EVALUATION OF COOLANT CONCENTRATION ON THE MACHINIABILITY OF CARBON STEEL DURING END MILLING

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This thesis is dedicated to my parents, my brothers and sisters.

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ABSTRACT

In machining, cutting tools are used to remove unwanted material from the surface of a workpiece. This operation will transform the mechanical energy into thermal energy, generating heat at a small location. The generated heat transferred into the workpiece, the removed material, the environment and also the tool. This directly affects the tool life, the cutting performance and the quality of the products especially the surface finish.

The cutting fluid is used to act as the coolant to reduce the generated heat and as lubricant to reduce the friction during the cutting process. This study explores the influence of coolant concentration on tool life, surface roughness of the product and the cutting force during end milling of mild steel S50C. High Speed Steel end mill of 4 flutes was used at various cutting conditions in the investigation. A design of experiment was planned, whereby the coolant concentration with cutting speed and feed being the factors and tool life, surface roughness and cutting forces were treated as responses. Mathematical models on the above responses were established based on the experimental results.

The results of this experiment show that coolant concentration significantly affects the tool life at certain milling condition especially lower cutting speed and lower feed. At higher feed or cutting speed conditions, the coolant concentration or the coolant itself does not have any impact on the tool life. Coolant concentration does not directly affects the surface roughness but its’ reaction with feed does influence the results. The influence of coolant concentration on cutting force is not significant in this experimentation.

ABSTRAK

Dalam pemesinan, mata alat digunakan untuk memisahkan bahan yang tidak diperlukan daripada permukaan bahan kerja. Dalam operasi ini tenaga mekanikal akan diubahbentuk ke tenaga haba, yang mana dihasilkan pada sesuatu tempat yang tertumpu. Haba yang dihasilkan akan diserap oleh bahan kerja, bahan yang dipisahkan, persekitaran dan mata alat. Ini seterusnya akan memberikan kesan terhadap jangahayat mata alat, prestasi pemotongan dan kualiti produk yang dihasilkan terutama kekasaran permukaan yang dihasilkan.

Bendalir pemotong digunakan sebagai bahan pendingin yang mengurangkan haba yang dihasilkan dan juga sebagai bahan pelincir untuk mengurangkan geseran semasa proses pemotongan. Kajian ini cuba menilai pengaruh kepekatan bendalir pemotong terhadap jangkahayat mata alat, kekasaran permukaan produk dan seterusnya tenaga pemotongan semasa proses pemotongan bahan kerja mild steel S50C. Mata alat “High Speed Steel” dengan 4 “flute” digunakan dalam beberapa keadaan pemotongan dalam experimen ini. Satu rekabentuk eksperimen dirancang dimana kepekatan bendalir pemotong, kelajuan pemotongan dan suapan dijadikan faktor-faktor eksperimen, jangkahayat mata alat, kekasaran permukaan produk dan tenaga pemotongan dijadikan sebagai hasil eksperimen. Model-model matematik terhadap hasil experimen dibentuk dari keputusan yang diperolehi.

Keputusan experimen menunjukkan bahawa kepekatan bendalir pemotong memberi kesan yang ketara terhadap jangkahayat mata alat pada keadaan pemotongan tertentu terutamanya apabila keadaan kelajuan pemotongan dan suapan yang rendah. Apabila kelajuan pemotongan atau suapan yang tinggi, kepekatan bendalir pemotong tidak memberi kesan terhadap jangkahayat mata alat. Kepekatan bendalir pemotong juga mempunyai reaksi dengan suapan dan memberi kesan terhadap kekasan permukaan produk. Kepekatan bendalir pemotong tidak kesan terhadad tenaga pemotongan.

TABLE OF CONTENT

LIST OF SYMBOLS

MQL - Minimum Quantity Lubricant

f - feed (mm/tooth)

CS - Cutting speed (m/min)

CC - Coolant concentration

DOE - Design of Experiment

V_B - Tool wear

CH - Chipping

μCH - Micro chipping

C - Carbon

HSS - High speed steel

TiN - Coated with Titanium Nitrate

TiCN - Titanium Carbonitride

TiAlN - Titanium Aluminium Nitrite

TiAlCrN - Titanium Aluminium Cromium Nitrite

PVD - Physical Vapour Deposition

PCB – Printed Circuit Board

PCD - Polycrystalline diamond

ASTM - American Society for Testing and Materials

AISI -The American Iron and Steel Institute

JIS – Japanese Industrial Standards

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Importance of study

A recent survey on world output of machine tools by 28 major producing countries shows that these countries produced $51.8 billion US dollars worth of machine tools in 2005 [1]. A machine tool here is defined as a power-driven machine, powered by an external source of energy. The machine tool is designed specifically for metalworking either for cutting, forming, physico-chemical processing, or a combination of these techniques [1]. This shows how vast is metalworking industries, furthermore this statistics covers only the industries that are directly involved in producing machine tools. There are numerous other industries that are related directly and indirectly which are worth huge magnitude in dollar values and have significant affect towards the global economics.

