Metal Injection Moulding of Aluminium Alloy 6061 with Tin

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1. Introduction

Aluminium metal injection moulding has the potential to combine the light weight advantages of aluminium with the cost benefits of injection moulding for the manufacture of small, intricately shaped parts. Potential applications include components in consumer electronic goods, office machinery, hand tools and the automotive industry. The key issue in the development of an Al MIM system is the sinterability of aluminium. The major problem to be overcome is the oxide film. This oxide is a sintering barrier and needs to be disrupted or removed before sintering can be effected. We found that under appropriate conditions, including compositional and environmental control, the oxide barrier can be overcome and aluminium can be sintered to near full density without the need for mechanical shear. Here, we describe the development of an aluminium MIM system that is based on AA6061 mixed with sintering additive tin powder. The aim of this work is to develop an alloy and a MIM processing route that produced a material with mechanical properties that approached those of conventionally processed aluminium alloys.

2. Experimental

Round AA6061 powders with D50 of 13.4 μm and Sn powders <43μm were used. For the initial examination of the sintering response, AA6061 powders with up to 2 wt.% Sn were mixed and sintered in argon or nitrogen atmosphere.

For the MIM process, the feedstock has a powder loading of 82.9 wt.%. The binder system consisted of 3% stearic acid, 52% palm oil wax and 45% high density polyethylene. The metal powders and the polymer binder ingredients were pre-mixed, then compounded and extruded. To approximate the injection moulding process, 25.4 mm diameter disc samples were prepared using hot compaction. The injection moulding of the test bars and demonstration components were performed using an Arburg moulding machine. Solvent debinding was conducted in hexane to extract more than 90% of the wax and stearic acid. The thermal debinding of the remaining binder and sintering were combined in one furnace cycle. Magnesium and alumina blocks were also placed on the sample tray surrounding the parts.

3. Results

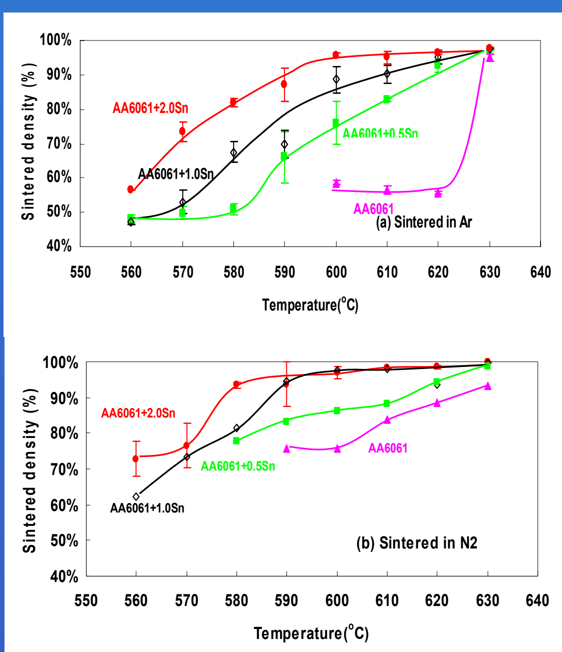

Fig. 1 Sintered density of AA6061+x%Sn powders at various temperatures for 2 hrs in (a) argon and (b) nitrogen. The Sn significantly increases the density and expands the sintering window.

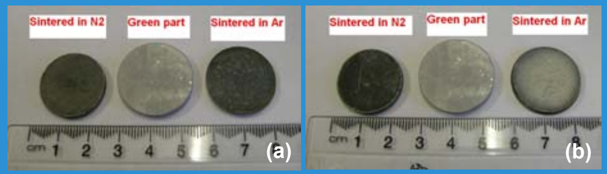

Fig. 2 Hot pressed samples of AA6061+2.0%Sn before and after sintering at 620°C for one hour in nitrogen and argon: (a) top surface (b) bottom surface. There is differential shrinkage between the top and bottom surfaces of the argon sintered sample, leading to a concave bottom surface. In contrast, the sample sintered in nitrogen is not distorted.

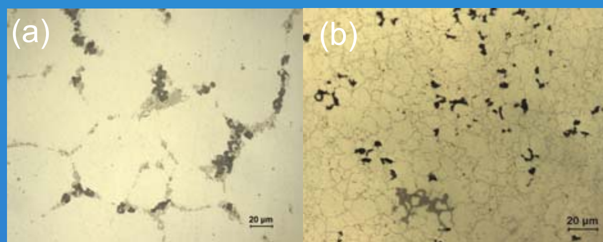

Fig.3 Optical micrographs of the hot pressed AA6061+2%Sn parts sintered at 620°C for 1hr: (a) in argon and (b) in nitrogen. The grain size grew to ~100μm in argon, but the original particle size of <20 μm was retained in the nitrogen sintered sample, where the AlN phase is clearly apparent on the grain boundaries.

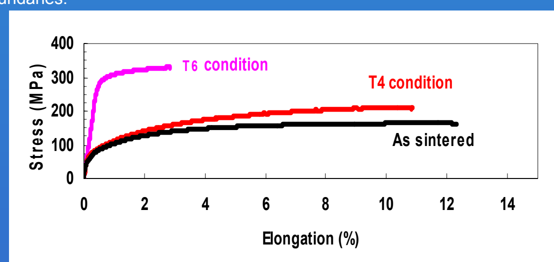

Fig.4 Typical tensile curves of PIM AA6061+2Sn materials tested in the as sintered, T4 and T6 conditions

Fig.5 The metal injection moulded demonstration parts, showing that thin walled sections and distortion free complex shapes can be fabricated.

4. Summary

- Components with intricate shapes and near full density can be fabricated from aluminium alloy AA6061 using metal injection moulding technology with Mg blocks in the furnace as oxygen getter, Sn as sintering aid and a nitrogenous atmosphere.
- The tensile strength achieved was about 160, 210 and 300 MPa and the elongation to failure of is about 9.5%, 10.4% and 1.5% in as sintered, T4 and T6 condition.