2005 –01-0334

Effect of HPDC Parameters on the Performance of Creep Resistant Alloys MRI153M and MRI230D

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ABSTRACT

The growing demand for the use of magnesium alloys in the production of automotive powertrain components led to the development of creep resistant diecasting alloys MRI153M and MRI230D.

The present paper addresses the main high-pressure die casting parameters, which significantly affect the performance of components, produced of these new alloys. A systematic study was carried out in order to correlate die-casting parameters to the performance of new alloys.

The results obtained clearly indicated that optimization of molten metal and die temperatures, injection profile parameters and lubrication mixtures allowed to improve the die castability and service properties of the new alloys and produce high performance components with intricate geometry. This was manifested by production of several practical demonstrators such as gearboxes, oil pans, oil pumps and crankcases.

INTRODUCTION

High pressure die casting (HPDC) is a high volume manufacturing process for components of different sizes and shapes. Mg alloys have become promising and reliable materials for die cast applications due to their low density and manufacturing advantages such as outstanding castability and machinability. Magnesium alloys can be cast into components with very low wall thickness and small draft angles having dimension tolerances 50% tighter than aluminum castings [1]. Magnesium alloys have a lower latent heat of fusion and reduced tendency to die pick-up and erosion compared to aluminum alloys. Magnesium die casting process requires reduced die casting machine cycle time and allows 2-4 times longer die life compared to their aluminum counterparts. Commercial magnesium alloys also exhibit good ambient temperature mechanical properties. However, poor creep properties of conventional magnesium alloys restrict their use for powertrain applications. In order to overcome the above limitations several new die casting alloys were recently developed [2-8].

The target to develop a HPDC alloy, which exhibits an adequate combination of die castability, creep performance, corrosion resistance, room temperature strength and affordable cost, was also addressed by DSM and Volkswagen AG [9,10]. This comprehensive work resulted in the development of two new magnesium alloys designated MRI153M and MRI230D.

MRI153M is a Beryllium free, low cost, creep resistant alloy with the capability of long-term operation at temperatures up to 150°C under high loads. This alloy exhibits die castability, corrosion resistance and mechanical properties similar to or better than those of AZ91D alloy with superior creep resistance at 130-150°C under stresses of 50-85 MPa.

This makes the alloy a superior alternative for applications such as gearbox housings, valve covers, intake manifolds and other high temperature applications for the automotive industry.

MRI230D is a die cast alloy that was developed to address the powertrain applications of the automotive industry such as engine blocks operating at temperatures up to 190°C. The alloy has excellent creep resistance combined with good castability, high strength and superior corrosion behavior. Automatic transmissions housings and bedplates are part of the applications, which can be produced by HPDC of MRI230D alloy.

The mechanical and physical properties of the above alloys are well known and documented [9,10]. It should be pointed out that the castability and the HPDC process characteristics of the newly developed alloys are different from those of conventional Mg alloys. Hence, in order to achieve high quality sound die cast components process optimization and die modifications are required. The present work aims at optimization of injection parameters and gating system design at HPDC of newly developed alloys. Special attention is drawn to determination of the effect of molten metal and die temperatures as well as the lubricant data on the properties of the newly developed alloys.

EXPERIMENTAL PROCEDURE AND RESULTS

In order to address the above objectives comprehensive experiments were performed using IDRA OL320 cold chamber die casting machine with locking force of 345 tons. The trials consisted of 3 main subjects:

1. HPDC process optimization.
2. The effect of molten metal and die temperature on the filling time.
3. Optimization of gating system.

HPDC PROCESS OPTIMIZATION

An oil pump consisting of three parts, weighing 0.19, 0.18 and 0.35 kg, was selected as a demonstrator component (Figure 1) and cast in MRI153M and MRI230D as well as AZ91D and AM50A, in order to determine the significant HPDC process parameters

The aim of these trials was to minimize the component defects such as:

- Insufficient filling
- Gas and shrinkage porosity
- Surface defects (hot cracking, soldering and tearing).

