CHAPTER – 1

CHAPTER – 1: INTRODUCTION

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1. INTRODUCTION

1.0 Introduction

Metal Matrix Composites (MMCs) are generally combination of two or more metals, stronger than monolithic materials, and designed for specific applications, with least negative properties. MMCs have enhanced specific strength and specific modulus at high temperature with low thermal conductivity [1].

MMCs can be modified for the required properties and have better properties as compared to monolithic alloys. Hence most of the researchers focus on MMCs, to fulfil the required demand from various sectors. In this direction, the researchers have developed different types of composites, which are made available in the market.

Advanced MMCs, especially Aluminium (Al) MMCs are developed in various industrial sectors to a larger extent [2]. The outstanding benefit of MMCs is that they can be altered to result in variety of strength and properties of MMCs [3-5]. These advanced materials can be modified to various applications with respect to their requirements. One of the advantages is selection of reinforcement as per requirement for end applications.

1.1 Definition of the composite

In modern material science, composite means a combination of heterogeneous materials with two or more physically separable constituents. The two phases i.e, matrix material and reinforcement
material can be physically and chemically identified in the composite. Matrix material is the binding material and reinforcement is the load bearing material [6-10].

Jeritz A.E [11] explained that composites have mainly metal alloying with one or more heterogeneous materials as reinforcement or filler materials. The binding between matrix and reinforcement occur during solidification or thermo physical processing [12]. Van Suchetelen et. al, [13] stated that two or more different homogeneous phases bind together at a microscopic scale. After processing, this material had improved mechanical properties, thermal properties etc., and hence the studies are highly interesting in the field of materials science [14].

1.2 Types Of Composites

Based on the type of reinforcement material, composites are classified as :

- Particulate-reinforced composites
- Fibre-reinforced composites
- Whisker-reinforced composites.

1.2.1 Particulate-Reinforced MMCs

Ceramic particulate-reinforced MMCs microstructure shows two distinct phases, ceramic phase(first phase) dispersed in the matrix phase with clear definite boundaries and the matrix alloy(second phase). The ceramic phase can be found in the matrix phase like an island i.e with no
significant length dimensions (almost spherical). The ceramic particulate size ranges from nano metres to few microns and their area varies from 5 to 25 % in the matrix alloy.

The dissimilar properties between two phases cause dislocations in the composites phase, which requires higher strength to break the interface phase. The hydrostatic force between the particulate and matrix alloy improves the hardness of the composites [15-16].

Addition of hard particles to matrix alloy results in remarkable enhancement of properties compared to their control phase. The selection of particulates is a crucial stage in the design of composites, which gives required strength and selection of application. The particulate enhances tensile properties considerably together with reduction of ductility and toughness.

Particulate based MMCs can be fabricated by various techniques such as stirring, compocasting, powder metallurgy, spray technique and even by electro-chemical methods. Only stirring method does not allow reaction between the particulate and matrix alloy due to minimum reaction time between liquid and solidification time. The faster solidification also avoids agglomeration among reinforcements and even segregation by gravity. These two problems can be tackled by selecting low melting temperature matrix alloy, high temperature coated reinforcements and with rapid solidification [17].
1.2.2 Fibre-Reinforced MMCs

In long fibre reinforced MMCs, fibre orientation is one of the factors which decides the mechanical strength of MMCs. Fibre based MMCs are produced in wide range of products in the industries. Mainly, the long fibre reinforced composites are fabricated using the filament winding method. In this process, long fibres are wound around the cylindrical structures with prescribed orientation along with matrix alloy. These materials find application mainly in space and aerospace where least density materials are required since they offer good stability at elevated temperatures upto 400°C. Many researchers studied the Al fibre reinforced composites at elevated temperatures with higher stability. The fibre breakage occurs due to the interaction with other fibres and the lack of matrix rigidity at the temperatures around its melting temperature.

1.2.3 Whisker-Reinforced MMCs

Whiskers are short, single crystals with almost no defects. They are discontinuous fibres that can be made from variety of materials. Ceramic whiskers have low densities, high moduli, good strength, resistance to heat, mechanical damage, high specific strength and high specific modulus which make them suitable for structures requiring reduced weight. The whiskers are incorporated into the composites with various techniques like powder metallurgy and slip-casting techniques to produce metal/whisker systems. Whisker incorporation in a metal
produces superior product, which will provide strength at elevated temperatures, but their finer sizes pose problem in handling and fabrication into fibre composites. Schuller and Wawner [18] have reported that the strength of hot rolled composites decreased with addition of whiskers due to rolling and successive heat treatments.

Experiments by Nieh and Chellman [19] pertaining to hot rolling on extruded whisker reinforced Al alloys showed homogeneous distribution of whisker and improved strain-to-fracture without significantly affecting the strength properties.

1.3 Motivation

The materials for microelectronic packaging applications such as electronic panels, thermal sinks, have stringent thermal and reliability requirements. Traditional metals for electronic packaging applications include Copper, Aluminium, Ni-Fe alloys and Cu-W, Cu-Mo blends. However, the higher value of co-efficient of thermal expansion (CTE) of these materials can produce thermal stresses which reduce the package reliability.

