Integrated HPDC Gigacasting Technology Based on Non-Heat-Treated (NHT)High-Ductility Magnesium and Its Application Trends

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Abstract: In recent years, there has been a growing demand for lightweight automotive components, such as magnesium alloy/aluminum alloy integrated die casting, which is different from traditional automotive castings. New body or chassis structural components require higher requirements for alloy materials, casting processes, and mold design. This report provides a detailed overview of the design and development of heat-treatment-free high-strength and ductile magnesium alloys, research on high-density Giga-casting processes, design and manufacture of die casting molds, die casting experiments and evaluation of microstructure and mechanical properties, and finally reports the application and trend of magnesium alloy integrated die casting technology in automotive structures.

Keywords: High-strength-ductility Magnesium alloy; HPDC Giga-casting; Automotive structural components

1 Introduction

With the world's energy becoming increasingly tight and stricter requirements for low-carbon and environmental protection, the full electrification of cars has become an irreversible trend. However, the problem of "range anxiety" has always existed in new energy vehicles, and light weighting is an important way to solve this problem. In recent years, the body of new energy vehicles has been developing rapidly towards a "diversified material system" and "replacing steel with aluminum/magnesium integrating design, and casting instead of forging." Especially after Tesla introduced an aluminum alloy rear floor part with Giga-casting in 2019, it further accelerated the above light weighting technology.

As the lightest metal structural material, magnesium alloys have excellent die-castability and can achieve higher lightweight effect than aluminum alloy material. Therefore, the development of new high-strength and high-toughness die-casting magnesium alloys and large-scale complex thin-wall die-casting technology to meet the requirements of vehicle body service conditions is of great significance to help the lightweight of new energy vehicles. This report systematically introduces the research and development of high strength-and-toughness die-casting magnesium alloys without heat treatment, integrated design of large thin-walled structural parts, die manufacturing, and high density die-casting technology and its application in automotive integrated die-casting.

Material development must be considered in conjunction with the casting process. As well-know, the inclusion of a certain amount of gas in die casting is the inherent characteristics of the die casting process itself, even if the use of high vacuum die casting is difficult to completely eliminate the porosity. Therefore, if the large thin-wall die-casting parts need to use heat-treated alloys to produce, on the one hand, it may cause the bubble blistering of the entrapped gas during the heat treatment process and be scrapped, and on the other hand, the parts are seriously deformed by heat resulting in unqualified dimensions. The development of high strength-and- toughness die casting materials without heat treatment is the fundamental way to solve this problem.

2 Result and discussion

In this project, based on the academic idea of regulating the precipitated phases during solidification, potential multiple-element alloy systems and ranges were screened by using high-output thermodynamic calculation in combination with the rapid solidification conditions in the die casting process, and then a new die-casting alloy of Mg-RE-Al-X series (EA54V) and one of Mg-Y-Zn-X series (WZ42AM) have been successfully developed, combined with the verification of die casting tests, as shown in FIG. 1 and FIG. 2. Their typical tensile properties at room temperature in the die-casting state can reach: tensile strength 260-300MPa, yield strength 140-160MPa, elongation 12-16% excellent performance, the comprehensive performance has exceeded aluminum alloys such as C611, BFA etc., which are currently used in integrated rear floor die-castings of auto-bodies.

Secondly, the shock tower and subframe, which are typical representatives of the vehicle body and chassis system, were selected as the research objects, and the integration design technology for large and complex thin-walled magnesium alloy structural parts was studied based on the characteristics parameters of the new magnesium alloy material, the decomposition of vehicle

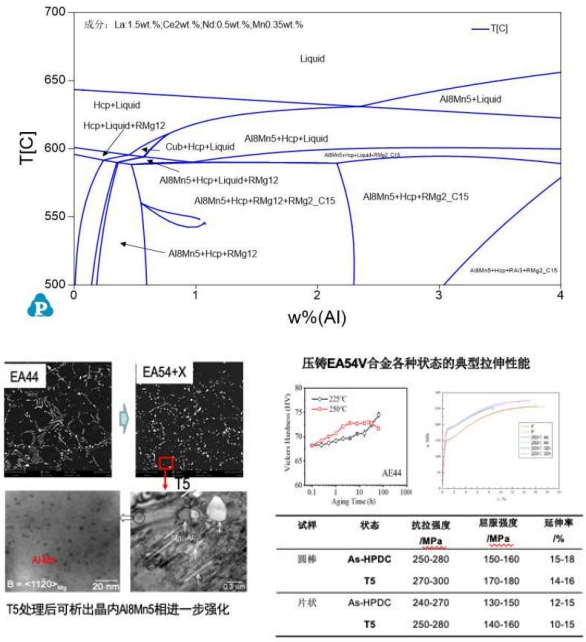

Fig.1 Design scheme of new high-strength-ductility HPDC Mg alloy EA54V and its typical microstructure and mechanical properties

