CHAPTER I

INTRODUCTION

1.1 Introduction

In the recent years, the demand for light weight, low cost and high quality performance materials has increased. Many researches have been done to develop new materials that meet these requirements. One of the newly developed materials is aluminum metal-matrix composites (Al-MMCs). Basically, there are three types of MMCs: particle reinforced, whisker reinforced and continuous fiber MMCs.

Metal-matrix composite (MMCs) are widely used in industry because of their excellent mechanical properties. Nowadays, there are various products used of MMCs especially for automotive and engineering applications. This is because of their high strength, high elastic modulus, low co-efficient of thermal expansion, light weight, low thermal shock, good wear resistance and many more advantages. This combination of these properties are not available in a conventional material. These mechanical properties also depend on the composite particles for the reinforcement of the aluminium. Most of the alloys that were used as matrices are light alloys, particularly those based on aluminium (Abd El-Azim, *et al.* 2002).

Most researches on metal matrix composite (MMCs) in recent years has been concentrated on the development of high performance continuous fibre-reinforced composites for specialized applications. In spite of their unique properties, such composites are expensive. Therefore, development of less-expensive composites for non-critical applications is desirable. Particulate-reinforced MMCs are cost-effective alternatives and have the advantage of being machinable and workable using conventional processing method. However, their poor mechanical properties such as low fracture strain and fracture toughness, which are important for the design of structural materials, have limit their applications (Soon-Jik Hong, *et al.* 2003).

In this study, particulate-reinforced aluminum metal matrix composites (Al-MMCs) was emphasized. Aluminum acted as matrix component while the 4.5% copper (5 micron) and silicon carbide particles act as the reinforcement materials. In addition,

Al-MMCs are relatively cheaper compared to other types of MMCs. Therefore, Al-MMCs are always being the first choice of material selections in industry's applications and attracting growing interest. In various industries, particularly the automotives and aerospace, application of aluminum alloy matrix composites reinforced with phases such as SiC or Al_2O_3 are increasing (S.Skolianos, 1996). It seems that Al-MMCs are in the right path to replace conventional materials such as cast iron in automotive industry especially in the braking system. Current drum and disk brakes are produced from gray cast iron. For instance, Lotus Elise has used Al-MMC as material for braking application while Chevy Corvette used it for automotive driveshaft.

Al-MMCs can be designed and engineered to perform most desirable properties in particular applications. This means that, the properties such as stiffness, density, strength, ductility and thermal properties of this material can be tailored or altered. This can be achieved by diversifying the matrix alloy, types of reinforcement, particle sizes, weight percentages. volume percentage and shapes of the reinforcement. By diversifying these factors, the distribution of the reinforcement material and bonding strength will be affected. Consequently, the mechanical properties such as tensile strength, toughness, hardness, density and wear resistance will also change significantly. Therefore knowledge of relationship and effects between mechanical properties of Al-MMCs and these factors are important to enable us to design desirable Al-MMCs.

There are three types of production methods in producing the Al-MMC. It includes liquid-state processing, solid-state processing and vapor-state processing. Among the variety of choices, stir casting method is the most suitable for large quantity of production. This liquid metallurgy technique is the most economical of all the available routes for MMC production and allows very large sized components to be fabricated (J.Hashim, *et al.*, 1999)

Particulate reinforced aluminium composites can be processed more easily by the liquid state i.e. melt-stirring process (K.M. Shorowordi, *et al.* 2003). Melt stir casting is an attractive process method since its advantages lie in its simplicity, flexibility and inexpensive casting compared to other method such as squeeze casting, spray casting and powder metallurgy. It is also offers a wide selection of materials and processing condition.

New development of aluminium based metal matrix composites with ceramic particles reinforcement for automotive application has a better future research. Although many researches are still done on particulate MMC, the mechanical properties are difficult to be predicted and measured because there are several factors that need to be considered during preparing of Al-MMC by this method. Appropriate testing, evaluation and better understanding on the properties and characteristics of the new developed material will be applied to provide better result and reliable data.

1.2 Backgrounds of the Problem

For the past few decades, conventional materials such as cast iron has played important role in automotive components. Gray cast iron, for instance, is used to produce automotive drum and disk brake, motor cylinders and pistons. The reasons why gray cast iron is more preferred; its low cost, good rigidity, good wear resistance, compressive strength and etc. However, gray cast iron is not a light material. This 'heavy' material will increase the fuel consumption of the vehicle. The market price of the petrol is increase continuously to the highest level in its history. Consequently, more money needs to be allocated for petrol by the car owners.

