THE MODELING OF END MILL AND HIGH SPEED MILLING OF P20 STEEL AND MILLING EXPERIMENT STUDY

Hemmas Adam Prakasa; Wijianto

Abstract

P20 steel is widely applied in mold industry. When it comes to determine an optimal parameter and suitable milling tool among tool available, experiments cost too much and may waste a lots of time to compared with some simulation methodologies. In this project, the geometry modeling for 2-3 flutes end mills with diameters of 6mm, 8mm, and 10 mm are to be generated with Catia V5 and thereafter milling simulations with the designed tools using Third Wave Advant Edge software would combined with several parameters are to be conducted to get an optimal parameter group and the best end mill. Finally, some milling experiments will conduct to verify the simulations.

Keywords: P20 Steel, End Mill, Catia V5, Third Wave Advant Edge.

1. INTRODUCTION

In today's manufacturing industry, the progress of developments in technology and science taking very rapidly. Everything should requires sophisticated tools and better technological qualities. Besides that, with this rapid development it should be offset by knowlegde of mechanical technology. Production process are the one of subject in Mechanical Technology to understanding the able of practice into land of works, especially in production machinery.

Surviving in today's highly competitive world is not an easy task, contemporary technology updates and heavy investments are needed in state of the art machinery and modern cutting tool systems (Keshari A., 2010). Cause of the must to be compete with other industries with a better quality and reduce any of cost and time also. The method to improving quality and productivity that should be done is by experimentation and research of simulation. By experiments and researching, it hopes that all the worst and mistakes possibilities will be avoided (Singh, Y.K., 2006).

End mills are basically most used operation of performing production, not too far from end mill there is must be a milling. Milling is one of the most universal and one of the most complicated machining methods. However, the material removal rate in milling is high and the possibilities of obtaining a good finish at surface are excellent (Najiha, M.S. et al., 2013). As we knows, in manufactured products qualities are determined by their surface quality. The fact is high friction between tool and work piece effect to high temperatures, tool wear, and poor surface quality, so the works is not get best outcome (Chockalingan, P., 2012).

P20 is include to P group steel, commonly known to be use in mold or dies because of have low resistance to softening at elevated temperatures (Moore, D., 1997). Therefore, because of lower absorbing of temperature many studies have try to observe and defined the effectivity of machine tool to obtain the best result of reduce failure in every aspects. (Buana B.R., 2017). But the problem is current machining processed and cutting tool designs are languid and too conservative, leading to high cost and significant waste.

Approach has been develop to milling mechanics models that the geometric model should including the cutting edge of geometry along the flutes for analyzing the mechanics and dynamics of the milling process (Engin, S., 2016). In the P.J Agnew paper said "when doing a slotting operation, unless doing a light cut of about 2D or less, it is best to use a two- or three-fluted end mill. The reason for this is the venerability of chip packing that can lead to destruction of the end mill.

Finally, based on the description above, all of amazing interest of modelling the tools which suites the most of simulation for manufacturing process in order for finding optimization efficient and comparison of the best result.

To know the best tools is by doing by an experimentation of the end mill. Experiment based on computer software could be more advancing and precisely, the reason is because that can be revamp and simulated easily with. Since as the aim to get best result of effectiveness according to optimal depth of cut, cutting force and temperature outputs in the simulations here would be shown with Third Wave AdvantEdge software with some parameter include, then would be compared with real experiments to finding the best of group of end mill.

1.1 Problem Limitation

In order on narrowing the problem limitation, here are some the problems to have more precautions to avoid problem expenditure:

a. The process had the use depth of cut parameters suggested are 0.5 mm and 1 mm on material P20 steel.
b. All of end mills are use carbide tools Cemented Carbide YT15 end mill type.
c. The software used to model the part is Catia V5.
d. The Software used to checking the model FEM and making program experiment simulation is Third Wave Advant Edge and Tecplot.

