
# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

## INVESTIGATION ON THE EFFECT OF MATRIX VARIATION TO THE MECHANICAL PROPERTIES OF METAL-METAL COMPOSITE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Engineering Materials) with Honours.

by

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FACULTY OF MANUFACTURING ENGINEERING

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**UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

## BORANG PENGESAHAN STATUS TESIS*

**JUDUL: INVESTIGATION ON THE EFFECT OF MATRIX VARIATION TO THE MECHANICAL PROPERTIES OF METAL-METAL COMPOSITE**

**SESI PENGAJIAN: 2/2008-2009**

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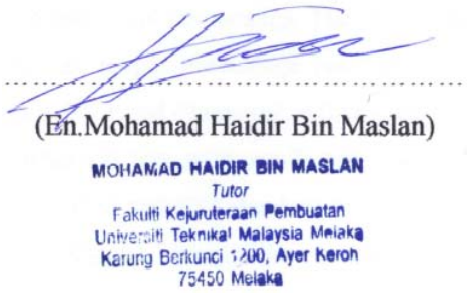
# APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Engineering Materials) with Honours. The member of the supervisory committee is as follow:



# ABSTRACT

Metal-metal composite is a new invention method to produce a material which has significant increases in elastic modulus (stiffness), wear resistance, strength and weight savings. In this study, investigation on effect of different matrix (Aluminium 2024 and Stannum) on the properties of the metal-metal composites is studied. In this project, Aluminium 2024 reinforced low carbon steel and Stannum reinforced low carbon steel were fabricated by using pressureless metal infiltration. This is a new method of liquid state to produce metal-metal composites. The best compounding formulation of composite was found at weight percentage (wt %) with 60 wt% of matrixes material (i.e., Aluminium 2024 and Stannum) with 40 wt% of reinforcement (Low Carbon Steel). The mechanical test such tensile test and charpy impact test were conducted under ASTM D3552 and E23 standard to compare the toughness, tensile strength and modulus of elasticity between the two matrixes (Aluminium 2024 and Stannum). The results showed Aluminium 2024 reinforced low carbon steel composite, shows that improvement in term of mechanical properties (i.e., tensile strength and impact strength) compared to Stannum reinforced low carbon steel. The presence of interphase-interface between matrix and reinforcement were observed under Scanning Electron Microscope (SEM) and Fractography analysis was carried out to study the microstructure characteristics related to the fracture surface materials.

# ABSTRAK

Komposit logam-logam adalah kaedah penemuan baru untuk menghasilkan sesuatu bahan komposit yang berupaya meningkatkan sifat kekakuan, ketahanan kehausan, kekuatan dan mempunyai berat yang ringan. Dalam kajian ini, penyiasatan terhadap matriks yang berbeza iaitu Aluminum 2024 dan Timah ke atas metal-metal komposit telah dipelajari. Dalam projek ini, penghasilan komposit Aluminium 2024 diperkuat keluli berkarbon rendah dan komposit Timah diperkuat keluli berkarbon rendah telah dihasilkan melalui kaedah baru dalam keadaan cecair iaitu *Presureless Infiltration*. Formula sebatian terbaik komposit didapati pada peratusan berat (wt %) dengan 60 wt% matriks (Aluminium dan Timah) dan 40 wt% tetulang (keluli berkarbon rendah). Setelah komposit itu terhasil, ujian mekanikal seperti ujian tegangan dan ujian hentaman dilakukan di bawah ASTM D3552 dan piawaian E23 untuk membandingkan keliatan, kekuatan tegangan dan modulus kekenyalan di antara dua matriks yang berbeza iaitu matriks Aluminium 2024 dan matriks Timah. Seperti yang telah dijangkakan, keputusan menunjukkan bahawa Aluminium 2024 diperkuat keluli berkarbon rendah telah meningkatkan sifat-sifat mekanikal (kekuatan tegangan dan kekuatan hentaman) jauh lebih baik berbanding Timah diperkuat keluli berkarbon rendah. Kewujudan antaramuka-antarafasa di antara matriks dan tetulang diperhatikan dengan menggunakan Mikroskop Pengimbas Elektron (SEM) dan analisis fractografi telah dilakukan untuk mengkaji dan mempelajari karakteristik permukaan spesimen yang telah retak.

# DEDICATION

For all your advice and encouragement, this thesis is gratefully dedicated to my beloved family (Mr. Mohd Arsad Osman and Mrs. Normah Binti Sulaiman) and friends. Thank you very much for their continuous support and effort towards the publication of this thesis.

