Enhancing Mechanical Property Consistency in AE81 Alloy Low-Pressure Die-Casting Wheels Through Ca Addition

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Abstract: AE81M and AE81M+Ca magnesium alloy were employed in the production of 16-inch wheels through a low-pressure die casting (LPDC) process. Defects in the castings were inspected and analysed, revealing entrained oxide films that composed of fluorides and oxides. The mechanical property consistency of the casting wheels was assessed using the Weibull distribution. The study found that while the addition of Ca lead to a slight reduction in the tensile strength of AE81 alloy, it enhances the overall mechanical property consistency of the cast wheels.

Keywords: Mg alloy, low pressure die casting, oxides

1 Introduction

Molten Mg alloys are prone to ignition upon exposure to air, leading to the formation of oxide-related defects, such as oxides or bifilms, within the castings. These defects can detrimentally affect the mechanical properties and its consistency of Mg-alloy castings, significantly impacting the yield rate of casting products. Therefore, in gravity casting processes, the mould chamber is normally flushed with a cover gas before pouring the melt[1]. However, in die casting processes, which are commonly used for producing Mg-alloy automotive products, the mould chamber is typically filled with air rather than a cover gas, exacerbating the oxide defect issue. Researchers are diligently working to reduce the oxide content in Mg-alloy castings.

The addition of Ca has been shown to effectively enhance the oxidation resistance of Mg alloys[2], rendering the oxide film protective and thinner, thus potentially resulting in fewer oxides during the mould filling process. In this study, AE81M Mg alloy and AME81+Ca alloy were utilized to produce 16-inch wheels using a low pressure die casting (LPDC) process. The defects present in the castings were inspected and analysed. The mechanical property consistency of the casting wheels was estimated using Weibull distribution, which is a widely utilized method for reflecting the defect content in castings.

2 Experimental procedure

The casting process was conducted using an LPDC machine provided by Wanfeng Technology Development Co. Ltd. Specially designed melting and holding furnaces for Mg-alloys were employed. During each round of the casting process, 500 kilograms of AE81M or AE81M+Ca alloys were melted and refined, and subsequently transferred to the holding furnace for casting 16-inch wheels.

Table 1. The composition (wt.%) of the AE81M and AE81M+Ca alloys utilized in this investigation, with the residual element (i.e., Mg content) omitted.

Alloy	Al	Ca	Ce	Zn	Mn	Sb	Sr
AE81M	7.6	-	1.15	0.53	0.21	0.18	0.11
AE81M+Ca	7.5	0.93	1.18	0.85	0.28	0.26	0.10

Figure 1 illustrates the dimensions of the wheels produced in this study. For each alloy, a total of 40 castings were manufactured. Given the different property requirements for the rims and spokes of a standard wheel, specific areas of the as-cast wheels were selected for further tensile strength testing. Each casting wheel yielded 40 specimens from the rim area and 10 specimens from the spoke area. The fracture surfaces of the fractured test bars underwent examination using a Scanning Electron Microscope (SEM, Philips JEOL7000) with an accelerating voltage of 5-15 kV. Additionally, the fractured test bars and residual castings were sectioned, polished, and inspected using the same SEM for further analysis.

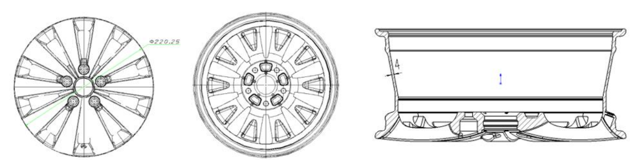

Figure 1. The dimensions of the 16-inch wheels that cast in this study. The wheel's diameter is about 400mm.

3 Result and discussion

Table 2 presents the Weibull modulus of the different sampling areas of the as-cast wheels, obtained using a traditional 2-p linear least square method. The estimator used is P = (i - 0.5) / N.

