1. Introduction

There have been intensive investigations on high strength lightweight alloys and composites with an aim to develop new alloy compositions and processing techniques to engineer the structure at different levels and thus achieve improvement in properties and performance. Aluminium alloys find applications in the area of aerospace, marine, automobile, special purpose machines, micro machineries etc. due to their lightweight, high strength and corrosion resistance properties. Aluminium-Scandium alloys have been in use in military applications for some time and interest in these alloys has grown since the breakdown of USSR. The limited use of Sc as an alloy addition to aluminium is because of the cost and availability of scandium. The cost of Sc is going down day by day with simultaneous increase in its availability. Increased use of this element commercially expected to further reduce its cost.

The addition of Scandium to Al offers several benefits; the most important are (a) excellent grain refinement and (b) substantial strengthening due to the formation of small and coherent $L1_2$ Al_3Sc dispersoids. With Sc content below the eutectic composition (0.55wt. %), the refinement of grains is not observed and coarse grains are observed. Primary precipitates of Al_3Sc form at hypereutectic concentrations of Sc. These primary particles have similar crystal structure and good lattice parameter match with Al and thus act as excellent nucleation sites for primary Al. Extensive investigations have been done on hypoeutectic wrought alloys and on hypereutectic cast alloys of the Al-Sc system, which take advantage of improvement of the ageing response and grain refining influence of Sc in these alloys respectively. However, only a few reported investigations are available on the microstructure and mechanical properties of hypoeutectic Al–Sc and Al–Sc–Zr alloys, produced by conventional casting processes followed by precipitation annealing. Reported literatures give importance to the strengthening of aluminium alloys by the fine precipitates of Al_3Sc formed on ageing. The room temperature solubility of Sc in aluminium is low (0.05 wt %). The maximum solubility at the eutectic temperature is 0.35wt%. Thus, a significant volume fraction of Al_3Sc precipitates in the eutectic under equilibrium conditions appear in the microstructure. At a higher solidification rate, volume fraction of Al_3Sc in the eutectic may reduce due to increased supersaturation of Sc in Al. Therefore, ageing is done after solutionising at a temperature close to the

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melting point of (600 to 648^{0}C) aluminium. The cast components cannot withstand exposure to this temperature. So, the solutionising treatment has to be eliminated and sufficient amount of Sc is to be retained in solution in the as-cast condition. The cooling rates attained in the conventional casting processes are often not sufficient to retain the required degree of Sc supersaturation. Retention of Sc in solid solution reduces grain-refining effect. Thus, for obtaining the best mechanical properties a balance between the level of Sc in solid solution and Sc precipitating as primary precipitate (to act as nucleating catalyst for Al) in the as-cast condition is very important. The addition of Zr reduces Sc required for refining grains of Al. These elements also have mutual solid solubility in each other. A significant amount of Zr (35 wt %) is present in solid solution of Al_3Sc. However, solid solubility of Sc in Zr is low (5 wt %). Zr segregates at the interface between Al and Al_3Sc. Zr layer formed at the shell of Al_3Sc, reduces growth of these precipitates. The growth is minimal even with ageing at elevated temperature for a long time. Mg is frequently added to this alloy to increase solid solution strengthening. There is also mutual reduction in solid solubility of Mg and Sc in Al. Thus, in the presence of Mg a lower Sc is sufficient for the precipitation of Al_3Sc, which is responsible for grain refinement of aluminium. With the addition of Mg, lattice parameter of Al increases. This in turn increases the critical diameter of the Al_3Sc precipitates for losing coherency ensuring the retention of hardness at higher temperature. Thus, there is a complex interplay of cooling rate and the alloy composition, which dictates the as-cast structure, and ageing response of the alloys.

