Optimization of Solid-Liquid Bimetallic Casting Process Parameters for Dual-Performance Blade

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Abstract: In this paper, the solid-liquid bimetal investment casting of turbine blade for nickel-based superalloys DD412 and K447A has been investigated by numerical simulation methods. The effect of investment casting process parameters on the depth of bimetallic bonding and the grain size of the disc casting has also been studied by combining Taguchi method and ANOVA (Analysis of Variance) method, and the solid-liquid bimetal investment casting parameters were optimized to obtain the best combination of process parameters, this work can provide a theoretical basis and experimental foundation for the preparation of high-quality bimetallic turbine blisk castings.

A quarter of the original casting was retained to improve the calculation accuracy on the premise of ensuring the calculation accuracy by the Soildworks software, due to the casting had the axisymmetric characteristics. The finite element model of turbine blisk casting for solid-liquid bimetallic casting process and the corresponding casting parameters for simulation were both established in ProCAST software, as shown in Fig. 1. The simulation parameters of the body shape nucleus boundary conditions, employed for CAFE advanced module, were obtained by inverse computation from the actual experiments under the conditions of pouring temperature of 1350 ℃ and preheating temperature of 1100 ℃, with the measured casting grain size of 0.2 mm , which were DTm = 1.5 K, DTs = 2 K, and Nmax = 5×10^{11} 1/m^3.

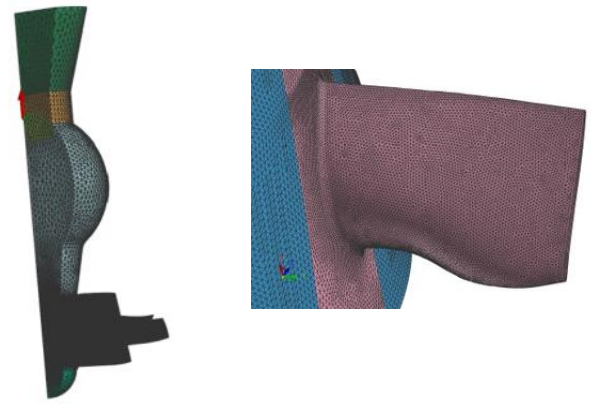

Fig. 1 The generation results of finite element mesh in casting and mold shell, (a) mesh of the casting, (b) mesh at the blade, (c) mesh of the mold shell, (d) overall finite element mesh

According to the analysis, three process parameters of solid-liquid bimetallic investment casting process, including pouring temperature, preheating temperature of mold shell, and pouring time, with great influence on the quality of dual-performance turbine blisk castings were selected, and a three-level, five-factor orthogonal test was designed, then 25 groups of numerical simulation experiments were carried out with the quality evaluation indexes of grain size and the depth of the bimetallic bonding. The simulation results were analyzed by Taguchi method and ANOVA method, the best combination of process parameters for the turbine blisk casting was finally optimized as follows: pouring temperature of 1350 ℃, preheating temperature of the mold shell of 1200 ℃, and pouring time of 5 s.

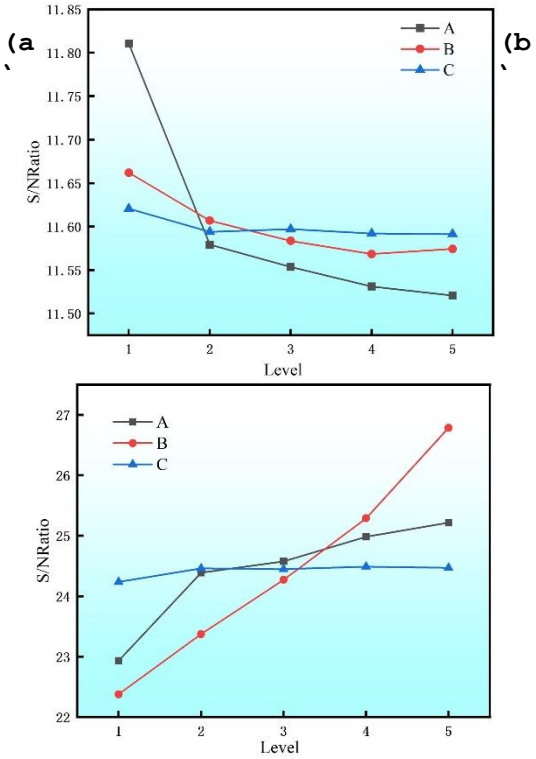

Fig.2 S/N response curve: (a) Grain size S/N response curve (b) Bimetallic bonding depth S/N response curve

Finally, the temperature field and microstructure under the best combination of process parameters and other combinations in the orthogonal design experiment were compared and analyzed, which verifying the accuracy and rationality of Taguchi method.

Key words: nickel-based superalloy; bimetallic casting; bimetallic bonding; grain size; Taguchi method.