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Castability of some magnesium alloys in a novel castability die

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Abstract. This paper reports on the results of the castability of three MRI alloys (153A, 153M and 230D). MRI153A was found to cast best, with castings produced rated with a quality approaching AZ91. MRI230D produced the next best castings, whilst MRI153M showed the worst castability across a range of conditions. However, these alloys showed a tendency to build-up oxide in the melt transfer tube leading to melt transfer problems. This was particularly severe in MRI230D.

Introduction

Castability is a difficult parameter to quantify as there are many factors that contribute to the castability of an alloy [1, 2]. These include its ability to fill a die (fluidity), resistance to cracking, either during solidification (hot tearing) or post-solidification (hot/cold cracking), achieve low porosity, particularly interconnected porosity, and obtain good surface quality. Furthermore the alloy needs to be easy to handle in the molten state, i.e. not burn readily, and not oxidize excessively which can lead to problems transferring the metal from the furnace to the transfer tube and into the mould. Whilst tests have been developed to measure individual casting parameters such as fluidity [3, 4] or hot tearing [5, 6], it has been difficult to assess the overall castability of an alloy. Hence often a qualitative assessment of an alloy is given. Some attempts have been made to quantify castability [7, 8], however, given the complexity to be measured, it is difficult to obtain a real understanding the castability of an alloy until it is cast into a commercial die. It is even more difficult than this because sometimes alloys can be highly castable in one die configuration and less castable in another.

In an attempt to assist with the alloy design effort, and to obtain useful information on castability of alloys before going to an industrial beta trial, a die has been designed to be difficult to cast into. This die has been base-lined on Mg-Al based alloys [9], where it was found that as the Al content increased the castability also increased, as is well known in industry. It has also been used to assist with optimizing the castability of other alloys [10]. This paper focuses on the castability of a family of creep resistant high-pressure die-cast alloys, known as the MRI alloys, as part of a larger activity where a wide range of creep resistant alloys are being assessed.

Experimental Methods

A detailed description of the casting set-up including the design of the die can be found elsewhere [9]. The casting procedure was the same as detailed previously [9] so that direct comparisons can be made between alloys, with ten castings made at two high-speed plunger velocities (1.3 and 2.0 m/s) at two die temperatures of 180°C and 250°C with a constant cycle time of 60 s being used. The castings were evaluated according to three criteria: filling, cracking and spangling with a rating out of five being given for each criteria with 5 being excellent. The ratings provided are an average of the ten castings. The composition of the three alloys to be reported is given in Table 1.

Table 1. Composition of the alloys determined by ICP-AES. Each composition is an average of two measurements.

Alloy	Al (wt.%)	Ca (wt.%)	Mn (wt.%)	Sr (wt.%)	Zn (wt.%)	Sn (wt.%)	Fe, Ni, Cu (ppm)
MRI153A	8.32	1.01	0.22	0.09	0.75	<0.01	<20
MRI153M	7.73	1.06	0.25	0.30	<0.01	<0.01	<20
MRI230D	6.49	2.00	0.28	0.43	<0.01	0.95	<20

Results and Discussion

Visual ratings for each of the three casting criteria are given in Table 2. In general the alloys filled the die reasonably well, with MRI153A being the best and all alloys performed much better at the higher high-speed plunger velocity. This appeared to be more important than an increased die temperature. The MRI153M alloy, and to a much lesser extent the MRI153A alloy were prone to cracking, particularly at the lower die temperature and low plunger velocity. An example of which is shown in Fig. 1. 'Spangling', or a mottled surface finish, was observed in the MRI230D (Fig. 2) and MRI153M alloys at the lower die temperature and plunger velocity. Whilst MRI153A was the alloy with the best castability, good quality castings could be obtained from all alloys (Fig. 3), particularly at the higher die temperature and high high-speed plunger velocity (Table 2).

Table 2. Ratings for each of the alloys for the (a) filling, (b) cracking and (c) 'spangling' criteria at each of the casting conditions.

(a)

Filling	MRI153A	MRI153M	MRI230D
1.3/180	2.5	1.3	2.6
2/180	3.35	2.9	3.75
1.3/250	2.7	2.2	1.65
2/250	3.5	3	3.8

(b)

Cracking	MRI153A	MRI153M	MRI230D
1.3/180	1.65	1.05	2.35
2/180	3.25	1.65	2.8
1.3/250	2.5	1.8	2.35
2/250	3.45	2.6	3.75

(c)

'Spangling'	MRI153A	MRI153M	MRI230D
1.3/180	2.6	1.2	1.8
2/180	3.15	2.2	2.35
1.3/250	2.9	2.55	2.95
2/250	3.55	2.5	3.3

Another important consideration for castability that is not quantified in these ratings is the melt stability and melt handling. In general, all of these alloys were stable under cover gas, in this case AM-Cover (HFC 134A in N_2). However, MRI230D in particular, was prone to excessive oxide build-up in the heated melt transfer tube and spout, resulting in blockage of the molten metal making it very difficult to cast. This was also observed in MRI153A and to a lesser extent in MRI153M although neither was as severe as MRI230D. All the alloys that we have cast, which contain significant amounts of Ca appear to have a tendency to do this. It has not been observed in Mg-Al based alloys without Ca.

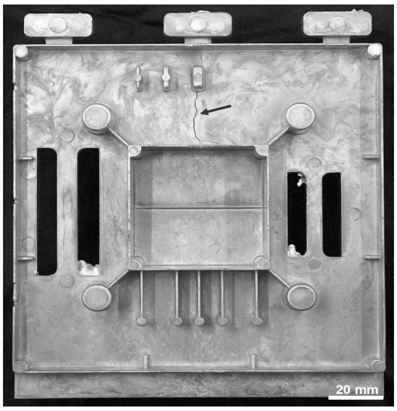

Fig. 1. Alloy MRI153M cast at a die temperature of 180°C and a high speed plunger velocity of 1.3 m/s, showing substantial cracking in the casting. This is the worst case observed.

