## Abstract

In the present investigation, a modified spray forming set-up has been designed to synthesis Al-2Mg-$TiO_2$ composites. It comprises of a set of two concentric tubes through which $TiO_2$ particles and Al melt are passed. The melt and $TiO_2$ particles are passed through outer and inner tube respectively. The melt is atomised into fine droplets by atomising gas at the orifice of the nozzle and subsequently the mixture (droplet and particles) are deposited on a rotating copper substrate. The modified process eliminates the need for separate injector(s) as employed in conventional spray forming process. Identical MMCs have also been prepared employing stir casting technique to make a comparative study. The major objectives of the present studies are:

- To design and fabricate a modified spray forming set-up to prepare Al-Rutile composites.
- To optimise the process parameters in the modified spray forming process to prepare Al-2Mg-6Rutile and Al-2Mg11Rutile composites, with uniform distribution of rutile particles in the matrix.
- To compare the properties of the composites produced through modified spray forming method with similar composites prepared by conventional liquid metallurgy vortex route.
- To study the effectiveness of rutile as reinforcement in the matrix.
- To study the influence of thermomechanical treatment on the mechanical properties of the composites.
- To investigate the influence of processing conditions and amount of rutile particles on the wear and corrosion behaviour of the composites.

Rutile ($TiO_2$) particles were selected as reinforcement due to its abundance in nature, low cost and good combination of mechanical and thermal properties. Apart from this, $TiO_2$ particles

have the potential to form intermetallics with Al during the processing of Al based MMCs, which has the capability of imparting enhanced high temperature strength. Up to 11% by weight of the rutile particles have been successfully incorporated in the Al-2Mg matrix using the modified spray forming technique. The microstructure, thermo-physical, mechanical, wear and corrosion properties of the composites have been characterised. The properties of spray formed composites are compared with stir cast composites containing same compositions. The as-prepared composites (spray formed and stir cast) are subjected to both hot (400°C) and cold rolling to enhance the mechanical properties. The maximum level of reduction that could be given to alloy and composites during hot rolling are 60% and 50% respectively, while in cold rolling reduction of 60% and 40% respectively could be given.

Uniform distribution of the ceramic particles in the matrix of metal is one of the most important aspect in the preparation of metal matrix composite and the present study shows that fairly uniform distribution of $TiO_2$ particles in the matrix of Al with good interfacial bonding between the matrix and particle can be achieved through the modified spray forming technique. Besides, spray formed composites exhibit fine equiaxed grains, imparting better mechanical and wear properties. This is in contrast to the stir casting process, which produces a columnar macrostructure with extensive segregation of $TiO_2$ particles. This could be due to the slow cooling rate aided by gravitational effect and wettability factor. Further, interfacial bonding in the stir cast composite is very poor and often the particles are surrounded by porosity.

Phase transformation in Al-2Mg-(6,11)$TiO_2$ composites has been studied by measurement of electrical resistivity and DSC. The results points to a phase transformation in the temperature range between 300-400°C, depending upon the composition of MMCs. Further, with increase in weight percentage of $TiO_2$ in the matrix, the onset temperature has been observed to decrease. XRD and TEM studies confirm the observation of electrical resistivity and DSC measurement and attribute to the precipitation of $TiAl_3$ at the particle/matrix interface.

The presence of $TiO_2$ particles in the matrix strongly influences the thermal properties. An increase in thermal conductivity and decrease in specific heat and thermal diffusivity is observed on incorporation of particles.

Secondary processing, like rolling (cold and hot), of Al-2Mg alloy and Al-2Mg-(6,11)$TiO_2$ composites resulted in considerable improvement in density and mechanical properties (viz. hardness and tensile strength) primarily due to the decrease in porosity and work hardening effect. Further, ageing of cold rolled alloy and composites show that the presence of $TiO_2$ in the matrix accelerates the softening pointing to a deciding role of particle/matrix interface in the recrystallisation process during ageing.

Microstructural refinement and higher degree of uniformity in the distribution of $TiO_2$ in spray formed composites are the primary factors leading to the improved wear resistance and lowered friction coefficients in these as compared to those of Al-2Mg alloy and stir cast composites. A change in wear mechanism from purely adhesive to mixed mode of oxidative-abrasive has been noted with the incorporation of $TiO_2$ particles in the Al matrix from microstructural observations of worn surfaces of Al-2Mg alloy Al-2Mg-(6,11)$TiO_2$ composites respectively.

The presence of $TiO_2$ particles in the Al matrix does not have a pronounced effect on pitting potential as observed from experiments on galvanic corrosion. However, $TiO_2$ particles are observed to serve as nucleating sites for pit formation and leading to enhanced pits formation in Al-2Mg-(6,11)$TiO_2$ composites vis-à-vis with those of Al-2Mg matrix alloy.

In conclusion, the present work illustrates that preparation of Al-$TiO_2$ based MMCs is feasible through a modified spray forming process with uniform dispersion of $TiO_2$ particles. Electrical resistivity and DSC measurement has revealed a phase transformation at temperature ranging between 350-400°C owing to the precipitation of $Al_3Ti$ phase as confirmed by XRD and TEM studies. Thermal conductivity of Al-2Mg-11$TiO_2$ composite is greater than that of the base alloy. The hardness of the spray formed Al-2Mg-(6,11)$TiO_2$ composites increases by 5-20 % over Al-2Mg alloy. About 4 -30% improvement in tensile strength is observed in as-spray deposited composite compared to stir cast composite and spray formed base alloy. However, with the increase in $TiO_2$ content tensile strength decreased. Tensile strength of stir cast composites is less than the spray formed alloy and spray formed composites. Precipitation $TiAl_3$ phase on ageing lead to the improvement in tensile strength and elongation. Further this study has lead to the understanding of effect of mechanical processing on microstructural evolution of the above mentioned alloy and composites and the influence of $TiO_2$ particles on various mechanisms taking part during tensile and wear test. The electrochemical response of composites has shown that the pitting potential has remained unaltered on incorporation of $TiO_2$ particles into the matrix alloy. However, the number of pits is more numerous and smaller in size in the MMCs than in the monolithic alloys under identical conditions of testing. This is due to the presence of intermetallics of Al-Mg or Al-Ti.