Faculty of Manufacturing Engineering

FINITE ELEMENT SIMULATION OF ALUMINIUM SILICON CARBIDE METAL MATRIX COMPOSITE MACHINING

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Master of Manufacturing Engineering (Quality System Engineering)

2020

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A thesis submitted in fulfilment of the requirements for the degree of Master of Manufacturing Engineering (Quality System Engineering)

Faculty of Manufacturing Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2020

DECLARATION

I declare that this thesis entitled "Finite Element Simulation of Machining Aluminium Silicon Carbide" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : ....

Name : Muhammad Akmal bin Ahmad Adli

Date : ……………………………………………

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Master of Manufacturing Engineering (Quality System Engineering).

Signature : …………………………………………………..

Supervisor Name : Assoc. Prof. Dr. Raja Izamshah bin Raja Abdullah

Date : …………………………………………………..

APPROVAL

I hereby declare that I have read this dissertation/report and in my opinion this dissertation/report is sufficient in terms of scope and quality as a partial fulfillment of Master of Manufacturing Engineering (Quality System Engineering).

Signature : …………………………………………………..

Supervisor Name : Assoc. Prof. Dr. Raja Izamshah bin Raja Abdullah

Date : …………………………………………………..

DEDICATION

In the name of Allah, The Most Beneficient, The most Merciful

Every challenging work needs self-efforts as well as guidance of elders especially those who were very close to our heart.

My humble effort I dedicate to my caring & loving
Father and Mother,
Ahmad Adli bin Abdullah and Alawiyatun bt Ab Muttalib

Whose affection, love, encouragement and prays of day and night make me able to have such success and honour.

Along with helpful and supportive Supervisor

Assoc. Prof. Dr. Raja Izamshah bin Raja Abdullah

ABSTRAK

Aluminium silikon karbida adalah salah satu daripada komposit matriks logam. Penggerudian dan penggunaan semula komposit Al / SiC sangat mencabar. Strategi pengoptimuman proses keseluruhan sangat diperlukan untuk pengeluaran sebenar. Ini mesti berdasarkan pemahaman mendalam mengenai mekanisme pemotongan. Geometri gerudi yang berlainan akan memberi kesan penjanaan haba dan daya tujah paksi. ketebalan mata gerudi, titik sudut dan helix sudut adalah factor geometry gerudi yang dikaji. Jadi, Pemodelan proses penggerudian tulang dijalankan dengan ANSYS untuk menjangka kesan daya tujah paksi dan penjanaan haba pada tulang untuk mengelakkan osteonecrosis terma. Simulasi unsur terhingga digunakan kerana ia mampu menjangka ubahan yang susah diukur ataupun yang susah memperolehi daripada proses tersebut. Terdapat dua peringkat metodologi Semasa peringkat 1, tujuannya adalah untuk mengesahkan simulasi sama ada model itu sah atau tidak dengan menguji simulasi dengan bit gerudi yang tersedia dengan batang lurus. Selepas itu, simulasi dijalankan dengan pelbagai kombinasi geometri gerudi bersama dengan model yang telah divalidasi dalam peringkat 1 Metodologi permukaan balas (RSM) digunakan untuk mengalpasti saiz eksperimen dan kaedah ANOVA digunakan untuk analisis data. Kesan haba dijumpa mempunyai kesan yang besar berbanding dengan kesan daya tujah paksi yang menunjuk kesan yang tidak menonjolkan. Terdapat 10 jenis reka bentuk dicadangkan dalam kajian ini, Reka bentuk pertama (31.92% untuk ketebalan mata gerudi, 90° untuk titik sudut, 31.32° untuk helix sudut) dan reka bentuk kedua (32% untuk ketebalan mata gerudi, 90° untuk titik sudut, 31.33° untuk helix sudut) adalah cadangan jangkaan yang paling sesuai dalam kajian ini.