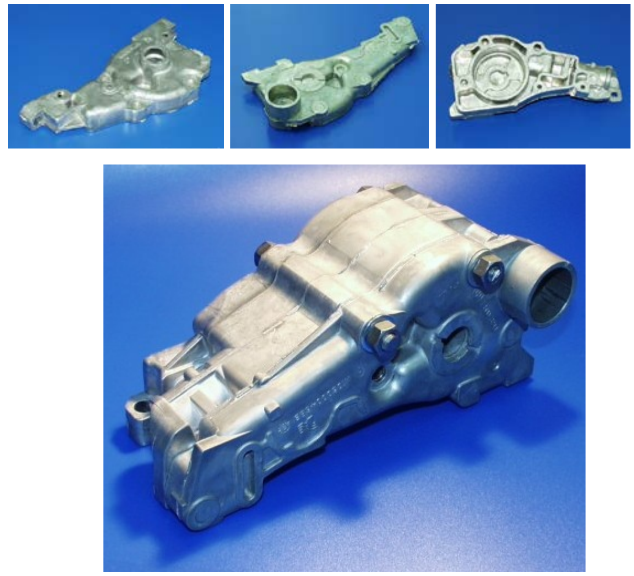

Figure 1. Oil pump selected as new alloys casting demonstrator

The parameters investigated were:

- Molten metal (alloy temp. in the furnace) and die temperature (Thermocouple measurement located 30mm from the die surface)
- Lubricant data (spraying time and mixing ratio).
- Dwell time.

The optimized parameters obtained in course of experiments are listed in Table 1. These parameters are very useful tools at die casting of actual components in MRI153M and MRI230D alloys.

Table 1. HPDC data for commercial and new alloys

Mg Alloy	Temperature data		Spraying and Lubrication		Dwell time (%)
	Melt (°C)	Die (°C)	Spraying time (%)	Mixing ratio	
AZ91D	650-670	150-200	100	1/40-1/80	100
AM50A	680-695	150-200	100	1/40-1/80	100
MRI153M	660-670	200-250	120-150	1/25-1/40	70-80
MRI230D	680-690	200-250	150-170	1/15-1/40	50-75

THE EFFECT OF MOLTEN METAL AND DIE TEMPERATURE ON THE FILLING TIME.

These trials were performed using the cavity presented in Figure 2.

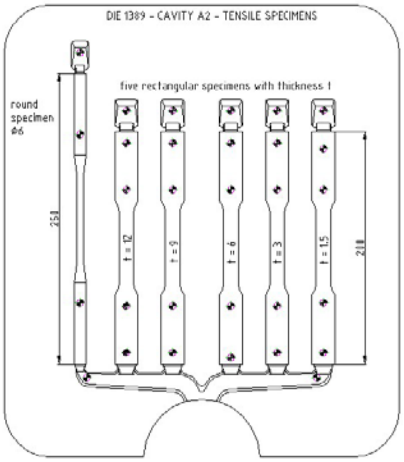

Figure 2. Cavity with different types of tensile samples

This cavity allows the production of six tensile specimens. One round specimen with 6 mm diameter and five rectangular specimens with thickness of 1.5, 3, 6, 9 and 12 mm.

In order to determine the optimal filling time for each thickness, several experiments were performed with a wide range of second phase velocities from 1 to 7m/s. for different melt and die temperatures (Table 2). The aim of these experiments was to determine the minimum second-phase velocity or maximum acceptable filling time, which would allow obtaining sound castings.

Table 2. Experimental parameters for evaluation of filling properties

Experiment No.	1	2	3	4	5	6
Casting temp. °C	710	690	690	690	670	670
Die temp. °C	200	200	160	140	160	130

For example, Figure 3 presents the map obtained for MRI230D alloy.