The critical need for high strength and high performance materials led to the development of hybrid materials as monolithic metals and alloys have their own limitation. A combination of ceramic and metals results in a significant improvement in properties. Aluminium matrix reinforced with ceramic phase has distinct advantages over other types of composites. Particle strengthened composites have isotropic properties. Different particles such as SiC, Al_2O_3, TiB_2, B_4C etc have been recognized as potential reinforcements and dispersion of these particles enhances the elastic modulus, hardness, strength at room and elevated temperature and wear resistance of these materials. These composite materials are getting attention because of cost considerations,

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isotropic properties and possibility of producing near net shaped castings, as well as secondary processing, facilitating fabrication of components. The particle-reinforced composites are conventionally produced by powder metallurgy or liquid metallurgy, where the ceramic particles are directly incorporated into solid or liquid matrices respectively. Another process for the production of metal matrix composite is insitu particle composites where the reinforcing particles are formed within the matrix by some chemical reaction. Solid or gaseous phases are introduced into metals at a temperature favorable for the nucleation of the desired reinforcement. The properties of the composite materials are strongly influenced by the reinforcement size, type, morphology, volume fraction and spatial distribution. Reinforcement particle size is an important consideration for choosing ceramic particles. Although toughness and yield strength are not greatly affected by the particle size, the tensile strength is strongly influenced and finer particles are preferred. With the addition of finer particles greater work hardening and less particle fracture are found. In an ex-situ process, there is size limitation for introducing reinforcement particles. The particles with smaller sizes are not easily dispersed in the ex-situ technique. The particles formed insitu are generally finer with a clean interface between matrix and reinforcement as compared to ex-situ process of introduction of particles. These insitu particles embedded in the matrix of aluminium alloy enhance strength properties and wear resistant of aluminium alloy.

The TiB_2 particle reinforced aluminium matrix composite is one of the hybrid materials of good wear resistant and strength properties. Majority of the study focused on the improvement of the commercial aluminium alloys by introducing insitu TiB_2 particles. The grain refining of aluminium by TiB_2 particles have been studied extensively. Fading and poisoning lose the nucleation potency of these particles. Fading occurs at the slow cooling rate and long holding time. Cr, Zr, Li and high levels of Si are observed to poison the grain refining of aluminium. However, Mg is observed to increase the grain refining potential of TiB_2 particles. Mg also reduces the interfacial energy of aluminium and ceramic particles and help in dispersing reinforcement particle in the matrix. The uniform dispersion of the reinforcing particles in the matrix is one of the most important criteria for developing good quality composites. These TiB_2 particles

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are seen to agglomerate at the grain boundary. Therefore, a new matrix composition and improved process techniques are being attempted to improve the quality of the TiB_2 reinforced composites.

The matrix properties and microstructure have a significant role in the production of composite materials. The matrix plays a significant role while there is a fracture or damage in the microstructure from the particle cracking. Substantial ductility of the matrix helps in stopping the crack growth. The crack wake plasticity of the matrix increases compressive force, present at the crack tip, preventing further crack growth. The detailed report on Al-Sc alloys is available in the literature. However, literature on the composites based on this alloy is scarce. The strength properties of these alloys, particularly yield strength is higher in comparison with the other commercial alloys coupled with good ductility. Thus, these alloys can serve as excellent matrix material. The precipitates formed not only increase the strength of the aluminium alloy but also are responsible for increased recrystallisation resistance of the material. As most of the commercial aluminium alloys are aged at 150 to 170^0C temperature, the service temperature has to be low for these aluminium alloys as beyond this temperature strength of the material drops due to the coarsening of the precipitates nucleated during ageing. Since the ageing temperature of Sc alloyed with aluminium alloy is around 300^0C, this alloy can be used at higher temperature compared to the available commercial aluminium alloys. The properties of aluminium alloy are influenced by the amount of the Sc addition. Presence of other alloying elements also strongly influences the effect of Sc addition.

Major objectives of the present investigation are to study the (i) distribution of Sc and the effect of Zr during solidification in conventional casting process, (ii) influence of cooling rate of the ternary Al-Sc-Zr alloy that can be obtained in casting process, (ii) influence of Mg and cooling rate of the ternary alloy, (iii) influence of cooling rate and Mg content of the Al-ScZr / $(TiB_2)_p$ composite on the microstructure development, ageing response, mechanical, wear and corrosion properties and (iv) establishment of the oil quench investment casting process for Al-Sc alloy in order to achieve higher solidification rate to maximize the Sc in solid solution of aluminium.

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