Fig. 2. MRI230D cast at a die temperature of 180°C and a high speed plunger velocity of 1.3 m/s showing spangled surface. This is the worst case observed.

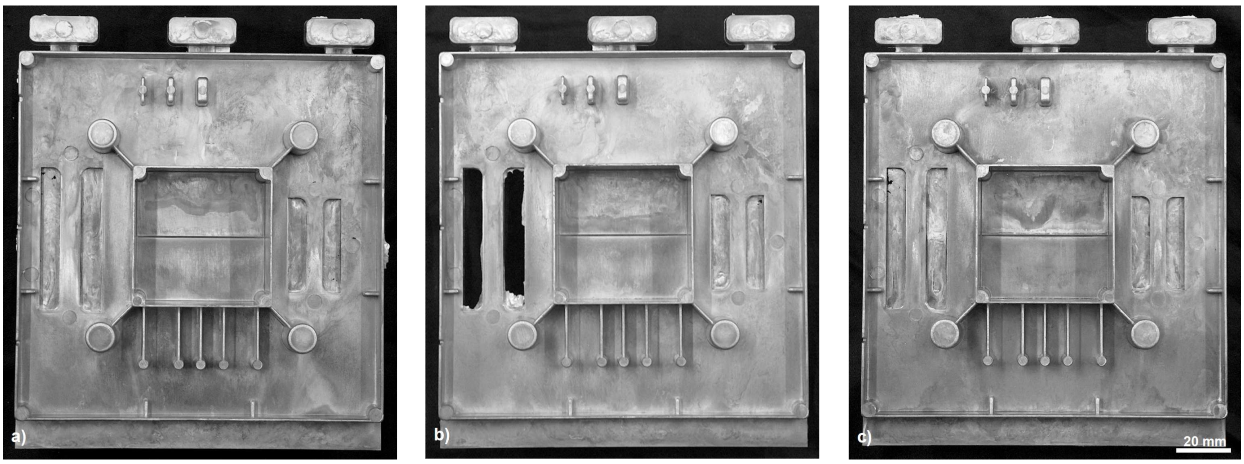

Fig. 3. Examples of the best castings for (a) MRI153A (b) MRI153M and (c) MRI230D.

A useful yardstick for a comparison in castability is to compare these alloys with the Mg-Al alloys. In the previous work [9], all of the castability data was averaged to provide an overall ‘castability rating’ for an alloy. Whilst this can be a little misleading, as it is really how well an alloy can be cast at its optimal parameters that matters, it does provide an indication of the extent of the operating window of an alloy, which is definitely useful for assessing castability.

This comparison suggests that the castability of MRI153A approaches that of AZ91, MRI230D casts better than AM60, whilst MRI153M is difficult to cast and is rated similar to AM20 (Fig. 4). However, it should also be noted that the Mg-Al alloys do not display the same difficulties associated with oxide build-up during melt transfer that were observed with the MRI alloys, particularly MRI230D. Hence the rating based only of the appearance of the final casting of these alloys over-estimates their castability. Consideration as to how to include this into the rating system is required.

Conclusions

A castability rating for some of the MRI alloys has been developed based on the appearance of the final castings. It was found that MRI153A cast very well, with a castability rating approaching AZ91. MRI230D also did not cast as well as MRI153A, and tended to 'spangle', but the final castings were rated to be better than AM60. The castability of MRI153M was relatively poor, similar to AM20, being very prone to cracking at lower plunger velocities. Whilst good quality castings could be achieved for these alloys, the alloys tended to cause the build up of oxide in the transfer tube leading to blockages, with it being particularly severe for MRI230D. This appears to be a difficulty with Ca containing alloys.

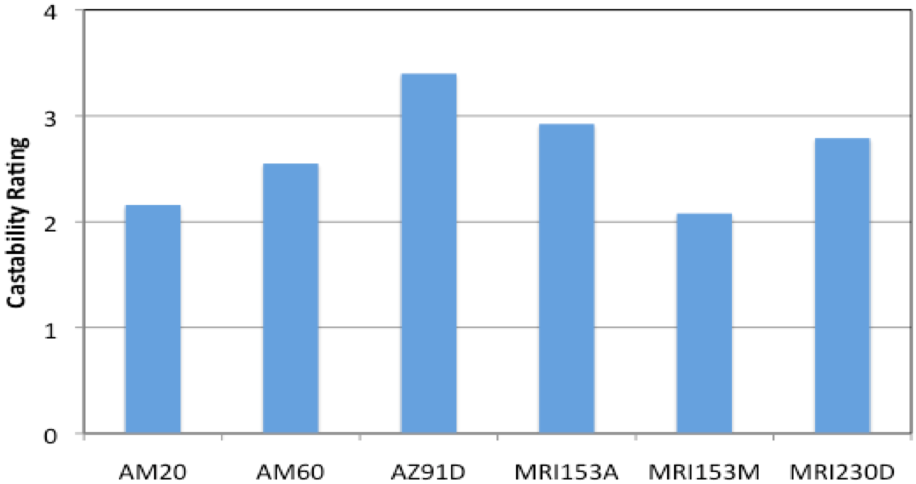

Fig. 4. Comparison of the castability ratings of the MRI alloys against selected Mg-Al based alloys.

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