Sintering Behaviour of Al-Cu-Mg-Si Blends

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Abstract

The increasing demand for automotive industries to reduce the weight of the vehicles has led to a growing usage of Al alloy powder metallurgy (P/M) parts. In order to control the sintered microstructure and mechanical properties of the aluminium alloy powder metallurgical (P/M) parts, it is essential to establish a fundamental understanding of the microstructural development during the sintering process. This paper presents a detailed study of the effect of temperature and initial starting materials on the evolution of microstructure during the sintering of Al-Cu-Mg-Si blends for PM.

Keywords : sintering, aluminium alloy, microstructure and differential thermal analysis

1. Introduction

Liquid phase sintering of Al alloy is currently the only accepted technique that is capable of producing P/M components with acceptable mechanical properties[1, 2]. The liquid phase usually are made up of either low melting point elemental additions such as Sn, Zn, Pb, etc or a low melting point eutectic phase such as Al-12%Si master alloy. The presence of a liquid phase enhances sintering but can give distortion and reduced ductility due to the formation of a brittle intergranular phase.

Current research is focussed on the optimisation of sintering conditions and effects of sintering aids to improve the mechanical properties of aluminium P/M components[3,4]. However, there is a limited amount of data available in the literature about microstructural developments undergone by different aluminium blends during sintering.

This paper presents a detailed study of the phase transformation occurring during the sintering of Al-Cu-Mg-Si blended powder mixtures as a function of initial starting particulate constituents and sintering temperature using a combination of differential scanning calorimetry (DSC) and scanning electron microscopy (SEM).

2. Experimental

2.1 Materials

Two types of aluminium blends namely *EleMix* and *AlloyMix* based on gas atomised elemental Al powders with size distribution (+45-150μm) optmised for maximum flow properties[5] and supplied by The Aluminium Powder Company Limited (Alpoco) were studied. *EleMix* consisted of elemental Mg and Cu powders and Al-12wt%Si master alloy powder, while *AlloyMix* consisted of Al-50wt%Mg, Al-54wt%Cu and Al-12wt%Si master alloy powders. The overall chemical composition of both blends was the same Al-4.4%Cu-0.5%Mg-0.6%Si.

2.2 Blending

Both *EleMix* and *AlloyMix* powder mixtures were blended in a Turbula mixer operating at 50 rpm and 25 mins.

2.3 Compaction

The blended powders were compacted into 5 diameter and 10mm thick discs inside a lubricated die using a pressure of 20tsi (≈310Mpa) at room temperature.

2.4 Sintering

The compacted samples were sintered at 475 ^oC, 510 ^oC, 540 ^oC and 600 ^oC for 10 minutes in a Themal Elite[TM] horiz ontal tube furnace with a dynamic flow of N_2 and a dew p oint of -45°C, before they were frozen by quenching them in a pool of liquid nitrogen.

2.5 Materials characterization

Microstructure of sintered components was studied using Jeol 6060 SEM coupled to an Oxford Instruments Energy Dispersive Analyser. The sintering behaviour was also studied using Netzch Jupiter DSC operating with a dynamic flow of nitrogen, a heating rate of 10 ^oC /min over a temperature range between 200°C and 700°C.

3. Results

Figures 1(a-b) show typical DSC traces of *EleMix* and *AlloyMix* AlCuSiMg powders, respectively together with binary elemental mixture of Al-4.4wt%Cu, Al-0.6wt%Si and Al-0.5wt%Mg for comparison.