1.2 Objective of Research

Based on the background and problem statement in this report, the objective of the research are:

a. Model the end mills with 2 and 3 flutes with diameter of each end mill 6 mm, 8 mm, and 10 mm.
b. Simulate with the Third Wave Advant Edge program FEM modeling and milling simulations with the model parameters.
c. To analyze optimal of depth of cut (DOC), cutting force, and temperature outputs to get the best group of milling parameters and end mills.

1.3 Benefit

The benefit of the research are expected after the experiments are:

a. This could be reduce some cost, times, and also improve production on the industrial world.
b. Reduced trial and error testing interactions to the next researcher.
c. To advise ourselves about Third Wave Advant Edge software, specifically on milling process simulation.
d. This could referenced to other advanced research or experiment in order to have better performance on manufacturing and cutting process.

2. Methodology

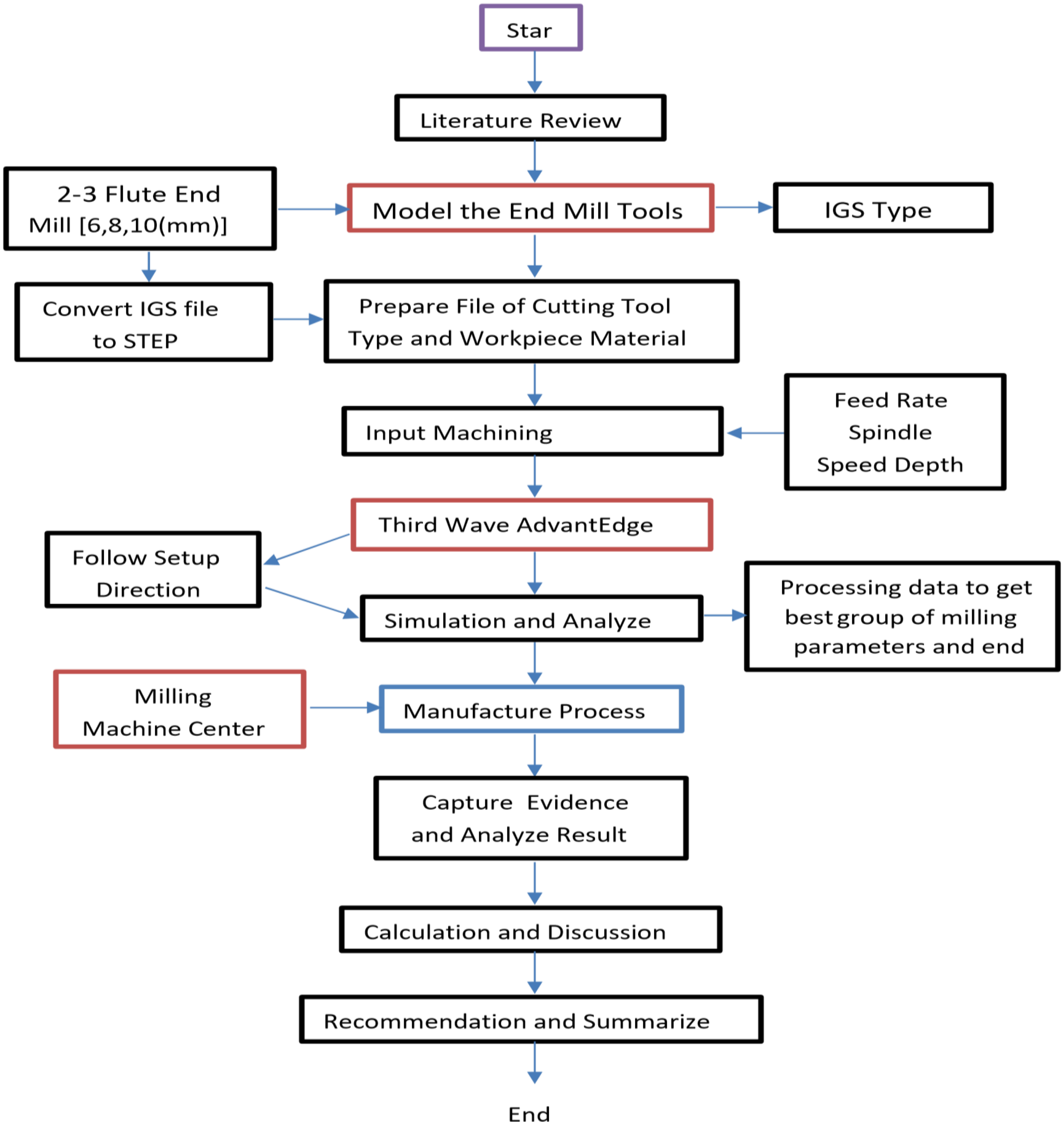


Fig. 1 Flow Card The location and implementation that do of the thesis as follows:

a. Model & FEM analyze: Room 405 of School of Mechanical Eng, WXIT.
b. Testing on milling : Machine Centre Laboratory, WXIT.
c. Time implementation : 10 April – 13 June 2018.

2.1 Preparation Procedure

a. CAD Setup Model

To begin the modeling of product, have been available the references of end mill model and accurate measurement tools to make easily and avoid guiltiness. In this experiment had be used Catia V5 to model end mill tools. There is follow the steps below:

