

**COMPARISON OF MACHINABILITY ALUMINIUM ALLOY LM6  
WHEN USING COATED AND UNCOATED CARBIDE CUTTING  
TOOL**

**KHUZAIMI BIN MOHD ARIS**

**A thesis submitted  
in fulfillment of the requirements for the degree of Master of  
Manufacturing Engineering (Industrial Engineering).**

**Faculty of Manufacturing Engineering**

**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

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## DECLARATION

I declare that this thesis entitled “Comparison of Machinability Aluminium Alloy LM6 When Using Coated and Uncoated Carbide Cutting Tool” 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 : ..... 

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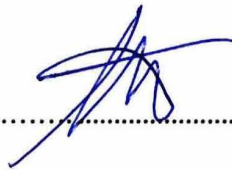
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## APPROVAL

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 (Industrial Engineering).

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## **DEDICATION**

To my beloved mother, wife and children. Thank you so much

## ABSTRACT

The applications of metal matrix composites (MMCs) are being increasing daily in many field especially aerospace and automobile industries. The demand for affordable, quality materials and low costs also increased in line and led to the development of MMC as alternative product for various industrial application. The typical Aluminium Alloy LM6 contains 10–13 wt.% of silicon and thus inherently solidifies with coarse grain sizes. The main composition of LM6 is about 85.95% of pure Aluminium. Machining test for this material will be conducted by using two types of cutting tools which is coated carbide and uncoated carbide. It will be test at different cutting speed (i.e., 5000 rpm and 6000 rpm) and different feed (i.e., 90 mm/min and 120 mm/min) at constant depth of cut 0.5 mm. The difference between both cutting tools will be study in term of its tool wear behavior and also the surface integrity of materials as well. Machining test will use CNC Milling Haas machine with dry cutting condition. The results showed that tool life for cutting tool influences by coated carbide tool rather than uncoated carbide tool. Better surface roughness provides from coated carbide with 6000 rpm and feed rate 90 mm/min.

## ABSTRAK

Aplikasi komposit matriks logam ( MMC ) dijangka meningkat naik setiap hari dalam bidang banyak terutamanya industri aeroangkasa dan kereta . Permintaan untuk bahan yang murah, berkualiti dan rendah kos juga meningkat dengan sejajar. Ini membawa kepada pembangunan MMC sebagai produk alternatif untuk pelbagai aplikasi industri. Aluminium Alloy LM6 biasanya mengandungi 10-13 wt % Silikon dan akan mengukuhkan dengan saiz bijian kasar . Komposisi utama LM6 adalah kira-kira 85,95 % Aluminium tulen. Ujian pemesinan untuk bahan ini akan dijalankan dengan menggunakan dua jenis alat pemotongan iaitu karbida bersalut dan karbida tidak bersalut. Kelajuan pemotongan yang berbeza akan digunakan iaitu ( 5000 rpm dan 6000 rpm) dan pada kadar hantaran atau suapan yang berbeza (iaitu, 90 mm / min dan 120 mm / min) pada kedalaman pemotongan yang stabil iaitu 0.5 mm. Perbezaan di antara kedua-dua alat pemotong akan kajian dari segi penggunaan alat tingkah laku dan juga integriti permukaan bahan-bahan juga. Ujian Pemesinan akan menggunakan mesin Kisar CNC Haas pada keadaan pemotongan kering. Hasil kajian mendapati bahawa jangka hayat mata alat dipengaruhi oleh mata alat bersalut berbanding mata alat tidak bersalut. Kekasaran permukaan yang baik juga terhasil melalui mata alat bersalut pada parameter 6000 ppm dan kadar hantaran, 90 mm/min.



