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High strength Al–Al_2O_{3p} composites: Optimization of extrusion parameters

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Composite aluminium alloys reinforced with Al_2O_{3p} particles have been produced by squeeze casting followed by hot extrusion and a precipitation hardening treatment. Good mechanical properties can be achieved, and in this paper we describe an optimization of the key processing parameters. The parameters investigated are the extrusion temperature, the extrusion rate and the extrusion ratio. The materials chosen are AA 2024 and AA 6061, each reinforced with 30 vol.% Al_2O_3 particles of diameter typically in the range from 0.15 to 0.3 μm. The extruded composites have been evaluated based on an investigation of their mechanical properties and microstructure, as well as on the surface quality of the extruded samples. The evaluation shows that material with good strength, though with limited ductility, can be reliably obtained using a production route of squeeze casting, followed by hot extrusion and a precipitation hardening treatment. For the extrusion step optimized processing parameters have been determined as: (i) extrusion temperature = 500 °C–560 °C; (ii) extrusion rate = 5 mm/s; (iii) extrusion ratio = 10:1.

1. Introduction

Particle reinforced metal matrix composites have already found commercial use on account of the fact that conventional processing techniques, such as powder metallurgy [1,2], vacuum hot pressing [3], co-spray deposition process, and squeeze casting methods [4–6] can be readily adopted for the processing of such materials. One important group of reinforced metal matrix composite materials includes the aluminium alloy-based composites. These composites combine high specific strength [5,6], high specific modulus [7], high wear resistance [8,9], high thermal conductivity [10], heat treatment capability and processing flexibility [11,12]. In recent papers [13,14], the structure/strength relationship has been discussed for Al_2O_{3p}/Al composites produced by squeeze casting followed by hot extrusion and precipitation hardening. It has been found that composites with good strength but limited ductility can be produced using this method. In this paper we describe an optimization of the extrusion conditions for such composites through an investigation of the key extrusion parameters. The parameters chosen are: (i) the extrusion temperature, (ii) the extrusion rate, and (iii) the extrusion ratio. It has already been demonstrated that composites with a range of volume fractions of Al_2O_3 particles from 20 to 60 vol.% can be successfully produced [13,14]. However, in the present study we limit our investigation to just one Al_2O_{3p} concentration, namely 30 vol.%, and to two alloy matrices, namely AA2024 and AA6061. This choice limits the data set to results which are typical for all the composites examined. For evaluation of the mechanical properties of the composites, tensile testing has been carried out at room temperature. The microstructures of the composites have also been characterized. Based on the data obtained, suitable parameter ranges are proposed for the optimum processing parameters.

2. Experimental

2.1. Composite fabrication

The billet material for the extrusion process was fabricated by a squeeze casting method [4]. This technique also known as liquid metal forging is a combination of a casting and a forging process. The molten metal is poured into the bottom half of the pre-heated die. As the metal starts solidifying, the upper half closes the die and applies a pressure on the metal during the solidification process. The amount of pressure is significantly smaller than used in forging, and parts of great detail and with a low porosity can be produced. Coring can also be used with this process to form holes and recesses. The nominal chemical compositions of the matrix alloys are shown in Table 1. Alumina (α-Al_2O_3) particles with an average size of 0.15–0.3 μm were used for the reinforcement phase.

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