1) Open Catia V5 software by selecting **Start ► Programs ► CATIA ►** Catia V5
2) Click **Start ► Mechanical Design ► Part Design**
3) Enter part name, and then **OK**

Referenced to journal by Kim J.H, Park J.W, Ko T.J (2008) and Catalog of K2 Plus End Mills. In order to select appropriate end mill geometry, 6 types of models must create using CAD Catia V5 software with each different parameter.

b. FEM use Third Wave Advant Edge

From e-book *Third Wave Advant Edge Workshop Manual Version 6*, there is display how to operating and to begin for preparation the analysis of the model using Third Wave Advant Edge Software. Project setup to begin the software as below:

1) Open Advant Edge FEM 2D by selecting **Start ► Programs ►** ThirdWaveSystemsAdvantEdge ► AdvantEdge
2) Click **Project ► New Enter for the project name**
3) Select **Milling** for project type
4) Make sure **3D Simulation** is checked and click **OK**
5) Select **Solid Tools** and **Side Cutting** and **OK** 7) Choose **Up Milling** and **OK Experiment Methodology**

3. FINDING AND DISSCUSION

3.1 Result of FEM Analyze

3.1.1 Temperature Distribution Representation

1) Process that used 6mm diameter end mill tools :

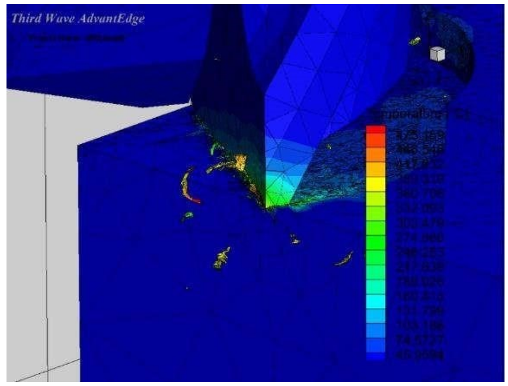


Fig. 2 Representation of 6mm Diameter 2 Flutes with DOC 0.5mm

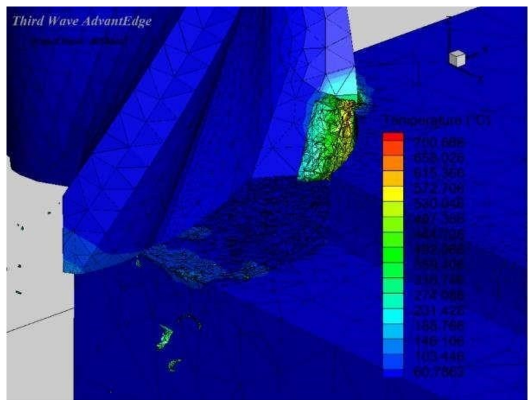


Fig. 3 Representation of 6mm Diameter 3 Flutes with DOC 1mm

2) Process that used 8mm diameter end mill tools:

