PREFACE

In recent time, lightweight structural materials are becoming popular in all fields of engineering applications. Because of safety measure, the weight of a vehicle increases tremendously in the 21st century resulting in increased fuel consumption. In order to decrease fuel consumption, there is enormous pressure on the design engineer to search and develop new lightweight materials. The traditionally lightweight materials are magnesium, aluminum, and titanium due to their capability of reducing the weight of component and devices, which was earlier made from the steel based material. Magnesium alloy is one of the lightest structural material, which is capable of replacing steel, aluminum alloy and some plastic-based materials due to its excellent thermal conductivity. The use of magnesium alloy can also reduce CO_2 emission by saving fuel in automobile and aerospace industries, which is the current demand for environmental legislation. The density of lightweight magnesium is lowest among all structural materials, and it is 1.74 g/cc. The magnesium is one third lighter than aluminum, three forth lighter than zinc and four fifth lighter than steels. Initially, magnesium was not the materials of choice for design engineers due to its high cost until about two and a half-decade back. Now scientists, researchers, and engineers are showing interest in magnesium-based materials primarily because of its gradually decreasing cost and the decreased energy consumption along with less greenhouse gas emissions. However, magnesium in pure form has limited application in structural application due to its prone behavior to atmospheric oxygen. Magnesium when used with aluminum as an alloying element, the resulting alloy improves the machinability and corrosion resistant. Magnesium is an excellent material for a lightweight structural application not only because of its low mass density, but it also renders a high specific strength and stiffness.

Apart from density magnesium possesses high damping capacity, good dimensional stability, high stiffness, excellent machinability, excellent casting properties, and good high temperature creep properties. There are several magnesium alloy systems such as Mg-Al, Mg-Al-Zn, Mg-Zn, Mg-Mn, Mg-Zr, Mg-RE, and Mg-Th systems. Among these Mg-Al-Zn (AZ) systems are widely used in the industrial application due to its convenient in fabrication and availability. AZ91 is one of the most commonly used magnesium alloys in which aluminum mainly improve strength, hardness, and castability. Zinc is added to increase corrosion resistance and strength without reducing ductility. AZ91 is extensively used in applications such as in automobile, aerospace transportation industries and other portable equipment.

Conventional alloying practices in case of magnesium alloy have not been enough to fulfill the national demands of high strength lightweight materials. The development of composite materials especially metal matrix composite (MMC) has been one of the major innovations in the manufacturing industry over the past three decades. The particulate reinforced metal matrix composite has got a wide range of application in automotive and aerospace applications by judiciously selecting different types (ceramics, metallic and carbon), size (micron, submicron and nano) and amount (0.5% to 30% depending on the size) of reinforcements. The objective of adding reinforcement is to improve the mechanical properties along with wear resistance and creep resistance. The properties of the MMCs can be tailored to meet the requirement of the end application. Various factors (type, size, amount, distribution and processing techniques) are involved in deciding the properties and their optimization for desire combination of properties in case of MMCs.

To address some of these issues, silicon carbide (SiC) and titanium carbide (TiC) particulates reinforced magnesium alloy composite were identified for the current study.

The magnesium alloy AZ91 has been selected as a metal matrix in this study. The primary objective of current research work "Casting and characterization of magnesium alloy metal matrix composites" is divided into three folds.

1. To develop the concepts of processing magnesium alloy through stir casting technology with special attention of uniform mixing of the reinforcements.
2. Evaluation of microstructure, mechanical properties and sliding wear behavior of SiC particulates reinforced AZ91 metal matrix composites developed through vacuum assisted inert atmosphere (VAIA) stir casting process.
3. Evaluation of microstructure, mechanical properties and sliding wear behavior of TiC particulates reinforced AZ91 metal matrix composites developed through VAIA stir casting process.

The entire thesis has been organized into seven chapters

Chapter 1 presents the introductory background of magnesium alloy, the scope of the current work and objective of the work. The chapter also highlighted the potential use of magnesium alloy based metal matrix composite for the application in automotive industries as an alternative of steel, aluminum alloy, including some plastic-based materials.

