FEASIBILITY STUDY OF ADOPTION PULSATION COOLANT ON CUTTING FORCE DURING END MILLING ALUMINIUM 6061

Submitted in accordance with the requirement of Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Hons.)

by

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DECLARATION

I hereby, declared this report entitled " Feasibility Study of Adoption Pulsation Coolant on Cutting Force during End Milling Aluminium 6061" is the results of my own research except as cited in reference.

Signature : ....

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as partial fulfilment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The member of the supervisory committee are as follow:

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(DR. MOHD SHAHIR BIN KASIM)

ABSTRAK

Aluminium aloi 6061 adalah digunakan secara meluas dalam industri aeroangkasa, automotif, dan aplikasi kejuruteraan kerana ciri khasnya mempunyai kekuatan spesifik, ketahanan tinggi terhadap kakisan dan ringan. Bahan ini dikenali sebagai kebolehmesinan yang baik. Walau bagaimanapun, masalah yang wujud adalah pinggir terbina (BUE) semasa proses pemotongan. Kajian ini memberi tumpuan kepada daya pemotongan apabila pemesinan aloi aluminium 6061 di bawah pelbagai kaedah penyejukan. Strategi baru penyejukan denyutan diperkenalkan dengan mengambil kelebihan daripada pembentukan gelombang kejutan pada aliran air yang dapat mengurangkan pembentukan BUE. Kajian ini adalah bertujuan untuk menyiasat kemungkinan terdapat kelemahan pada ujikaji daya pemotongan. Metodologi permukaan tindak balas (RSM) menggunakan reka bentuk data sejarah digunakan untuk menjalankan eksperimen dan menganalisis hubungan antara pembolehubah dan respons kawalan. Sebanyak 29 eksperimen telah dijalankan dengan dua faktor berangka dan satu kategori pada tiga tahap. Parameter pengisaran yang dijalankan adalah kelajuan pemotongan (150 - 200 m / min), kadar suapan (0.15 - 0.35 mm/gigi), dan sistem penyejuk (denyutan, banjir, kering). Mata alat berbola CVD yang dilapisi tungsten karbida (WC-10% Co) telah diuji sepanjang kajian ini. Daya memotong semasa operasi pengisaran diukur dan direkodkan oleh dinamometer Kistler. ANOVA digunakan untuk mengenal pasti kesan ketara faktor-faktor pada tindak balas. Berdasarkan analisis, kadar suapan didapati sebagai faktor yang paling ketara bagi daya yang dihasilkan. Walau bagaimanapun, kelajuan pemotongan dan sistem penyejuk didapati tidak ketara. Model matematik telah dibangunkan bagi model tindak balas daya yang dihasilkan dengan ralat purata 14.8 N (8.87%). Ralat ini dianggap sebagai korelasi yang kuat dengan nilai R^2 0.71. Daya yang optimum (paling rendah) dicapai apabila Vc = 200 m / min, fz = 0.15 mm / gigi, untuk daya yang dihasilkan dari 114N, 107N dan 119N semasa denyutan, kering dan banjir. Dari penyelidikan ini dapat disimpulkan sebagai strategi denyutan tidak akan mempengaruhi kekuatan pemotongan.

ABSTRACT

Aluminium alloy 6061 is a widely used in aerospace industry, automobile, and engineering applications due to its special characteristic of high specific strength, high resistance to corrosion and light in weight. This material is well known as good machinability. However, the gummy feature creates a problematic issue of build up edge (BUE) formation during the cutting process. This research is focused on the cutting force when machining Aluminum alloy 6061 under different coolant condition. A new strategy of pulsation coolant was introduced by taking advantage of shock wave formation of water stream which can minimize BUE formation. The study is to investigate the possibility of drawback on cutting force. The response surface methodology (RSM) using the Historical data design was used to conduct the experiment and analyse the relationship between control variables and responses. A total of 29 experiments were conducted with two numerical and one categorical factor at three levels each. The investigated milling parameters were cutting speed (150 - 200 m/min), feed rate (0.15 - 0.35 mm/tooth), and coolant system (pulsation, flooded, dry). The CVD coated of TiAlN ball nose tungsten carbide (WC-10%Co) cutting tools were tested throughout this study. Cutting forces during end milling operation were measured and recorded by dynamometer Kistler. ANOVA was used to identify the significant effect of the factors on the response. Based on the analysis, the feed rate was found to be the most significant factor for the resultant force. However, cutting speed and coolant system was found to be not significant. The mathematical models were developed for the response of resultant force with an average error of 14.8 N (8.87%). The error is considered a strong correlation with the R^2 value of 0.71. The optimum (lowest) responses were achieved when the Vc = 200 m/min, fz = 0.15 mm/tooth, for the resultant force of 114N, 107N and 119N during pulsation, dry and flooded respectively. From the research, it can be concluded as the pulsation strategy will not affect on cutting force.

