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THE PRODUCTION AND ELEVATED TEMPERATURE MECHANICAL BEHAVIOUR OF Mg-BASED BULK METALLIC GLASSES

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Overview

Magnesium-based bulk metallic glasses (BMG's) are a new family of materials that exhibit high specific strength and hardness at room temperature, extraordinary ductility/superplasticity at slightly elevated temperatures, and superior corrosion resistance to Mg crystalline alloys.[1]

A repetitive low-pressure die-casting technique was developed for optimising the processing parameters for casting amorphous $Mg_{65}Cu_{25}Y_{10}$ samples of dimensions 3mm \times 7mm \times 125mm. An investigation of the effect of various die-casting control parameters, such as the charge temperature, injection pressure and injection velocity on the length and porosity of these samples was carried out.

In conjunction with this work, deformation behaviour in the supercooled liquid region of the $Mg_{65}Cu_{25}Y_{10}$ BMG over a range of temperatures (150°C to 170°C) and various strain rates (10^{-1} to 10^{-3} s $^{-1}$) was investigated.

Sample Production and Preparation

A low-pressure injection die-casting technique [2] was used over a range of injection temperatures (490°C-585°C) and pressures (0.3-1.0Bar) to generate a comprehensive processing map to determine the optimum casting conditions for the $Mg_{65}Cu_{25}Y_{10}$ BMG (Figure 1(a)). The amorphous structure of these samples was determined using XRD analysis and TEM foil pattern imaging.

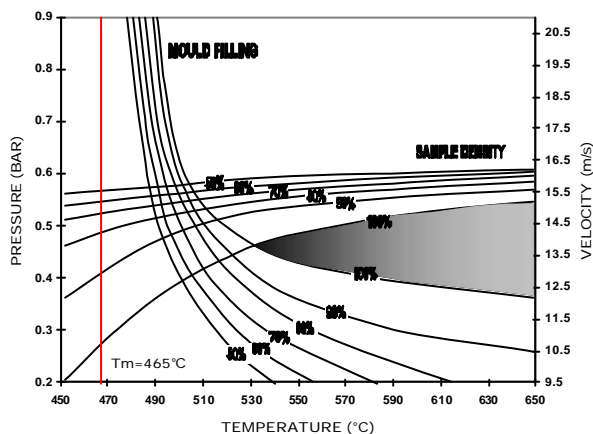


Figure 1. Comprehensive processing map, showing the effect of casting pressure/velocity and melt temperature (on mould filling capacity and sample density (degree of voiding/porosity)). The shaded zone indicates the optimum processing window for generating high quality $Mg_{65}Cu_{25}Y_{10}$ BMG samples [2].

Once the optimal casting window had been determined, a number of high-quality samples were produced for further testing. (Figure 2. (a)). These were then sectioned and ground into tensile samples in accordance with ASTM E8-04. (Figure 2(b)).

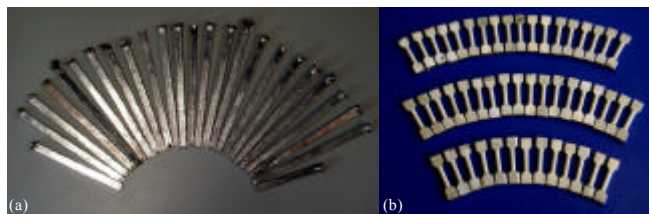


Figure 2. (a) A number of BMG samples produced by low pressure injection die-casting ($T = 585^{\circ}C$ and $P = 0.5$ bar). (b) Tensile samples of 3mm in diameter and 12.3mm gauge length in accordance with ASTM E8-04.

Elevated Temperature Mechanical Behaviour

$Mg_{65}Cu_{25}Y_{10}$ bulk metallic glass samples were deformed over a range of temperatures within the supercooled liquid region (150°C to 170°C) and various strain rates (10^{-1} to 10^{-3} s $^{-1}$). Of the samples that displayed superplastic ductility, a peak flow stress was observed, followed by stress relaxation and near zero flow stresses [3] (Figure 3(a)). A majority of these samples showed elongations in excess of 1300%, most of which retained substantial ductility[3] as seen in Figures 3(b) and (c).

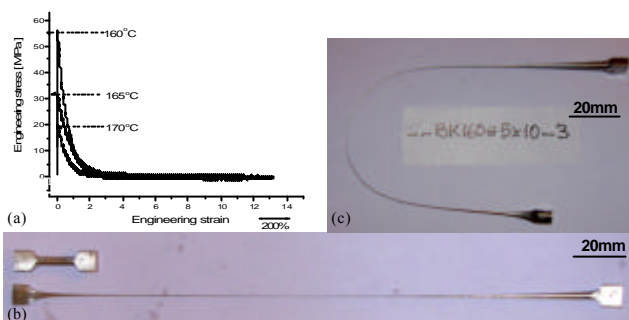


Figure 3. (a) Stress-strain plots for samples tested at 160°C, 165°C and 170°C at a strain rate of 10^{-2} s $^{-1}$. (b) An as prepared and deformed (165°C at 10^{-2} s $^{-1}$) tensile test sample showing an extension in excess of 1300% and (c) a sample exhibiting substantial ductility after tensile testing at 160°C at a strain rate of 5×10^{-3} s $^{-1}$ [3].

Deformation Mapping and Characterisation

Using data gathered from $Mg_{65}Cu_{25}Y_{10}$ BMG samples tested and using specific criteria (Newtonian viscosity [3]), deformation maps showing the boundaries between Newtonian or non-Newtonian flow regimes and brittle fracture modes were developed (Figure 4).

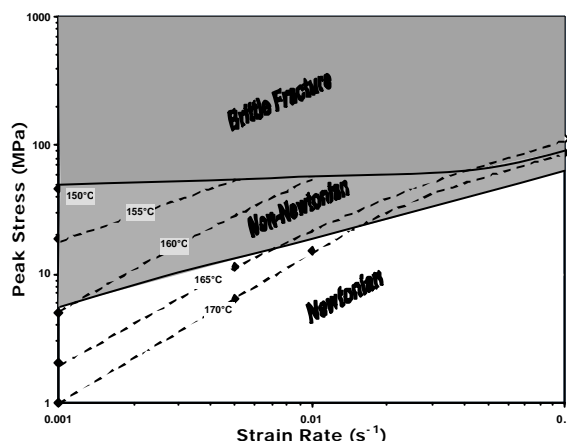


Figure 4. Deformation map showing the boundaries between Newtonian flow, Non-Newtonian flow and Brittle Fracture mode in the $Mg_{65}Cu_{25}Y_{10}$ BMG for a given range of temperatures and strain rates [3].

References

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