CHAPTER-8

SUMMARY AND SUGGESTIONS FOR FUTURE WORK

8.1. Introduction

Based on the experimental findings and important observations in the present investigation a few major conclusions can be drawn and are summarized in the present chapter. The chapter further includes the suggestions made for future researches in this area.

8.2. Summary

8.2.1. Effect of Mg-content on A356-Mg_2Si FG composite

The effect of varying Mg content on in-situ A356-Mg_2Si composite functionally graded material have been investigated. The microstructure of centrifugally cast Al-Si-Mg alloy base in-situ composites consist of mainly four phases such as, α-Al, Al-Si eutectic, Al-Mg_2Si pseudo-eutectic and primary blocky Mg_2Si. The primary Mg_2Si have a shape of truncated octahedron. Apart from these phases, Fe forms blade-shaped Al-Fe-Si intermetallic which is detrimental to the mechanical properties. The blocky primary Mg_2Si particles are predominantly segregated at the inner layer of the centrifugally cast tubes due to the relative density effect with respect to molten Al. Ultimately after solidification, three distinct zones are formed in the radial direction of cross-section viz. highly particle populated inner zone, and gradually particle-depleted middle transition zone and the outer zone. This distribution gives rise to a functionally graded composite. The solidification time is most rapid at the outer zone due to sudden chilling and SDAS are the finest which gradually become coarser towards the inner zone because of slower cooling rate. The Mg_2Si particles are refined due to finer SDAS. Since the cooling rate in the inner zone is slower the volume% of Fe-intermetallic is higher. Dislocations in the matrix surrounding Mg_2Si particles are observed generated during solidification due to mismatch in co-efficient thermal expansion of Mg_2Si and the matrix.

8.2.2. Mechanical behavior in as-cast condition

The effects of varying Mg contents on room temperature and elevated temperature mechanical properties of in-situ A356-Mg_2Si composite in as-cast conditions have been investigated. The microstructural features are correlated with hardness profile, high temperature tensile properties and fracture behavior of different zones of FG composites. The maximum hardness are obtained at the inner zone and this again increases with increasing wt.% of Mg. The hardness values are gradually decreasing from inner zones towards outer zones. The ultimate tensile strength (UTS) at room temperature are also maximum at the inner zone and UTS values are increasing with increasing Mg content. While the test temperature is raised to 150°C, FGM shows a maximum peak value and a further increase in test temperature to 300°C causes softening. The fracture behavior reveals a change in the mode of fracture from mixed mode to ductile mode as the test temperature is increased. At lower test temperatures, cracking of eutectic Si and Fe-intermetallics as well as porosities are responsible for failure while at higher temperatures due to softening of the Al-matrix the strength of the particle/matrix interfaces decrease. Cracks are initiated at these interface regions. This results in decohesion of the particles and void nucleation. In addition, under these conditions the brittle intermetallic particles were found to shatter into multiple pieces as a result of the increasing stress build-ups at the particle/matrix interfaces.

8.2.3. Effect of solution treatment and ageing

The eutectic Si showing a remarkable change from coarse acicular to spheroidized refined particles in base alloy A356 upon solution treatment and ageing. This is due to fragmentation or dissolution of eutectic Si branches and subsequent spheroidization of separated branches.

The primary Mg_2Si particles undergo shape change. Sharp corners are rounded up during solution treatment as a result of diffusion of Si and Mg from preferential sites. Flaky Fe-intermetallics are reduced but some $CuAl_2$ intermetallics with script morphology are still remaining. Freshly formed nano-sized β”, β’ –Mg_2Si, Q and θ are formed during ageing from clusters of GP zones which strengthens the matrix by precipitation strengthening in sequence. The ageing curves (hardness vs. ageing time) show triple peak phenomenon- three hardness peaks are observed with the progress of ageing. This conforms the precipitation sequence. The first peak arises due to the formation of metastable β” phase and subsequently the β’ and Q’’phase formation gives rise to second peak. The third peak is developed due to the formation of phases like Q’ and θ’. But microstructures corresponding to third peak could not be checked. Improvements in tensile strengths and ductility are observed after solution treatment and ageing as compared to those in as-cast conditions. As expected, inner zones develop maximum strength due to segregation of primary Mg_2Si particles in combination with fine nano-sized precipitations formed during ageing.

8.2.4. Tribological Characteristics

The effect of magnesium content on the room temperature dry sliding wear behaviour and high temperature linear reciprocating wear of graded A356-Mg_2Si in situ composites have been characterized. The composites show better wear resistance due to their better load bearing capacity and capacity to maintain a protective stable oxide film along with mechanically mixed layer, protecting against metal-tometal contact. A mild wear regime is observed below about a normal load of 30 N beyond this the wear is in severe regime. This perhaps due to the disruption of oxide film with mechanically mixed layer by a process of delamination. Subsurface microstructures confirm the delamination wear by specific microstructural features.

The mass loss at high temperature at high temperature reciprocating wear decreases with increase in %Mg from 2.5% to 7.5% and raises little bit with 10%Mg. This is perhaps due to coarser primary Mg_2Si particles and higher % porosity present in 10%Mg composite. The COF values show a complex nature. It increases with increase in Mg-content from 2.5% to 5%, then decreases with 7.5% and finally again increases with 10%Mg. The initial increase is due to higher volume% of Mg_2Si in 5%Mg composite than in 2.5%Mg composite which causes more asperities and reinforcement interaction. Further increase in Mg_2Si content in 7.5%Mg composite generates large amount of frictional heat which produces oxidized MML layer. This layer reduced the COF value. Shearing of coarse Mg_2Si particles from the softened matrix of 10%Mg composite causes adherence of ball and block. This leads to increase in COF value. So far as the high temperature wear resistance and COF are concerned, 7.5%Mg shows best combination of wear characteristics.

8.3. Suggestions for future work

The following suggestions are made based on the present investigation:

1. Study on the effect of centrifugal casting variables viz. speed of mold rotation, mold pre-heating temperature and pouring temperature on the morphology of primary Mg_2Si and dendritic arm spacing.
2. Quantification and assessment of individual effect of different intermetallic phases on mechanical properties.
3. Study on the effect of variation in solution treatment and ageing temperature on microstructural evolution.
4. Characterization of thermo-mechanical fatigue behavior of the FG composites.