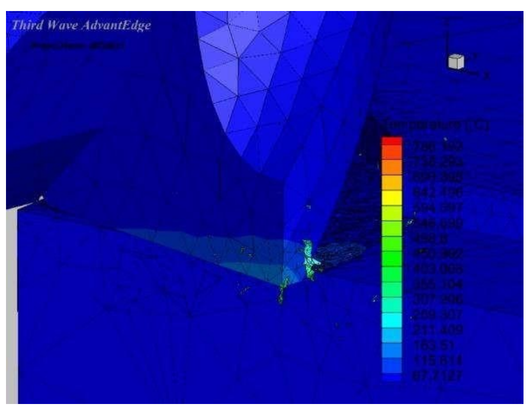


Fig. 4 Representation of 8mm Diameter 2 Flutes with DOC 1mm

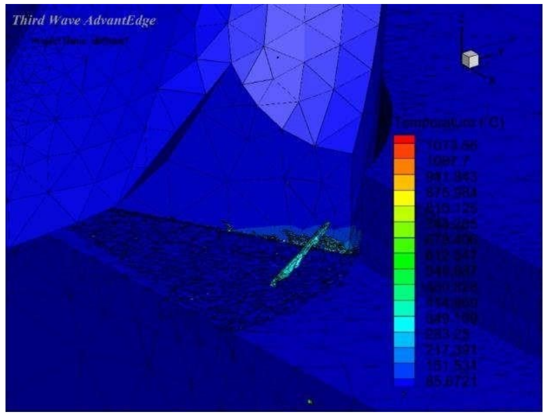


Fig. 5 Representation of 8mm Diameter 3 Flutes with DOC 1mm

3) Process that used 10mm diameter end mill tools:

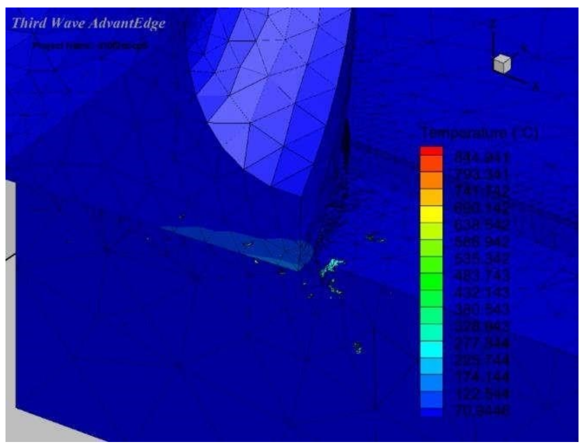


Fig. 6 Representation of 10mm Diameter 2 Flutes with DOC 0.5mm

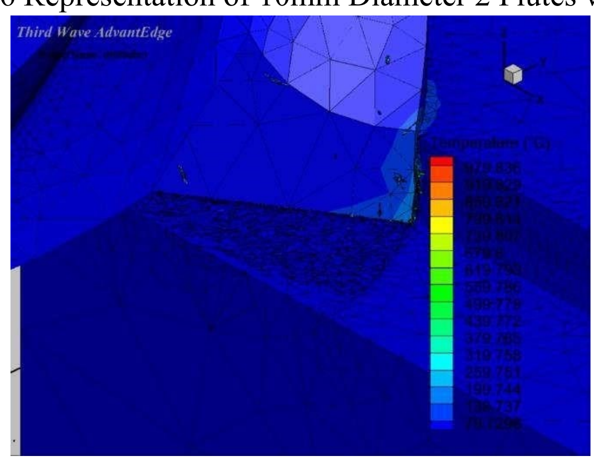
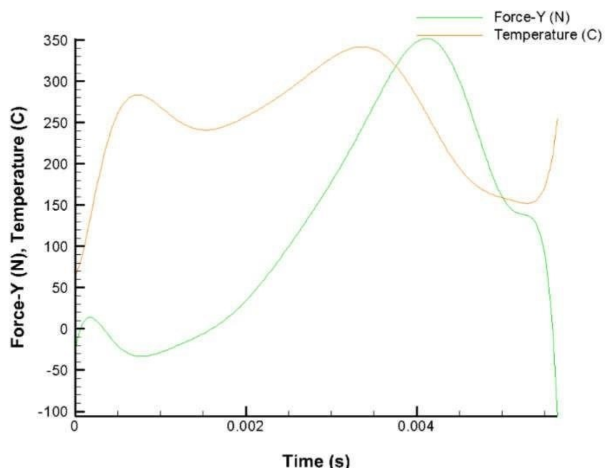


