MILING OF INCONEL 718 UNDER DIFFERENT LUBRICATION CONDITIONS

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DECLARATION

I Mimi Khairunnisa Zachary (BK18110269) hereby declare that this project progress report entitled "Milling of Inconel 718 Under Different Lubrication", submitted to Universiti Malaysia Sabah, is an original work under the supervision of Prof. Dr. Willey Liew Yun Hsien, and it is submitted as partial fulfilment the requirement for the degree of Bachelor of Mechanical Engineering, which has not been submitted to any other university for a degree. I also certify that the work described is entirely mine, except for quotations and summaries of sources that have been duly acknowledged.

26th July 2022

MKZ

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First of all, I am grateful to God who is willing in giving me the opportunity to finish this Final Year Project with the research title of 'MILLING OF INCONEL 718 UNDER DIFFERENT LUBRICATION'. It is always a pleasure to remind all people in the University Malaysia Sabah (UMS) for the guidance that I have received to enhance my skills in Mechanical Engineering. Basically, this project was proposed to apply the knowledge received by students from the Mechanical Engineering program as well as to complete the requirement for the degree of Bachelor of Mechanical Engineering with Honors.

Second, I would like to express my special appreciation to Prof. Dr. Willey Liew Yun Hsien for his guidance in finishing this project. Not to forget, I also want to thank the lecturers and staff in the Faculty of Engineering especially Mechanical Engineering for their support in giving us the information, knowledge, and guidance to finish this project.

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OVERVIEW INTRODUCTION

This report is written as the Progress Report for Final Year Project 1 where fourth-year Mechanical Students needed to submit as partial fulfillment of the requirement for the degree of Bachelor of Mechanical Engineering. They were been given 12 weeks to finish this progress report specifically the due date is on 15th January 2022 and present their findings on the 19th January 2022 to their respective supervisors and examiners.

This project progress serves as a platform for students to be able to control their project process, critically evaluate research in their field of interest and design their own experimental testing procedure. This includes chapter 1 which mostly covers the general overview, significance, and contributions of the project. Meanwhile, in Chapter 2 where works of literature are reviewed, the project can be put into perspective on what should be done to improve previous research. Other than that, Chapter 3 is where the students would design their own experimental procedure after taking into account of the previous works of other researchers. Lastly, Chapter 4 is where they can tabulate results from experiments and discuss the observations and analysis done. Lastly, Chapter 5 is where they can conclude the works they have done in this project the and problems they have faced with more information in future suggestions. Any changes made to the project will also be included inside the last chapter.

ABSTRACT

Milling of Inconel 718 is challenging because Inconel is a type of superalloy that is hard to machine because of its particular property of high thermal resistance. This means that it has low thermal conductivity. When milling is conducted without optimum lubrication conditions, heat generated will accumulate on the cutting tool hence resulting in severe wear. That is how flood lubrication conditions play a role in dissipating the heat generated. However, this method is detrimental to the environment from the toxicity of the lubricant. Hence this study proposes an optimum lubrication condition with consideration of environmental factors. This study made a comparison between the flood lubrication condition and Minimum Quantity Lubrication (MQL) from their milling results such as cutting tool wear and surface quality of Inconel 718. From the data obtained, it is found that the flood lubrication conditions have the lowest cutting tool wear and better surface quality of Inconel 718 than milling in MQL conditions. The experimental errors in this study have been discussed and future recommendations have been suggested to improve the study.

ABSTRAK

Proses 'milling' Inconel 718 adalah mencabar kerana Inconel ialah sejenis pancalogam yang sukar untuk dimesin kerana sifatnya yang mempunyai rintangan haba yang tinggi. Ini bermakna ia mempunyai kekonduksian haba yang rendah. Apabila proses 'milling' dijalankan tanpa keadaan pelinciran optimum, haba yang dijana akan terkumpul pada alat pemotong seterusnya mengakibatkan kehausan yang teruk. Begitulah keadaan pelinciran banjir memainkan peranan dalam menghilangkan haba yang dihasilkan. Walau bagaimanapun, kaedah ini memudaratkan alam sekitar daripada ketoksikan pelincir. Oleh itu kajian ini mencadangkan keadaan pelinciran yang optimum dengan mengambil kira faktor persekitaran. Kajian ini membuat perbandingan antara keadaan pelinciran banjir dan Pelinciran Kuantiti Minimum (MQL) daripada hasil proses 'milling' seperti haus alat pemotong dan kualiti permukaan Inconel 718. Daripada data yang diperolehi, didapati keadaan pelinciran banjir mempunyai kehausan alat pemotong yang paling rendah dan kualiti permukaan Inconel 718 yang lebih baik berbanding dalam proses 'milling' dalam keadaan MQL. Kesilapan eksperimen dalam kajian ini telah dibincangkan dan cadangan masa hadapan telah dicadangkan untuk menambah baik kajian ini.

