this research was to modify and optimized the design of vacuum clamping. In this investigation of this research, the process that was carried out to fabricate vacuum jig by using conventional milling machine and also Computer Numerical Control (CNC) of advance milling machine. The material used for vacuum clamping jig is mild steel. A few changes need to done from the past planning such as to combine body part and base part. This changes was to ensure the stability of the base to support body part. After the vacuum jig have been developed, test was done to make sure its design and functionality meets the specification needed. Next, Some experiment on suface roughness workpiece using Portable Surface Roughness Tester, SJ-401 have been carried out in order to compare between conventional vise with vacuum clamping and to compare the suitable maximum depth of cut for machning.

In general, the result of the surface roughness indicate workpiece that clamp using vacuum clamping has the lowest Arithmetic mean value, Ra compare to workpiece that clamp by using conventional vise. This show and proved by by using vacuum clamping it produce less vibration and more dynamic stability while doing machining. The second comparison was to examine the suitable depth of cut and in result, the maximum depth of cut for each machining is 0.20mm.

Based on the findings on this research, this vacuum clamping is capable and functionable as one of the clamping method.

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