ABSTRACT

Present research aims to address the challenges associated with the preparation of cast magnesium alloys, particularly regarding their reactivity with oxygen and susceptibility to oxidation and fire. To achieve this, present study focuses on the development and evaluation of nine magnesium melting and refining fluxes with varying chloride, fluoride, and oxide content. By TG/DTA analysis, the decomposition behavior, mass change, and fusing/melting characteristics of the fluxes were investigated. Visual observation and scanning electron microscopy were employed to examine the surface morphology of the fused fluxes. The weight loss of magnesium was measured after utilizing each flux for melting. The thermal analysis confirmed that all fluxes fused before the melting of magnesium, however flux 9 (consisting of 23% KCl, 72% $MnCl_2$, 2.5% $BaCl_2$, and 2.5% CaF_2) exhibiting superior performance in terms of the type of outer flux protecting layer and the recovery of cast magnesium metal.

After utilizing the best flux, the development of the Mg-Mn system begins to understand the effect of manganese on mechanical properties and corrosion resistance behaviour. The literature shows varying data on the solubility and recovery of manganese in magnesium, necessitating a comprehensive examination of the topic. The solubility of manganese in magnesium is primarily influenced by factors such as temperature, the source of manganese, and the presence of other elements etc. To address all technical details, the present research focuses on the Mg-Mn system. Five different Mg-Mn systems were developed by adding various sources of manganese. The recovery of manganese in pure magnesium was assessed by adding 5 wt.% of the manganese-containing source at a consistent temperature of 850°C. Electrolytic manganese flakes showed the highest recovery among all the manganese sources. Optical images of the developed systems revealed grain refinement in pure magnesium due to the presence of manganese. The addition of manganese from all sources increased the hardness and ultimate tensile strength of magnesium. However, the elongation percentage decreased as the weight percentage of manganese increased, as observed in the case of the system containing electrolytic manganese flakes.

Moving forward, the solubility of manganese in pure magnesium was also investigated by using electrolytic manganese flakes with varying the temperatures (750°C, 800°C, 850°C, 900°C, and 950°C) in Mg-Mn systems. The results demonstrated that maximum manganese recovery was achieved at 950°C. Moreover, the presence of manganese (up to 2.66 wt.%) led to the refinement of the coarse grain structure of pure magnesium. In terms of corrosion resistance, the systems with higher manganese content exhibited excellent performance in a 3.5 wt.% NaCl solution for both 24 and 48 hours.

Further studies are being conducted to understand the behaviour of manganese in magnesium alloys containing nickel or copper. These studies aim to explore the effects of manganese on the microstructure, mechanical properties, and corrosion behaviour of these alloys. Previous research has indicated that excessive amounts of copper, nickel, and iron can intensify the corrosion rate of magnesium alloys. If copper concentrations exceed 0.05 wt. % and nickel concentrations above 0.004 wt. % it reduces corrosion resistance and ductility significantly. However, it has been observed that copper enhances high-temperature strength and overall mechanical properties, while nickel improves yield strength and ultimate tensile strength. Furthermore, the presence of copper and nickel contributes to the precipitation or formation of secondary phases, which can further enhance the mechanical properties of the alloys. Despite the limitations associated with copper and nickel, higher concentrations of these elements are being investigated in the ongoing studies to gain a comprehensive understanding of their behaviour and their impact on microstructure, mechanical properties, and corrosion behaviour.

The investigation continues with the Mg-Cu and Mg-Ni systems, incorporating varying percentages of Mn. Alloys such as Mg-1Cu, Mg-2Cu, Mg-3Cu, Mg-1Cu-1Mn, Mg-2Cu-2Mn, Mg-3Cu-2Mn, Mg-0.7Ni, Mg-1.4Ni, Mg-1.7Ni, Mg-0.7Ni-2.33Mn, Mg-1.7Ni-3.15Mn, and Mg-2.3Ni-1.96Mn were developed and analyzed using techniques like optical microscopy, SEM, X-ray diffraction, tensile tests, and Vickers hardness tests. Corrosion rates were also determined through immersion tests in a 3.5 wt.% NaCl solution. The results reveal that the addition of Mn leads to a reduction in grain size, with presence of α-Mg, Mg_2Cu, and α-Mn phases identified as the principal phases through XRD analysis. Furthermore, the presence of 2 wt.% manganese in Mg-Cu alloys demonstrates the maximum ultimate tensile strength and hardness, while also significantly improving corrosion resistance. However, in Mg-Ni alloys, the findings indicate that the presence of nickel and manganese refines the grain size of magnesium, with the presence of α-Mg, Mg_2Ni, and Mn phases confirmed by XRD analysis. The addition of nickel and manganese enhances the mechanical properties of pure magnesium, but the presence of manganese in Mg-Ni alloys adversely affects corrosion behaviour, leading to an accelerated corrosion rate. Finally, the addition of manganese in Mg-Cu system improves mechanical and corrosion properties both. But in case of Mg-Ni alloys system the presence of Mn was not beneficial in terms of corrosion resistance performance.