Investigation of compressive creep behaviour of die-cast MRI153M and MRI230D magnesium alloys

A. K. Mondal[a,*], Hrishikesh Shastri[a], A. K. S. Bankoti[a] and S. Kumar[b]

[a]Department of Metallurgical and Materials Engineering, National Institute of Technology, Rourkela-769008, India

[b]Department of Materials Engineering, Indian Institute of Science, Bangalore-560012, India

Abstract

Two Mg-Al-Ca containing alloys MRI153M and MRI230D have been developed by high pressure die casting. The as-cast microstructures of MRI153M alloy consists of primary Mg (α-Mg), $Mg_{17}Al_{12}$ and $(Mg,Al)_2Ca$ (C36) phases, whereas, the MRI230D alloy consists of α-Mg and $(Mg,Al)_2Ca$ (C36) phases. The MRI230D alloy exhibited superior creep resistance as compared to that of MRI153M alloy. The microstructures of both the alloys following creep test revealed increased amount of C36 phase. However, the quantity of pre-existing $Mg_{17}Al_{12}$ phase in the MRI153M alloy has increased, which is responsible for inferior creep resistance in MRI153M alloy. The additional precipitation of C36 phase during creep test resulted in improved creep resistance in MRI230D alloy.

Keywords: Magnesium alloys; MRI153M; MRI230D; Microstructure; Creep; Precipitation

1. Introduction

Magnesium (Mg) alloy with high specific strength is the potential candidate for application in automobile industries [1]. The major growth area of Mg alloys is in the automobile powertrain components that require good creep resistance in the temperature range of 150–250°C [2,3]. The addition of Al to Mg alloy promotes the formation of low melting point (437°C) β-$Mg_{17}Al_{12}$ phase along grain boundaries (GBs) resulting poor creep resistance. In contrast, the addition of Ca forms thermally stable intermetallic phase along grain boundaries preventing grain boundary sliding at elevated temperature, which enhances creep resistance of Mg alloys. Two Ca-containing MRI153M (Mg-8Al-1Ca) and MRI230D (Mg-7Al-2Ca) alloys were developed for such applications. However, the creep behaviour of these two

---

[*] Corresponding author. Tel.: +91 661 246 2571; fax: +91 661 246 2022.

E-mail addresses: mondala@nitrkl.ac.in, ashok.mondal@gmail.com (A.K. Mondal).

alloys is not reported till date. The objective of the present investigation is to study the creep behaviour of the MRI153M and MRI230D alloys emphasising the role of intermetallic phases on it.

2. Experimental procedure

The alloys were fabricated by high pressure die casting. Phase analysis was carried out by XRD. Microstructural characterization was done using SEM equipped with an EDS. Creep tests were carried out in compression using specimen of 6 mm diameter and 15 mm length at a stress level of 70 MPa and temperature of 150 and 200°C.

3. Results and discussion

3.1. As-cast microstructure

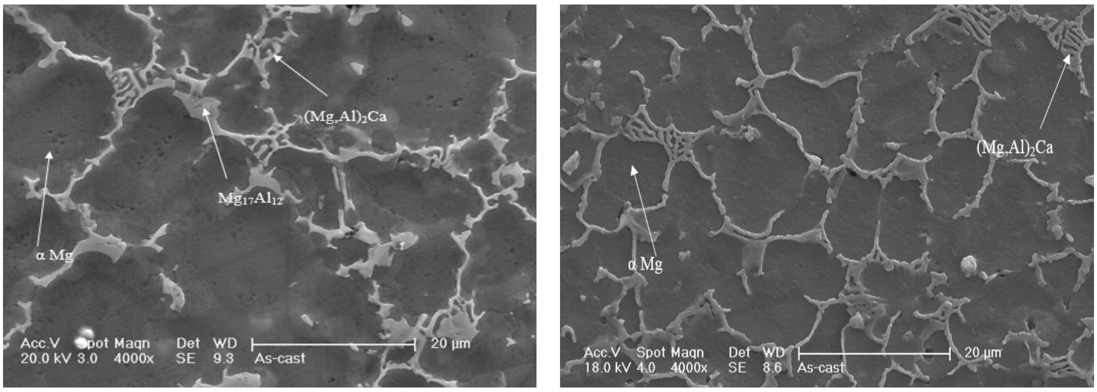

Fig. 1. SEM micrograph of the (a) MRI153M and (b) MRI230D alloys

Fig. 1(a, b) shows the SEM micrographs of MRI153M and MRI230D alloys. Both the alloys consist of primary Mg i.e., α-Mg phase. The β-$Mg_{17}Al_{12}$ and C36 phases were present along the GBs of the MRI153M alloy. The β-phase looks bulky with dull contrast, whereas, the C36 phase is lamellar with bright contrast. Furthermore, the C36 phase was the only phase present at the GBs of the MRI230D alloy. There was no presence of β-$Mg_{17}Al_{12}$ phase.