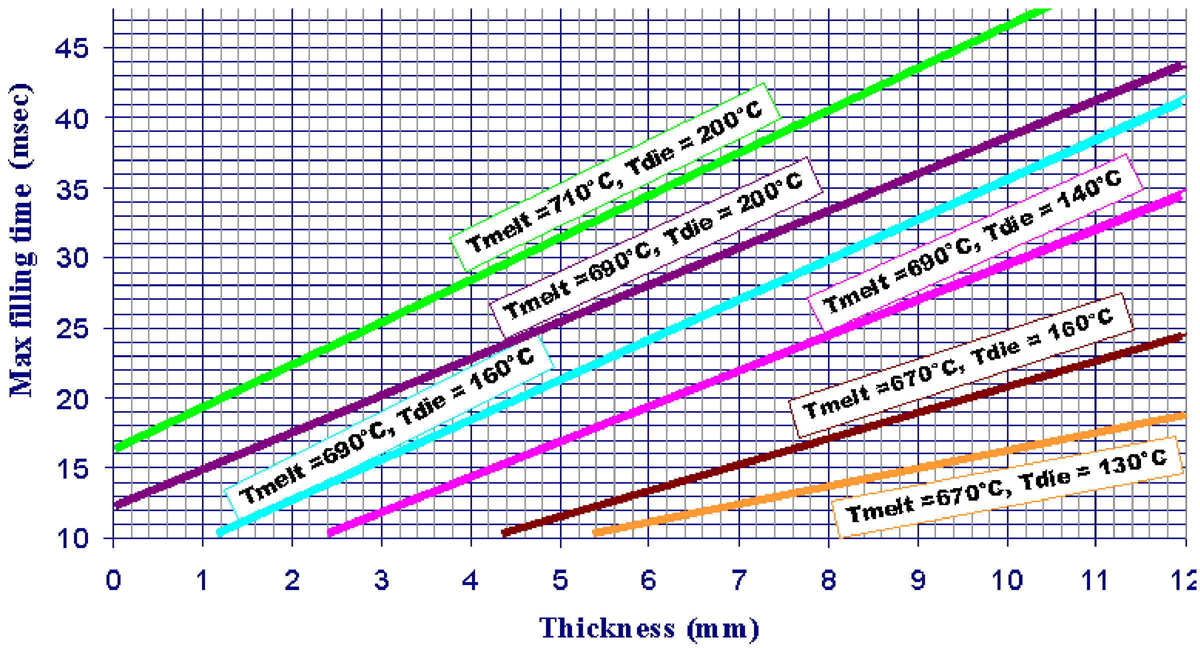

Figure 3. The correlations between molten metal and die temperatures, and the maximum filling time.

GATING SYSTEM OPTIMIZATION

In order to optimize the gating system for MRI153M and MRI230D alloys the following parameters were selected and studied:

- Gate velocity.
- Gate thickness.
- Die temperature.

The die and the part used during this study are presented in Figure 4. The part net weight was 0.83 kg. The gating system was machined during the trials in order to alter gate area from 1.17 cm^2 to 2.35 cm^2. The die temperature was varied from 80 to 160°C while second phase velocity was altered from 1 to 5 m/s for three different gate areas (Table 3). Molten metal temperature was 670ºC for MRI153M and 685ºC for MRI230D.

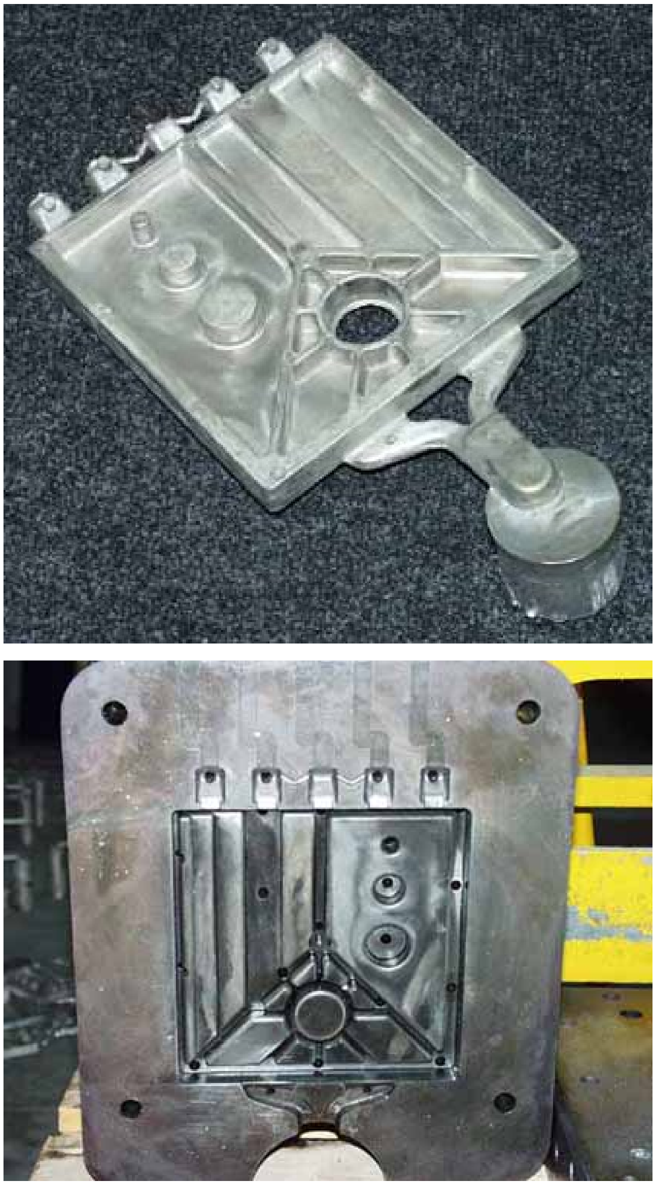

Figure 4. The die used for gating system optimization

Table 3: Experimental parameters

Gate area [cm^2]	1.17			1.8			2.35		
T $_{die}$ [°C]	80	120	160	80	120	160	80	120	160
Second phase velocity [m/sec] (Plunger vel.)	1, 2, 3, 4, 5								

The trials were stopped when soldering was detected. Figure 5 and Figure 6 present the correlations obtained for MRI153M and MRI230D, respectively.

