PREFACE

INTRODUCTION

Conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the ever increasing demand of modern day technology, composites are the most promising materials of recent interest.

Metal matrix composites (MMCs) constitute an important class of design and weight-efficient structural materials that encourage every sphere of engineering applications. It generally consists of metal matrix and a ceramic reinforcement in various forms such as whiskers, particulates or fibres. Among all the available types of composite materials, particle reinforced composites are the most promising ones owing to their isotropic material properties and low cost. They can be tailored to have superior properties such as high specific strength and stiffness, increased wear resistance, enhanced high temperature, performance better thermal and mechanical fatigue and creep resistance than those of monolithic alloys. Use of metallic coated reinforcements during processing of MMCs became popular due to several advantages that can be achieved, such as excellent bond between matrix and reinforcement, better wettability of reinforcement in molten metal etc.

Current research of MMCs are focused on development of Aluminium, Copper, Magnesium, Titanium based metal matrix composites and have been exploring their possible applications in several high-tech areas.

In recent years, aluminium alloy based metal matrix composites are gaining wide spread acceptance in several interesting applications in the field of automobiles, aerospace, marine, sports, etc. owing to their excellent wear resistance in addition to superior mechanical properties such as strength, modulus and hardness when compared with conventional alloys. Of all the available aluminum alloys, 6000 series are quite popular choice as a matrix material owing to their numerous benefits including medium strength, better formability characteristics and superior corrosion resistance. Further, it is well known that aluminum 6000 series alloys are heat treatable.
In recent years, the secondary processing of composites have been gaining impetus as these processes such as extrusion, rolling and forging have profound impact on improvement in mechanical properties, wear and corrosion resistance of the primarily processed composites.

Although abundant literature is available on primary processing and characterization of the composites, no published information is available as regards the secondary process, in particular the hot forging. Further, it is well known that among many secondary processes available hot forging process ensures the best mechanical properties. This is why forgings are almost always used where only the best, reproducible, statistically guaranteed and repeatable performances are required always. Some typical examples are aeronaautical parts, components for military application, automotive and other high demanding parts with high safety demands. The presence of hard ceramics reinforcement in the matrix alloy introduces significant amount of brittleness in to the composites, although drastic improvement in the strength is noticed. This factor poses a challenge to engineers and technocrats as regards the forging of metal matrix composites.

The various reinforcements that have been tried out to develop the metal matrix composites are graphite, silicon carbide, titanium carbide, tungsten, boron, Al₂O₃, fly ash, Zr, Si₃N₄, TiB₂, etc. TiO₂ which is very hard and possess low density, high fracture toughness and excellent strength exhibits excellent wear resistance and antifrictional properties, has not gained much importance as a reinforcement in aluminium alloys.

Further, meagre information is available in the literature as regards the mechanical, tribological and corrosion properties of metallic coated TiO₂ reinforced aluminium based composites subjected to hot forging.

In the light of the above, the present investigation deals with development and characterization of hot forged Al6061-TiO₂ composites.

METHODOLOGY

Al6061-TiO₂ composites were prepared by liquid metallurgy route. TiO₂ particles are nickel coated using electroleless coating technique prior to addition in to the molten metal to improve its wettability and to avoid possible reaction between matrix material
and reinforcement. Percentage of TiO$_2$ particles in Al6061 matrix alloy was varied from 2-8wt% in steps of 2wt%. Cast Al6061 alloy and Al6061-TiO$_2$ composites were hot forged at a temperature of 500°C. After forging, both Al6061 alloy and Al6061-TiO$_2$ composites were subjected to heat treatment by solutionizing at a temperature of 530°C for 2 hours followed by rapid quenching in ice media. Both natural and artificial ageing was adapted after quenching. Artificial ageing was carried out at a temperature of 175°C for different ageing duration ranging from 2 to 8 hrs in steps of 2 hrs.

Both Al6061 alloy and Al6061-TiO$_2$ composites are subjected to microstructural studies (Optical and scanning electron microscopy), grain size analysis, microhardness test, tensile test, compression test, friction and wear studies, dry sand abrasion test, and corrosion studies in 3.5% NaCl solution. All these tests were performed in both as forged and heat treated conditions. Further, SEM studies were also carried out on fractured surfaces, worn surfaces and corroded surfaces of the forged alloy and its composites before and after heat treatment.