Table 1. Summary of the phases present in both the alloys

Alloy	α-Mg	$Mg_{17}Al_{12}$	$(Mg,Al)_2Ca$
MRI153M	Yes	Yes	Yes
MRI230D	Yes	No	Yes

3.2. Creep behaviour

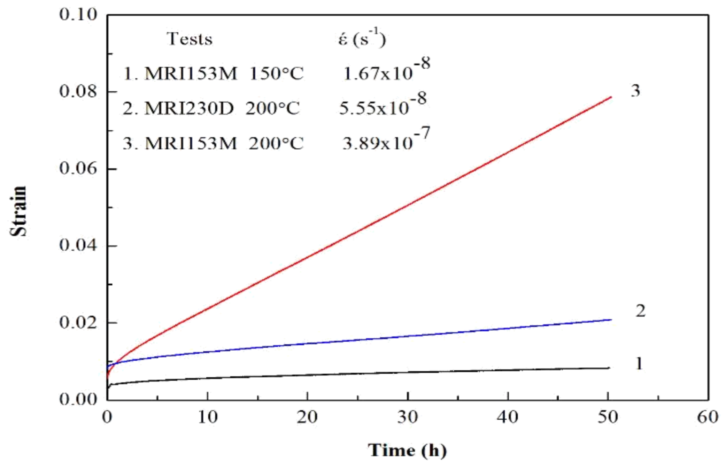

Fig. 2. Strain vs. time plots for both the alloys

Table 2. Summary of strain rates of the alloys

Alloy	MRI153M		MRI230D
Temperature	150°C	200°C	200°C
Strain rates ($\dot{\varepsilon}$)	1.67×10^{-8}	3.89×10^{-7}	5.55×10^{-8}

The steady state creep rate of the MRI230D alloy was superior to that of the MRI153M alloy tested at the same stress and temperature.

3.3. Microstructure of crept specimens

Following creep exposure the volume fraction of the pre-existing β-$Mg_{17}Al_{12}$ phase increased in both the specimens of the MRI153M alloy; however, it was more in the specimen tested at 200°C.

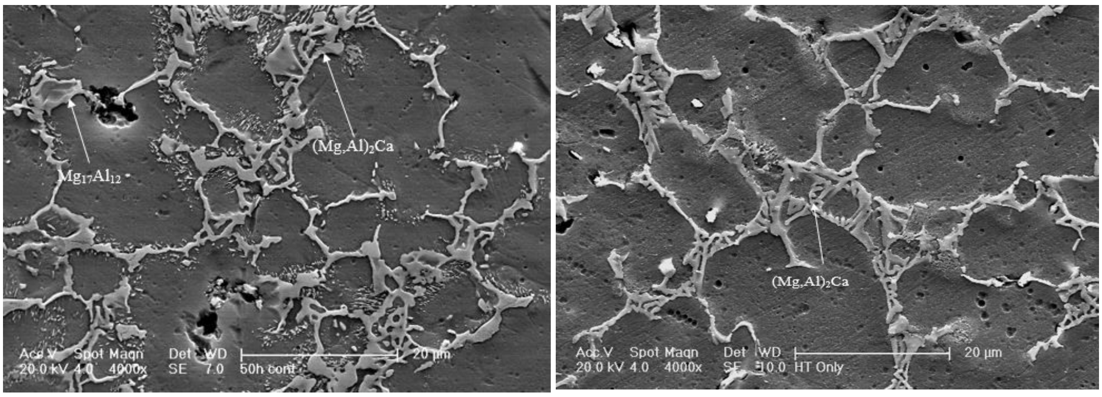

Fig. 3. SEM micrograph of the (a) MRI153M alloy and (b) MRI230D alloy tested at 200°C

The volume fraction of the C36 phase in the MRI153M alloy also increased. The amount of the pre-existing C36 phase increased as well in the MRI230D alloy following creep exposure. Superior creep resistance of the MRI230D alloy was attributed to the increased volume fraction of the thermally stable high melting point C36 phase. The beneficial effect of the increased C36 phase in the MRI153M alloy was overcome by the increased amount of the β phase, which contributed to creep resistance negatively.

4. Conclusions

1. Primary Mg (α-Mg), β-$Mg_{17}Al_{12}$ and $(Mg,Al)_2Ca$ (C36) phases in the MRI153M alloy, whereas, α-Mg and C36 phases were present in the MRI230D alloy in as-cast condition
2. The MRI230D alloy exhibited better creep resistance than that of the MRI153M alloy at the same stress and temperature
3. Following creep exposure the amount of β-$Mg_{17}Al_{12}$ phase increased in the MRI153M alloy, which deteriorated its creep resistance
4. Superior creep resistance of the MRI230D alloy was attributed to the increased volume fraction of the thermally stable high melting point C36 phase

References

[1] B.L. Mordike, T. Ebert, Mater. Sci. Eng. A 302 (2001) 37–45.

[2] M. Celikin, A.A. Kaya, M. Pekguleryuz, Mater. Sci. Eng. A 550 (2012) 39-50.

[3] A.A. Luo, M.P. Balogh, B.R. Powell, Metall. Mater. Trans. A 33 (2002) 567-573.