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PROJECT INTRODUCTION

1.1 INTRODUCTION

Milling is a machining operation that requires rotating cutting tools at a fixed speed and then bringing them into contact with a work item. Clamping devices are commonly used to hold the work piece in place. The cutting tools start removing material as soon as they come into contact with the work piece (Saif M., 2021).

There are several different types of milling cutting tools available (Saif M., 2021):

- End mill - Possibly the most common type. An end mill can be used to cut laterally. Some end mills can cut both laterally and axially.
- Face mill - While a face mill is used to make lateral cuts similar to an end mill, a face mill is also used to cut the entire surface of a material instead of just a portion.
- Other milling cutting tools include thread mills, side and face mills, and thread mills.

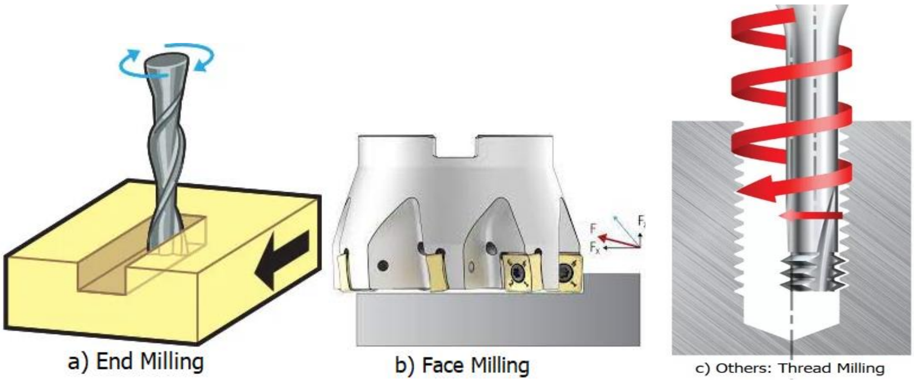

Figure 1.1: a) End milling b) Face milling and c) others: Thread Milling illustrations

Source: Tyler W. (2014); Seco (2019); Sue R. (2017)

Along with milling, lubrication is important while processing this machining. Lubrication is required to reduce friction, wear of moving parts, operating temperature, and system corrosion. Machine failure, lubricant replacement costs, and associated downtime are all consequences of incorrect lubrication. As a result, overall costs such as machine part failure, oil replacement, and flushing costs have increased. As a result, appropriate lubrication of machine parts is essential for longer milling machine life and increased reliability (Saif M., 2021).

One of the most milled materials in manufacturing is called Inconel. Nickel-based superalloys like Inconel are key materials in the aerospace, energy, and nuclear industries due to their high strength at high temperatures and outstanding corrosion resistance (Daniel et al., 2019). The Table 1.1 below shows the applications that uses Inconel 718 as its components.

Table 1.1: Applications that uses Inconel 718 as its components

Applications	Components of Inconel nickel-based alloy-718
Aerospace industry	Jet engines, gas turbines, space re-entry vehicles, rocket technology reactors
Marine Applications	Gas turbines, combustors, propeller shafts.
Power Plants (Nuclear)	Reactor Springs, fuel element recovery
Processing Industry	Shipping Drums, Processing equipment

Source: Syed Q. et al. (2020)

It is, nevertheless, difficult to treat due to its high temperature strength compared to its low thermal conductivity and specific heat. Resulting in tool wear that is rapidly increasing. It is critical to comprehend wear mechanics and examine wear causes. Hence, this study serves the purpose to analyses tool wear by milling of Inconel under different lubrication. The major reason of this study is for utilizing milling tool to manufacture Inconel to take advantage of the lubrication effect caused by high cutting rates to increase machinability.

1.2 PROBLEM STATEMENT

In this section, the components that will be focused on are milling's cutting tool and the workpiece which is Inconel 718.

