STRENGTH AND TOUGHNESS OF NOVEL MMCs BASED ON HYPEREUTECTIC Al/Si ALLOYS

J. Valer Goñi, J.M. Rodríguez-Ibabe and J.J. Urcola

Conventional mechanical properties and toughness of an Al/25Si/5Cu MMC formed to near-net shape by a combination of spray-forming, extrusion and thixoforming have been measured. Toughness values between 9.5 and 14 MPa√m have been obtained. Microstructure parameters and principally local clustering of Si particles play a very important role in MMC mechanical behaviour. Fracture starts at particle clusters growing rapidly through $CuAl_2$ eutectic and the matrix. Microstructural optimisation, decreasing Si particles connectivity, would bring to a better mechanical behaviour.

INTRODUCTION

Hypereutectic Al/Si alloys are used in automotive industry and in other applications where good wear behaviour is necessary. The Al/Si phase diagram shows that high temperatures are required for high Si content alloys and in consequence, a coarse network of primary Si particles appears leading to adverse ductility and toughness. Novel metal matrix composites (MMCs) based on the Al/Si system and containing 25% Si have been prepared by a combination of spray-forming and thixoforming (1). In the present study the strength and the toughness and their relationship with the microstructure of these novel MMCs are considered.

MATERIAL AND EXPERIMENTAL PROCEDURE

The material used is an Al/25Si/5Cu MMC formed to near-net shape by a combination of spray forming (Osprey, UK), extrusion and thixoforming (at 570°C)

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(University of Sheffield, UK). The material was studied in two different conditions: as-extruded and extruded + thixoformed. The objective of the extrusion is to break the continuous Si particles network, which appears in the as-spray microstructure. The microstructure is composed of primary Si particles, spherical α-Al and an $CuAl_2$ eutectic (Fig. 1). Quantitative measurements of Si particle volume fraction and distribution were made using a Quantimet image analysis system. Si particle mean value in the as-extruded condition was ≈ 4μm. After thixoforming the Si particles, volume fraction ≈ 30%, grow to a mean value of 9 μm. Histogram of particle distributions in as-extruded and extruded + thixoformed conditions are shown in Fig. 2. As it can been observed, during the thixoforming process there is an important modification of Si particle size distribution. It is worth emphasising that some particle agglomeration takes place also during thixoforming.

Tensile and three point bending, 3PB, test specimens (W = 11mm, B = 5,5mm) were machined from extruded bars (60 mm diameter, parallel to the extrusion direction) and thixoformed plates (12x120x120mm). Toughness specimens were fatigue precracked in agreement to E399 standards (2). Fractographic examination was performed on fracture surfaces in a SEM microscope.

RESULTS AND DISCUSSION

Tensile properties are shown in Table 1. As it can be observed, after thixoforming there is an improvement in the strength (thixoforming exerts an effect equivalent to a heat treatment) but elongation decreases dramatically. Microscopic examination of the longitudinal specimens shows that fracture starts by cracking of Si particles. Fracture toughness measurements are reported in Table 2. In the as-extruded conditions, K_Q values do not fulfill minimum thickness requirements to become K_{Ic} values. For the as-extruded microstructure, toughness values are ≈ 7 to 8 MPa$\sqrt{m}$ and after thixoforming, toughness increases to 9.5 to 11 MPa$\sqrt{m}$.

Fig. 3 corresponds to the fracture surface of a 3PB specimen. Fractography of different specimens shows an increase in the particle density on the fracture surface compared with the volume fraction of the matrix. On the other hand, fractography analysis and crack profile examination show that the predominant micromechanisms

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ACKNOWLEDGMENT

This work is supported by the BRITE/EURAM programme N° BREU 0129-C. The Partners are: CEIT (Spain), Ederlan (Spain), Sheffield Univ. (UK), Lucas Automot. Ltd. (UK), Osprey Metals Ltd. (UK) and Ruhr-Universität Bochum (Germany).

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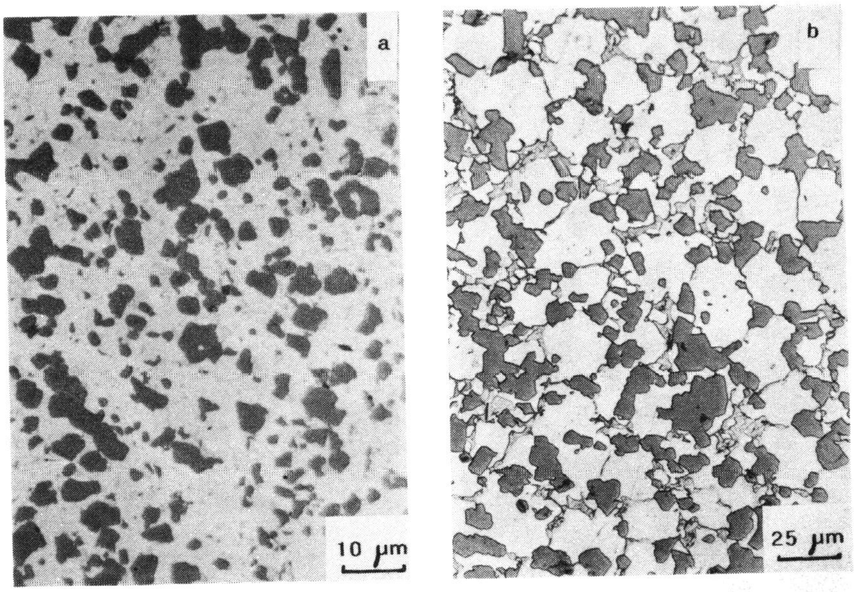

Figure 1 Typical microstructures of Al/25Si/5Cu material: a) spray-formed + extruded and b) spray-formed + extruded + thixoformed.