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# LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

| | | |
|---|---|---|
| % | - | Percent |
| μ | - | Coefficient of friction |
| $^0C$ | - | Degrees Celsius |
| $^0F$ | - | Fahrenheit |
| 150 x | - | 150 times magnification |
| Al | - | Aluminium |
| $Al_2O_3$ | - | Aluminum Oxide |
| AMCs | - | Aluminum matrix composites |
| ASTM | - | American Society for Testing and Materials |
| CFs | - | Carbon fibers |
| CMC | - | Ceramic Matrix Composites |
| Cu | - | Copper |
| *D* | - | Diameter |
| *E* | - | Modulus of Elasticity |
| eg. | - | Example |
| et al. | - | Et alia (and others) |
| etc. | - | Et cetera |
| GPa | - | Giga Pascal |
| HDPE | - | High Density Polyethylene |
| i.e., | - | That is |
| J | - | Joule |
| LDPE | - | Low Density Polyethylene |
| M | - | Mega |
| mm | - | milimeter |
| MMC | - | Metal Matrix Composites |
| MPa | - | Mega Pascal |
| Pa | - | Pascal |

| | | |
|---|---|---|
| PMC | - | Polymer Matrix Composites |
| s | - | Second |
| SEM | - | Scanning Electron Microscopy |
| Sn | - | Stannum |
| UTM | - | Universal Tensile Machine |
| V | - | Volume fraction of component |
| wt% | - | Percent of weight fraction |
| $ZrO_2$ | - | Zirconium Oxide |
| $\sigma$ | - | Tensile Strength |
| $\sigma_f$ | - | Tensile Strength of the Fiber |
| $\sigma_y$ | - | Yield Strength, |
| $\tau_c$ | - | Shear yield Strength of the Matrix |
| $\tau i$ | - | Interfacial shear strength |

# CHAPTER 1

# INTRODUCTION

## 1.1 Research Background

A composite is a combination of two or more material that can be arranged to be reinforcement or matrix. The matrix is a percolating "soft" phase with in a general excellent ductility, formability, and thermal conductivity in which are embedded the "hard" reinforcements (high stiffness and low thermal expansion). The combination forms a useful material to increase the properties of materials. The chemical reaction between reinforcement and matrix form an interface and interphase that separating them insoluble in each other.

Metal matrix composites with aluminum as the matrix material have been heralded as the next great development in advanced aluminum material for at least 20 years. Aluminium metal matrix composites are one of several classes of advanced materials which are expected to play a significant role in the development of future aerospace, automotive and military applications.

Reinforcement that had been used in this investigation was a low carbon steel. When combined with an aluminum matrix, the resulting material has significant increases in elastic modulus (stiffness), wear resistance, strength and fatigue resistance.

Pressureless metal infiltration is a process to produce the composite. By using different matrix of Aluminium 2024 and Stannum reinforced with rod low carbon steel, the mechanical properties of different matrix can be compared to study the material properties. Tensile test, charpy impact test and matrix-reinforcement boundary observations was conducted under ASTM standard to obtain the mechanical properties of this composite material. Besides, the study of the surface between matrix and reinforcement were also facilitated to observe the bonding that developed from physical or chemical interactions, interfacial frictional stress and thermal stresses.

## 1.2 Problem Statements

Nowadays, metal-metal composites has not been paid much attention and used extensively in industry although it has excellent mechanical and thermal properties (Hassan *et al*., 2008). The attractive physical and mechanical properties that can be obtained with this composites, such as high specific modulus, strength, and thermal stability, high impact strength and have been documented extensively. However, there is no detailed information can be found for this metal-metal composite which is used reinforcement and matrix as backbone for building structure. This project will investigate the effect of different matrix (Aluminium 2024 and Stannum) on the properties of the metal-metal composites it is a research developed to study the mechanical properties of Aluminium 2024 and Stannum. These matrixes (Aluminium 2024 and Stannum) will continuously reinforce with low carbon steel in geometry of rod. This reinforcement is embedded into the different matrix (Aluminium 2024 and Stannum) separately and their mechanical properties are compared and analyzed. It emphasizes the study on mechanical behavior of different effect of matrix which is Aluminium 2024 and Stannum in metal matrix composites. This project also using the pressureless metal infiltration which is a liquid state method to produces this metal-metal composite.