Today, almost all industries one way or another related and dependant on metalworking. The metalworking varies from extraction of precious metals to make jewelry, building more efficient electronics, and for industrial and technological applications from construction to shipping containers to rail, and air transport. Without metalworking, goods and services would cease to move around the globe.

Machining is a major part of metalworking that plays important role in metal cutting and forming. In machining, the machine tools especially cutting tools play an important role. This is because of their roles in producing shapes and forms. Their importance is not only in technical aspects but financial too due to their cost. Their performance and tool life is very much an important criteria to every cost conscious management.

This study involved the analyzing of the important factors that contribute to the efficiency of cutting tool during end milling of carbon steel using High Speed Steel (HSS) tool. Improving the efficiency of the machining performance and the quality of product produced was explored.

1.2 Background of study

In machining, cutting tools are used to remove material from the surface of a less resistant body of a work-piece. Though the geometry of cutting tools varies from each type of metal removing process, the basic fundamentals are the same. Through relative movement and application of force the removal process takes place. This operation will transform the mechanical energy into thermal energy, generating heat at small location which will affect the tool life, the cutting performance and the quality of the product. Cooling of this area is very critical in machining to have longer tool life and improve product quality.

Here, end milling is chosen as the area of study to determine the impact of process parameters and cutting fluid concentration on the performance of a cutting tool as well as the surface roughness and the cutting force. The tool life performance of the cutting tool is determined through the wear of cutting edge. The wear is a product of the material properties of tool such as wear resistance and the adverse impact of the cutting operation itself. During cutting process, the tool is subjected to load, friction and high temperature. Adhesion, abrasion, diffusion, oxidation and fatigue during the cutting operation will cause tool to wear.

The cutting fluid is used to act as the coolant to reduce the generated heat between the workpiece and tool and also as the lubrication agent to reduce the friction at the tool-chip interface. The correct selection of cutting fluid and the optimum concentration have a great impact on the overall performance of the cutting tool. Cutting fluid concentration has impact on causing too much foaming, rusting of workpiece and poor tool life.

N. R. Dhar et. al. [2], investigated the effect of Minimum Quantity Lubricant (MQL) on temperature, tool wear and product quality in turning AISI 9310 steel. They concluded that MQL was better than dry cutting as it reduced cutting temperature and produced better surface finish and dimension accuracy.

In another study also by N.R. Dhar et. al., [3] on the effects of cryogenic cooling on temperature, tool wear, surface roughness and dimensional deviation in turning AISI 8740 steel by coated carbides, indicated that the cryogenic cooling by liquid nitrogen jets provided lesser tool wear, better surface finish and higher dimensional accuracy as compared to dry and wet or the conventional flood machining.

The above studies [2,3] are the examples of today’s trend moving away from conventional flood or wet machining. One of the arguments put forward on conventional wet machining is that it fails to penetrate into the chip-tool interface, thus cannot remove the heat effectively. The reason behind is that the addition of extreme pressure additives in cutting fluids does not ensure penetration on the coolant. It is also claimed that cutting fluid is costly and causing serious threat to the environment due to its complex chemical compositions.

There may some truth in all these claims but in wet machining, an area is seriously overlooked in these studies is the correct type and optimum concentration of cutting fluid. This area has a lot of potential as the cutting fluid industries grow rapidly and producing better environmentally friendly and better performance cutting fluids.

This study is not venturing on which is the better method cooling for machining but rather concentrate on better machining performance could be achieved if optimum concentration is used.

1.3 Objectives

This study involves the establishment of design of experiment (DOE) plan with 3 factor 2 level factorial design, whereby the input variables are the feed (f), cutting speed (CS) and the coolant concentration (CC) during end milling process of medium carbon steel using High Speed Steel (HSS) tool. The output variables are tool wear, the surface roughness of the workpiece and the cutting force. The main objectives of this study are:

i to establish the relationship between coolant concentration with the tool wear, surface roughness and cutting force during end milling carbon steel.

ii to determine the optimum condition of coolant concentration and machining parameters for tool life and surface finish.

iii to establish mathematical models for cutting force, surface roughness and tool life when end milling carbon steel

1.4 Expected results

Higher feed and cutting speed should increase the tool wear. This is expected as more mechanical energy is transformed into thermal energy thus causing adverse effect on the cutting tools. Reducing the generated heat during cutting can extend the tool life. Increase in coolant concentration may improve the performance of the tool and should plateau at certain concentration as additional increase in concentration may not improve the tool performance. This is probably due to coolants are designed to perform best at specific concentration. Overly diluted coolant may reduce tool life as its function as lubricant will not be effective, and too much concentrated coolant results in using more coolant than necessary which will be a waste to the process.