Investigation on Tool Life and Wear Progression of Carbide Tool in Turning Nimonic C-263 under Multi-Conditions.

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This report is submitted in accordance with requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor Degree of Manufacturing Engineering (Hons.)

by

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Date : 29th June 2022

APPROVAL

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

………………………………………………………

(Associate Professor Dr Mohd Amri Bin Sulaiman)

ABSTRAK

Proses memusing melibatkan penyingkiran bahan daripada bahan kerja berputar dengan alat pemotong tunggal untuk membentuk silinder atau profil yang rumit. Dalam penyelidikan ini, alat karbida bersalut (PVD 1105) digunakan dalam memusing bahan kerja Aloi Nimonic C-263. Aloi Nimonic ini adalah permintaan yang besar dalam industri berat pembuatan kerana ciri-cirinya iaitu kestabilan haba yang sangat baik, rintangan kepada rayapan, keletihan haba, kakisan, dan pengoksidaan, aloi ini telah semakin popular. Walau bagaimanapun, terdapat pelbagai kesukaran yang diperhatikan semasa pemesinan aloi Nimonic C-263 pada pelbagai peringkat kerana kekonduksian yang rendah pada suhu yang lebih tinggi, kecenderungan pengerasan kerja, dan pembentukan zarah kasar dalam strukturnya. Objektif kajian ini adalah untuk menentukan faktor yang signifikan ke atas hayat alat sisipan karbida bersalut melalui Analisis ANOVA dan untuk menyiasat hayat alat dan kemajuan haus semasa memusing Nimonic C-263 Aloi dalam keadaan kering dan banjir. Proses operasi dijalankan menggunakan mesin pelarik CNC Haas ST-20 3 paksi. Metodologi Permukaan Tindak Balas (RSM) telah digunakan untuk mereka bentuk eksperimen dalam menentukan kesan parameter pemotongan seperti kelajuan pemotongan, kadar suapan dan kedalaman pemotongan terhadap hayat alat sisipan karbida bersalut. Daripada RSM, reka bentuk Box-Behnken telah dipilih untuk mengatur parameter pemotongan kelajuan pemotongan 60-120 m/min, kadar suapan mm/rev 0.05 -0.15 mm/rev dan kedalaman potong 0.3- 0.5mm. Haus rusuk diukur menggunakan mikroskop pembuat alat. Nilai masa pemotongan direkodkan untuk setiap 20mm pada bahan kerja sehingga haus flank Vb mencapai kriteria hayat alat diikuti oleh piawaian JIS B4011-1971. Daripada eksperimen, nilai maksimum hayat alat untuk sisipan karbida bersalut (PVD) dalam keadaan pemesinan kering ialah 17.50 minit dan nilai minimum hayat alat ialah 1.21 minit. Manakala bagi keadaan pemesinan banjir nilai maksimum hayat alatan ialah 19.15 minit dan nilai minimum ialah 1.96 minit. Berdasarkan Analisis ANOVA, kelajuan pemotongan adalah faktor yang paling signifikan daripada kadar suapan kemudian diikuti dengan kedalaman pemotongan dalam menentukan hayat alat untuk kedua-dua keadaan pemesinan.

ABSTRACT

Turning process involves the removal of material from a rotating workpiece with a single cutting tool to form a cylinder or intricate profile. In this research coated carbide tool (PVD 1105) were used in turning workpiece Nimonic C-263 Alloy. This Nimonic alloy are great demand in the manufacturing heavy industry due to its characteristics which is are excellent thermal stability, resistance to creep, thermal fatigue, corrosion, and oxidation, these alloys have grown more popular. However, there are various difficulties are observed while machining the Nimonic C-263 alloy at various stages due to its low conductivity at the higher temperature, work-hardening tendency, and rough particle formation in its structure. The objective of this study is to determine significant factor onto tool life of coated carbide insert through ANOVA Analysis and to investigate the tool life and wear progression during turning Nimonic C-263 Alloy under dry and flood condition. The operation process was carried out using a 3-axis CNC Haas ST-20 lathe machine. Response Surface Methodology (RSM) has been used to design the experiment in determining the effect of cutting parameters such as cutting speed, feed rate and depth of cut towards tool life of coated carbide insert. From RSM, Box-Behnken design been selected to arrange the cutting parameter of cutting speed 60-120 m/min, feed rate mm/rev 0.05 -0.15 mm/rev and depth of cut 0.3- 0.5mm. The flank wear was measured using toolmaker microscope. The cutting time value were recorded for each 20mm on the workpiece until flank wear Vb reaches the tool life criterion followed by JIS B4011-1971 standard. From the experiment the maximum value of tool life for coated carbide insert (PVD) in dry machining conditions is 17.50 minute and minimum value of tool life is 1.21 minute. Meanwhile for the flooded machining conditions the maximum value of tool life is 19.15 minute and the minimum value is 1.96 minute. Based on ANOVA Analysis, cutting speed is most significant factor than feed rate then followed by depth of cut in determining the tool life for both machining conditions.