The co-efficient of thermal expansion of composites can be modified by varying the nature, volume fraction and morphology of the reinforcements in the composites. But, along with the co-efficient of thermal expansion, thermal conductivity also decreases in the composites. It causes thermal accumulation in the electronic panels
(decreases the thermal performance of thermal sink), which reduces the reliability of electronic instruments.

The present investigation will be focused on metal matrix composites to improve the mechanical and thermal properties by adding SiC particulates for electronic applications.

1.4 Objectives

Many applications of Aluminium MMCs require controlled thermal expansion characteristics in order to match with other components. Low CTE and high thermal conductivity are desirable for applications such as for electronic heat sinks and space structures. Furthermore, low density is desirable for aerospace and electrical structure applications. With these considerations, SiC particulate reinforced-aluminium matrix composites are potential MMCs for variety of uses in advanced electronic packaging.

The specific objectives and scope of the proposed investigations are:

1. To experimentally demonstrate the feasibility of dispersing SiC particles of size 50-80 microns in aluminium alloy melt above the liquidus temperature by using liquid metallurgy technique.

2. To evaluate the mechanical properties of the prepared composites in terms of ultimate tensile strength, ductility and hardness.
3. To evaluate the thermal properties such as co-efficient of thermal expansion and thermal conductivity of the composites and thus to observe the effect of SiC reinforcement on the properties of Al alloy.

1.5 Research Methodology

Research Methodology adopted in the present work is given in Fig. 1.1

Fig. 1.1 Flowchart of Research Methodology
1.6 Scope of Research Work

The scope of present investigation includes:

1) Preparation of composites with five different weight percentage of reinforcement viz 0, 5, 10, 15 and 20 % wt.

2) Investigating the effect of SiC on the ageing behaviour of Al 6061 MMCs.

3) Investigation using Taguchi’s method and ANOVA tests on the effect of SiC and ageing duration on mechanical properties.

4) Investigation of wear load and sliding distance effect on mild wear transition in dry sliding using Taguchi technique.

5) Determination of the thermal properties using Taguchi’s technique.

The requirements of aviation industry for reinforcement include high specific strength, high young’s modulus, the small thermal expansion co-efficient, high temperature resistance and high conductivity of the strengthened light alloys. For example: axle tubes, rotors, housing covers and structures for electronic devices. A compilation of potential and realized applications shows that only, MMCs can be substitute for them. This research work focused on selection of materials for fabrication of MMCs, characterisation of mechanical wear, corrosion, thermal properties and sea water degradation of Al/SiC composites as per ASTM standards.
1.6.1 Limitations

One of the limitations of the developed composites is that they are being more brittle than wrought metals and thus more easily damaged. Another disadvantage of MMCs is that they offer increased performance but at increased cost. The benefit must always be balanced with the related costs. However, there may be a misconception here, i.e., if an aluminium based MMC is offered against a conventional aluminium component, then a major increase in its performance is vital. MMC component design must also take into account the cost effective processing techniques.

1.7 Expected Results

The reinforcement of light metals opens up the possibility of application of these materials in areas where weight reduction is the top priority. The pre-condition here is improvement of the component properties. The expected results for light metal composite materials are:

- Increase in yield strength and tensile strength at room temperature and above while maintaining the minimum ductility or rather toughness
- Increase in Young’s modulus
- Improvement of corrosion resistance,
- Reduction of thermal elongation
- Increase in strength of conducting materials while maintaining high conductivity
Reduction in wear rate

Reduction of sea water degradation properties

1.8 Organization of thesis

Chapter One explains about introduction to MMC, Definition of composite, types of composites, Motivation, Objectives, Scope for the present investigation, expected results and conclusion. The chapter discusses about metal matrix composites, basic definition of composites defined by other researchers and motivation for selecting the problem followed by research methodology adopted in this research. Limitations of the present work, expected results and conclusions are discussed.

Chapter Two deals with theoretical background and literature survey related to MMCs. This chapter discusses about mechanical properties, corrosion and tribological behaviour of MMCs reported by other researchers. Analytical models of prediction of strength of composites are discussed.

Chapter Three describes formulation of the present research problem involving the measurement of some important physical, mechanical, corrosion, sea water degradability, thermal conductivity and tribological properties.

Chapter Four presents experimental studies of composites preparation and their characterization. Mechanical properties, wear properties, thermal properties, corrosion, sea water degradation and
fracture studies are discussed.

**Chapter Five** details the statistical model for mechanical properties, thermal properties, wear and corrosion resistance. The results are tabulated for various tests performed.

**Chapter Six** deals with results and discussion of mechanical behaviour, wear transition mechanism, corrosion rate, sea water degradation, thermal expansion, thermal conductivity and fracture studies of MMCs.

**Chapter Seven** presents conclusions and scope for future work. The results obtained by the effect of SiC and ageing on mechanical, thermal, wear, sea water degradation and corrosion rate are discussed. It also presents scope for future research in this field.