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The effect of ultrasonic vibrations prior to high pressure die-casting of AA7075

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ABSTRACT

The effects of introducing ultrasonic vibrations prior to high pressure die casting have been experimentally investigated. Results suggest reductions of up to 73% in grain size and up to 5% on porosity levels due to cavitation, leading to enhanced structural performance. The typical values of ultimate tensile stress and yield stress increased respectively to 590 MPa and 502 MPa and elongation improved to 18%. Wetting of the oxides by the collapse of cavitation bubbles along with enhanced degassing appears to be the responsible mechanisms for these property improvements. The effect of relaxation time after ultrasonic vibrations examined and results indicate slight grain size increase from 68 to 80 μm. Proving ultrasonic treatment above liquidus appears to be a stable phenomenon where its effects remaining active for a considerable time, making the process feasible for industrial scale applications.

1. Introduction

Fine grain size leads to improved mechanical properties and therefore enhances structural performance. Two major methods are in current use for microstructure refinement; chemical and physical. The chemical approach is based on addition of grain refiners, such as Al–5Ti–1B master alloy for aluminium and Zr for Al free Mg alloys [1]. However, just 1% of the grain refiners act as nucleation sites and the rest turn into impurities that adversely affecting the mechanical properties [2]. The physical methods involve the application of melt conditioning or Electromagnetic techniques [3], with the possible erosion of screws for the former or ingot size limitations for the latter proving of concerns. The introduction of ultrasonic vibrations to a melt is an attractive approach used for ingot making either by itself or in combination with other methods, but its effects decrease with increasing pool size [3].

Die casting technology is one of the most widely employed manufacturing processes for producing various automotive components, where the main advantages are high productivity and the casting of components with thin walls and complex geometries [4]. However, Die casting aluminium alloys for safe critical automotive parts is restricted due to internal defects and corresponding reductions in material performance. Major internal defects include porosity, solidification shrinkage and non-uniform microstructures [5–7]. The application of ultrasonic vibrations prior to die casting might provide an alternative route of treating the melt that could alleviate some of these problems. In this paper, the effects on mechanical properties and microstructural evolution have been studied through a combination of die casting with ultrasonic vibrations, using aluminium AA7075 as the model material.

2. Experimental approach

2 kg of AA7075 with the composition shown in Table 1 was melted in a furnace. The melt was treated with an ultrasonic probe and switched on before dipping it 3 mm below the liquid surface. Treatment performed for 60 s at frequencies of 10, 14, 17.5 and 20 kHz with an input power of 4 kW. The ultrasonic probe is designed to provide a hollow shell defining a flow path for transporting argon gas bubbles into liquid. After treatment, the liquid, through a melt flow indexer electronically monitoring weight, flow and temperature, is transferred to the launder and shot chamber for casting; 450 g of melt required for three tensile samples. Fig. 1 illustrates the apparatus, the ejection side of mould and the size of the samples.

The specimens were sectioned in the middle and the as-cast grain structures observed using conventional metallographic techniques where the samples anodised at 20 V DC in 3% HBF_4. Grain size measurements performed using the linear intercept method (ASTM E112-96) [8]. For tensile tests a CMT5105 universal machine

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employed at a strain rate of 1 min^{-1}. The porosity of ultrasonically treated and non-treated samples was assessed by the Reduced Pressure Test (RPT) [9]. Both types of melt were poured into thin walled steel moulds and allowed to solidify in atmospheric pressure and under a partial vacuum of 70 mbar, in order to calculate and compare the resulting density indices. Moreover, Archimedes' method was used for comparison between RPT and Archimedes' routes.

3. Results

Fig. 2 depicts the effect of various frequencies on the refinement of microstructure. Results suggesting for 10 and 14 kHz no refinement compared with non-treated microstructure whilst applying 17.5 kHz and 20 kHz provided grain size of 68 and 60 μm, respectively. Fig. 3 shows the microstructures of ultrasonically treated and non-treated samples. The treated sample at 17.5 kHz shows fine microstructure of around 68 μm whilst the non-treated one a coarser less uniform one of around 118 μm.