DEDICATION

The name of Allah, the Most Gracious and the Most Merciful

I dedicate this final year project to:

My beloved parents,

Kamaruzaman Bin Ismail & Siti Haliza Binti Mohamed Subandi

To my lovely siblings who always support me.

To my lecterer who gives the guidance and motivation along my studies in Universiti Teknikal Malaysia Melaka (UTeM)

And to all my friends who always accompany me along the difficult path in my university life, thanks for your help and support.

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LIST OF ABBREVIATIONS

PVD	-	Physical Vapor Deposition
CVD	-	Chemical Vapor Deposition
CNC	-	Computer Numerical Control
Vb	-	Flank wear
DOC	-	Depth of cut
HSM	-	High-Speed Machining
Wc	-	Tungsten Carbide
Co	-	Cobalt
TiC	-	Titanium carbide
TiN	-	Titanium nitrate
Al_2O_3	-	Aluminium oxide
TiAlN	-	Titanium aluminium nitrate
MRR	-	Material Removal Rate
DOE	-	Design of experiment
RSM	-	Response Surface Methodology
CF	-	Coolant Fluid
Cr	-	Chromium
V	-	Cutting Speed, (m/min)
F	-	Feed Rate, (mm/rev)
DoC	-	Depth of Cut, (mm)

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CHAPTER 1

INTRODUCTION

This chapter outlines how the research was introduced "Tool life and Wear progression of carbide tool in turning Nimonic C-263 Alloy under multi conditions" In extension, this chapter will elaborate on the problem statement, objectives and scopes of the research.

1.1 Project Background

Over the last decade, Jangali Satish et al., (2021) stated that the nickel-based alloys play a very significant role, are becoming more and more popular, and are widely used in a variety of industries.Jadhav et al., (2020) stated that Nickel-based alloys are employed in a variety of sectors, including aviation, shipping, and gasoline turbine engines, because of their exceptional characteristics then according to A. Thakur & Gangopadhyay, (2016) and Wang et al., (2017) claimed that the admirable mechanical properties at excellent temperature strength such as high hardness, tensile strength, thermal fatigue resistance to corrosion, thermal stability and oxidation have made this alloy to be employed in different fields so they are a more widely used in aerospace, defence and nuclear industries since they can work efficiently even at high stress environment of long-term and high temperature

Kale & Khanna, (2017) stated that aerospace industry is one of the pioneers in development of super alloy because if the jet engine is able to withstand higher temperature, it will lead to more powerful and efficient engine. However, Jadhav et al., (2020) also stated that various difficulties are observed while machining the Nimonic C-263 alloys at various stages due to its low thermal conductivity at a higher temperature, work-hardening tendency, and rough particle formation in its structure. Normally, its consist of 50 % Nickel and another 20% chromium coupled with a lower percentages of Aluminium, Cobalt and Titanium that mostly used in a gas turbines and internal combustion engines, said by Jadhav et al., (2020). In this study, Nimonic C-263 is selected. But, Nimonic C-263 material presents a number of difficulties during machining because of the formation of various phases at elevated temperatures, a propensity to work harden, a chemical affinity for tool materials, and the presence of hard and abrasive particles in its microstructure, according to the statement. by Koyilada et al., (2016) mentioned that heat concentration at the cutting tool chip contact is a result of work hardening and poor thermal conductivity, and this leads to thermomechanical stress. This in turn affects tool life, and causes considerable surface damage. Ezilarasan et al., (2011b) mention that the right choice of cutting condition and tool is very important to increase the surface finish, and tool life.

Many studies have been undertaken to explore difficulties in machining of Nimonic C-263. As Nimonic C-263 is difficult to cut, cutting tool often gets worn out immediately during its machining so it is very important to select an appropriate cutting for machining of Nimonic C-263. According to D'Addona et al., (2017) mention that the high-speed machining technology has become more prevalent in recent years in many industries because of development of tougher, more refractory tool materials of high-speed machining spindles This paper presents use of high speed machining while turning of Nimonic C-263 so that the surface roughness and tool wear are the main issues which have been addressed in this investigation. In the present study, the effect of cutting parameters on the performance tool life and surface roughness during machining of the Nimonic C-263 alloy was studied by utilizing a PVD coated carbide insert.