This study is based on the needs to find an alternative material for brake application material. The alternative material should not only be light weight but also has the properties such as high strength, hardness, toughness and wear resistance. The superior properties offered by particulate reinforced aluminium based MMCs make these materials attractive for automotive and engineering applications (Seah, *et al.* 2003). Al-MMCs specimens with various particle sizes and weight percentage of SiC were tested in order to determine its effect on the mechanical properties and other important characteristics of Al-MMC. By controlling the processing condition as well as the relative amount of the reinforcement material, it is possible to obtain a composite with a broad range of mechanical properties (J. Hashim, *et al.* 1999). Besides from that, the effect of additional reinforcement (copper) also will be determined. This will directly contribute to the performance of Al-MMCs as brake material, because of its tendency to alloy with aluminum and its higher thermal conductivity.

One of the superior characteristics of Al-MMCs is to allow its mechanical properties to be altered. This has established a need for better understanding of relationship between mechanical behavior and various factors such as particles sizes and percentage of weight of reinforcements.

Apart from that, the high production cost in preparing MMCs has also increased the needs to find other techniques which offer lower cost of production. Stir casting method is used in this study because of its low production cost compared to the powder metallurgy technique. The high cost of production process such as powder metallurgy has limited commercial applications of Al-MMCs (Hashim, *et al.*, 1999). It is hoped that this study will be a guideline for future research and applications of Al-MMCs produced via stir casting in other industries especially in automotive applications.

1.3 Statement of the Problem

This experimental study is aimed to find out the answer for the following questions:

(1) Is the newly developed Al-Cu-SiC_p MMC in this experimental study suitable to be an alternative material as disc brake material?

(2) What is the influence of particle sizes of SiC, its weight percentage, pouring temperature and stirring time to the wear, hardness, density and compressive strength of the Al-Cu-SiC_p MMCs?

(3) Which is the most significant factor which will affect the hardness, wear, density and compressive strength of Al-Cu-SiC_p MMCs?

1.4 Objectives Of The Study

The objectives of this research are to determine the significant effect of weight percentage, size of reinforcement particles, pouring temperature and stirring time to the mechanical properties of the newly developed material and to produce the Aluminium alloy based metal matrix composite using silicon carbide (SiC) and copper powder as the reinforcement particles through stir casting method.

1.5 Importance of the Study

As stated earlier, heavier vehicle will increase fuel consumption of the vehicle. Therefore, the usage of materials with reduced weight and higher performance in automotive components such as disc brake is vitally important. Lighter weight will ensure less fuel consumptions for the vehicle. One of the reduced weight materials is Al-MMCs. Al-MMCs' attractive properties include high strength, wear resistance, hardness and low density and so it seems suitable to be an alternative material for brake application.

This study also helps to highlight the usage and capability of stir casting method in preparing Al-MMC. Generally, stir casting method offers the most economical production cost and yields higher metals compared to other methods. Stir casting method also does not damage to the reinforcement. Results from the study will attract more interest of people in using this method in preparing Al-MMCs.

The experiment is conducted using the Taguchi's Robust Parametric Design approach by applying L_9 orthogonal array. Statistical analysis (Pareto-ANOVA) is applied to the results and findings manually. This approach is capable of determining significant factors which affects the properties of Al-MMC and determines the optimum conditions for maximum or minimum objective function.

1.6 Scope Of The Study

(i) Matrix material that used in this experimental study were Aluminium LM6 (A413) while Copper (99.7 % purity, 5 μm) and SiC particles (40, 59 and 106 micron) were used as reinforcement materials. Stir casting was performed by using portable electric furnace complete with stirrer and temperature controller.

(ii) Sand mould was used to produce the specimens according to the testing needs. The testing is done include hardness, wear, compressive strength and density.

(iii) Parameter design approach which applying L_9 orthogonal arrays was used

to design the experiment. Statistical analysis method known as Pareto-ANOVA is used to analyze the data. Effect of noise factors is eliminated by repeating the experiment under each set of conditions.

(iv) The automotive application that will be emphasized in this study is brake disc.