PREFACE

Demands to improve fuel economy and pollutant emission control necessitate alternative materials and design improvements of automotive engine components. Replacement of cast iron components in cylinder blocks with a lighter and more thermally efficient material can be one of the best suitable options for improvement in fuel economy. Use of Al-Si hypoeutectic alloys such as A319 and A356 alloys or hypereutectic alloy like A390 are being considered and used to some extent for in a significant weight reduction. However, each of these aluminum alloys has their inherent merits and demerits and cannot fulfill all the requirements.

With the advent of functionally graded materials (FGM), gradient microstructure and compositions in composite materials could be produced. Surface wear resistance increases due to high population of hard reinforcing particles. Gradual increase in plasticity and toughness in middle and the opposite side layers due to gradual depletion in reinforcing phase. Functionally graded aluminum based composites reinforced with ceramics and intermetallic phases have superior high temperature surface wear resistance, surface friction and thermal properties, adjusted thermal mismatching, reduced interfacial stresses, can sustain the load bearing capacity.

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, low density, high hardness, a low thermal expansion coefficient, and a moderately high elastic modulus. The segregation of Mg_2Si particles in the inner reinforced layer by centrifugal force in centrifugal casting imparts an increased wear resistance in these castings.

The present study deals with synthesis and development of A356-Mg_2Si in-situ graded composites with varying volume% of Mg_2Si reinforcement with 0, 2.5, 5, 7.5 and 10 wt.% of Mg additions by centrifugal casting route. The functionally graded composites were characterized in as-cast and in T6 conditions for microstructural evolutions and consequent mechanical and wear properties at room temperature and elevated temperatures.

Chapter-1 presents a brief introduction of the problem, the scope and the objectives of the study.

Chapter-2. deals with the detailed survey of the present state of knowledge about the development of Al-Si alloys for automotive engine applications and their inherent merits and demerits, how Functionally Graded Materials (FGMs) could be a suitable alternative material for such applications, different fabrication routes of FGMs. The chapter also describes characteristics of Al-Mg_2Si composite as a potential material, the growth morphologies of the Mg_2Si reinforcement, different solidification processing and chemical processing for reinforcement refinement and modification and consequent microstructural and mechanical properties of functionally graded Al-Mg_2Si composites.

Chapter-3. elaborates about the experimental techniques adopted to fulfill the objectives of the study. The synthesis and fabrication of A356-Mg_2Si FG composites have been made by centrifugal casting route with varying Mg contents. The FG composites have been characterized for microstructural evolution in as-cast as well as solution treated and aged conditions by X-ray diffraction analysis, optical, scanning electron and transmission electron microscopy. The consequent hardness, room temperature and elevated temperature tensile and wear properties have been evaluated.

Chapter-4. In this chapter the microstructural characterizations have been presented. Microstructures were observed in three distinct zones along the radial direction of FGMs tubes namely, inner zone, middle transition zone and the outer zone near the mold wall. The analysis of XRD pattern of the as-cast FGM specimens reveals three phases namely α-Al, Mg_2Si, and Si in the composites fabricated and α-Al and Si in the base A356 alloy. Al-Fe-Si intermetallics are not detected in XRD analysis probably due to their small percentage in the composites. The microstrucural characterization of fabricated FG-Composites has been presented in this chapter. The chapter includes the results and interpretations of XRD analysis for phase identification, microstructural features observed under optical microscope, Scanning Electron Microscope and Transmission Electron Microscope. The effects of solidification rate and secondary dendrite arm spacings have been correlated with size, shape and distributions and volume fractions of phase constituents along the radial cross-sectional direction. Fe-intermetallic phases such as π and β phases, Pseudo-binary phases (Chinese script) have been characterized. The microstructures of the composite FGMs show predominantly three phases namely, the primary α-Al dendrites, Si eutectic phase, and Mg_2Si. The outer chill zone dendrite arms of α-Al are fragmented due to the centrifugal force similar to the base alloy. So far as the morphology of the Mg_2Si is concerned, two forms of Mg_2Si are discernible, one is the primary blocky type and another one is in the pseudo-eutectic phase. These pseudo-eutectic phases of Al-Mg_2Si are formed in the interdendritic regions of α-Al. The pseudo-eutectic Al-Mg_2Si micro-constituent exhibits the characteristic morphology of ‘‘Chinese script.’’ The population of primary Mg_2Si particles in the inner zone of the tubes is quite high while in the transition zone the particles are gradually disappearing. However, in the outer zone, a few Mg_2Siparticles are observed. The size and volume fraction of primary Mg_2Si particles at different zones are the direct consequence of solidification time or SDAS.

Chapter-5 describes the mechanical behavior of FG-composites in as-cast condition with varying wt.% of Mg. The mechanical properties have been evaluated in three zones – inner, middle and outer peripheral of the functionally graded composites. The measurement of Vickers hardness values along outer to inner zones of FG composites and zone-wise tensile properties at room and elevated temperatures are presented. The microstructural features are correlated with hardness variation profile and room and high temperature tensile properties at 25°C, 150°C and 300°C. Since the populations of Mg_2Si particles are highest at the inner zones, the hardness and tensile strengths at these zones are maximum among the three zones. The mechanism of tensile fracture has been explained based on the features in the tensile fractographs.

Chapter-6 chapter deals with the effects of solution heat treatment and subsequently artificial ageing (T6) of developed FG-composites. The purpose of this study was to evaluate the effect of T6 heat treatment on the mechanical and wear properties of as-cast A356 Alloy. Al-Mg_2Si in-situ composites in as –cast condition does not exhibit appreciable tensile properties due to coarse Mg_2Si particles and silicon morphology in eutectic. This restricts the wide spread applications of this composites. Solution treatment and ageing are effective means to refine the structure as well as to form additional extra-fine precipitates during ageing. The dissolution of Mg_2Si particles is attributed to high rate of diffusion of Mg in the Al matrix at the pretty high solution treatment temperature. The objective of the solution treatment is not to dissolve totally the primary Mg_2Si particles formed during solidification but to refine the coarse particles by surface diffusion.

Chapter-7. The present chapter has two sections; the first section deals with the room temperature dry sliding wear characteristics of as-cast A356-Mg_2Si in-situ FG composites and the second section is on the evaluation of reciprocating wear characteristics of the FG composites at 200°C in as-cast as well as in T6 condition. As wear characteristics at room temperature and at elevated temperatures around 200°C are very much essential for automotive components like engine block liner, pistons etc the developed A356-Mg_2Si FG composites have been characterized for these two wear properties. From the cumulative wear loss of the samples from inner zones of the composite, the wear loss is found to be remarkably improved. This is obvious due to the combined action of grain refinement of α-Al and higher volume fraction of hard Mg_2Si reinforcing particles. However, in high temperature reciprocating wear, the resistance is minimum with 7.5 wt.% Mg but it is deteriorating with further increase in Mg% to 10% perhaps due to coarser primary Mg_2Si particles as these could not sustain the severe high temperature shearing force.

Chapter-8 presents the concluding remarks arising out from the present investigation along with the suggestions for the future scope.