ABSTRACT

Wrought 7075 aluminium alloy is a prevalent high-strength and lightweight in the automobile and aerospace industries. The 7075 quaternary alloy having primary alloying elements is Zn; others are Mg and Cu. There is a broad applicability of Al7075 in wrought conditions after machining, which is costlier and time-consuming. The casting route is cost-effective but has a problem with hot tearing and solute segregation because of its wide solidification range. The solidification behaviour of 7XXX aluminium alloy is a little sluggish because of its three elements and distribution within the α-Al matrix.

There are multiple ways to alter the segregation pattern during solidification and finally into the microstructure. It can be possible thermally, chemically and mechanically, or by combining any two treatments. This research mainly focuses on modifying the solute position within the microstructure by creating heterogeneous nucleation sites. The high-temperature oxides like ZrO_2, TiO_2, and $ZrTiO_4$ create heterogeneous nucleation sites and alter the solidification behaviour after casting. The results are compared without oxide-added cast Al 7075. The oxide powders were added with a fixed 2.5 weight percentage. SEM-EDS was carried out to check the oxide particle size and chemical composition of the as-received powders and their purity. The final oxide-added samples of Al 7075 were studied in detail using microstructure examination, SEM-EDS study to check the local chemistry, and XRD analysis to confirm the generated phase. Among all the oxides addition, the best mechanical properties and microstructure modification were observed in 2.5 wt.% ZrO_2-added Al 7075. The higher mechanical properties were achieved due to the reduction in average grain diameter and uniform distribution of the intermediate phases like η($MgZn_2$), S(Al_2CuMg), and T(AlCuMgZn) in the α-Al matrix. The SEM-EDS and XRD confirmed the intermediate phases. The SEM-EDS analysis also helps to determine the closest intermediate phase by checking the local Zn/Mg ratio in the micrograph. To investigate the segregation pattern changes by natural ageing, a batch of (1) oxide-added samples and (2) different quenching media applied on cast Al 7075 samples were preserved for two years. It results in the increment of micro-hardness values.

To understand the segregation issue generated by solid-liquid interface movement and solute rejection by the solid phase during solidification, changes to quenching phenomena were also investigated. The cast Al 7075 was quenched in three variants: ice water, hot water for

30 minutes and hot water until it cooled down. The effect of quenching was observed on microstructure and mechanical properties both. The ice and hot water influenced the formation of primary α-Al and eutectic phases. In the case of ice-quenched Al 7075, the observed eutectic phase morphology quite differed in terms of dendritic to non-dendritic. The best results were achieved for 30 minutes of quenching in hot water, i.e. 197 MPa UTS and 100 BHN.

The solutionizing heat treatment attributes temperature-dependent equilibrium solid solubility of 7XXX aluminium alloys, and quenching in water provides a supersaturated solid solution which produces solute clusters. The time-dependent low-temperature ageing treatment below the equilibrium solvus temperature forms translational precipitates. The third phase of the present research work includes the effect of heat treatment response for high-temperature oxides added cast Al 7075. The 2.5 wt.% oxides like ZrO_2, TiO_2, and $ZrTiO_4$ were added to cast Al 7075 and heat treated by solution treatment followed by double-step ageing. Usually, Al 7075 is age-hardened by T6 treatment (artificially aged), but in the present study, for reduction of ageing time to achieve homogeneous precipitate distribution within a matrix, double-step ageing was given to oxide-added cast Al7075. The samples were solutionized at 480 °C for 1hr. for homogenization and then quenched in cold water to get a supersaturated solid solution (α_{ssss}) followed by double-step ageing at 100 °C for 4 hr. + 135 °C for 17 hr. At low temperatures, the first step of ageing forms fine precipitates of η' phase in the α-Al matrix of Al 7075. In the second stage growth of fine precipitates controls the strength and hardness. The microstructure, mechanical properties, SEM-EDS, and XRD analysis were performed to study the effect of double-step ageing of oxide-added Al 7075. The highest mechanical properties were achieved in the ZrO_2-added Al 7075 before and after double-step ageing. The homogeneous distribution of precipitates improved the mechanical properties. The tribology study was also performed on the samples before and after heat treatment. The wear rate of ZrO_2-added Al 7075 is the lowest.

The effect of different casting techniques on the mechanical properties of the cast alloys was studied in the present work. The heat dissipation from a different mould generates the thermal gradient and controls the microstructure and mechanical properties. Three casting methods, permanent mould casting (gravity die casting), green sand casting, and investment casting, were used to check the solidification pattern. The microstructure, mechanical properties, and SEM-EDS analysis were performed to understand the segregation pattern and response of the different casting techniques. The tensile strength achieved by gravity die casting is 183 MPa. The hardness value of 59 BHN, 100 BHN, and 86 BHN was noticed in the gravity die casting, green sand casting, and investment casting, respectively. The observed high hardness is due to the formation of eutectics within the grain and inter-dendritic channels at grain boundaries.

Wrought Al 7075 is very costly in the market. From the market survey, the cost per kilogram varies between Rs. 600 to 950 and is even higher. Attempts were made to develop 7075 alloys by adding alloying elements into the pure aluminium in a resistance heating furnace to reduce cost. The four attempts were performed, and the last attempt successfully adjusted the final chemistry of Al 7075 as per the standard. The addition of the alloying elements and their sequence is a crucial parameter while developing an alloy. The design of an alloy was adjusted by considering the recovery of alloying elements. The final chemical difference was adjusted in the next heat. The microstructure and mechanical properties were compared with wrought Al 7075. The developed alloy costs Rs. 280 to 300 per kg, 50% less than the market price.

The insightful research on the characterization of Al 7075 was done by the following:

- Chemical method (oxide additives).
- Use of different quenching media to understand the cooling effect.
- Use of different cast techniques.
- Use of different heat treatment cycles.
- Preparation of cost-effective cast Al 7075.

Keywords: cast 7075 aluminium alloy, quenching media, double step ageing, oxide addition, intermediate phases.