Fig. 7 Representation of 10mm Diameter 3 Flutes with DOC 1mm

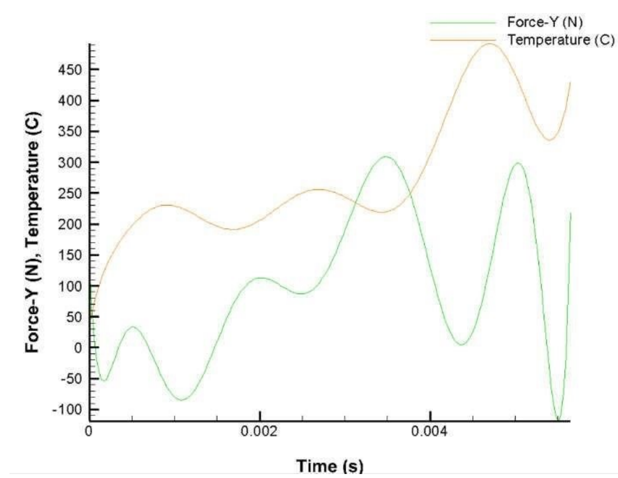
From the observation figures above were present of predicted temperature by color and showed numbers with SI temperature unit from the beginning of cutting process. Figure above that represent also will be considered on the accuracy from the analysis furthermore.

3.1.2 Force and Temperature Analyze Result

1) Process that used 6mm diameter end mill tools :

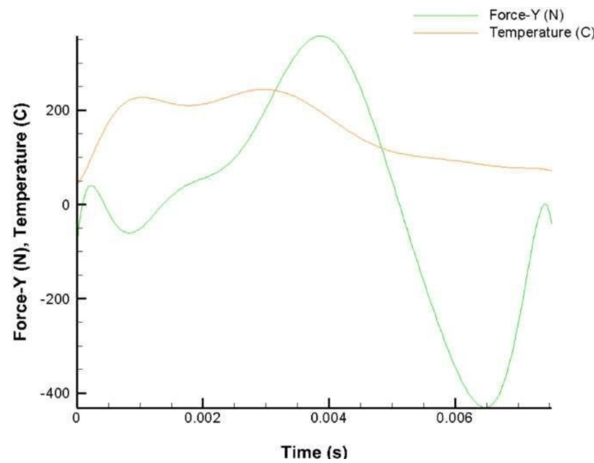


Graph 1 Graph for 6mm with 2 Flutes

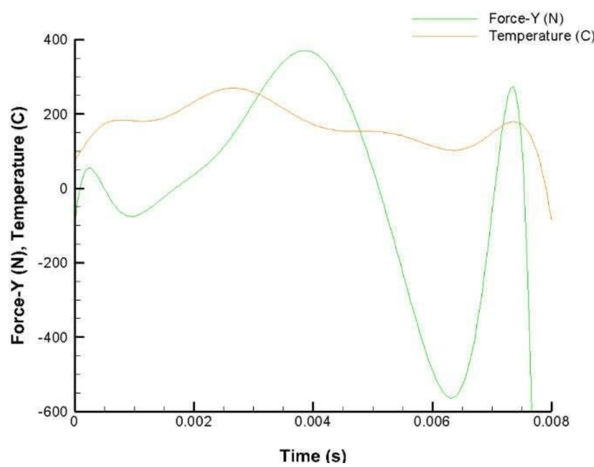


Graph 2 Graph for 6mm with 3 Flutes

2) Process that used 8mm diameter end mill tools :

