ABSTRACT

There is a thirst for light materials in the automotive and aerospace industries, which has been a strong driving force behind magnesium alloy research over the past two decades. Among the various alloys, AZ91 is the most widely used because of its good combination of castability and low cost. However, the creep resistance (> 120 ˚C) of these alloys are poor due to low thermal stability of $Mg_{17}Al_{12}$ phase, which restricts the usage of Mg alloys for power train applications. In order to widen the usage of magnesium alloys in the automotive sectors, there is a demand for new creep resistant Mg alloys. Generally, many of the commercial magnesium alloys are made using High Pressure Die-Casting (HPDC), which can directly fabricate the component in the liquid state. However, porosity occurs in die-castings from the turbulent flow of the molten metal into the die cavity. In addition, magnesium possesses poor formability, difficult to be deformed at room temperature because of its hexagonal closed packed structure. To overcome these problems, Semi-Solid Metal (SSM) processing has been extensively studied. SSM processing is an advanced method for material forming using the thixotropic behavior of materials with non-dendritic microstructure in the semisolid state to form near net shaped products. The main purpose of the present study is to identify a suitable creep resistant Magnesium alloy amenable for thixoforming processing. The criteria we have selected for the evaluation of thixoformability are as follows: Solidification interval, fraction liquid sensitivity, highest knee point and processing window. However, the perfectly suited and commercially used alloys for SSM processing are very limited in types.

This research began with a fundamental study of Mg-Al-Sr, Mg-Zn-Y and Mg-Sn-Y ternary alloy systems: Despite the fact that these alloys have the potential for widespread applications, the investigations on phase equilibria of these systems are rather limited. Therefore, in the present work, the phase equilibria of Mg-Al-Sr, Mg-Zn-Y and Mg-Sn-Y alloys have been thermodynamically calculated using Calculation of Phase Diagram (CALPHAD) approach. The partial isothermal section phase diagram for these three alloy systems have been calculated and validated with key experiments. Furthermore, the vertical section phase diagrams in the Mg-rich region for Mg-Al-Sr and Mg-Sn-Y ternary systems have been constructed by means of cooling curves and Differential Scanning Calorimetry (DSC), X-Ray Diffraction (XRD) and Scanning Electron Microscope (SEM) analysis, and compared with thermodynamically calculated phase diagram.

Thermodynamic approach, Thermal Analysis (TA) and Differential Scanning Calorimetry (DSC) were used to investigate the liquid fraction changes during cooling of Mg-Al-Sr, Mg-Zn-Y and Mg-Sn-Y systems. Thermo-Calc software has been used to predict the fraction liquid versus temperature relationship. A comparison of the predictions with experimental data revealed that the simulation results show a good correlate well with the experimental results in the fraction liquid-temperature relationship for the Mg-Al-Sr system and vice versa for Mg-Zn-Y and Mg-Sn-Y systems. This is potentially a significant result as determining the liquid fraction versus temperature for the heating of a billet for semi-solid processing remains one of the challenges. The newly identified thixoformable alloys were subjected to Semi-Solid Isothermal Transformation (SSIT) process to produce non-dendritic starting material. Optimum processing conditions for achieving an ideal globular microstructure have been determined based on the results of SSIT process. Then, the non-dendritic semi-solid slurry was thixoformed successfully. Finally, the mechanical properties of the thixoformed alloys have been evaluated and compared to gravity cast material.