Cutting fluids specifically flood coolants are crucial during machining, but they have significant disadvantages, such as detrimental impacts on the environment and worker health, as well as costs related with equipment, fluids, and waste fluid treatment. All of these factors, as well as government restrictions, are prompting manufacturers to build more efficient and long-lasting lubrication and cooling systems. That explains why the majority of manufacturers are under pressure to "become green" these days. Alternative techniques such as dry machining, mist lubrication and Minimum Quantity Lubrication (MQL) are introduced. These may be more efficient than the standard flood coolant. Cutting fluids cannot, however, be removed from some applications (E. Benedicto et al., 2017).

Figure 1.2: Flood Coolant used in milling

Source: Shane W. (2018)

Dry machining has a lower environmental effect and has fewer health concerns to workers. Furthermore, there is no fluid residue in the workpiece or chips, lowering cleaning costs and energy consumption (E. Benedicto et al., 2017). However, due to the rigorous requirements of particular machining operations, dry machining conditions are not always attainable. Excessive heat generated during the process, increased friction between the tool and the workpiece and the necessity to evacuate the chips generated are all possible causes.

Figure 1.3: Dry machining

Source: Mark K. (2020)

Mist lubrication in the other hand is having nozzle to deliver a very small amount of oil with compressed air to the end mill. Problems such as contamination of the environment or deterioration of the working environment caused by the use of a large amount of cutting fluid are unlikely to occur when this lubricating method is utilized. Similarly, mist lubrication is extremely unpleasant to be around, creates nearly as much mess as flood coolant, and coats everything in oil residue once the water has dried. Yet, introducing new cutting fluid formulas are being developed in response to the demand for environmentally friendly solutions. One of it is Minimum Quantity Lubrication (MQL) where it only leaves enough residue for the vice (shown in Figure 1.4) to make a light wipe. Several MQL advantages over other lubrication-cooling systems include reduced cutting fluid consumption, cost, and tool wear, improved surface roughness, reduced environmental and worker health hazards and improved lubrication, as the cutting fluid used in such a small quantity eliminates lubricant disposal problems (Carou D. et al, 2015).

Figure 1.4: MQL used in milling

Source: Adhip S. et al (2020)

The problem statement that arises is that is using MQL as lubricant really can reduce tool wear when milling Inconel as the workpiece better than other types of lubrications including flood coolants and mist machining conditions? This is because the characteristic of Inconel material that is low in specific heat capacity and low thermal conductivity need an effective cooling effect while machined. Besides, what is the surface behavior of Inconel after milled under different lubrication? This is to observe the quality of the milling process under different lubrication. Lastly, which lubricant will create the optimal condition for milling of Inconel? For this is needed to justify the best lubricant to use with the emphasized on the economic, environmental, and technical aspects.

1.3 RESEARCH OBJECTIVES

In this paper, new research is performed for milling of Inconel using different lubrication. With this performance, the main objective is obtaining tool behaviour specifically milling tool wear and Inconel surface behaviour for each proposed lubrication in order to establish optimal milling condition leading to more sustainable and eco-friendly process. For this, Minimum Quantity of Lubricant performance are carried out and compared with conventional cutting fluids conditions. By this, the objectives can clearly be seen as below:

1.3.1. To analyse wear of cutting tool after cutting Inconel as workpiece under different lubrication.

1.3.2. To analyse Inconel surface behaviour after milling under different lubrication.

1.3.3. To identify most effective lubrication to use for optimal milling condition by taking into consideration of environmental factor.

1.4 SCOPE OF WORKS

In order to ensure the project to be in line of success, it is crucial to follow the scoped line in earlier stages. Below shows the scopes of work of the project:

1.4.1. Conducting research and literature review related to the Milling of Inconel under different lubrication.

1.4.2. Identifying and designing an experimental procedure that may be used in the data collection regarding milling of Inconel under different lubrication

1.4.3. Analyzing data collected using correct laboratory equipment.

1.4.4. To confirm that the result is retrieved successfully, various engineering simulation tools were used to test it.

1.5 PROJECT METHODOLOGY

In this research, the methodology is comprised of completing literature review, planning the experiment of milling of Inconel 718 under different lubrication, conducting the experiment of milling of Inconel 718 under different lubrication and lastly performance evaluation and documentation. Flowchart of project methodology is presented to visualize the project systematically.

i. Literature Review

   Literature Review is conducted for searching existed past papers about milling of Inconel 718 under different lubrication in order to gain more information and aid in understanding of the experiment. The reference from the literature review also will act as guidance in success of this paper.

ii. Planning the experiment of milling of Inconel 718 under different lubrication.