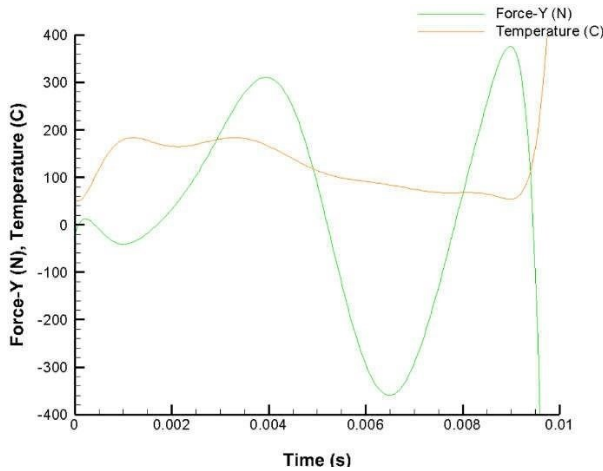


Graph 3 Graph for 8mm with 2 Flutes

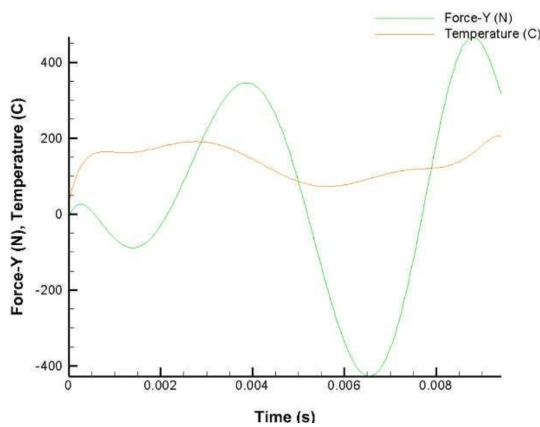


Graph 4 Graph for 8mm with 3 Flutes

3) Process that used 10mm diameter end mill tools :



Graph 5 Graph for 10mm with 2 Flutes



Graph 6 Graph for 10mm with 3 Flutes

The figures on section 4.1.1 above are shown the represent of temperature field distribution on end mill's cutting edge. From the graph are approved that the temperatures rises from friction outer diameter of cutting tools with the workpiece. The table 1 below will be shown the maximum temperature of tools.

In this result, 10mm diameter end mill with 2 flutes produce lowest temperature rather than any others. This will be the optimal tools for chosen, regarding the theory to the fact that increased feed rate led to a corresponding change in temperature, leading to shorter tool life. Because that if tools gaining lowest temperature that will be last any longer of tool life rather than the high temperature gained tools. Therefore, within the range can be concluded that there are no significant peak tool temperature and have no effect on tool wear.

Diameter (mm)	N Flute	n (rpm)	Feed (mm/min)	Depth of Cut (mm)	T (°C)	Optimal Tools
6	2	5307.856	530.7855626	0.5	341.7	
	3		796.1783439	1	491.9	
8	2	3980.892	398.089172	1	244	
	3		597.133758	1	269.1	
10	2	3184.713	318.4713376	0.5	183.6	✓
	3		477.7070064	1	191.1	

Table 1 The Result of Maximum Temperature

Diameter (mm)	N Flute	n (rpm)	Feed (mm/min)	Depth of Cut (mm)	Force (N)	Optimal Tools
6	2	5307.856	530.7855626	0.5	351.8	
	3		796.1783439	1	308.3	✓
8	2	3980. 892	398.089172	1	357.1	
	3		597.133758	1	370.4	
10	2	3184.713	318.4713376	0.5	376.6	
	3		477.7070064	1	466.2	

Table 2 The Result of Average Force

In table 2 that shown below, from the table it is obvious that geometries generated the different magnitudes of force. More faster rpm of the tools means less force that works on workpiece, because contradiction with friction force very fast. The different magnitudes of force also support the results by analysis of chip shape and temperature field distribution presented in the section 4.1.1. Based upon results from numerical analysis the model of 3 Flute End Mill with diameter 6 mm was the optimal than any tools because of better direction of chip in to the flute of solid end mill and less using force.

