Integrated Evolution Process of Large Integrated Castings Based on Digital Simulation Analysis

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Abstract: This paper explores the application of integrated die casting technology in the automotive industry, focusing on the development and application of heat-treatment-free, high-strength, and high-toughness aluminum alloys to overcome the limitations of traditional materials. These alloys can prevent deformation and surface defects caused by heat treatment during high vacuum die casting, reducing part scrap rates and production costs. The study emphasizes the importance of controlling the eutectic structure and improving impurity tolerance to enhance alloy performance. Using MAGMASOFT® simulation analysis, the design schemes for components such as the front cabin and lower floor were optimized, addressing molding defects and gas porosity issues. Additionally, the paper examines the selection of mold steel and its heat treatment process, which significantly impact mold performance and lifespan. Experimental and numerical simulation results confirmed the adverse effects of bainite content on toughness. Overall, this paper highlights the importance of material development, design optimization, and process control in advancing the industrial application of ultra-large integrated die-cast vehicle body structures.

Keywords: MAGMA; Simulation; Material; GIGA Part

1 Introduction

Since the integrated die casting technology proposed, it has quickly become a focal point in the automotive industry, widely applied in the integrated production of vehicle body structures. The automotive industry's shift towards lightweight and integrated vehicle designs has highlighted the importance of advanced manufacturing technologies. Integrated die casting has quickly become a key focus, offering significant advantages for producing large, complex vehicle body structures. Traditional materials like Silafont-36 alloy, used with high vacuum die casting and heat treatment, face challenges such as deformation and surface defects in large, thin-walled components, leading to increased scrap rates and costs.

To overcome these issues, developing heat-treatment-free, high-strength, and high-toughness aluminum alloys is essential. These alloys need excellent eutectic structure control, high impurity tolerance, strong toughness, good fluidity, and low shrinkage to meet the demands of large integrated castings. This paper explores the development and application of such alloys, optimizing their performance and design through MAGMASOFT® simulation and experimental analysis. The study aims to enhance the efficiency and effectiveness of integrated die casting technology in automotive manufacturing.

2 Experimental procedure

This paper studies and optimizes large integrated die-cast aluminum alloys and mold steels through several key experiments. At first, the heat-treatment-free, high-strength, and high-toughness aluminum alloys were developing, testing various compositions for mechanical properties, fluidity, and shrinkage rates. Using MAGMASOFT® simulation, it refines the design of components like the front cabin and lower floor to address potential defects. Then, different mold steels and their heat treatment processes, assessing their hardness, toughness, and thermal stability. By analyzing molding defects with optical and SEM methods and optimizing process parameters, it aims to reduce defects. Lastly, mechanical performance tests using DEFORM software simulations confirming the alloys' and steels' suitability for large-scale integrated die casting in the automotive industry.

3 Result and discussion

The development of heat-treatment-free aluminum alloys

The experiments successfully developed high-strength, high-toughness heat-treatment-free aluminum alloys, addressing traditional materials' limitations in large integrated die casting. Using efficient modifiers improved impurity tolerance, with tests confirming superior mechanical properties, fluidity, and shrinkage rates suitable for large structures.

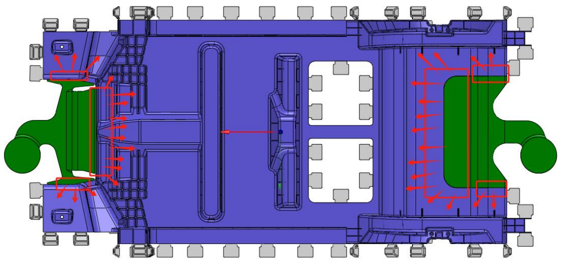

Fig.1 Design of Integrated lower floor

Design optimization

Design optimization using MAGMASOFT® simulations refines the front cabin and lower floor components. Adjusting thickness, filling time, and gate velocity to resolve defects and gas porosity issues, significantly enhancing molding quality and efficiency.

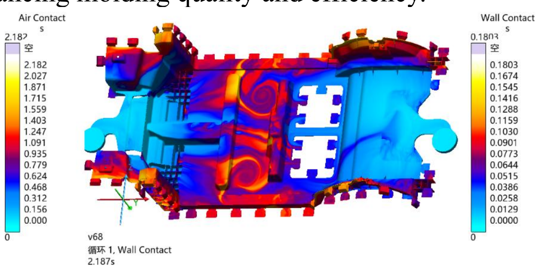

Fig.2 Simulation of the casting process

Mold steel selection and heat treatment

Mold steel selection and heat treatment identified suitable hot work mold steels, with experiments showing that proper quenching and tempering improved hardness, toughness, and thermal stability, extending mold lifespan.

Molding defect analysis

The problem areas were identified by molding defect analysis using optical and SEM methods to optimize process parameters and reduce defects. Mechanical performance tests on mold steel samples showed that cooling rates affected phase composition and material performance. Higher bainite content reduces toughness.

Mechanical performance testing

The problem areas were identified by molding defect analysis using optical and SEM methods to optimize process parameters and reduce defects. Mechanical performance tests on mold steel samples showed that cooling rates affected phase composition and material performance. When the bainite content is higher, the toughness decreases.

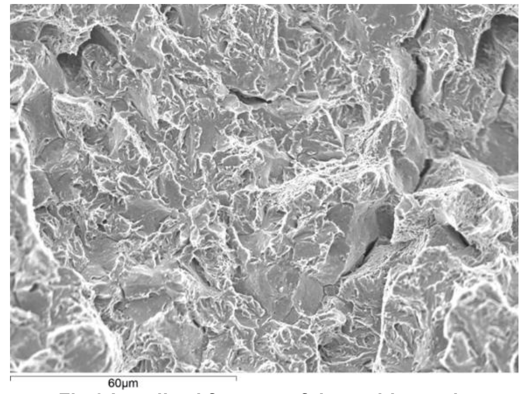

Fig.3 Localized fracture of the mold sample

4 Conclusion

The development of heat-treatment-free aluminum alloys successfully addresses the limitations of traditional materials in large integrated die casting, offering superior mechanical properties, fluidity, and shrinkage rates. Design optimization using MAGMASOFT® simulations significantly improves the quality and efficiency of components like the front cabin and lower floor. The selection and heat treatment of suitable hot work mold steels extend the lifespan of the molds by enhancing hardness, toughness, and thermal stability. Molding defect analysis and mechanical performance testing, including the impact of cooling rates on phase composition, provide critical insights for reducing defects and ensuring the reliability of die-cast components. Overall, these findings support the application of large-scale integrated die casting technology in the automotive industry, enhancing component quality and laying the foundation for future advancements.

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