## 1.3 Objectives

There are few reasons to accomplish this project, which are:

(a) To investigate the mechanical properties of Aluminium 2024 and Stannum in metal-metal composites.
(b) To compare the mechanical properties effect of different matrix Aluminium 2024 and Stannum reinforced with low carbon steel.

## 1.4 Scope of Study

The emphasis of this report is on the establishment of studies on investigation effect of different matrix (Aluminium 2024 and Stannum) on the properties of the metal-metal composites. The comparison between the two different matrixes was investigated in order to acquire the mechanical properties. Besides, pressureless metal infiltration which is a liquid state method is using to produce this metal-metal composite. The mechanical properties was obtained via tensile test and charpy impact test conducted under ASTM standard to determine the toughness, tensile strength, yield strength and modulus of elasticity. The matrix-reinforcement boundary is observed using SEM (Scanning Electron Microscope) to understand and analyze the interphase-interface between reinforcement and matrix and physical properties. Fractography analysis was carried out to study the microstructure characteristics related to the fractured surface materials.

## 1.5 Research Question

(a) What is the effect of mechanical properties when using different matrix?

(b) Which matrix (Aluminium 2024 or Stannum) will increase the mechanical properties of metal-metal composites?

(c) What will be formed when matrix and reinforcement are insoluble in each other?

## 1.6 Hypotheses

Different uses of matrix material such as Aluminum 2024 and Stannum with the same reinforcement (low carbon steel) will results a different effect behaviors and mechanical properties of a composite material. It was predicted that Aluminium 2024 matrix composites reinforced with low carbon steel will increase the mechanical properties of the metal-metal composites compared to copper matrix composites because Aluminium 2024 is quite attractive due to its low density, its capability to be strengthened by precipitation, its good corrosion resistance, high thermal and electrical conductivity, and its high damping capacity. In addition, processing Aluminium 2024 is more practical for their isotropic mechanical properties (higher than their unreinforced alloys) and their low costs (cheap processing routes and low prices). The chemical reaction between reinforcement and matrix form an interface and interphase that separating them insoluble in each other.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Composites

### 2.1.1 Introduction

The term “composite” broadly refers to a material system that composed of a discrete constituents (the reinforcements) distributed in a continuous phase (the matrix) which derives its distinguishing characteristics from the properties of its constituents, from the geometry and architecture of the constituents, and form the properties of the boundaries (interfaces) between different constituents, as depicted in Figure 2.1. Composite materials are usually classified on the basis of the physical or chemical nature of the matrix phase such as polymer matrix composites (PMC), metal matrix composites (MMC) and ceramic matrix composites (CMC).

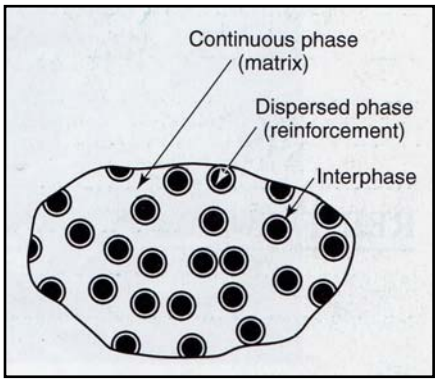


**Figure 2.1:** Formation in composites material (Helsel and Liu, 2001)

### 2.1.2 Composites Properties

Composites consist of two major parts in its constituent which is matrix and reinforcement. According to Matthews and Rawlings, (2002), each of materials (i.e. matrix and reinforcement) must exist of more than 5 wt% to be classified as composites material. The purposed of introduced the composites material is to improve the properties that have been performed by monolithic material. Thus, the composite is expected to improve the mechanical characteristics such as stiffness, toughness, ambient and high-temperature resistance (Callister, 2003).

The final properties of a composite with strengthener in fiber form are determined by fiber content, matrix material, fiber material, fiber orientation, and to a smaller extent by the fiber length and distribution in the composite. The reinforcing effects of the fiber in the composite are best explained by the rule of mixtures. In this rule, the properties of the composite depend directly on the volume fractions of each component in the mixture and the respective properties of the fiber and the matrix.

$$\sigma_c=\sigma_f V_f+\sigma_m V_m \quad \text{and} \quad E_c=E_f V_f+E_m V_m \longrightarrow \text{Rules of Mixtures}$$

Where σ = Strength of the material, V= Volume fraction of component, E=Modulus of elasticity of the material. The subscripts c is for the finished composite, f is for the fiber,