3.2 Experimental Result

Experiments are conducted to investigate the effects cutting parameters on the tool wear a Cemented Tungsten Carbide tool on the steel workpieces. In this experiment there are had to find Performance of Surface Roughness (Ra), µm in order to have better quality of machining in Finish Milling.

Diameter (mm)	N Flute	n (rpm)	Feed (mm/min)	ft (mm/tooth)	Surface Roughness (µm)
6	2	5307.856	530.7855626	0.05	▼7
	3		796.1783439		▼7
8	2	3980.892	398.089172		▼7
	3		597.133758		▼7
10	2	3184.713	318.4713376		Fail
	3		477.7070064		▼7

Table 3 The Result of Surface Roughness

Something gone wrong with 10mm diameter with 2 flutes, author try twice of processing with two different tools but same parameter also with 10mm diameter 2 flutes. But it accidentally still failed, the tools looks like fatique to doing cutting process. Accroding to *Kuttolamadom M.A.,* (2012), on his dissertation he said such unpredictable and catastrophic tool failures are not uncommon in industrial scenarios when machining titanium alloys; in fact, it was the aerospace industry that was one of the first to describe titanium alloys as “difficult-to-machine” materials. So, it was called catastrophic tool failure that it will takes author to agreed not to proceed for the process at the failed end mill.

Fig. 8 Experiment Surface Result

Note :

a is processing with 6mm diameter 2 flutes, success

b is processing with 8mm diameter 2 flutes, success

c is processing with 10mm diameter 2 flutes, failed

d is processing with 6mm diameter 3 flutes, success

e is processing with 8mm diameter 3 flutes, success

f is processing with 10mm diameter 3 flutes, success

C` is second processing with 10mm diameter 2 flutes, failed

At the figure 4.7 above, there are proof that process of C` is the second try author try to processing again but still fail. But for other process are normal and giving nicely smooth condition of surface roughness.

4. CONCLUSSION

4.1 Conclusion

From the result of analyzing project, the conclusions are:

a. The effect of all machining parameters Cutting speed, feed rate and depth of cut and their interactions are evaluated using Finite Element Method (FEM) and with the help of Thirdwave Advant Edge system software.
b. The tecplot has underestimate the outcome of the chip shape compared to the experiment result which in actual has no significant change. The observation has led to the first outcome

of nature drill's flute which is chip shape temperature, the temperature over the chips varies from 200° to 500° C, which is in the safe range of temperature.

c. Theory of end mill that have small number of flutes would have a big chip room to make more good chips for ejection are not accurate enough, in the fact of this experiment does not show significantly the big or much of chip that be wasted.
d. Based on the graph of force and temperature above that already explained. The optimal tool's temperature is shown on Table 4.1 the 10mm diameter with 2 flutes 183.6°C and optimal tool's force is shown on Table 4.2 the 8mm diameter with 2 flutes 308.3 Newton.
e. All of the tools can make nicely smooth of surface roughness with scale of surface roughness (Ra) ▼7 which means average of 0.8 μm. But not for the failed one (10mm diameter with 2 flutes).
f. Measurement of temperatures at nano-scale is practically not possible, therefore Thirdwave is used for predicting the value before the experiment in order to avoid failure in machining and reduce cost time and cost in machining.
g. No one possibly predict the failure of operation like in this experiment using 10mm diameter with 2 flutes, even had been frequently visually checked.
   Tools can always failed catastrophically without a warning.

4.2 Suggestion

From the result of analyzing project, the suggestions are:

a. To have best cost time and cost machine, it is a must to use the least efficient way in choosing the proper cutting tool, machining parameter, and measurement or calculation.
b. To observe and set up the initial data, should have great focus in all chances to have more experience. The ability on variety of machines are different. Therefore, the environment factor has big effect on production parameters.
c. The variety of material properties has big effect on demand and needs. Hence the treatment process are necessary to have better production parameters, as example cooling system or liquid. Therefore, a simulation could be the suggestion in the next of experiments.
d. At last, the author hope this research report could be the best consideration in other experiments or as reference for next production.

