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CLASSIFICATION OF DEFECTS IN AUTOMOBILE WHEEL MANUFACTURING AND THEIR ROOT CAUSES

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Abstract

This article presents a comprehensive analysis of defect classification in automobile wheel manufacturing and the underlying causes of their formation. Particular attention is given to aluminum alloy wheels, where internal and external defects significantly influence mechanical performance and operational reliability. Based on a systematic review of scientific literature and analytical evaluation, defects are classified according to their nature, origin, and manifestation. The study further investigates metallurgical and technological mechanisms responsible for defect formation. The findings demonstrate that proper control of process parameters and understanding of defect mechanisms can significantly reduce defect occurrence and improve product quality.

Keywords

automobile wheel, casting defects, porosity, shrinkage, aluminum alloy, quality control

1. INTRODUCTION

In modern automotive engineering, aluminum alloy wheels have become increasingly widespread due to their favorable characteristics such as low weight, high corrosion resistance, and improved mechanical properties. Despite these advantages, the manufacturing process of such wheels is highly complex and involves multiple stages where defects may occur, potentially compromising product performance and safety. Since automobile wheels are critical structural components subjected to dynamic loading conditions, their integrity must be ensured through strict quality control measures. Therefore, understanding the classification of defects and identifying their root causes is of great importance in both scientific research and industrial practice.

During casting processes such as low-pressure die casting, gravity casting, and high-pressure die casting, various physical and chemical phenomena occur, including solidification shrinkage, gas evolution, and turbulent flow of molten metal. These phenomena are often responsible for the formation of defects such as shrinkage cavities, gas porosity, oxide inclusions, and microcracks [1]. Among these, shrinkage and porosity are considered the most critical, as they directly affect the mechanical strength and fatigue life of the wheel. Additionally, oxide films and inclusions formed during pouring can act as stress concentrators, initiating crack propagation under cyclic loading conditions [2].

With the advancement of digital technologies, simulation and modeling tools are increasingly used to predict defect formation and optimize manufacturing parameters. However, the effectiveness of these tools largely depends on a clear understanding of defect classification and formation mechanisms. Without a systematic approach to categorizing defects, it becomes difficult to implement effective preventive measures. Therefore, this study aims to provide a structured classification of defects in wheel manufacturing and to analyze their formation mechanisms based on both theoretical and practical perspectives.

2. LITERATURE REVIEW

The classification of defects in aluminum alloy wheel manufacturing has been extensively studied, and various approaches have been proposed in the scientific literature. One of the most comprehensive classification systems was introduced by Fiorese and Bonollo, who categorized defects based on their origin, morphology, and location within the casting. According to their framework, defects can be grouped into internal, surface, and geometrical types, each associated with specific formation mechanisms [3]. This classification provides a systematic foundation for analyzing defects and is widely adopted in industrial quality control systems.

Further studies have focused on the impact of defects on the mechanical performance of wheels. Dong et al. investigated the influence of shrinkage and porosity defects on the fatigue behavior of aluminum alloy wheels and found that these defects significantly reduce fatigue life by acting as crack initiation sites [4]. Their findings highlight the importance of minimizing internal defects to ensure long-term reliability. In addition, silicon segregation in aluminum alloys has been identified as a factor contributing to structural inhomogeneity, leading to localized stress concentration and reduced mechanical strength.

The formation of gas-related defects has also been extensively analyzed in the literature. It has been shown that hydrogen solubility in molten aluminum plays a critical role in porosity formation, as hydrogen is released during solidification and forms gas bubbles within the material [5]. Moreover, turbulent flow during mold filling can result in the entrapment of oxide films, leading to the formation of bifilm defects, which are particularly detrimental to mechanical properties [6]. These oxide layers are difficult to detect and often remain hidden within the casting, posing a significant challenge for quality control.

Recent research has also emphasized the use of numerical simulation and predictive models to reduce defect formation. For instance, the Niyama criterion has been widely used to predict shrinkage defects based on temperature gradients and cooling rates [2]. Such approaches enable engineers to optimize casting parameters and minimize defects before actual production. Overall, the literature indicates that defect formation is a complex, multi-factorial process that requires an integrated approach combining metallurgical knowledge, process control, and advanced analytical tools.

3. METHODOLOGY

The methodology of this study is based on a combined theoretical and analytical approach aimed at identifying, classifying, and analyzing defects in automobile wheel manufacturing. Initially, an extensive review of existing literature was conducted to establish a comprehensive classification framework for defects. Based on this review, defects were categorized into three main groups: internal defects, surface defects, and geometrical defects. This classification allowed for a structured analysis of defect formation mechanisms and their relationships with manufacturing parameters.

To analyze defect formation, key process parameters such as pouring temperature, cooling rate, mold design, and metal flow characteristics were examined. These parameters were selected due to their significant influence on the solidification process and defect formation. Metallurgical analysis techniques were considered to evaluate the microstructural characteristics of defects, including their size, distribution, and morphology. Additionally, non-destructive testing methods such as X-ray inspection were incorporated to detect internal defects such as porosity and shrinkage cavities, which are not visible on the surface.

A statistical approach was also applied to assess the relationship between process parameters and defect occurrence. By analyzing variations in manufacturing conditions, it was possible to identify the most critical factors contributing to defect formation. This approach enabled a deeper understanding of cause-and-effect relationships and provided a basis for developing strategies to minimize defects. The combination of classification, analytical evaluation, and statistical interpretation ensured a comprehensive investigation of defects in wheel manufacturing.