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## **LIST OF ABBREVIATIONS**

<b>BUE</b>	- Built-up edge
<b>CBN</b>	- Cubic Boron Nitrate
<b>CNC</b>	- Computerizes Numerical Control
<b>HSS</b>	- High Speed Steel
<b>IKM</b>	- Institut Kemahiran MARA
<b>LM</b>	- Light Metal
<b>MMC</b>	- Metal matrix composites
<b>PCD</b>	- Polycrystalline Diamond
<b>TiAlN</b>	- Titanium Aluminium Nitride

# CHAPTER 1

## INTRODUCTION

### 1.1 Background of Study

Metal matrix composites (MMC) was the best engineered materials where merged more than two materials. One of those particular materials was metal. This type of materials was very special due to its special properties which can be achieved by systematic combination of different constituents. In the new technology nowadays, the uses of Aluminium and its alloying are becoming more important in industries. It is the second most abundant metallic element and the most abundant structural metal in the earth's crust. It is commercially available either wrought or cast in the form of bars, ingots and sheets. Most of the field that applies the use of Aluminium Alloy LM 6, are automotive, transportation, sports and also variety of industrial consumer products. Machining of MMCs would be especially useful for manufacturing prototype parts and low volume custom. Besides that it also required for complex shape and frequently modified designs (Chamber, 1996).

The study of LM 6 Alloy focused in silicon dioxide reinforcement is scarce and rare especially studied done by using milling process. Nowadays need for machining Aluminium Alloy LM 6 become more important. This leads to investigate need in order to improve machinability of Aluminium Alloy LM 6. For instance, the objective that include proper method to reduce machining cost and time without ignoring quality issue. In machinability, ductility plays an important role. Some



engineering materials such as pure Aluminum, Copper and even Gold have poor machinability properties due to their extreme ductility. Although not as pure Aluminium, Aluminium Alloy LM6 still has weakness in machinability particularly in ductility aspects. (Hajjaji et al. 2007). This properties will creates the drag effect which cause newly cut chip rather than simply falling away from the cutting zone. In certain period time this effect will cause to the increasing in tool wear.

Besides that, the capabilities of proper cutting tool used also need consideration. The tool wear and its life time needs to be analyzed in order to increase its quality. Aluminium Alloy LM6 basically consists of certain percentage of silicon dioxide as particulates with Aluminium as matrix to formed combination of reinforced Metal Matrix Composites (MMC). This study describes the wear mechanism and surface integrity when machining coated carbide cutting tools with Aluminium Alloy LM6. The experiment was conducted using Ø10 mm End Mill with 4 flute cutting tool under dry condition. The cutting tool was coated with TiAlN. The wear mechanism of this cutting tools were investigated at various parameter with the main combination is between feed rate and cutting speed.

To fulfill the demand of market, machining process always play a major role in order to achieved the target. Therefore, conventional machines have been developed throughout the years. One of the machining scopes is call milling machine, lathe machine, drilling machine, grinding machine and etc. Besides conventional, there is also more advanced machine uses called as Computerizes Numerical Control (CNC). Generally, machining is a process of removing raw material by using cutting tool to gain the objective of converting the remaining material into the desired part shape (Şeker et al. 2004). It is also known as a processes which is influenced by the

quality and reliability of the materials surfaces produced in terms of topography. The main criteria in this process are the existed of material, cutting tool and also the cutting parameter. All of these factors will lead to efficiency and perfection of a machining process.

Milling machine is a machining task that use cutting tool to machine complex shaping of solid materials. It's an operation that needs cutting tool to rotate about the spindle axis and then movable table to which the workpiece is clamped. In order to have most efficient process while maintaining high quality level, it should produce material removal rate as large as possible. But, the material removal rate is often limited due to tool wear and failure. While operates milling machine using carbides cutting tool under certain cutting conditions, the gradual wear of the flank and rake faces becomes the important process where cutting tool will fails. The flank wear in carbide tools occur cause by the abrasion. In this situation, when the wear progresses the temperature also will increases and resulted to diffusion. .

Basically there are two types of cutting tool used in metalworking which categorized as single point and multi point designs. End mills cutting tools can be used on either in horizontal or vertical milling machines for a any types of operations. There are various types of cutting tool that can be applied for cutting process in milling machines such as High Speed Steel (HSS), carbide and advanced tool such as polycrystalline diamond (PCD) and Cubic Boron Nitrate (CBN). To provide greater durability and a longer life expectancy, there is a tool that is coated with a specific coating.

