Rapid Simulation Platform and Application in Investment Casting Process

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Abstract: A rapid simulation platform for high-temperature alloy investment casting process was constructed to address the issues of cumbersome process parameter operation and low simulation efficiency in numerical simulation of investment casting. This platform integrates the process from CAD design to CAE simulation, functions such as parameterization of pouring system, design of casting process parameters, and dynamic display of simulation results. It has established 10 types of simulation templates and 237 sets of model libraries, achieving automated and rapid simulation. Taking a certain power turbine casing as an example, using this platform to construct a simulation model, parameter design variables, and result prediction optimization indicators for simulation calculation; The simulation prediction analysis results are consistent with the actual production defects; Simulation efficiency increased by 89.8%.

Keywords: Investment casting; Rapid simulation of casting process; Template Library

1 Introduction

With the real arrival of big data and the "Internet plus" era, the traditional casting production mode has been seriously challenged, and intelligent casting came into being [1]. In recent years, numerical simulation technology has been flourishing in the investment casting process, and software such as ProCAST, MAGMA have been widely used [2]. Among them, ProCAST can effectively and accurately predict the defects produced by castings [3]. The use of ProCAST simulation in the above research requires a high level of simulation technology, and the simulation operation is cumbersome, resulting in low efficiency and inability to achieve rapid process prediction. CHENG H et al. [4] proposed an automatic optimization design method based on Isight platform digital modeling, mesh partitioning, numerical simulation for the design of multi-objective and multi parameter cavity structures under the influence of flow fields. However, the above research lacks direct calls to various modules of ProCAST, and requires researchers to write corresponding script files.

Based on the simulation of investment casting process and analysis of simulation results, this article aims to design a rapid simulation platform for casting process with the goal of automated rapid simulation. This platform achieves automated rapid simulation and efficient prediction of casting process defects.

2 Experimental procedure

In order to achieve the automation of casting simulation process and the efficient prediction of defects. The rapid simulation platform for casting process will be divided into two modules: pre-processing, post-processing.

Pre-processing module: This module establishes 10 types of simulation templates, and through parameterized design of the pouring system in 237 sets of model libraries, the adjustable parameters of 15 simulation design variables and 3 simulation results for predicting optimization indicators are uniformly encapsulated, such as geometric models, 2D meshes, and boundary conditions. After submitting the calculation, the ProCAST software is automatically called for simulation calculation using batch processing, ultimately achieving the associative storage of simulation results.

Post-processing module: This module extracts simulation results and dynamically displays temperature field, flow velocity field, and contour maps through visualization. The shrinkage porosity map can be generated based on the specified porosity; At the same time, simulation reports can also be downloaded to view the process parameters and result cloud maps of castings, achieving efficient defect prediction and analysis.

3 Result and discussion

Taking the filling and solidification of a certain power turbine casing of an aircraft engine as an example, this casing serves as the core component of a certain helicopter engine model, as shown in Figure 1. In the 237 sets of pouring system model library, select the parameterized design and assembly of the casing pouring system. The material of the casing casting is nickel based high-temperature alloy K4169, and the shell material is mullite. The shell roasting temperature is 950 ℃, the pouring temperature is 1450 ℃, and the pouring time is 5 s. The casing template library is called for simulation. The simulation results are shown in Figure 2.

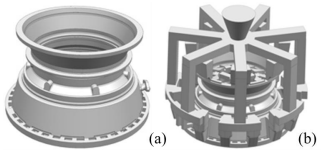

Fig.1 (a)Power turbine casing model(b)pouring system model

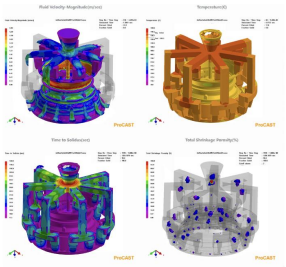

Fig.2 Post processing result interface

The shrinkage porosity diagram of the casting is shown in Figure 2, with shrinkage porosity appearing in the bottom end face and the lower thin-walled area. As shown in Figure 3, not all thin-walled areas between the risers show shrinkage and looseness. This is because the feeding distance of the riser is not long enough, resulting in the formation of isolated liquid phase zones between the thin-walls, with a high shrinkage porosity (as shown in Figure 3(b)). The casing was put into actual production and it was found that the defect results predicted and analyzed by the casting process rapid platform were consistent, as shown in Figure 3(c).

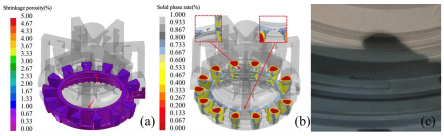

Fig.3 (a)Casting profile solidification defect distribution (b)Solid phase fraction distribution in casting profile (c)Defects in power turbine casing casting

As shown in Table 1, during the numerical simulation process, it takes about 31 minutes to use general finite element simulation software for the power turbine casing, while using the casting process rapid simulation platform only takes about 3 minutes, saving nearly 28 minutes and improving efficiency by 89.8%, greatly shortening the simulation time.

Tab.1 Comparison of simulation time

Category/time	Pre-process	Post-process
General simulation	17min28s	14min41s
Rapid simulation platform	<1min	2min13s

4 Conclusion

Based on the simulation of investment casting process and analysis of simulation results, a rapid simulation platform for casting process has been successfully constructed by integrating the process from CAD design to CAE simulation. Taking a certain power turbine casing as an example, a simulation model, parameter design variables, and result prediction optimization indicators are constructed through a fast simulation platform for simulation calculation; Compared with general simulation software simulation, the simulation time was saved by 28 minutes and the efficiency was improved by 89.8%; It is found that the simulation results are consistent with actual production defects.

5 Acknowledgments

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