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4. RESULTS

The results of the study demonstrate that defects in automobile wheel manufacturing can be effectively classified into internal, surface, and geometrical categories, each with distinct characteristics and formation mechanisms. Internal defects were found to be the most critical, as they directly affect the structural integrity of the wheel. These include shrinkage cavities, gas porosity, and microcracks, which are primarily formed during the solidification process due to volumetric contraction and gas evolution. The analysis revealed that uneven cooling and improper feeding of molten metal are the main causes of shrinkage defects, while gas porosity is closely related to hydrogen content and turbulence during pouring [4].

Surface defects, on the other hand, were observed to result mainly from mold conditions and metal flow behavior. These include rough surfaces, cracks, and oxide layers formed during the casting process. The findings indicate that poor mold quality and inadequate control of pouring conditions lead to the formation of such defects. Geometrical defects, including dimensional inaccuracies and shape distortions, were found to be associated with mold design and thermal deformation during cooling. These defects can affect the assembly and performance of the wheel, even if the material itself is free from internal flaws.

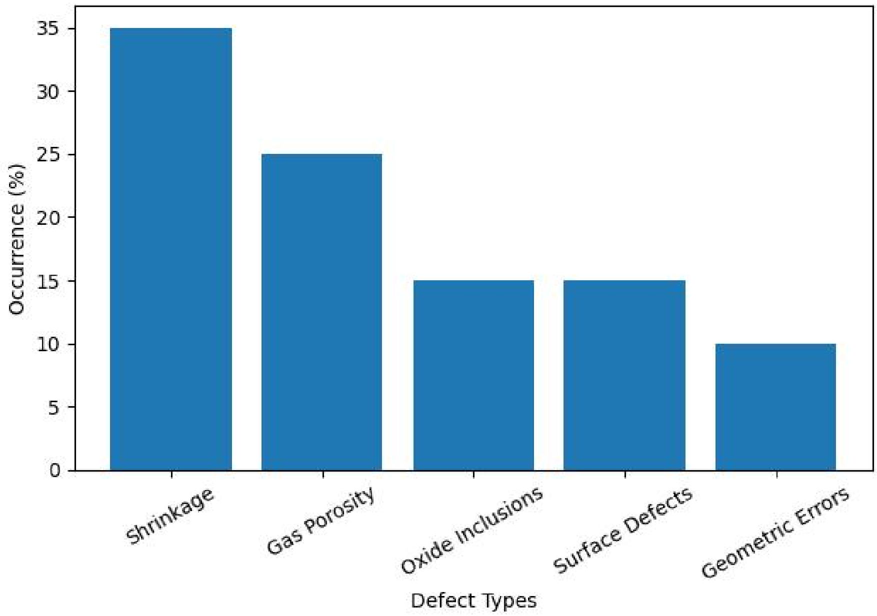

Fig. 1. Disturbution of defects in automobile wheel manufacturing

Furthermore, the analysis identified three main groups of factors contributing to defect formation: metallurgical, technological, and design-related factors. Metallurgical factors include alloy composition and gas content, technological factors involve process parameters such as temperature and pressure, and design factors relate to mold geometry and feeding systems. The interaction of these factors determines the type and severity of defects, highlighting the need for a holistic approach to defect prevention.

5. DISCUSSION

The findings of this study are consistent with existing research, confirming that defect formation in aluminum alloy wheel manufacturing is a complex and multi-dimensional process. Shrinkage and porosity defects were identified as the most prevalent and critical, which aligns with previous studies emphasizing their impact on mechanical performance [5]. These defects not only reduce strength but also serve as initiation points for fatigue cracks, significantly affecting the durability of the wheel.

The role of metallurgical factors, particularly hydrogen content and oxide formation, was found to be crucial in defect formation. The presence of bifilm defects resulting from turbulent flow highlights the importance of controlling metal flow during casting [6]. This suggests that improving gating system design and minimizing turbulence can significantly reduce defect occurrence. Additionally, the study confirms that process optimization, including temperature control and cooling rate management, is essential for achieving defect-free castings.

The application of simulation tools and predictive models offers promising opportunities for defect prevention. By using criteria such as the Niyama parameter, engineers can predict areas prone to shrinkage and adjust process parameters accordingly. However, the effectiveness of these tools depends on accurate input data and a thorough understanding of defect mechanisms. Therefore, integrating experimental observations with simulation results is necessary for reliable defect prediction and control.

6. CONCLUSION

This study provides a comprehensive classification of defects in automobile wheel manufacturing and identifies their primary causes. It was established that defects can be categorized into internal, surface, and geometrical types, each influenced by different factors. Internal defects such as shrinkage and porosity were found to be the most critical, as they significantly affect mechanical performance. The study also highlights the importance of metallurgical, technological, and design-related factors in defect formation.

The results demonstrate that effective defect prevention requires a holistic approach that combines process optimization, material control, and advanced analytical methods. The use of simulation tools and non-destructive testing techniques can further enhance quality control and reduce defect rates. Overall, the findings contribute to improving manufacturing processes and ensuring the reliability and safety of automobile wheels.

REFERENCES

1. Dong G. et al. Process optimization of A356 aluminum alloy wheel hub // Journal of Materials Research and Technology. – 2023.
2. Niyama E. et al. A method of shrinkage prediction // AFS Cast Metals Research Journal. – 1982.
3. Fiorese E., Bonollo F. Classification of defects in aluminum castings // International Journal of Metalcasting. – 2015.
4. Yang L.M. Numerical simulation of aluminum wheel defects // Materials Science Forum. – 2013.
5. Li S. et al. Fatigue properties of aluminum wheels // Materials Science. – 2025.
6. Dispinar D. Bifilm defects in aluminum alloys // Metals. – 2019.