Tool with coated on its surface influences contact conditions which leads by modification, generation of heat, heat flow and altering friction as well. It is seems to

be the influencing wear by decreasing wear problem. Generally, there are 4 main types of coating source supplied in the market. The famous coated known as titanium-based coating materials which included TiC, TiN and Ti(C,N). Coating materials (TiAlN) play an important role to increase material behavior such as oxidation resistance and hardness. This is successful coating types with metallic phase normally supplemented by Cr and Al (F.Klocke 1999).

## 1.2 Problem Statement

Since Aluminium have certain kind of weakness, it should have study on the possible solution to control that problem. In this study, Aluminum Alloy LM6 will be used to examine the effectiveness and capabilities of these materials for use in manufacturing processes and other areas especially in automotive field. Most of industries currently use Aluminum as their core materials which have been well known for their advantages in various aspects such as capability and applicability. Unfortunately for Aluminum Alloy LM6, it still faces with its poor machinability properties. This factor will attributed to the hardness, shape and size of its silicon grain as well. Additionally, there are limited studies for this kind of materials to improve its performance due to minimum journal and research paper about it.

To assess the capabilities and attributes of Aluminum Alloy LM6, the tool to be used is End Mill cutter that has been suggested by previous researchers. Two types of tools will be used in this study which is coated and uncoated tool. Both tools chosen due to its frequently use in manufacturing industry nowadays. Generally coated tool is harder and longer use than the uncoated tool, but its ability to accommodate the load level of wear is still occurring. Therefore, this study will also examine the differences between the wear of both tool when it's achieved 0.2 mm on target.

### **1.3 Objectives**

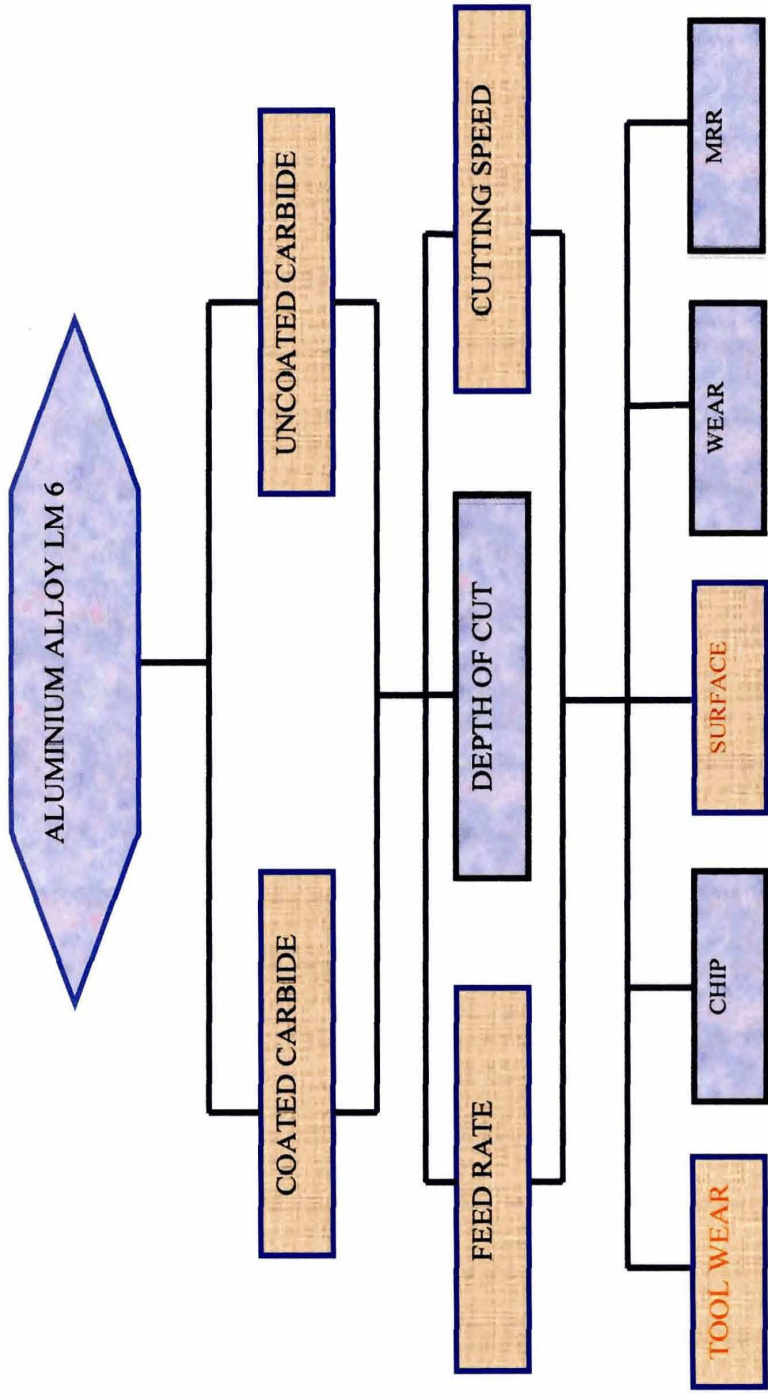
The objectives to be achieved in this project are consists of three major issues:

