CHAPTER-1

INTRODUCTION

1.1 Introduction

Historically, cast iron was used in engine blocks. However, demands to improve fuel economy and pollutant emission control necessitate alternative materials and design improvements of engine components. Replacement of cast iron in cylinder blocks with a lighter and more thermally efficient material can be one of the best suitable options for improvement in fuel economy. The application of Al-Si hypoeutectic alloys such as A319 and A356 alloys used for engine blocks results in a significant weight reduction with the additional benefit of better thermal conductivity, three times better than cast iron. However, this substitution is not an easy task for the automotive industry. Performance of hypoeutectic Al-Si alloys is not satisfactory with respect to the surface wear characteristics of cylinder bore walls. The cylinder bore wall either to be modified or replaced with a more appropriate material [1-4].

The cylinder bore wall is generally fortified with either a 'cast-in' or 'pressed-in' grey cast iron cylinder liner to meet the surface characteristics. But this is associated with some intrinsic deficiencies such as different thermal expansion co-efficient causing distortion and increase the size and weight of engines. Use of monolithic hypereutectic Al-Si alloy cylinder blocks was the earliest approach to replace cast iron liners. In these alloys primary Si particles formed during solidification enhances the hardness and results in the required tribological characteristics. A uniform distribution of primary Si crystals in the alloy is of primary importance for wear properties of the cylinder bores. However, there are certain limitations restricting the widespread applications of these hypereutectic alloys. Those include the difficulty in production of uniform and homogeneous microstructure, process is expensive as additional alloying addition like Ni is often made and need for chemical etching to protrude primary Si particles from the Al cylinder bore surface. The second potent alternative for replacing the traditional aluminium cylinder block fitted with cast iron liner is by use of metal matrix composites (MMCs) and functionally graded metal matrix composites [5-8]. There are several ways of fabrication of functionally graded materials [9-21]. Centrifugal casting technique is one of the unique liquid metallurgy routes to fabricate FG –composites. Various types of metal/reinforcements combination FG composites have been reported [22-41]. Other than centrifugal casting, liquid metallurgy routes viz. by application of electromagnetic field [42-45], infiltration processing [46-53], and directional solidification are also reported. A highly promising alternative is Al–Si-Mg_2Si composites because the in-situ formed intermetallic compound of Mg_2Si possesses a high melting point (1085°C), low density (1.99x 10^3 kg m^{-3}), high hardness (4.5x10^9 Nm^{-2}), a low thermal expansion coefficient (7.5x 10^{-6} K^{-1}) and a moderately high elastic modulus (120 GP) [54]. However, the mechanical properties of the Al-Si-Mg_2Si composites are not satisfactory due to the presence of coarse primary Mg_2Si particles [55,56]. The coarse and rough Mg_2Si intermetallic is responsible for low ductility in these materials. Hence, refinement of coarse Mg_2Si particles is essential to develop adequate mechanical strength and ductility. Several approaches have been made to modify the primary and eutectic Mg_2Si structure for the property improvement of these composites. These are by faster solidification rate [56-58], intensive melt shearing [59], melt superheating [60,61], semi-solid processing [62], chemical modification [63–92]. Different additions have been investigated to chemically modify the structure such as extra Si [63-66] and Mg [67-68] addition, Cr [69], Ni [70], Sr [71-74], Bi [73,75], Sb [73], Li

[76-79], Ce [80,81], Y [82-84], Nd [85] La [86], mischmetal [87], rare earth oxides and $CaCO_3$ [88], Gd [89], P [90,91], salt mixtures [92] and K_2TiF_6 [93].

Apart from the monolithic in-situ composites there is development of functionally graded Al-Si-Mg_2Si composites having the reinforcement phase in the matrix segregated in a particular surface [94-105]. The base alloy studied is mostly hypereutectic Al-Si alloys. The reinforcement segregation at the surface result in significant improvement in the surface wear properties. The other end with gradual decrease in reinforcement population provides better ductility and toughness. When these graded composites are fabricated by centrifugal casting route, the primary Mg_2Si particles formed in the alloys were highly segregated and enriched in the inner zone of castings by the centrifugal force because of its lesser density (ρ_{Mg2Si} = 1.99 g/cm^3) than that of Al melt (ρ_{Al} = 2.37 g/cm^3). The segregation of primary Si and Mg_2Si particles in the inner reinforced layer imparts an increased wear resistance in these castings. The Mg_2Si particles are also refined to some extent due to the centrifugal action. These tubular products with reinforced internal surface are best suited for liner or piston material. The cast structures of the in-situ Al-Mg_2Si composites are further improved by subjecting to solution treatment and ageing. Consequently the mechanical properties, wear and corrosion properties are improved [106-114].

1.2 Scope of present investigation

Presently the most widely used material for cylinder block manufacture is either A356 or A319. Since these alloys are lacking in wear resistance properties in the bore walls, liners are inserted to have adequate properties for which a proper matching in thermal properties is required. In this respect FGMs made from A356 alloy will be perfect. From the review of literatures it is evident that no elaborate studies have been made so far on the functionally graded composites based on either hypoeutectic Al-Si alloys A356 or A319.

As Mg_2Si as reinforcements in aluminum matrix has the several lucrative properties, due to which Al-Mg_2Si appearing to be a potent FG- composites. Several studies have been made on the microstructural features and mechanical properties of as-cast and aged monolithic Al-Mg_2Si composite. However, detailed studies on FG composites are yet to be explored in regard to the microstructural features and consequent mechanical and tribological characteristics. In view of this, the present study was undertaken to carry out a systematic investigation on the aforesaid aspects.

1.3 Objectives of the present study

- Synthesis of FGM Based on A356-Mg_2Si in-situ metal matrix composites by vertical centrifugal casting process with varying wt. % of Mg.

- Characterization of the different phases in the matrix, reinforcements and the matrix reinforcement interface of the synthesized A356-Mg_2Si as-cast FGM.

- Evaluation of the zone-wise mechanical properties from inner to outer periphery of FG composite viz. Hardness, Room temperature and high temperature tensile properties.

- Effect of solution and ageing treatment on microstructure and mechanical properties of the Al-Mg_2Si FGMs.

- Characterization of Dry Sliding Wear behavior at room temperature and linear reciprocating wear behavior at elevated temperature.