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THE IMPACT OF THE THICKNESS OF THE CERAMIC LAYER OF WAX PATTERN ASSEMBLY OF TURBINE BLADE ON THE (γ+γ') EUTECTIC IN THE IN713C SUPERALLOY

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Nickel-based superalloys are mainly used in aircraft and power-generation turbines. Creep-resistant turbine blades are typically produced by complex investment casting process. In the study the influence of thickness of ceramic layer of wax pattern assembly of turbine blade on (γ+γ') eutectic in the IN713C nickel-based superalloy was described.

It is well known that microstructure of material effect on its properties. Superalloys develop high temperature strength through solid solution strengthening. The most important strengthening mechanism is through the formation of secondary phase precipitates such as gamma prime and carbides through precipitation strengthening. The microstructure of IN713C consists, regardless of the casting parameters used, of γ-grains, interdendritic (γ+γ') eutectic, γ/MC eutectic and coherent γ' precipitates distributed uniformly within the γ-matrix. The precipitation and growth kinetics of the γ' phase are highly sensitive to the rate at which the alloy is cooled through the solvus temperature.

The (γ+γ') eutectic is an indication of the remaining melt at the end of the solidification process [2]. After solution heat treatment the microstructure with (γ+γ') eutectic should be homogenized [3].

Two castings formed as a blade from two wax pattern assemblies were analysed. In the experiment in one pattern the thick ceramic layer was obtained on pressure side of blade and in another one on suction side. The microstructure of the cross-sections of the castings were observed on polished and etched metallographic specimens. The microstructure and phases chemical compositions of specimens was analyzed by using the scanning electron microscope Hitachi S-4200 equipped with EDS.

It was established, that thickness of ceramic layer of wax pattern assembly of turbine blade from IN713C superalloy influence size, shape and volume fraction of ($\gamma+\gamma'$) eutectic in the material.

The analysis was provided in accordance to the typical statistical methodology [4] augmented by the directional statistics [5], the non-parametric methods [6] and the fuzzy statistics [7] approach. The stability of achieved results was verified by a jackknife procedure [8] involving systematic sub-sampling. The empirical non-parametric likelihood approach [9] was involved to obtain the confidence intervals and region of confidence for the results.

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REFERENCES

[1] R.C. Reed, *The Superalloys, Fundamentals and Applications*, Cambridge University Press, New York, 2006
[2] Y. Huang, L. Wang, Y. Liu, S. Fu, J. Wu and P. Yan, Microstructure evolution of a new directionally solidified Ni-based superalloy after long-term aging at 950°C upto 1000h, *Trans. Nonferrous Met. Soc. China*, Vol. **21**, pp. 2199-2204, 2011.
[3] J. Safari and S. Nategh, On the heat treatment of Rene 80 nickel-base superalloy, J. Mat. Proc. Technol., Vol. **176**, pp. 240-250, 2006.
[4] *The Springer Handbook of Engineering Statistics*. H. Pham (ed.), Springer, 2006.
[5] K.V. Mardia and P.E. Jupp, *Directional Statistics*. John Wiley & Sons, 2000.
[6] A.J. Izenman, *Modern Multivariate Statistical Techniques. Regression, Classification and Manifold Learning*. Springer, 2008.
[7] J.J. Buckley, *Fuzzy Statistics*. Springer, 2004.
[8] J. Shao and D. Tu, *The Jackknife and Bootstrap*. Springer, 1995.
[9] A.B. Owen, *Empirical Likelihood*. Chapman & Hall/CRC, 2001.