- a) To investigate the machinability effect of Aluminium Alloy with coated carbide cutting tools
- b) To investigate the machinability effect of Aluminium Alloy with uncoated carbide cutting tools
- c) To compare and propose both cutting tools which has the optimum result for usage

### **1.4 Scopes of Project**

This study have two main scope as stated below :

- a) Evaluate the performance of Aluminium Alloy LM6 while machine with different types cutting tool
- b) Perform surface integrity analysis of Aluminium Alloy LM6 using Surface Roughness equipment.
- c) Analyze tool wear characteristic between coated carbide end mill and uncoated carbide end mill with Stereo Microscope.



1.5 K-Chart

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Material (Aluminium Alloy, LM6)

Basically, Aluminium was categorized as non ferrous metal materials. It's characteristic can be describe as soft, silvery white, ductile metal especially noted for its density and low of melting point. It is a chemical element in the Boron group and had atomic number of 13 with Al symbol. Furthermore, it is third most huge element and the most abundant metal can be found in the world. Some of the limitations of Aluminium are lower strength at elevated temperatures, limited formability and relatively higher cost compared to steel. (Kuttolamadom et al. 2010). The oxide layer formed on freshly machined aluminum insulates it against further attack thus providing good corrosion resistance. Despite of the limitation in certain area, Aluminium still useful in many area such as in the food and chemical industry, in metallurgical applications, the electrical industry, for structural applications, cryogenic applications and of course extensively in the transportation industry.

Previously, some research has been carried out on metal matrix composites (MMC). Elements of TiC, TaC and SiC are the most commonly used particulates to reinforce in the alloy matrix, metal and the matrices like Aluminium or iron. According to researcher, silicon dioxide reinforcement in LM6 alloy is still rare and hard to found (Sulaiman et al. 2008). Unfortunately, the limitation of the studies leads

to lack of information for this material. Previous research, discovered that the machining of aluminium MMC apparently is an important area of study, but only few studies have been conducted in machining of LM6 aluminium MMC.

The main content of LM6 is 85.95% of Aluminium and 11% to 13% of Silicon. This type of material is not pure Aluminium due to its alloying elements contains. In Table 1, stated the composition of LM6 in percentage. Aluminium Alloy LM6 also known as Eutectic Aluminium Silicon Alloy and holding the lowest melting point as stated at Al-Si phase diagram below (Figure 2-1).

Table 1: Composition of LM6 (%)

Al	85.95
Cu	0.1
Mg	0.1
Si	12
Fe	0.6
Mn	0.5
Ni	0.1
Zn	0.1
Lead	0.1
Tin	0.05
Titanium	0.2
Other	0.2