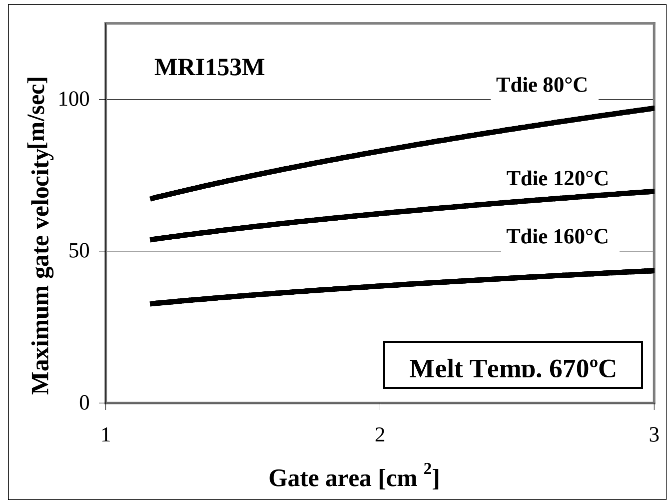

Figure 5. MRI153M gating system optimization.

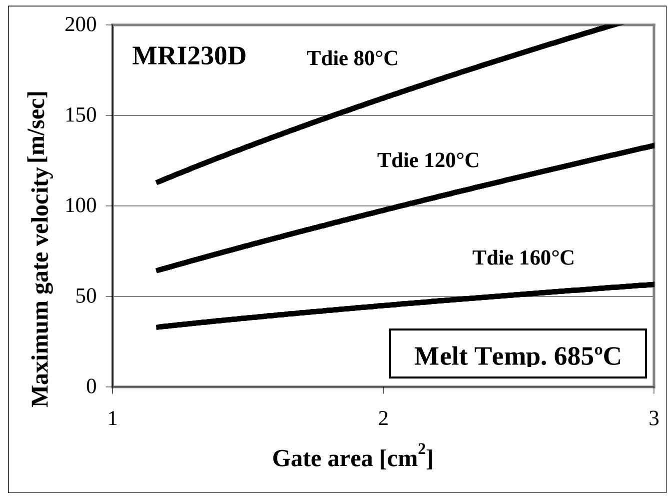

Figure 6. MRI230D gating system optimization.

DISCUSSION

The first series trial indicated that casting defects could be minimized by HPDC process optimization. It was found that sound parts could be obtained with increased spraying time, increased mixing ratio and decreased dwell time. (Table 1). Adherence to the recommended procedure would contribute to decreased cycle time and high productivity.

In addition, it is also recommended to consider the parameters map (Figure 3), which demonstrates correlation between the molten metal and die temperatures and the second phase velocity or the cavity filling time.

It is evident from the developed map that for a given wall thickness higher melt and die temperatures allow the use of lower injection velocities and consequently higher cavity filling time. On the other hand, it should be taken into consideration that too high second phase velocity may result in atomized flow pattern and a potential for increased gas porosity and decreased properties.

In order to minimize surface defects such as soldering, it is recommended to use for given gate area and die temperature the values of gate velocities lower than outlined by curves shown in Figs.5 and 6.

The presented procedures were used in several casting trials with both MRI153M and MRI230M alloys. Following their implementation, the productivity and the process characteristics have been improved and high quality components such as oil pans, gearbox housing and transfer cases were easily die cast. Recently Audi has successfully die cast hybrid magnesium aluminium engine blocks using MRI153M and MRI230D alloys [11,12].

CONCLUSIONS

1. Adequate HPDC process parameters related to melt and die temperatures, lubrication and injection parameters are available for MRI153M and MRI230D.
2. Based on various casting trials it was manifested that proper die design and HPDC process optimization result in high quality components cast in MRI153M and MRI230D.
3. MRI153M and MRI230D are promising and suitable materials for powertrain applications.

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