   The planning of doing experiment is very crucial in this paper as the result obtained will be related to the objectives, hence it is important to plan the experiment according to desired results.

iii. Conducting the experiment of milling of Inconel 718 under different lubrication.

   This is the stage where every variable from the planning of the experiment have been carefully conducted. This is because where results will be extracted and influence the findings of the report. A lot of experiment will be done based on the objectives that needed to be achieved in this paper.

iv. Performance evaluation and documentation

   After collecting the data, performance evaluation and documentation will be the proof of this experiment whether it is a success or a failure in meeting the objectives of this paper.

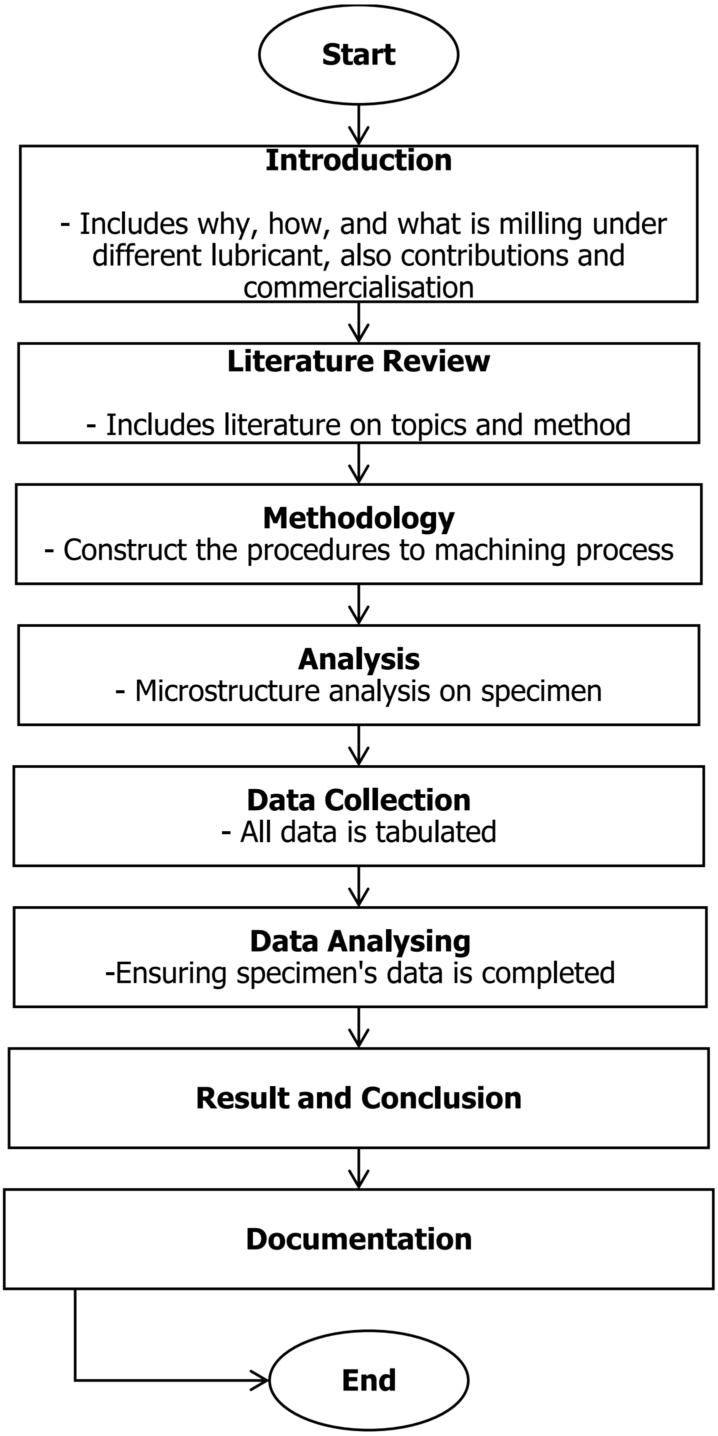

Figure 1.5: Project Flow Chart

The Project Flow Chart above are referred as guidance to complete this thesis paper.

1.6 RESEARCH EXPECTED OUTCOMES

The expected outcome for this research is that the ability to prove that milling of Inconel needed an effective lubrication that can cater to problem like tool wear, high fluid consumption, disposal and maintenance cost as well as problems related to the environment. The outcomes should be able to show all data that are collected from the experiments and analysis.