**RESULTS AND DISCUSSION**

Micro structural studies of forged Al6061-TiO$_2$ composites (both optical and SEM) has clearly revealed a fairly uniform distribution of reinforcement particles throughout the matrix alloy. An excellent bond between matrix and reinforcement particles has been observed.

It is observed that the microhardness of hot forged Al6061-TiO$_2$ composites increases with increase in weight percent of TiO$_2$ in the matrix alloy. On heat treatment, for a given content of TiO$_2$ after quenching in ice, results in maximum hardness of the composites. Also, it is observed that increase in ageing time increases the hardness of both matrix and composites studied. Of all the heat treated studied, 6hrs heat treated specimen exhibits maximum hardness.

Compressive and tensile strength tests results have revealed that compressive strength and tensile strength of hot forged Al6061-TiO$_2$ composite increases with increase in content of TiO$_2$ particles in matrix material. Further, Ductility of the hot forged composites decreases with increased content of reinforcement in the matrix alloy.
in both as forged and heat treated conditions. However, heat treatment has resulted in improved ductility when compared with as forged composites.

Co-efficient of friction of hot forged composites reduces with increase in content of TiO₂ in both as forged and heat treated conditions. A marginal increase in co-efficient of friction has been observed with increase in sliding distances for both matrix alloy and composite systems.

An increase in load leads to drastic reduction in co-efficient of friction for both heat treated and un-heat treated hot forged composites. At all the loads studied, composites exhibit lower co-efficient of friction when compared with matrix alloy. It is also observed that co-efficient of friction of both matrix alloy and its composites decreases with increase in ageing duration. Of all the ageing duration studied 6hrs heat treated composites showed improved results.

Adhesive wear studies on hot forged composites have revealed that wear rate decreases with increase in content of TiO₂ particulates in the matrix alloy. It is observed that wear rate decreases with the increase in sliding distance. Further, it is also observed that wear rate increases with increase in load. For all the loads studied, wear rate is lower for composites when compared with matrix alloy. Further, an increase in ageing time resulted in decrease in wear rate for both the forged matrix alloy and the studied forged composites. The reduction in wear rate is significant up to an ageing duration of 6 hours beyond which there is a marginal decrease in wear rate of both the matrix alloy and the studied composites.

Dry sand abrasive wear studies have revealed that increased content of reinforcement enhances the abrasive wear resistance of the hot forged composite. Heat treatment has a beneficial effect on abrasive wear resistance of matrix alloy and it’s composite. An ageing duration of 6hrs has resulted in lowering the abrasive wear loss for both the matrix alloy and its forged composites.

The studied forged composite system possesses inferior corrosion resistance in 3.5%NaCl medium when compared with the matrix alloy. However, heat treatment has improved the corrosion resistance of forged composites in 3.5%NaCl.
CONCLUSION

Forged Al6061-TiO₂ composites possess higher hardness, ultimate tensile strength, compressive strength, improved adhesive and dry sand abrasion resistance, lower co-efficient of friction and inferior corrosion resistance when compared with forged Al6061 matrix composites.

THESIS

The thesis is divided into seven chapters.

CHAPTER ONE- INTRODUCTION presents the composite material, Metal matrix composites, Aluminium matrix composites, application, their advantages over other materials, physical and mechanical properties, as a rationale behind the selection of material system for the research.

CHAPTER TWO- SURVEY OF LITERATURE presents the available scanty literature on metal matrix composites and latest development. It is the purpose of this chapter to describe the present position of the metal matrix composites and to indicate where and why they are being used to advantage based on the open literature. Methods of fabrication, heat treatment procedure. Enormous literature has been collected and presented in this chapter related to aluminium matrix composites.

CHAPTER THREE- SCOPE OF PRESENT INVESTIGATION profiles the scope of the present research in the context of advances in material technology.

CHAPTER FOUR- EXPERIMENTAL DETAILS: This chapter of the thesis deals with material selection, pre casting procedure, preparation of particulate reinforced composite, post casting procedure (hot forging) specimen preparation for various tests, microscopy and scanning electron microscopy.

CHAPTER FIVE- RESULTS AND DISCUSSIONS: The chapter presents the results and discussion of various tests conducted and effect of different parameters on mechanical and tribological characteristics of the composite.

CHAPTER SIX AND SEVEN- CONCLUSION AND FURTHER STUDIES presents the conclusion on the research studies undertaken on the topic. Scope for extending the research on the topic is also included.