CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

High strength and lightweight materials are essential requirement in transportation, automotive and aerospace applications. Automotive industry faces challenges in improving the efficiency and performance of engines due to stringent emission regulations[1, 2]. Therefore, aluminum metal matrix composites are most commonly utilized in manufacturing engineering components in the automobile and aerospace industries because of their high strength-to-weight ratio, excellent wear resistance, good electrical and thermal properties, etc. [1, 3]. Materials with superior tribological and thermal properties are preferred for engine block, cylinder head, cylinder blocks, cylinder liners, pistons, clutch and brake systems, connecting rods etc.[4–9]

Aluminium metal matrix composite (AMCs) can be produced employing various methods such as liquid casting like stir casting, squeeze casting, liquid infiltration, solid-state techniques like powder metallurgy, friction stir processing and semisolid methods such as ultrasonic vibration, magneto-hydrodynamic stirring, cooling slope (CS) casting etc. [10–17]. Among these methods, stir casting is simple and economical method to fabricate AMCs[16]. The CS casting technique is an effective semisolid method for producing billets having nondendritic and spherical microstructures. It has significant advantages over other approaches, such as ease of setup and operation [18]. The shear force exerted on the moving semisolid slurry on the cooling plate induces dendritic arm fragmentation during the cooling slope process. Reinforcing elements can be added into the matrix by exsitu or insitu methods.

In exsitu method, externally synthesized reinforcements are added to molten matrix. Major drawbacks of exsitu methods are poor wetting properties, particle agglomeration, thermal instability, poor bonding, and casting defects. To overcome these drawbacks insitu technique is extensively used by researchers in which reinforcements are synthesized with in the melt and that leads to various advantages such as good particle wetting, clean interface, better bonding with the matrix, thermodynamically stable phases and even distribution of particles in the matrix[19, 20]. Along with monolithic composites, hybrid composites are being developed in which two or more reinforcement phases are used to meet specific properties.

Hybrid composites are second generation of composites in which two or more phases are reinforced into the matrix. Hybrid composites enable more flexibility and reliability for engineering parts because their properties can be readily modified by selecting appropriate combination and composition of reinforcing particles. Hybrid composites offer better properties than single reinforced composites because they incorporate the benefits of more than one reinforcement particle [21, 22]. Recent investigations indicate that the mechanical and wear behaviour of hybrid composites are better than mono reinforced composite [23]. Due to improved wear resistant properties with high thermal conductivity of aluminium hybrid composites can be potential material for tribological applications in automotive components [6].

The tribological behaviour of composites are influenced by surface characteristics, loading condition, medium of working, sliding velocity and distance, and other factors. When tribological characteristics are crucial criteria, high functional load, sliding velocity and distance induce significant wear leading to component failures in automobiles [24–26]. It is crucial to accurately anticipate the wear parameters in order to prevent catastrophic and expensive loss. The outcome of the study offers many statistical modelling methods for determining optimal wear parameters. Statistical modelling methods aid in shortening the iterative process by optimising parameters with minimal tests [27]. To optimise tribological characteristics for MMCs, several researches used statistical modelling methods such as Design of Experiment (DoE), Taguchi, factorial design, Response surface methodology, Artificial Neural network (ANN), etc.[28–34]. Response surface methodology (RSM) is a multivariate approach for optimizing factors for most effective material performance. It works by fitting a polynomial equation to statistical data [35, 36]. Ponugoti et al. [37] analysed the wear behaviour of an Al-based hybrid composite using RSM and multi-objective optimisation and optimised the factors that determine wear properties.

Various researchers have fabricated insitu Mg_2Si/Al metal matrix composite. Reinforcement Mg_2Si can be easily produced by adding extra Mg in the A356 matrix alloy. The insitu produced intermetallic Mg_2Si has excellent characteristics such as high melting point (1085°C), low density (1.99×10^{-3} kgm^{-3}), low coefficient of thermal expansion (7.5×10^{-6} K^{-1}) high hardness (4.5×10^{9} Nm^{-2}) and relatively high modulus (120 GPa) [38, 39]. However, coarse primary Mg_2Si particle with sharp edges act as stress raiser and pseudo-eutectic Mg_2Si phase having flake-like morphology and nonuniform distribution in Al-Mg_2Si composite leading to poor mechanical properties [40]. Thus, it is critical to transform coarse Mg_2Si particle and flake-like eutectic Mg_2Si phase morphologies to improve mechanical and tribological behaviour of composite [41]. Morphological transformation and refinement of Mg_2Si phase may be accomplished using alloying element such as Mn, Zn, Ni, Li, Sr, Bi, Ca, Sb, Be, Ce and TiB_2, either by heat treatment processes or semisolid processing [42–46]. Among these, the addition of TiB_2 particles is the most viable technique to transform the Mg_2Si phase since it refines the Mg_2Si phase morphology while simultaneously acting as reinforcement [47]. The

TiB_2 particles offer outstanding reinforcing properties such as high melting point, low coefficient of thermal expansion, high hardness, high strength and modulus, and high wear resistance [48]. However, producing in-situ TiB_2 volume percents greater than 5% through the salt metal reaction technique is difficult [49].

1.2 SCOPE OF PRESENT INVESTIGATION

Presently Al alloys are utilised in manufacturing of automotive component because of its castability, high strength to weight ratio and excellent thermal conductivity. Since Al alloys are lacking in wear resistance properties, various secondary processing and cast-iron liners are used in cylindrical blocks to have adequate properties that may have different thermal expansion coefficients leading to distortion and raising engine weight. Therefore, Al based hybrid composites can be the potential alternative for tribological application in engine component.

The Mg_2Si and TiB_2 phases as reinforcements in aluminum alloy matrix has several lucrative properties, and can be a potent material for tribological application in automotive industry. Very few studies on microstructural and mechanical characteristics of Al-Mg_2Si-TiB_2 composite have been conducted. However, detailed studies on the hybrid composites are yet to be explored in respect to fabrication techniques, microstructural and consequent mechanical and tribological behaviour of A356-Mg_2Si-TiB_2. Tribological parameters can be optimised using response surface methodology. Hence, in the present study extensive investigation was carried out to address the above aspects.

1.3 OBJECTIVES OF THE PRESENT STUDY

Objective of the study is to achieve superior combination of wear and friction properties for auto industries and to achieve it following methodology has been used:

- Synthesis of A356-10Mg_2Si-xTiB_2 in-situ metal matrix hybrid composites through stir casting and CS casting technique with varying wt.% of TiB_2 in order to find a suitable fabrication technique.
- Microstructural characterization of A356 alloy and composites to examine the phase morphology, particle size, size distribution and dispersion of the reinforcements in synthesized A356-10Mg_2Si-xTiB_2 hybrid composite to understand their role on tribological properties.
- Evaluation of mechanical properties of the hybrid composites viz. Hardness and tensile properties and their effect on other parameters.
- Study the influence of different variables such as applied load, sliding distance, sliding velocity and wt.% of TiB_2 on tribological behaviour of the hybrid composites to understand the influence of casting technique.
- Study of the worn surfaces and wear debris under different tool such as SEM, EDS and AFM to comprehend the various wear mechanism involved during wear process.
- Statistical modelling and optimization of wear parameters for optimal wear of the hybrid composites using Response Surface Methodology.