PROPERTY DEVELOPMENT OF NEW GENERATION PM ALUMINUM MATERIALS VIA INNOVATIVE PROCESSING

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ABSTRACT

The weight savings associated with PM aluminum and the ability to produce precise, consistent net-shaped parts have been key driving forces for growth. High cooling rates experienced in the gas atomization process extends the solubility of alloying elements, particularly transition and rare earth elements, and refines the structure of intermetallic phases. This technology has provided a series of next generation, high performance aluminum PM materials, which use evenly dispersed nano-sized crystals and quasi-crystals to provide significant improvements in strength and wear properties. These powders have been consolidated into useful forms by hot extrusion; however, part size, complexity and cost can be limitations. This work describes the properties developed in these next generation alloys through the application of specialty processing technologies, such as, Additive Friction Stir (AFS), Field Assisted Sintering Technology (FAST), Cold Spray Consolidation (CSC), and Inertia Rotary Friction Welding (IRFW).

INTRODUCTION

Alloy Background

Although the current PM aluminum alloy powders can develop useful properties, these materials are frequently restricted to low stress applications,[1-3] which include automotive cam caps and power tools. Furthermore, the mechanical properties of existing PM aluminum alloy powders, particularly, Young's modulus, wear resistance and elevated temperature property stability, do not meet the requirements for an expanded range of more demanding applications, e.g., automotive engine and transmission components, aerospace, military and high performance transportation and other vehicle applications. The development of a wide range of high performance PM aluminum alloys for medium to high stress applications, such as those subjected to cyclic stresses at elevated temperature, is required for continued growth of aluminum PM. New material development will include robust processing technologies and innovative product design.

Current development work focuses on a new generation of enhanced aluminum PM alloys using additions of transition metals (TM) including Ti, Cr, Mn, Mo, Fe, Ni, Si and other additives may be included as well. Thus, the "AL-TM" designation has been used for the new alloys included in this study. The maximum addition of the TM alloying element(s) is about 15% by weight. These AL-TM materials are designed to be strengthened by amorphous and quasi-crystalline (icosahedral) phases.[4] The AL-TM powders used in this study were produced by induction melting, followed by an inert gas atomization process, and screened to remove oversize (+400 μm) particles and yield specific fractions of interest, e.g. -100 μm powder.

Figure 1 shows scanning electron microscope (SEM) images of a typical microstructure of the AL-TM aluminum alloy compared with a cast sample of the same alloy composition. Because the difference in size of the microstructures is so large the SEM images were taken at a variety of magnifications. The PM alloy exhibits a homogenous microstructure with very fine and evenly distributed TM-rich particles in a crystalline aluminum matrix, as shown in Figure 1 (a) to (c). This microstructure is in strong contrast to the cast sample, which has a relative heterogeneous microstructure, and the TM-rich phases are much