UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Investigation on Mechanical Properties of Stainless Steel 304-Stannum Composite

Thesis submitted in accordance with the partial requirements of the Universiti Teknikal Malaysia Melaka for the Degree of Bachelor of Engineering (Honours) Manufacturing (Material Engineering)

By

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DECLARATION

I hereby, declared this thesis entitled "Investigation on Mechanical Properties of Iron-Stannum Composite" is the results of my own research except as cited in references

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ABSTRACT

The composites material is considered to be any multiphase such that exhibits a significant proportion of the properties of both constituent phases such that a better combination of properties is realized. This report is about the investigation of study on mechanical properties of iron-stannum composite. This composite is fabricated by using pressureless metal infiltration by casting method and this is a new method to produce a metal matrix composites. The composites properties compared with ordinary stannum. The mechanical test such as tensile test and charpy impact test is carried out under ASTM D3552 and E23 standard to determine the mechanical properties of this iron-stannum composite. The SEM machine is used to study the behavior of the composite. The result showed that, the stannum reinforced stainless steel 304 have higher tensile strength and toughness compared to ordinary stannum. The SEM results showed that, there was no interface region between the matrix and reinforcement.

ABSTRAK

Bahan komposit adalah bahan yang terhasil daripada gabungan dua bahan yang berlainan. Laporan ini adalah mengenai penyisatan mengenai ciri – ciri mekanikal pada bahan komposit yang dihasilkan. Komposit tersebut dihasilkan daripada campuran besi dan timah. Ia dilakukan secara proses penuangan dan ini adalah proses yang baru iaitu dilakukan tanpa mengaplikasi tekanan pada proses tersebut. Sifat mekanikal komposit ini akan dibandingkan dengan timah biasa atau asli. Setelah komposit itu terhasil, ujian mekanikal seperti ujian tegang dan ujian hentaman dilakukan untuk membantu penyaisatan mengenai sifat komposit ini. Kesemua ujian akan dilakukan mengikut standard ASTM E 23 dan D3552. Kajian mengenai interface akan dilakukan dengan mengunakan mesin SEM. Setelah kajian dilakukan, didapati bahawa timah-stainless steel 304 mempunyai sifat ketegangan dan kekuatan hentaman yang tinggi berbanding dengan timah biasa. Pada permukaan pula, didapati tiada interface yang terhasil diantara fiber dan matrik.

DEDICATION

to my family

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LIST OF ABBREVIATIONS, SYMBOLS, SPECIALIZED NOMENCLATURE

MMC	-	Metal Matrix Composites
PMC	-	Polymer Matrix Composites
CMC	-	Ceramic Matrix Composite
MA	-	Mechanical Alloying
PVD	-	Physical Vapor Deposition
DDQ	-	Deep Drawing Quality
ASTM	-	American Standard Testing Material
SEM	-	Scanning Electron Microscopy
ASM	-	ASM Handbook
°C	-	Degrees Celsius
G	-	Giga
M	-	Mega
Pa	-	Pascal
MM	-	millimeter
ASTM	-	American Standard Testing Material

CHAPTER 1

INTRODUCTION

1.1 Introduction

Many of our modern technologies require materials with unusual combinations of properties that cannot be met by the conventional metal alloys, ceramics and polymeric materials. This is especially true for materials that are needed for aerospace, underwater and transportation applications. Metal Matrix Composites are characterized of light weight, very high strength and a high stiffness (J.P.Davim, 2006).

Metal Matrix Composites (MMC) has been paid much attention and used extensively in industry over several years due to its excellent mechanical and thermal properties (Dejian Liu, 2007). The attractive physical and mechanical properties that can be obtained with MMC, such as high specific modulus, strength, and thermal stability, have been documented extensively. Interest in MMC for use in the aerospace and automotive industries, and other structural applications, has increased over the past 20 years as a result of the availability of relatively inexpensive reinforcements and the development of various processing routes which result in reproducible microstructure and properties (William D. Callister, 2003). The family of discontinuously reinforced MMCs includes both particulates and whiskers or short fibers. More recently, this class of MMCs has attracted considerable attention as a result of:

(a) Availability of various types of reinforcement at competitive costs,

(b) The successful development of manufacturing processes to produce MMCs with reproducible structure and properties,

(c) The availability of standard or near-standard metal working methods which can be utilized to fabricate these MMCs .

The particulate-reinforced MMCs are of particular interest due to their ease of fabrication, lower costs, and isotropic properties. Traditionally, discontinuously reinforced MMCs have been produced by several processing routes such as powder metallurgy, spray deposition, mechanical alloying (MA) and various casting techniques, i.e. squeeze casting, rheocasting and compocasting.

1.2 Objectives of the Project

There are few reasons to realize this project, which is:

1. To develop a new metal matrix composite base on stainless steel and stannum.
2. To study the new metal matrix composite mechanical properties.
3. To understand the metal matrix composite behavior.

1.3 Scope of Study

The scope of these studies consists of:

1. Produce Stainless Steel 304 -Stannum Composites using new techniques.
2. Conduct a tensile test, impact test and microstructure studies to analysis the new metal matrix composite.