ABSTRACT

Aluminium Silicon Carbide is one of the metal matrix composite. Drilling and reaming of Al/SiC composites is very challenging. An overall process optimization strategy is very needed for the actual production. This must be based on a deep understanding of the cutting mechanism. Different drill geometry may give different effect on the heat generation and thrust force on bone. Web thickness, point angle and helix angle are the drill geometry factors studied. So, modeling of Al/SiC drilling process by ANSYS to simulate the effect of axial thrust force and heat generation on bone in order to prevent thermal osteonecrosis. Finite element simulation is applied because the process variables are difficult to measure and directly measurable from the cutting process. There are 2 stages of methodology. During stage 1, the purpose is to validate the simulation whether the model valid or not by testing the simulation with available drill bit with straight shank. During stage 2, simulation is preceded with the drill geometry by using the validated model setting. Response surface methodology is used to design the experiment and ANOVA method is used to analysis the data. It was found that there is significant effect on temperature by the drill geometry involved, and not significant effect on thrust force. There are 10 optimized solutions suggested in this study. First solution (31.92% web thickness, 90° point angle, 31.32° helix angle) and second solution (32% web thickness, 90° point angle, 31.33° helix angle) are predicted as highly desirable for the study.

ACKNOWLEDGEMENT

First and foremost praise to Allah, the Almighty, the greatest of all on whom ultimately we depend for sustenance and guidance. I would like to thank Almighty Allah for giving me opportunity, determination and strength to do my research.

Next, I would like to thanks and express my deep and sincere gratitude to my supervisor, Associate Professor Doctor Raja Izamshah bin Raja Abdullah from the Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka (UTeM) for his continuous support, guidance and encouragement.

In addition, I would also like to thank to my master colleagues especially Muhammad Najib bin Tugiman, Mohammad Zarref Afiq bin Norizan, Ammar Aizat bin Mastuki and Aina Nazirah binti Ahmad Rafiee for the encouragement, thoughtful advices, and guidance along the way I completed this project.

Last but not least, I owe everything to my family who encouraged and helped me at every stage of my personal and academic life and longed to see this achievement comes true. Every breath of my life and drop of blood in my body is dedicated to my family.

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LIST OF ABBREVIATIONS

ANSYS	-	Analysis System
AISI	-	American Iron and Steel Institute
AMG	-	Automatic Mesh Generation
‘ANOVA	-	Analysis of Variance
BMD	-	Bone Mineral Density
CAD	-	Computer-Aided Design
CNC	-	Computer Numerical Control
CT	-	Computed Tomography
DF	-	Degree of Freedom
FI	-	Factor interaction
FEM	-	Finite Element Method
MR	-	Magnetic Resonance
P	-	Probability
PMMA	-	Poly (methyl methacrylate)
RSM	-	Response surface methodology
rpm	-	Revolution per minute
STL	-	StereoLithography

LIST OF SYMBOLS

°	-	Degree
%	-	Percent
°C	-	Degree Celsius
ε	-	Plastic strain
ε	-	Plastic strain rate
ε_0	-	Reference strain rate
σ	-	Stress
A	-	Yield stress
B	-	Hardening modulus
C	-	Strain rate sensitivity coefficient
e	-	Power of ten
GPa	-	GigaPascal
g	-	Gram
g/cm^3	-	Gram per centimeter cube
J/kgK	-	Joule per kilogram Kelvin
J/m^2	-	Joule per meter square
kg/m^3	-	Kilogram per meter cube
$MN/m^{3/2}$	-	Mega Newton per meter power of three over two
MPa	-	MegaPascal
mm	-	Millimeter
mm/min	-	Millimeter per minute
mm/rev	-	Millimeter per revolution
m^2/s	-	Meter square per second
N	-	Newton
N/s/mm/°C	-	Newton per second per millimeter per degree Celcius
n	-	Strain hardening exponent
W/mK	-	Watt per meter Kelvin

rev/min	-	Revolution per minute
s	-	Second
T_{melt}	-	Melting temperature
T_{room}	-	Room temperature

CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter contains the background, problem statement, objective and scope of research. Background of MMC, drill and parameter will briefly describe in the background section. Problem encountered before the study, objective and scope of the study will stated in this chapter.

