ABSTRACT

Studies have been conducted on cast Al-Fe-V-Si alloys. The results of the investigation have been presented and discussed in four chapters dealing with (a) solidification characteristics (b) microstructural characteristics (c) mechanical properties and (d) wear characteristics of the experimental alloys.

The experimental techniques used included alloy preparation, casting and thermal analysis, light and electron metallography, X-ray diffraction, EDX and image analysis, mechanical testing and pin-on-disc wear test.

The first phase to precipitate during the solidification of a Al-8.3Fe-.8V-.9Si alloy is $Al_3Fe(V,Si)$. Thereafter the solidification proceeds through several invariant reactions. The final invariant reaction is associated with a pronounced arrest. The temperature of this arrest is a function of the cooling rate and modification treatment with Mg added either as pure Mg, Al-20%Mg master alloy or Ni-20%Mg master alloy. In a normal unmodified structure, massive iron aluminide precipitates and microshrinkage pores induce brittleness and reduce the tensile strength. These precipitates transform to an interesting ten armed star like morphology at a high G/R ratio, as in chill casting from above 900^0C or during water quenching from above 800^0C. But Mg treatment alters the morphology to finer and more uniformly dispersed rectangular or square rod shaped precipitates. Extensive microanalysis of the precipitates in unmodified and modified alloys revealed the basic difference in the compositions of the precipitates of different morphologies. For instance, the star shaped precipitates corresponded approximately to the composition $Al_3Fe(V,Si)$.[Typical analysis Al- 24.48at%Fe- 1.18at%V- 0.78at%Si]. These precipitates are replaced by blocky, rectangular, hexagonal or partial hexagonal primary phases on cooling the melt slowly down to temperatures around 700^0C and then quenching in water. Such precipitates are characterized by a higher V ($\approx$5-7 at%) and lower Fe contents ($\approx$15-19 at%) than the star shaped precipitates. On raising the Si content of the Al-Fe-V-Si melt (to $\approx$ 2wt%), the star shaped precipitates degenerate to various irregular morphologies such as six armed, stars, fractured stars etc. These degenerate precipitates are invariably rich in Si. The cuboidal / hexagonal / rectangular primary precipitates in Mg treated alloys are, on the other hand, rich in Mg [0.5-1.6at%]. In case of Ni-Mg alloy treatment certain

amount of Ni also enters the precipitate lattice by replacing Fe and V. The iron aluminide crystals have been found to undergo multiple twinning and are believed to grow by the twin plane reentrant edge mechanism.

Mg treatment of the Al-8.3Fe-0.8V-0.9Si alloy melts also alters the morphology of the interdendritic iron aluminium silicide particles from needle like to fibrous. The net effect of the changes in the morphology, size and distribution of the intermetallic phases following Mg treatment is to increase the as cast strength and ductility. Typical values are: 0.2%PS:27.5 kg/mm^2, UTS: 32 kg/mm^2, elongation: 9%. The mechanical properties can be further enhanced by deformation through hot extrusion or hot rolling. The hardness of the cast alloys are retained even after long exposure at 250^{0}C. At higher temperatures upto 500^{0}C, some softening has been noted.

The wear characteristics of the Al-Fe-V-Si alloys, as determined by the pin-on-disc test during dry sliding, are excellent. Wear resistance of an unmodified alloy is far superior to that of a eutectic Al-Si alloy, particularly at a high load of 68.6N. Modification improves the wear resistance further. Delamination is the predominant mode of wear. Extensive plastic deformation and work hardening of the pin samples of modified alloys occur during the wear test. As a result, the wear rate of the modified alloys decreases with increasing load. Oxidation of the α-Al matrix is conspicuous, particularly in case of the unmodified alloy. Increasing oxidation with increasing wear load contributes to rise in the friction coefficient. The Mg treated alloys recorded lower coefficient of friction than that of the unmodified alloy under identical wear test condition, presumably because the extent of oxidation of the α-Al matrix itself was reduced in the presence of Mg.

The investigation has contributed to the development of a technique for modification of the as cast microstructures of Al-Fe-V-Si alloys. The mechanical properties of the modified and cast Al-8.3Fe-.8V-.9Si alloys, particularly after modification with 1.5wt% Al-20%Mg master alloy or 1.0wt% Ni-20%Mg master alloy, compare favourably with those of identical alloys processed through the rapid silodification- powder compacting- extrusion route and reported in the literature.

Key Words: Solidification, modification, iron aluminide, wear.