The introductory review of magnesium, magnesium alloy and its application in the different field of engineering and technology especially in automobile and aerospace applications has been reported in **Chapter 2**. The chapter discussed different series of magnesium alloy and the effect of alloying elements on its behaviors. It also includes the different processing technique for the magnesium alloy and its composites. This chapter also discussed different melt protection techniques to avoid oxidation of molten magnesium. The criteria for the selection of matrix materials and the reinforcements have also been done in this chapter. Further, this chapter demonstrates mechanical and dry sliding wear behaviors of the magnesium alloy and composites evaluated by different researchers. The motivations for present work based on the literature review are presented in the last section.

Chapter 3 deals with the detail experimental procedure, materials preparation, and its characterization and testing procedures used in this research work. The prepared composite is characterized by different characterization technique such as optical microscopy, scanning electron microscopy, and X-ray diffraction techniques. The mechanical properties such as Vickers microhardness, tensile test, and compression test are performed for the fabricated composites along with matrix material. Finally, Pin on disk, dry sliding wear behaviors have been evaluated for all the fabricated composites in this study.

Conceptual design and development of two different types of stir casting set-up have been discussed in **Chapter 4**. Magnesium alloy based composites are initially tried to prepare by a stir casting process which was developed by the authors in Production Engineering Lab of IIT (BHU), Varanasi and further improvement were made by using a vacuum-assisted inert atmosphere (VAIA) stir casting process. The VAIA stir casting process was developed with the technical support of V.B. Ceramics Consultants, Chennai that was financially supported by WB- TEQIP-II. The chapter also discusses the different method of addition of reinforcement in the magnesium alloy for the uniform distribution of reinforced particles into the matrix materials.

The synthesis and characterization of SiC particulates reinforced AZ91 metal matrix composite is discussed in **Chapter 5.** The optical microstructure reveals that the alloy grain has been refined on the addition of SiC_p (size 40 μm). The scanning electron micrograph shows the fairly uniform distribution of the reinforcement in the alloy matrix. In the XRD analysis of the magnesium alloy and its composites, the various peaks are identified as α-phase Mg, β-phase $Mg_{17}Al_{12}$ and few peaks of SiC reinforcements. The Vickers microhardness values for the composites are showing a higher value than the matrix alloy due to the presence of a hard particle in the matrix. The ultimate tensile strength and yield strength of the composite are increases with an increase in the percentage of SiC_p reinforcement. The sliding wear resistant of the composite is improved in comparison to monolithic alloy under the given load and velocity. The hardness value is increased by 78% on addition of 12% SiC particulates. The ultimate tensile strength and yield strength also increases by 72% and 71 % respectively with an increase in the percentage of reinforcements from 3% to 12%. The tensile and compressive factograph of the tested sample is examined using a scanning electron microscope along with worn surfaces in wear test.

Chapter 6 reports on the synthesis and characterization of TiC particulate reinforced magnesium alloy metal matrix composite. The optical microstructure of the composite shows the refinement in the grain on the addition of TiC_p (size 20 μm). The accumulation of reinforcement is observed in some places of the fabricated composites with the help of scanning electron microscope. In the XRD analysis has been performed for the magnesium alloy and its composites, reinforced with TiC particulates. The various peaks are identified as α-phase Mg, β-phase $Mg_{17}Al_{12}$ only, the TiC phase is not recognized in this case. The Vickers microhardness values, the ultimate tensile strength of the composites showed a similar trend as discussed in Chapter 5. The sliding wear resistant of the TiC particulate composites is found to be lower than SiC particulate composite under the given load and velocity. A 75 % improvement in microhardness is observed on addition of 12% TiC particulates as reinforcement.

Similarly, the ultimate tensile strength and yield strength also increases by approximately 21% and 18 % respectively with an increase in the percentage of reinforcements from 3% to 12%. The factograph by scanning electron microscope of tensile fracture and compressive fracture are examined and discussed. The different wear mechanisms based on normal load and sliding velocity are also discussed.

Chapter 7 presents a summary of the conclusions arising from the present investigation along with suggestions for future work.