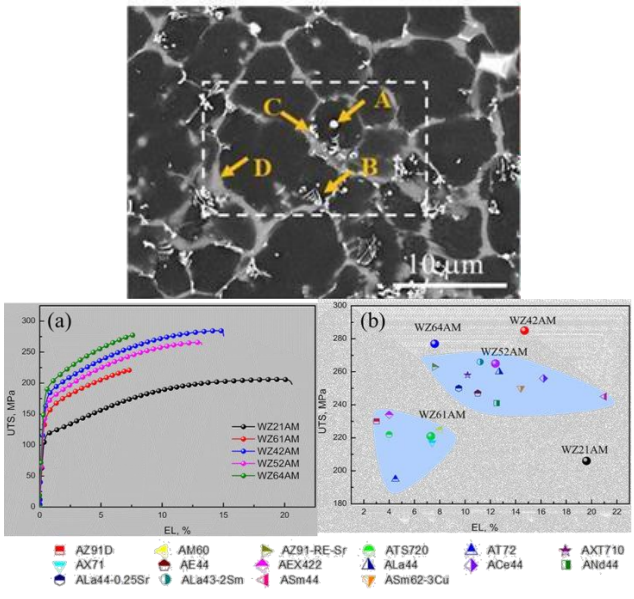

Fig.2 The microstructure and mechanical properties of new high-strength-ductility HPDC Mg alloy WZ42AM

load and performance indicators, FEM finite element strength analysis, and casting process simulation. "Five-in-one" and "seven-in-one" highly integrated magnesium alloy casting structural parts were designed, achieving a maximum weight reduction rate of 62% compared to the original steel parts. As shown in Figure 3.

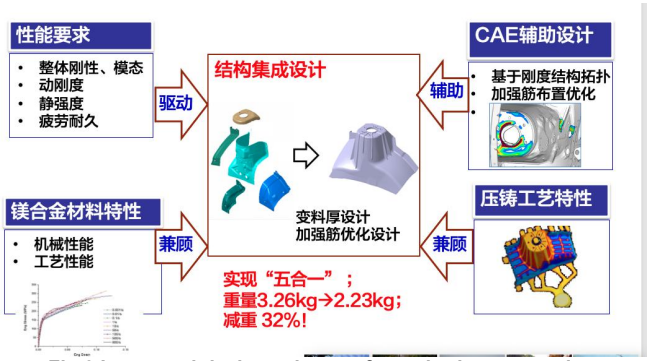

Fig.3 Integrated design scheme of auto-body structural components of Mg alloys

Meanwhile, to solve the manufacturing and defect control problems of large thin-wall magnesium alloy castings, this project redefined the technical connotation of high-density HPDC, and we closely combined "moderate vacuum technology, reliable process simulation, pre-crystallization control, and precise mold thermal balance technology" to develop a genuine high-density HPDC technology for magnesium alloys. We achieved casting and machining of magnesium alloy shock tower and subframe, and solved the dissimilar-material jointing technology between magnesium alloy castings and steel body parts, becoming the first in the world to pass bench and on-vehicle tests for magnesium alloy body and chassis structural parts. In 2023, the team successfully developed the world's largest and more functionally integrated giga casting of magnesium alloy for body structural component - the rear floor of FAW Co. As shown in Figure 4.

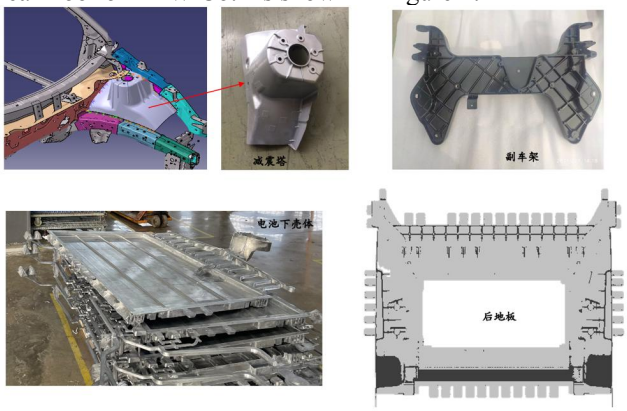

Fig.4 Partial auto structural parts made by new HPDC Mg alloys

3 Conclusion

The large integrated casting technology based on non-heat-treated magnesium alloys shows a very promising application prospect.