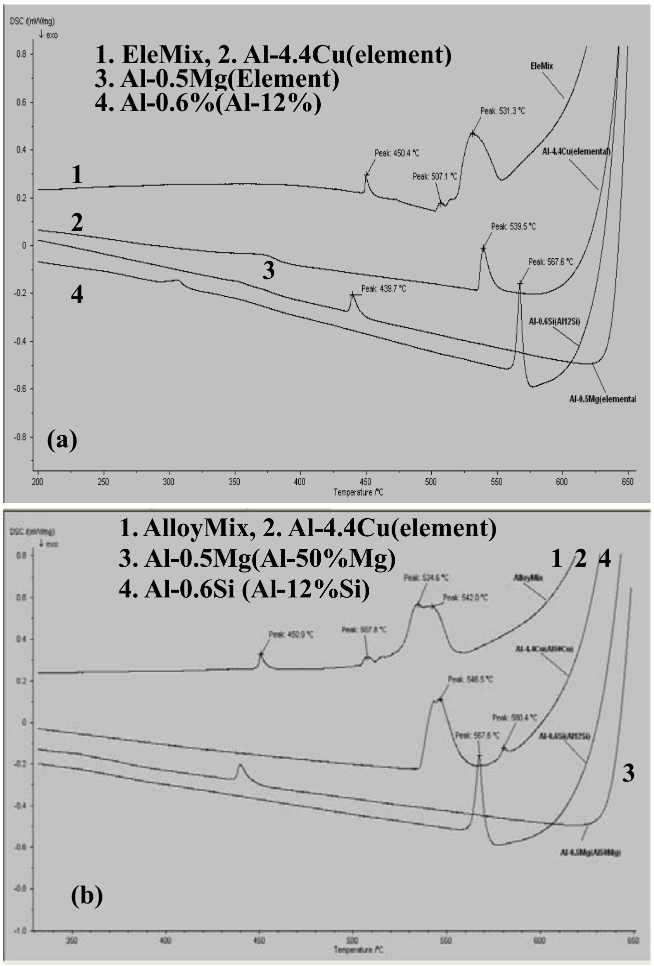

Fig. 1. DSC traces of (a) EleMix and (b) AlloyMix Al-Cu-Si-Mg powder blends together with binary mixture using either elemental or master alloy additions.

For the *EleMix* samples, the DSC trace in figure 1(a) consisted of three endothermic peaks at 450 °C, 507 °C and 530 °C. *AlloyMix* samples show a very similar DSC trace in Fig 1(b). The 450 °C peak is believed to correspond to the formation of Al-Mg eutectic liquid. However, the subsequent peaks at higher temperature are believed to be caused by formation of a ternary liquid phase.

At 475 °C the microstructure consisted of Al matrix with undissolved Cu particles (1), Si rich eutectic regions (2) and pores (3). At 540 °C the microstructure consisted of large melt pools (1) which have a composition of mainly Al-Si but traces of Cu and Mg were found. At 600 °C the microstructure consisted of a fully developed Al grains with a grain boundary phase rich in Cu and Si(2). However, remnants of the Al-12%Si eutectic liquid can still be observed (1).

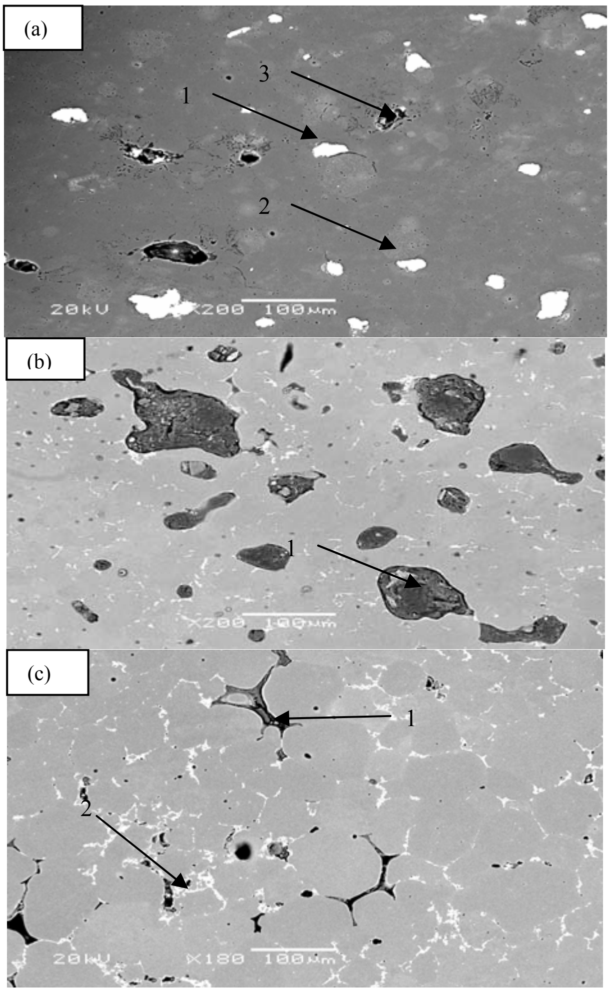

Fig. 2. SEM micrographs of AlloyMix Al-Cu-Si-Mg powder blend heated upto (a) 475 °C, (b) 540 °C and (c) 600 °C for 10mins and quenched in liquid nitrogen.

4. Conclusions

-DSC studies suggest the formation of a series of liquid phases (eg. Al-Mg, Al-Cu and Al-Si)

-Low sintering temperature involves the diffusion of Mg and Cu into the Al matrix.

-High sintering temperature involves formation of eutectic liquids leading to liquid phase sintering.

5. References

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