The results of porosity measurements are displayed in Fig. 4 where D_a and D_v, represent the densities of samples solidified in air and under partial vacuum, respectively. D_i is the density index indicating the porosity content level [9]. The porosity level of the treated sample appears to have decreased significantly in comparison with the non-treated one; level decrease from 5.5% to 1.72%.

Table 1
The chemical composition of the examined AA7075 alloy.

Zn	Mg	Cu	Mn	Si	Ti	Al
5.5	2.4	1.6	0.1	0.2	0.1	Bal.

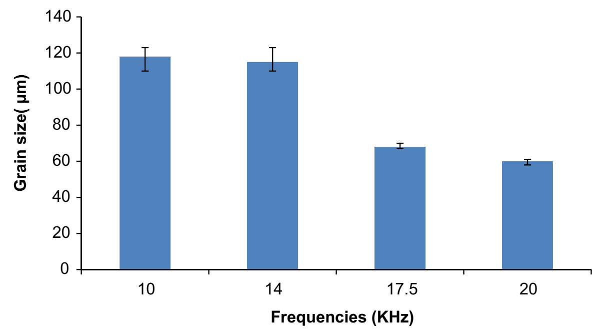

Fig. 2. The grain size variation at various frequencies.

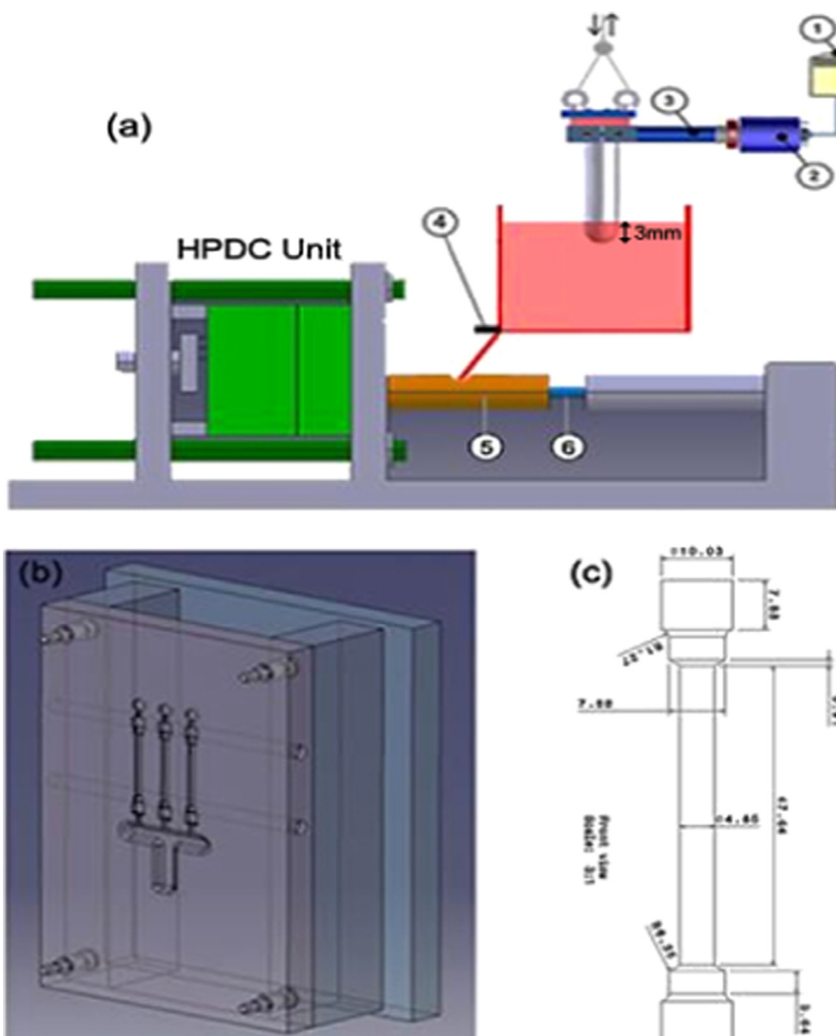

Fig. 1. The schematic view of (a) the apparatus: (1) power, (2) Converter, (3) wave guide, (4) melt flow indexer, (5) shot sleeve, (6) piston (b) the ejection side of the mould, and (c) size of the sample.