DEDICATION

To my beloved family,

Wong Veng Mun

Yap Lai Peng

Wong Wai Kit

Wong Pui Yeng

My respected supervisor,

Dr. Mohd Shahir bin Kasim

for giving me moral support, encouragement and also understanding

Thank you so much and love all of you forever

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To my family, who raised and taught me that all the knowledge of life that we cannot learn from school. Learned of the mistake is one of the best ways to gain knowledge. All the mistakes that have been done can make us stronger and turn us to a wise person. It is not easy to learn something that new to us, learning can be hard sometimes but with hard and strong perseverance, nothing can stop us to learn and gain experience.

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LIST OF ABBREVIATIONS

AISI	-	American Iron and Steel Institute
ANOVA	-	Analysis of Variance
BUE	-	Build up edge
CNC	-	Computer Numerical Control
CVD	-	Chemical Vapour Deposition
DoE	-	Design of Experiment
HB	-	Brinell hardness
MMC	-	Metal Matrix Composites
MQL	-	Minimal Quantity of Lubrication
MR	-	Machinability rating
PVD	-	Physical Vapour Deposition
RSM	-	Response Surface Methodology
SPC	-	Statistical process control

LIST OF SYMBOLS

Vc	-	cutting speed
fz	-	feed rate
a_p	-	depth of cut
a_e	-	width of cut
Ra	-	surface roughness
Fr	-	resultant force
wt %	-	weight percentage
°C	-	degree celcius
V	-	volt
Hz	-	hertz
°	-	degree

CHAPTER 1

INTRODUCTION

This chapter provides the background of study, problem statement, objectives, scope, importance of study and the report outline. Furthermore, there is information related to the process of end milling of aluminium alloy 6061.

1.1 Background of Study

Aluminium alloy 6061 is a ductile material. It contains the combination of both magnesium and silicon which allows enhancing the strength of the material. It is one of the main materials that used in various daily life and engineering applications, such as automobile, aerospace, transportation, shipping and military industries due to its high specific strength, good conductivity, lightweight and low in price (Demer and Gundus, 2009; Hovsepian et al., 2006). The low weight of aluminium alloy minimizes the environmental impact result in energy consumption (Davies et al., 2002).

The end milling process was universally implemented in particular fields such as biomedical, electronics and aerospace industries. As mentioned by Omid and Joshua (2015), 3

Axis of CNC milling machines broadly used in metal-based industries to manufacture parts from different types of materials with a set of cutting tools. During the milling operation, the selection of a set of cutting tools are based on the geometry and part function. Cutting tools will simply rupture as if the machining operation did not complete in a proper manner which occasioned waste of time and money. Moreover, it was supported by Kang et al. (2007) that detection of tool wear or rupture is difficult to be determined by operator who operates the machine. Consequently, in end milling, cutting force acts an essential character in the resolve of the features of cutting processes such as surface roughness and tool wear.

The performance of the mechanical process can be predicted on the surface roughness as an abnormality on the surface may cause nucleation sites for fracture. Even though surface roughness is normally unappealing, it is hard and costly to manage while manufacturing. The lower the surface roughness caused the higher the manufacturing costs. According to M.S.Sukumar et al. (2014), the manufacturing cost of the process and its performance are usually the consequence in a trade-off manner.

The mission of metal-based industries is increasing productivity by controlling the quality of the products. Greater the surface finish greater will be the quality. Regarding Natha.D et al. (2014), surface roughness measurement can be used to assess the surface quality of the part. Cutting speed, feed rate and depth of cut will directly affect surface finish. Because of an infinite number of parameters that will actually affect the quality of the part, the user normally will choose the "appropriate" parameter to get a path and machine the part (Omid and Joshua, 2015). However, Dhole et al. (2012) declare that it is not possible to produce a product with flawless surface finish in the manufacturing process with present technology.

In the analysis of surface finish, tool wear and cutting tool rupture in the end milling process, the basic feature that can present precious insight is cutting force. The relationship between cutting force and machining factor can be analyzed to determine the process parameters in the milling operation. Eventually, the analysis capable to enhance efficiency and quality of production. As supported by Yang et al. (2013), it is a consequential challenge to predict cutting force since cutting force is influenced by the inherent unpredictable at the end milling process.