During Nimonic C-263 be machining, it categorised as a material that is notoriously difficult to machine and have a significant impact on the alloy's machinability because they are easier to form plastic deformation, have a higher cutting force, higher viscosity and cutting temperature, and have serious tool wear and processing hardening degree. that stated by Sibalija et al., (2011) Because of the increased tool wear caused by higher temperatures, it substantially reduces machining efficiency and drives up processing costs. Meanwhile, regarding to Wang et al., (2017) mention that Based on the above mentioned data, the primary causes of tool wear during the machining process are the high temperature and cutting speed. Then, Nimonic family of Nickel based super alloy is gradually getting importance. Hard turning needs coolants then to maintain the cutting temperature within limit, suitable cutting fluid is applied in the cutting zone. Regarding to Debnath et al., (2014) Flood cooling, which supplies a constant stream of fluid to the tool work or tool chip interface for machining operations, was the approach with the highest dimensional accuracy when using synthetic cutting fluid. then regarding to Goindi & Sarkar, (2017) stated that machining in the dry state results in non-pollution towards the atmosphere or water, hence lowering the risk of health problems, particularly skin and respiratory harm, between this two coolant conditions there have their own pro and conns.

Several researchers have used Response surface methodology (RSM) method for the design of experiment. RSM method is a statistical tool, adopted experimentally to investigate the influence on the performance of tool life and surface roughness in the cutting parameter such as cutting speed, feed rate and depth of cut (Ezilarasan et al., 2011a). In this experiment Box- Behnken design was employed to carry out the trials, and ANOVA is utilised to determine the best cutting conditions. Utilizing the analysis of variance, research are conducted on the impact of the cutting parameters on the flank wear while working with the Nimonic C-263 alloy (ANOVA). The purpose of this study is to study tool life and tool wear progression of carbide tool in turning Nimonic C-263 alloy under multi cooling condition.

1.2 Problem Statement

Nimonic C-263 alloy is a unique and highly uses in heavy industries such a turbine blade, nuclear industry, and aerospace parts industry. It is a reliable, and high resistance to heat materials. However, according to Jadhav et al., (2020) machinability of Nimonic C-263 alloy is a challenging metal cutting process because due its' characteristic and low thermal conductivity. High cutting temperature will lead to dimensional inaccuracy of the machined work piece and rapid tool wear progressions of work hardening tendency, and rough particle formation in the structure. Then according to the Wang et al., (2017) stated that Materials made of nickel-base alloys, such as Nimonic C-263, are utilised in aircraft but are difficult to machine and quickly wear out cutting tools. The major cause is the cutting zone's high temperature.

M. Singh, (2016) mentioned that to machining these super alloy such a complex task for the critical application. Because of their poor heat conductivity and work hardening, which increases cutting force, nickel alloys are particularly difficult to machine. As a result, tool wear is quite high and extending the tool's life is difficult. Then, Nimel Sworna Ross & Manimaran, (2019) stated that during lower speeds, only the mechanically-activated wearing takes place. When the speed is increased, the temperature also increases leading to thermally activated wearing. Jadhav et al., (2019) said that when the material of the tool is heated, its strength is lost, and chemical wear and diffusion wear takes place, thereby increasing the rate of tool wear. Then for machining between dry and with coolant assists are required, to study the reduction of heat generated during cutting this material by using PVD coated insert tool.

Regarding to Khatri and Jahan,(2018) stated that problem with the dry machaning it is associated with several problems arise due to high cutting temperature, such as accelerated tool wear, reduced tool life, oxidized surface, residual stress, poor machinability and etc but in dry machining regarding to Goindi & Sarkar, (2017) stated that without the use of cutting fluids, excellent machining performance and meanwhile, regarding to Debnath et al., (2014) mentioned that Cutting fluid-related problems including contamination, waste, and dangerous components are eliminated with dry machining. Water sources or the environment are not harmed by dry machining. As a result, cutting fluid disposal costs are minimised.

On the other hand, for the flood coolont it is free from severe damages owning to high cutting temperature. Variety purpose of cutting fluid during machining process which are cool the work piece, reduce friction also wash away the chip but regarding to the Sreejith, (2008) stated that because of the harmful impacts of cutting fluids (Flood coolant) as well as rigorous environmental rules, a lot of study has recently concentrated on minimising or doing away with the usage of cutting fluids. From previous study, Dhananchezian and Pradeep Kumar, (2011) majority were claimed that dry machining unsuccessful to control the cutting temperature within the cutting zone. Heat generation and friction that generated in the cutting zone were two frequent issues that affected the surface finish and tool life in dry machining. These characteristics in machining can worsen wear on the cutting tool, a drawback that reduces tool life. Lastly, various types of wear can occur with different cooling condition during machining, and these are taken into account in this study.