In the rims area of the AE81M alloy wheel, the UTS Weibull modulus is 3.9, and the elongation Weibull modulus is 1.33. In contrast, the UTS and elongation Weibull moduli of the AE81M+Ca alloy wheel's rims are 10.2 and 1.77, respectively, which are higher than those of AE81M alloy castings. Similarly, in the spoke area, both the UTS and elongation Weibull moduli of the AE81M+Ca castings (36.4 and 7.33, respectively) are higher than those of AE81M alloy wheels (19.5 and 5.65, respectively). These findings suggest that the tensile property consistency of the AE81M+Ca alloy castings is higher than that of AE81M alloy castings.

Table 2. Weibull Modulus of the different sections of the as-cast wheels.

Sampling area	Alloy	Weibull modulus of UTS	Weibull modulus of Elongation
Rim	AE81M	3.9	1.33
	AE81M+Ca	10.2	1.77
Spoke	AE81M	19.5	5.65
	AE81M+Ca	36.4	7.33

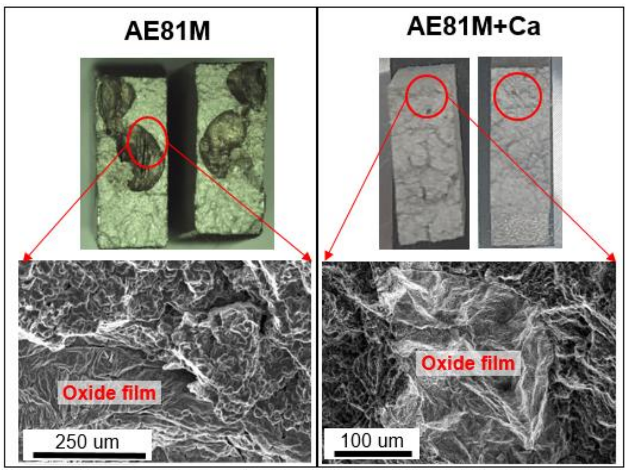

Figure 2. fracture surfaces of an AE81M alloy tensile test bar and an AE81M+Ca alloy test bar, indicating symmetrical oxide films on the fracture surfaces. The dimension of the fracture surface is 4 mm × 10 mm.

Figure 2 shows the fracture surfaces of an AE81M alloy tensile test bar and an AE81M+Ca alloy test bar, both sampled from the rim of the wheels. Symmetrical dark oxide films are evident on both sides of the fracture surfaces. The corresponding EDS results (Table 3 and 4) reveal the presence of fluorine, sulphur, and nitrogen exclusively in the dark regions, indicating that these regions comprise surface protective films entrained into the melt. Therefore, it is plausible to suggest that the dark regions are bifilms, given their symmetrical nature.

Furthermore, the oxide film formed in the AE81M+Ca alloy does not exhibit a higher Ca content compared to the surrounding alloy area. However, it does contain significantly higher cerium content compared to the oxide film formed in the AE81M alloy. This suggests that the addition of Ca may promote the formation of cerium compounds in the oxide film, although further experiments are required to confirm this hypothesis.

Table 3. EDS results corresponding to the AE81M alloy sample shown in Figure 2 (wt%)

	C	O	N	F	Al	Ce	Sr	Sb
Alloy area	2.25	0.5	-	-	7.3	-	0.06	0.08
Oxide film	14.75	16.53	0.80	0.68	6.46	1.00	1.84	-

Table 4. EDS results corresponding to the AE81M+Ca alloy sample shown in Figure 2 (wt%).

	C	N	O	F	Al	Ca	Ce	Sr	Sb
Alloy area	3.76	-	0.67	-	15.43	4.89	0.08	0.17	-
Oxide film	16.46	5.03	16.70	0.73	9.94	3.87	7.67	0.12	0.06

4 Conclusion

The addition of Ca in AE81 alloy led to an enhancement in the mechanical property consistency of the corresponding LPDC wheels. This may be attributed to Ca's role in promoting the formation of a more protective film.

References

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