In the year 1980, coated carbide tools have been introduced and it attracted to various industries. The development of coated tools has improved the durability of cutting tool (Graham, 2008). Therefore, the advantages of the coated tool have influenced demand of using coated carbide tool is higher compared to uncoated carbide tool in any machining operations (Trend and Wright, 2000). In the past 20 years, the surface engineers have cast materials and fabricated as tool material which able enhances the performance of machining in cutting soft materials (Hovsepian et al., 2005). The fabricated tool with carbon-based coatings able to minimize the formation of BUE and thus enhance the machining performance (Fukui et al., 2004).

On the other hand, cutting speed, feed rate and depth of cut of the milling operation will affect cutting force. Therefore, it is very important to choose an appropriate value for the parameter during the milling operation. According to Miroslav and Ivan (2012), it can be effective and economical to machine aluminium alloy 6061 as if the cutting parameter, geometry of a tool and cutting material have chosen correctly. Thus, this research was established to propose a new combination of machining parameters in order to minimize cutting force during end milling of aluminium alloy 6061.

1.2 Problem Statement

Aluminium alloy 6061 is the combination of both magnesium and silicon which allows enhancing the strength of the material. Although aluminium alloy 6061 has the characteristics of high strength, it is vulnerable to break. The ductility this alloys affected difficult chip control while it required cutting tools with high wear rate. In addition, it is a soft grade of material which caused the formation of edge build-up that affected the low quality of surface finish of work material. Hence, the increasing of cutting force which associated with rake angles and cutting speeds are more undesirable (Trent and Wright, 2000). There is a problem arise while machining aluminium alloys as the coefficient of thermal expansion will increase and affected the dimensional of the workpiece (Semih 2018).

Since the mechanical properties of the cutting tool is not able to change as aluminium alloys have the features of low melting point. Therefore, cutting temperature while machining aluminium alloys are not the main problem (Kishawy et al., 2005). In addition, the tool life is regulated by cutting temperature, thus no high wear rates will occur (Kelly and Cotterell, 2002; Nouari et al., 2003). However, when the cutting temperature is increased to certain level, it may influence tool wear, tolerance errors and stick of the workpiece to tool edges (Kelly and Cotterell, 2002).

The sticking property of aluminium causes the formation of built-up edge (BUE) during machining. The BUE change the cutting geometry especially on tool-chip interface of the rake face. Decreasing rake angle cause increase in cutting force and cutting temperature. Unsteady chip flow causes vibration behaviour of the machine-tool work system which affecting tool life. It was supported by Mustapha and Zhong (2013) indicates, the vibration of cutting tools during milling cutting operations causes unsatisfied results. The examples of unsatisfied results are degradation of the quality of expected surface roughness; compromise tolerances; modification of chip size caused dynamic instability, and decreasing of productivity and tool life. Moreover, the determination of district of stability in machining operation relies on many elements between cutting condition and cutting tool system of the machine (Altintas et al., 2001).

The mission of metal-based industries is increasing productivity by controlling the quality of the products. The higher the surface finish of the work material produced can enhance the quality of the product. According to Ganesh and Radhakrishnan (2014), the higher the quality of the product is produced will bring the advantages of longer product life, shorter cycle time, minimum warranty cost and minimum reworks and scraps.

Observing the problematic issue during machining aluminium material, it was motivated to investigate which lubricant strategy that effectively removes BUE hence reduce cutting force, besides the other two prominent parameters; cutting speed and feed rate.

1.3 Objectives

During the cutting operation, the effectiveness of the cutting tool will affect by the changes in the shape of the cutting tool. To understand this phenomenon, a research activity on the workpiece and cutting parameter are required:

i. To investigate the effect of machining parameters; lubrication strategy, cutting speed and feed rate on the cutting force during end milling of aluminium alloy 6061.

ii. To develop a prediction model to optimize cutting force parameter by using Response Surface Methodology.

iii. To validate the prediction model of the cutting force exerted during the machining operation.

1.4 Scope

The work material to be used in this research is aluminium alloy 6061. The strategy of machining is straight cutting by using 3 Axis CNC milling machine. The cutting force is measured in every single path the cutting tool removes material from the workpiece with different machining parameter. In this study, there will be three machining parameters that being considered which are, cutting speed (Vc), feed rate (fz) and cooling/lubrication types (dry, flooded and intermittent). Meanwhile, depth of cut (ap) and width of cut (ae) are fixed variable in this research. The CVD coatings of insert will be used during the milling operation. Response surface methodology analysis will be used as a statistical tool of the design of