1.3 Objectives

The objectives are as follows:

1. To determine the significant factors onto tool life of carbide tool for both conditions (Dry and Flood) through ANOVA analysis.

2. To investigate the tool life and tool wear progression during turning Nimonic C-263 under dry and flood conditions.

1.4 Scopes of the Project

This study aims to study the tool life and wear progression of carbide tool in turning Nimonic C-263 alloy under multi conditions. This project uses a CNC lathe to turn nimonic C-263 alloy. Three characteristics or factors—cutting speed, feed rate, and cut depth of cut—were looked at in this study. Variables include cutting speed, feed rate, and depth of cut. A series of studies were carried out using a combination of three criteria to examine how tool life and tool wear progression change under several settings. The Design of Experiment (DOE) approach is used to plan the experiment run schedule. In Chapter 3 (Methodology), the value of parameters is addressed.

The experiment was conducted with several sets of combinations of different values of cutting speed, feed rate and cutting depth based on the arrangement of the RSM method. The experimental combination arrangement technique is guided by the box-behnken technique RSM method. The RSM is a to generate the mathematical model of the tool life for multi conditions.

1.5 Significant of Study

Nimonic C-263 is generally utilized as a part of the aerospace business and is being implemented extensively in various sectors due to mechanical characteristics that are outstanding at high temperatures and can function well in a long-term high-stress situation that can cause various challenges during machining The incidence of nimonic C-263 alloy hard and abrasive particles in its microstructure, the production of various phases at high temperatures, low thermal conductivity, the propensity to work harden, the chemical affinity towards tool materials, and the tendency to work harden. This work hardening and low thermal conductivity cause heat concentration at the cutting tool chip interface, which causes thermomechanical stress. This in turn, affects tool life, tool wear and causes considerable surface damage. The importance of the study is to determine the differentiate tool life value of carbide tool (PVD 1105) in turning Nimonic C-263 alloy by using a CNC lathe machine under multi conditions. Additionally, the impact of dry and flood machining on the evolution of tool wear such as wear progression and tool life is also being studied. The study is also utilised to develop the tool life mathematical model for dry and flood circumstances.

1.6 Organization of Chapter

In this thesis contain five chapter describing the tool life and wear progression of carbide tool (PVD 1105) in turning Nimonic C-263 alloy under multi conditions. The following below is how the study was organized. In this study, for the chapter 1 cover the introduction which is consist general information of study background, problem statement, objective, scope of project and significant of study. Then in the chapter 2, cover the literature review of Nimonic C-263 alloy, machining process, flood machining, cutting tools, cutting parameters, tool life, tool wear progression and design of experiment. Meanwhile, for the chapter 3 cover the methodology of the project including the information of experimental equipment, design procedures, experimental procedures and methodology of flowchart. Next for the chapter 4, cover the overall results and discussion for the project where the data will be analyzed. Lastly chapter 5, cover for the conclusion and recommendation for the study.

CHAPTER 2

LITERATURE REVIEW

This chapter contains the data acquired for the project's title, which is "Tool life and wear progression of carbide tool in turning Nimonic C-263 alloy under multi conditions." Every expectation that will be engaged in this research will be well examined and clarified by past researchers such as workpiece material (Nimonic C-263), turning operation, cutting state, cutting tool, tool life, tool wear progression and experimental design are all included in this study.

2.1 Turning Process

Turning process was the traditional method to convert the raw material into desired product. According to Radha Krishnan & Ramesh, (2020) stated that in CNC machining process used to upgrade the efficiency and output parameters compare with the manual methods like manually and semi-automatic lathe. Then according to Radha Krishnan & Ramesh, (2020) stated that turning is a form of machining or a material removal process which is used to create rotational parts by cutting away unwanted material. In addition Krishankant et al., (2012) mentioned that the turning process requires a turning/lathe machine, workpiece, fixture, and cutting tool. The workpiece is a piece of re-shaped material that is secured to the fixture, which itself is attached to the turning machine, and allowed to rotate at high speeds. The cutter is typically a single-point cutting tool that is also secured in the machine. The cutting tool will feed into the rotating workpiece and cuts away material in the form of small chips to create the desire shape. In order to smoothly remove material, three relative motions between tool and workpiece are to be provided. Turning machines are additionally ready to be computer controlled and known as a