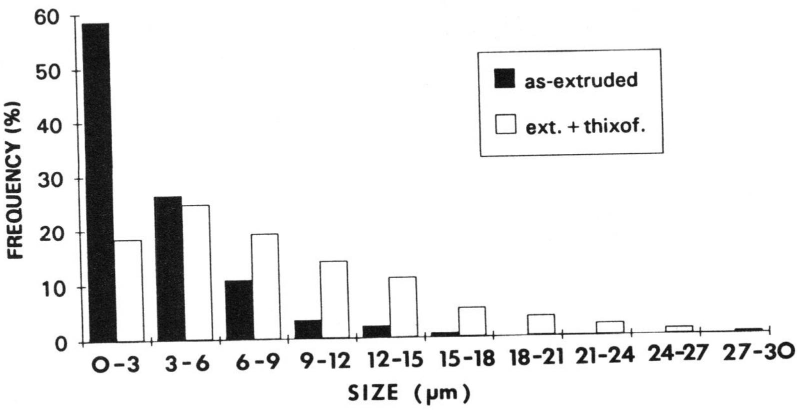

Figure 2 Histograms of the average dimension of Si particles.

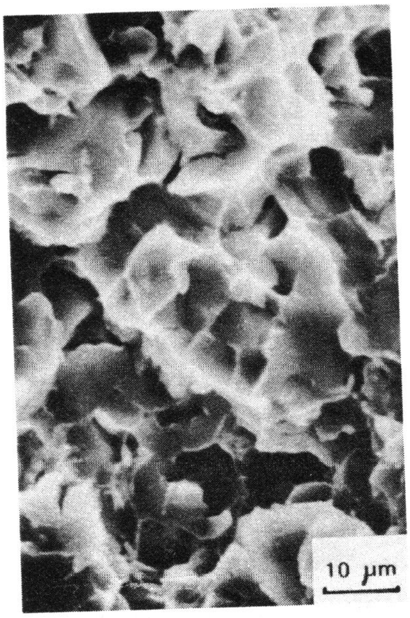

Figure 3 Fracture surface of a 3PB specimen (K_{Ic} = 9.6 MPa√m).

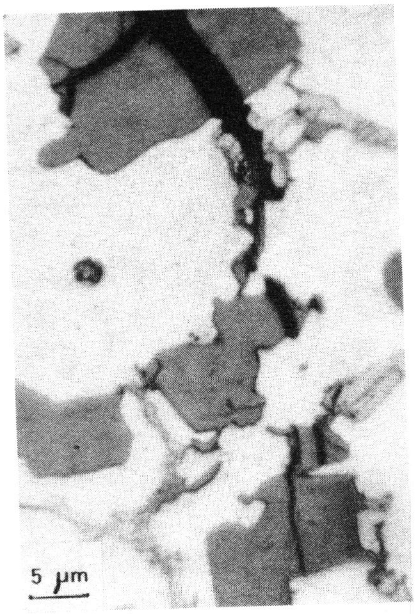

Figure 4 Crack nucleations on Si particles.

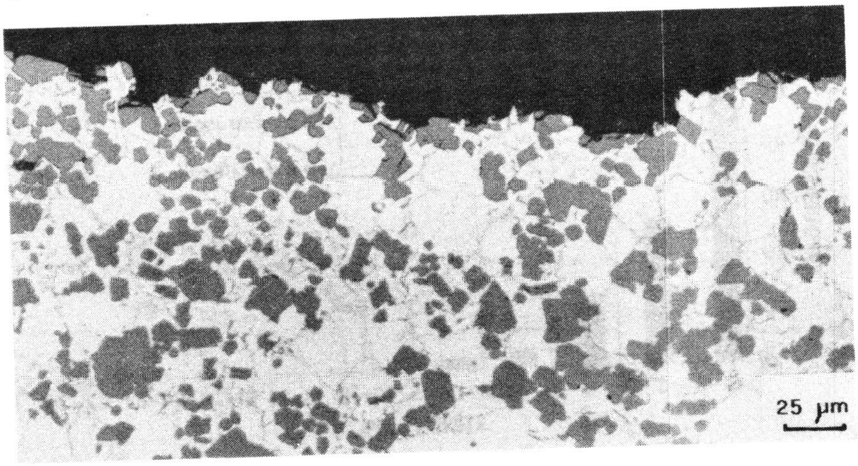

Figure 5 Section normal to the crack plane of a fracture toughness specimen (extruded + thixoformed, K_{Ic} = 10.5 MPa√m).