Precision Casting Technology for Superalloy Transfinite Components

Jun Wang[1, 2], Yahui Liu[1, 2], Ying Ning[1, 2], Guoxiang Wang[1, 2], Jianzhong Li[1, 2]
1. School of Materials Science and Engineering, Shanghai Jiao Tong University, No. 800, Dongchuan Road, Minhang District, Shanghai 200240, China
2. Jiangsu Zhongchao Aerospace Precision Casting Technology Co., Ltd., No. 9, Changxing Road, Yixing City, Jiangsu Province 214242, China
*Corresponding address: junwang@sjtu.edu.cn (Jun Wang)

Abstract: High performance aircraft engines are one of the domestically produced large-scale equipment. Precision superalloy castings (such as turbine casings) formed by investment casting are key load-bearing components of aircraft engines, and their dimensional accuracy and metallurgical quality determine multiple service performance of aircraft engines. For example, dimensional accuracy can affect the starting performance of the turbine casing, while metallurgical defects can reduce the fatigue life of castings. Due to the fact that controlling the dimensional accuracy and metallurgical quality of precision superalloy castings has always been an important way to improve the service life of engines, it has attracted the attention of the aviation manufacturing industry.

With the structural integration and lightweight design of aircraft engines, the profile dimensions of casing structural components continue to increase, the wall thickness decreases, and the quality requirements are significantly improved, which poses a huge challenge to traditional investment casting processes. This article focuses on the technical bottlenecks of casing castings, including micropore defects, under casting, and dimensional deviations. Relevant research has been conducted and four key technologies have been achieved, including:

(1) Melt processing and melt state control technology: Specifically, by utilizing the structural transformation and genetic characteristics of the melt, a high-temperature treatment process for the melt has been established, which reduces segregation and TCP phase precipitation. During the high-temperature treatment process, there was no severe element burnout, the grain size of the casting was refined, and the performance was significantly improved. The comprehensive use of melt treatment and new thermal control processes can reduce casting defects and comprehensively improve microstructure and properties.

(2) Design technology for transfinite precision casting process: Based on hydraulic models, a shape following distributed pouring system has been developed to achieve rapid and stable filling, ensuring the rapid transportation of molten metal and the uniformity of overall temperature. A design criterion for transfinite casting process of large complex thin-walled castings has been proposed, breaking through traditional casting design methods and forming a new casting process system.

(3) Pressure regulating precision casting technology: We have conducted research on pressure regulating precision casting equipment and processes for 1.0mm superalloy castings, achieving complete filling of large-area thin-walled castings with a wall thickness of 1mm.

(4) Full process dimensional accuracy and surface quality control technology. A wax material flow and pressure holding calculation model has been constructed, realizing simulation calculation of wax material flow and shrinkage deformation, breaking through the long-term dependence on the experience + "trial and error" method in wax mold forming. We have established a reverse compensation deformation design method based on the full process displacement field and a reverse compensation deformation design method for node displacement transfer, and invented a new method for controlling the dimensional accuracy of various parts of castings.

These technologies have successfully solved the manufacturing problem of casing castings and played an important role in the independent development of commercial aviation engines.

Keywords: superalloy; investment casting; rear casing; metallurgy defects; dimensional deviations