BIBLIOGRAPHY

AdvantEdge. 2002-2003. *Ultimate AdvantEdge V.1.5 User Guide Manual*. Third Wave Systems. Copyright Third Wave Systems

Agnew P.J. *What to Consider When Evaluating Solid Carbide End Mill Machining*. Moldmaking Technology magazine. Mitshubishi Materials USA Corp. 2003

Anderson, M. 2010. *Integrating AdvantEdge with Knowledge and Product Development Process on Microsoft Platform.* Process CIO R&D Sandvik Tooling at International Users Conference Third wave AdvantEdge

Anonymous. 2009, 2010. *Catalog Products of K-2 Plus End Mill (End Mill Guides)*. YG-1. Co., Ltd. Bupyeong-Gu, Incheon, Korea

Avallone E.A., Baumeister T., Sadegh A.M. 2007. Marks' Standard Handbook For *Mechanical Engineers*. RR Donneley, McGraw-Hil Companies, Inc. USA. ISBN- 13: 978-0-07-142867-5 ISBN-10: 0-07-142867-4

Bathe. K.J. 2014. *Finite Element Procedures – Second Edition*. Massachusetts Institute of Technology, USA. K.J. Bathe, Watertown, MA. ISBN: 978-0-9790049-7

Keshari A. 2010, 2011. *Advanced Techniques for Monitoring, Simulation and Optimization of Machining Processes*. PhD Thesis of Production Technology and Systems. Università Degli Studi Di Napoli Federico Ii

Kim J.H., Park J.W., Ko T.J. 2007. *End Mill Design and Machining Via Cutting Simulation*. School of Mechanical Engineering, Yeungnam University, Republic of Korea. ComputerAided Design, Vol.40, 324–333

Ku H., Chia W.C. 2006. *Design of Multi-Purpose Carbide End Mill*. Journal of the Institution of Engineers, Malaysia. Faculty of Engineering and Surveying, University of Southern Queensland, Australia. Vol. 67, No. 2, June 2006

Kumar V., Eakambaram A., Arivazhagan A. 2014. *FEM Analysis to Optimally Design End Mill cutters for Milling of Ti-6Al-4V*. 12th Global Congress on Manufacturing and Management, Gcmm 2014. Procedia Engineering 97 (2014) 1237 – 1246

Kuttolamadom M. A. 2012. *Prediction of the Wear & Evolution of Cuting Tools in a Carbide / Ti6Al-4V Machining Tribosystem by Volumetric Tool Wear Characterization & Modeling*. Dissertations of Materials Science & Engineering Clemson University.

McGraw-Hill. 1983. *Tool and Manufacturing Engineers Handbook - Fourth Edition*. Vol 1 Machining. McGraw-Hill Book Co. Society of Manufacturing Engineers

Segebade E., Gerstenmeyer M., Zanger F., Schulze V. 2017. *Cutting Simulations Using a Commercially Available 2D/3D FEM Software for Forming*. 16th CIRP Conference on Modelling of Machining Operations. Elsevier B.V. Procedia CIRP 58 (2017) 73 – 78

Singh, Y.K. 2006. *Fundamental of Research Methodology and Statistics*. 4835/24, Ansari Road, Daryaganj, New Delhi – 110002. New Age International (P) Limited. ISBN : 978-81-2242418-8

Varmma M. a/l Suparmaniam & Yusoff R.A. 2010. *Investigation of Surface Roughness and Tool Wear Length with Varying Combination of Depth of Cut and Feed Rate of Aluminium Alloy and P20 Steel Machining.* Faculty of Manufacturing Engineering, Universiti Malaysia Pahang, 26600 Pekan, Malaysia

Walker, J.R. 2000. *Machining Fundamentals: from Basic to Advanced Techniques.* The Goodheart-Willcox Company, Inc. Tinley Park, Illinois. ISBN: 1-56637-662-9