CHAPTER 2

LITERATURE REVIEW

2.1 Composites Materials

When two or more forms of materials are mixed to combine the best properties of each for specific type of applications, a new class of materials is formed which we refer to as composites materials (William F.Smith, 2004). In a strict sense, precipitation-hardened metal alloys may be thought of as intrinsic composites, since they have a metal matrix with dispersed, microscopic, intermetallic compound particles. We have maintained the forming properties of the ductile matrix while adding an additional strength factor from the brittle precipitates. The resultant material has therefore been improved, if the application requires both strength and ductility. There are many attractive properties of composites that make them unique in the material selection process. Thermal expansion can be either very low or tailored for the design. Characteristics such as corrosion resistance, fatigue and fracture behavior, electrical conductivity and transparency, thermal insulation, wear and flexural and torsional stiffness can often be adjusted.

By convention, the reinforcing constituent or dispersed phase, of the composite is macroscopic, compared to the microscopic precipitates of an alloy. However, the concept of improving the final product by summing properties of each constituent (the principle of combined action) is the same. The rule of mixtures defines this relationship foe many properties. As an example of the effect on mechanical properties, the modulus of elasticity of the composite is

$$E_c = f_M E_M + f_R E_R \quad \text{mixture of moduli}$$

Where E_c is the modulus of the composite, $_M$ and $_R$ refer to the matrix and reinforcing constituent, respectively and f is the volume fraction. Likewise, although the bonding of constituent and matrix are major considerations, tensile strength of a composite may sometimes be approximated by

$$\sigma_c = f_M \sigma_M + f_R \sigma_R \quad \text{mixture of strengths}$$

Where σ_M is the tensile strength of the matrix and σ_R is that of the dispersed phase. Physical properties often follow the rule of mixtures, provided the reinforcement is uniformly dispersed, continuous and unidirectional. Example include

$$\rho_c = f_M \rho_M + f_R \rho_R \qquad \text{mixture of densities}$$

$$K_c = f_M K_M + f_R K_R \qquad \text{mixture of thermal conductivities}$$

The summation properties of composites are therefore functions of the properties of both the matrix and dispersed phases and their fractional amounts. Equally important are the shape, size, distribution and orientation of the reinforcing constituent. The most common classifications for composites are based on these factors.

2.2 Characteristics Influence the Properties of Composites

In designing composite material, scientists and engineers have ingeniously combined various metals, ceramics and polymers to produce a new generation of extraordinary materials. Most composites have been created to improve combinations of mechanical characteristics such as stiffness, toughness and ambient and high temperature strength. In designing the composite material, several considerations should be taken in order to have optimum properties result. The properties of the composite are function i.e. properties of the constituent phases, their relative amounts and the geometry of dispersed phase which means the shape of the particles and the particle size, distribution and orientation.

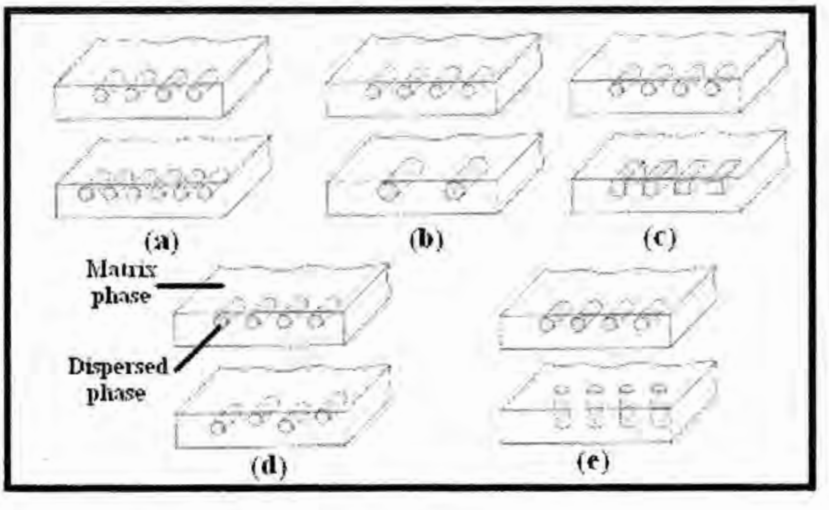

Figure 2.1 : Schematic representations of various geometrical and spatial characteristics of particles of the dispersed phase that may influence the properties of composites: (a) concentration, (b) size, (c) shape, (d) distribution and (e) orientation. [William D.Casllister,Jr, 2003]

2.3 Types of Composites

2.3.1 Metal Matrix Composites (MMC)

Metal matrix composites are the class of advanced materials that are commonly used for aerospace and automotive industries because of their high specific strength (strength-to-density ratio), high specific stiffness (modulus-to-density ratio) and for electronic industry because of their low thermal expansion coefficients and high thermal conductivity (A. Higgins, 1994). The demand for structural materials to be cost effective and also to provide high performance has resulted in continuous attempts being made particularly in areas of alloy design and the use of novel processing techniques to develop composites or hybrid materials as serious competitors to the traditional engineering alloys.