1.7 RESEARCH CONTRIBUTIONS

This research contributes to both manufacturing and the environment. From this research, manufacturers may apply the effective lubricant proposed by this research that can save their costs and workers' health. Similarly, this research caters to problems related to the environment by suggesting the best lubricant to use when milling Inconel that is eco-friendly.

1.8 RESEARCH COMMERCIALIZATION

This research can be commercialized as the book of guidance or standard operation guidelines before milling Inconel as Inconel is known for the high price and must be taken into the proper machining process.

1.9 RESEARCH GANTT CHART

No.	Item	Week													
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
01 – 2021/2022															
1	First FYP Briefing	■													
2	FYP Proposal Preparation	■	■												
3	Literature Review	■	■	■	■	■									
4	Brainstorm Ideas			■	■	■									
5	Material Selection			■	■										
6	Introduction				■	■									
7	Literature Review					■	■								
8	Methodology						■	■	■						
9	Test-Run Machining						■	■	■	■	■				
10	FYP I Documentation		■	■	■	■	■	■	■	■	■	■			
11	FYP I Report Submission												■	■	
12	FYP I Presentation														■
02 – 2021/2022															
13	Milling of Inconel for flood lubrication	■	■												
14	Milling of Inconel for mist lubrication			■	■										
15	Milling of Inconel for MQL				■	■									
16	Microstructure Analyzing & Data Collection					■	■								
17	FYP II Documentation	■	■	■	■	■	■	■	■	■	■				
18	Plagiarism verification											■			
19	FYP II Report Submission												■	■	
20	FYP II Presentation														■

This Gantt Chart is used in order to keep on track with the schedule proposed.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this section, a literature review is conducted in order to critically evaluate research in the field and to explore data sources that have been used by other researchers. A number of online journal search engines like Science Direct, Scopus, Springer, and many more serve as a platform for sources of scientific and technical research papers for this thesis use. This step is crucial in order to put this thesis into the perspective of what has and has not been investigated. The field that will be focused on is essentially related to the title covered in this thesis which is 'Milling of Inconel Under Different Lubrication'. Hence, the topics that will be covered will mainly be explaining the ideas of milling, characteristics of Inconel, and different types of lubrication for starters. After that, annotations from selected research papers will be included and evaluated based on the relationship between the topics. Lastly, to sum up, the findings will be listed in summary in this section.

2.2 INCONEL

Inconel is a registered trademark of Special Metals Corporation and is well known for its different grades designated by numbers such as 600, 617, 625, 690, 718, and X750.

ALLOY 600 - Tensile Data

Temperature (°F)	Ultimate Tensile (ksi)	Yield Strength at 0.2% Offset (ksi)	Elongation %
Room Temp.	93.0	37.0	-
1000	84.0	28.5	-
1200	65.0	26.5	-
1400	27.5	17.0	-
1600	15.0	9.0	-
1800	7.5	4.0	-

ALLOY 601 - Tensile Data

Temperature (°F)	Ultimate Tensile (ksi)	Yield Strength at 0.2% Offset (ksi)	Elongation %
Room Temp.	100.0	54.0	45.0
1000	90.0	48.0	44.0
1200	60.0	41.0	45.0
1400	34.0	26.0	70.0
1600	18.0	15.0	120.0

ALLOY 625 - Tensile Data

Temperature (°F)	Ultimate Tensile (ksi)	Yield Strength at 0.2% Offset (ksi)	Elongation %
Room Temp.	144.0	84.0	44.0
400	134.0	66.0	45.0
600	132.0	63.0	42.5
800	132.0	61.0	45.0
1000	130.0	61.0	48.0
1200	119.0	60.0	34.0
1400	78.0	59.0	59.0
1600	40.0	39.0	117.0

ALLOY 718 - Tensile Data

ANNEALED 1800°F, AGED 1325/1150°F

Temperature (°F)	Ultimate Tensile (ksi)	Yield Strength at 0.2% Offset (ksi)	Elongation %
Room Temp.	210.0	175.0	22.0
400	198.0	163.0	20.0
800	191.0	156.0	19.0
1000	185.0	155.0	18.0
1200	168.0	149.0	19.0
1400	111.0	110.0	27.0

Figure 2.1: Tensile Data for Inconel 600,601,625 and 718

Source: E.B&F. (2016)