1.1 Background

Composite material with at least two component elements is a metal matrix (MMC) composite material, the first one being a metal and the second one a metal or a substance other than a plastic such as a ceramic or organic compound. When there are at least three components, the composite is considered a blend. MMCs are formed when a hardened substance is spread into a metal matrix. To avoid a chemical reaction with the material, the hardened surface should be sealed. For example, in aluminium matrix carbon fibres are used to synthesise low density and high strength composites. Carbon reacts on the fibre surface with aluminium to create Al4C3 as a porous and water-lösable material. In order to stop this reaction, nickel or titanium boride protect the carbon fibres.

During MMC machining, very hard hardened particles are broken and debonded, which play a vital role in the production of surfaces, tool wear and chip. Especially fractures and decomposition are regulated by contact between tool and material, as well as by tension, strain and strain at various machining zone locations. Study on MMC fracture in tensile and compression testing has investigated, but a great deal of phenomenon, such as particulate fracture and debonding process, is still unknown although major research in this area is under way.

Al / SiC composites have a broader scope and common use in the areas of aerospace, naval, vehicle and sports equipment (Ozben, Kilickap, & Çakir 2008) due to their substantial advantages over traditional materials including lightweight , high physical strength , rigidity and a low thermal expansion factor (Singh, Singh, & Dvivedi, 2013). SiCp / Al composites, particularly suited to thermal management applications, such as electronic packaging, with high refurbishment volume fractions. DEM, spinning, milling, crushing, drilling and reaming are essential processes for the manufacture of such SiCp / Al composites. Drilling and reaming small-hole SiCp / Al composites with large percentages of volume is very difficult. For the actual output, an overall process optimisation approach is important. This must be based on a thorough awareness of the process of cutting.

At present, the most successful means for speeding the development of the analysis of the mechanism of cutting is the integration of laboratory, theoretical and simulation approaches. The simulation based on the finite element principle (FEM) has made significant progress in recent decades. Cutting power, temperatures and residual stress to tool wear are estimated for the chip forming processes in processing different materials with typical or advanced mechanical technology and many main global and field variables were forecast (Iwata, Osakada & Terasaka, 1984). The main focus is on 2D FE modelling (Zhou, Huang, Wang, & Yu, 2011). However, the simplification of boiling process as a 2D problem would lead to a significant deviation from the reality in view of the inadequate geometry of the exercise and the joint effects of chisel tip, lips and margins in chip shape or flow, only 3D FE simulation can describe correctly the dril process.

With the decrease of the hole size, issues such as cooling and elimination of the chip become more severe. Many thin, discontinuous chips are shaped and liable to go down to the bottom of the hole rather than flute out. The wear of instruments thus increases dramatically when dangerous abrasive particles occur. Furthermore the trapped chips fill the distance between the void and the instrument and raise the torque such that the torque is easier to break.

1.2 Problem Statement

Drilling small hole percentages and reaming Al / SiC composites in large volume is particularly problematic. For the actual output, an overall process optimisation approach is important. This must be based on a thorough awareness of the process of cutting. For example, when the tool cut surface is in contact with hard SiC particles during the drilling of Al / SiC MMCs, the SiC particle acts as small cutting edge, contributing to rapid tool wear, low surface finish, high drilling forces and burr forming.

Study on MMC fracture in tensile and compression testing has investigated, but a great deal of phenomenon, such as particulate fracture and debonding process, is still unknown although major research in this area is under way.

To predict the drilling behaviour of MMCs, it is important to create a generic finite element (FE) model. Research into improving the FE model for predicting the driving force in boiling MMCs is unusual. The final result is however changed such that a better solution to a particular problem is presented.

1.3 Objective

The primary objective is to research the reduction of tool wear and lower the thrust force. Therefore, the report lists three objectives.

i. To comteplate an FE model for predicting the magnitude of thrust force generated and signal during the drilling of Al/SiC.

A significant feature of drilling is the thrust force generated, as the consistency of the drill hole in terms of burr formation is determined much of the time.

ii. To examine the effects of feed rate and drilling speed on the stress distribution of the drill bit and drill force during the cutting of Al/SiC.

The drilling process and geometries are explored from the simulation model. This is done to verify if the cutting speed and feed rate have an impact on the thrust force.

iii. To evaluate the particle fracture and debonding in details during machining of Al/SiC in primary, secondary and tertiary deformation zones.

Debonding and particle fracture are regulated by contact between tool and material, as well as by stress, strain and strain at different machining zone locations.