A metal matrix composite (MMC) is a type of composite material with at least two constituent parts, one being a metal. The other material may be a different metal or another material, such as a ceramic or organic compound. When at least three materials are present, it is called a hybrid composite. This composite material has been so intensely researched over the past years that much new high strength to weight has been produced. The matrix for metal matrix composite is a ductile metal. This material may be utilized at higher service temperatures than their base metal counterparts. Furthermore, the reinforcement may improve specific stiffness, specific strength, abrasion resistance, creep resistance, thermal conductivity and dimensional stability. Metal matrix composite is much more expensive than polymer matrix composites (PMC).

The super alloys, as well as alloys of aluminum, magnesium, titanium and copper are employed as matrix materials. The reinforcement may be in the form of particulates, both continuous and discontinuous fibers and whiskers. Continuous fiber materials include carbon, silicon carbide, boron, alumina and the refractory metals. On the other hand, discontinuous reinforcement consists primarily of silicon carbide whiskers, chopped fibers of alumina and carbon and particulates of silicon carbide and alumina. Some matrix reinforcement combinations are highly reactive at elevated temperatures.

Metal matrix composites are more expensive than the more conventional materials they are replacing. As a result, they are found where improved properties and performance can justify the added cost. Today these applications are found most often in aircraft components, space systems and high-end or sports equipment. The applications will certainly increase as manufacturing costs are reduced. In comparison with conventional polymer matrix composites, metal matrix composites are resistant to fire, can operate in wider range of temperatures, do not absorb moisture, have better electrical and thermal conductivity, are resistant to radiation, and do not display out gassing.

2.3.1.1 Properties of Metal Matrix Composites

The matrix is the monolithic material into which the reinforcement is embedded, and is completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. In structural applications, the matrix is usually a lighter metal such as superalloys as well as alloys of aluminum, magnesium or titanium, and provides a compliant support for the reinforcement. These metals are used as the matrix in structural applications as they have low density. In high temperature applications, cobalt and cobalt-nickel alloy matrix are common as they have high service temperatures, creep, wear and abrasion resistance as well as have dimensional stability.

The reinforcement material is embedded into the matrix. The reinforcement does not always serve a purely structural task (reinforcing the compound), but is also used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity. The reinforcement can be either continuous, or discontinuous.

Discontinuous MMCs can be isotropic, and can be worked with standard metalworking techniques, such as extrusion, forging or rolling. In addition, they may be machined using conventional techniques, but commonly would need the use of polycrystaline diamond tooling (PCD). Discontinuous reinforcement uses "whiskers", short fibers, or particles. The most common reinforcing materials in this category are alumina and silicon carbide. Particle-reinforced metals provide very good specific strength and stiffness, isotropic properties, ease of manufacturing to near net shape, excellent thermal and electrical properties and affordability. Example of particle-reinforced MMC is aluminium reinforced with silicone carbide particles.

Continuous reinforcement uses monofilament wires or fibers such as carbon fiber or silicon carbide. Because the fibers are embedded into the matrix in a certain direction, the result is an anisotropic structure in which the alignment of the material affects its strength. They are stronger and stiffer in the direction of the fibers than perpendicular to them. The transverse strength and stiffness of unidirectional MMCs (materials having all fibers oriented parallel to one axis), however, are frequently great enough for use in components such as stiffeners and struts. This is one of the major advantages of MMCs over PMCs, which can rarely be used without transverse reinforcement. One of the first MMCs used boron filament as reinforcement. The discovery of borsic, silicone carbide coated with boron fibers which combines the properties of both materials has lead to the production of MMC with superior properties. Example of this MMC is titanium reinforced with borsic fibers.

Silicone carbide is the most common used reinforcement nowadays. The high thermal conductivity coupled with low thermal expansion and high strength gives this material exceptional thermal shock resistant qualities. Silicone carbide is able to maintain its strength to very high temperatures approaching 1600 °C with no strength loss. Besides that, chemical purity, resistance to chemical attack at various temperature and strength retention at high temperatures has made this material suitable as reinforcement in MMC.

2.3.1.2 Metal Matrix Composites Processing

Metal Matrix composite materials can be produced by many different techniques. The focus of the selection of suitable process engineering is the desired kind, quantity and distribution of the reinforcement components (particles and fibers), the matrix alloy and the application (Karl U.Kainer, 2006). By altering the manufacturing method, the processing and the finishing, as well as by the form of the reinforcement components it is possible to obtain different characteristic profiles, although the same composition and amounts of the components are involved. The production of a suitable precursor material, the processing to a construction unit or a semi-finished material and the finishing treatment must be separated. The individual composite productions operations are briefly outlined below under these groupings. There are 4 types of process to produce Metal Matrix Composite and that is:

1. Liquid state processing
2. Solid state processing
3. Deposition processing
4. In –situ processing

2.3.1.3 Liquid State Processing

(a) Stir Casting

This involves stirring the melt with solid ceramic particles and then allowing the mixture to solidify. This can usually be done using fairly conventional processing equipment and