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Anomalous Hardness Behaviour of High Pressure Die-Cast Mg-Al Alloys

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Abstract

The yield stress (0.2%) of 5 mm thick high pressure die-cast AZ91 and AM60 alloys has been compared to the respective Vickers hardness. The yield stress and hardness were measured in as-cast specimens, and in specimens directly aged (from the as-cast condition) at 120°C for up to 10000 h. Unlike a range of sand cast and permanent mould cast Mg-Al alloys and an AZ91 alloy, for which the hardness increase proportionally to the yield stress, in high pressure die-cast magnesium alloys the hardness tends to be lower than expected from their yield stress.

Riassunto

Sono stati messi a confronto i valori di carico di snervamento e i valori di durezza Vickers di campioni pressocolati di 5 mm di spessore, realizzati nelle leghe magnesio-alluminio AZ91 ed AM60.
Le misure sono state effettuate su campioni as cast, e su campioni sottoposti ad invecchiamento alla temperatura di 120 °C per tempi fino a 10000 ore.
A differenza di quanto riscontrato su getti prodotti in sabbia ed in gravità nelle medesime leghe AZ91 ed AM60, per i quali i valori di durezza ed di carico di snervamento sono direttamente proporzionali, per i getti pressocolati i valori di durezza misurati sono inferiore di quanto ci si aspetterebbe dai corrispondenti valori di carico di snervamento.

INTRODUCTION

Hardness is a widely used quality control tool often used to estimate the yield stress. Theoretical work and semi-empirical work [1-3] on a wide range of metallic materials, including gravity cast AZ91 [4], indicate that the Vickers hardness number, *Hv*, can be expressed as:

$$Hv = c\,Y_h\,, \qquad (1)$$

where Y_h is the (true) flow stress of the material at a characteristic (true) strain, e_h, and c is a constant of order one. Both the e_h and c-values depend somewhat on the shape of the indenter and the prior deformation state of the material. A relationship similar to Equation 1 can be found between the yield stress (0.2%) and hardness. Sand and gravity cast Mg-Al alloys (1wt.% to 9wt.%) in a range of heat treatment conditions have been shown to exhibit such a relationship [4], as can be seen in Fig. 1, and it was considered of interest to examine the relationship between hardness and yield stress in high pressure die cast AZ91 and AM60 alloys.

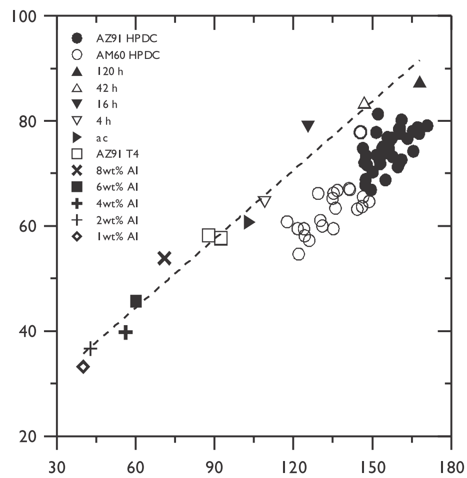

Fig. 1: Plot of Vickers hardness (10 kgf load) versus the yield stress (0.2%) of sand cast, AZ91 [4], permanent mould cast, binary Mg-Al alloys [4] and high pressure die cast AZ91 and AM60 directly aged at 120°C from the as-cast condition for up to 10000 h. The dashed line is the line of best fit to the gravity cast Mg-Al and AZ91 alloys. T4 indicates solution heat treated and quenched; ac indicates as-cast; times in h indicate ageing at 160°C. Binary Mg-Al alloys tested in T4 temper.

EXPERIMENTAL DETAILS

Two alloys, AZ91D and AM60B with melt compositions (wt.%): AZ91D 9.0Al/0.8Zn/0.2Mn and AM60B 5.9Al/0.01Zn/0.3Mn were used in this study. Tensile specimens were cold chamber high pressure die-cast. The specimens were 5 mm thick, with a 10 mm wide gauge length of 50 mm. Specimens of each alloy were aged in air at 120°C for up to 10^4 hours. Tensile testing was carried out on a screw driven testing machine, with a nominal strain rate of 0.06 min^{-1}. Vickers macrohardness measurements were performed on the grip ends of the tensile specimens, with a 10 kgf load.

RESULTS AND DISCUSSION

Figure 1 shows the yield stress (0.2%) plotted versus the hardness for AZ91 and AM60 high pressure die castings (filled and open circles respectively).

The data for the high pressure die castings is shown for all ageing times (as-cast to 10^4 h) [5, 6]. Also plotted in Figure 1 are the data for sand cast, solution heat-treated and aged AZ91 and permanent mould cast solution heat-treated, binary Mg-Al alloys. It can be seen that the sand cast and permanent mould data points all lie on a single straight line, while the high pressure die castings lie to the right of that line. That is, for similar hardness values the high pressure die castings have higher than expected yield stress values than the gravity cast alloys. This behaviour is somewhat puzzling given that for the gravity cast alloys the hardness scales with the yield stress over a range of values well above and below those observed in high pressure die-castings. It is speculated that the sub-surface porosity layer that is often observed in high pressure die cast magnesium alloys [7-10] may collapse during the hardness measurement, resulting in lower than expected hardness values. Alternatively, it is possible that the fine structure of intermetallic that forms the "skin" [9-11] of the die castings reinforces the material when tested in monotonic tension, but its effects do not extend to the localised deformation imposed by the indenter during hardness testing, hence the lower than expected hardness values. This seems to be an area worthy of further investigation.

ACKNOWLEDGMENT

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