Chapter 5
Mechanical Alloying of Magnesium and Titanium Alloys

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ABSTRACT

Mechanical alloying (MA) creates advanced Mg-Ti alloys via controlled microstructural changes and uniform elemental distribution. High-energy ball milling induces solid-state reactions, refining alloys. Parameters like duration, ball-to-powder ratio, and speed impact microstructure. Analytical tools reveal phase changes, microstructural evolution, and element distribution. Mg-Ti alloys exhibit enhanced mechanical properties. MA shows promise for aerospace and automotive applications, with challenges to address for full potential realization. This chapter discusses the different approaches opted for mechanical alloying of magnesium and titanium alloys.

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INTRODUCTION TO MAGNESIUM ALLOYS

Magnesium, discovered in 1774, ranks as the sixth most abundant element on Earth, representing approximately 2% of the Earth's crust. Due to its classification in the alkaline earth metals group, magnesium is naturally found in compound forms rather than as a pure element. Notable sources of magnesium extraction include magnesite, dolomite, carnallite, and seawater. With an approximate density of 1.738 g/cm3, magnesium stands as the lightest structural metal, yet it boasts remarkable strength and stiffness. To enhance its properties, magnesium is alloyed with various elements, and these alloys are identified using an ASTM-based naming convention. In the realm of material processing, powder metallurgy plays a vital role in enhancing magnesium's mechanical characteristics and corrosion resistance. Subsequently, sintering is employed to promote uniformity and facilitate interdiffusion between particles, thereby improving the material's performance (Giridasappa et al., 2023; Guan, 2015). The realm of cast magnesium (Mg) alloys can be divided into two groups based on chemical composition: Mg- Aluminium (Al) alloys with controlled Al content and additional elements for cost-effective manufacturing, and Al-free alloys with Zn, RE, Y, and Zr for high-temperature applications. Wrought Mg alloys have heat treatable and non-heat treatable variants, limited by the hexagonal close-packed crystal structure of Mg. Advanced processing techniques offer potential for microstructure refinement. Cast Mg alloys dominate with around 90% usage. Incorporating 1-9% Al in Mg alloys enhances tensile strength, ductility, and castability below 120 °C, but beyond 2% Al, corrosion resistance improves while mechanical properties decline at higher temperatures. Adding Zinc (Zn) improves tensile properties but affects weldability. Mg-Zn based alloys exhibit strength and ductility, with research focusing on optimizing properties through alloying elements like the Mg-Zn- Zirconium (Zr) system. Mn enhances corrosion resistance but has limited strengthening effects. Adding Mn to Mg-Gd alloys increases strength but reduces ductility. Ca enhances mechanical properties and corrosion behavior in Mg alloys for biomedical applications, but excessive Ca content can render the alloy brittle. Mg-Zn- Calcium (Ca) alloys are considered for biodegradable implants. The addition of Yttrium (Y) in Mg alloys aims to enhance elevated temperature plasticity and creep resistance, while RE elements refine crystals and improve creep and corrosion resistance in Mg alloys for automobile engineering. Gd, in particular, shows high solubility in Mg, enabling solid solution and precipitation strengthening. Mg alloy systems containing large amounts of rare-earth elements result in high costs for practical applications (Cheng et al., 2016; Rajendrachari, 2023).

Researchers have developed magnesium alloys with the Mg2Si phase, exhibiting excellent mechanical properties. Al-Mg- Silicon (Si) alloys, including Mg2Si, show improved characteristics, making them attractive in automotive and aerospace

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