As-Cast Microstructure of the Heat-Resistant René N5 Nickel-Based Superalloy

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Abstract: This work focused on the microstructure and mechanical properties of nickel-based superalloy René N5 prepared by investment casting. The microstructure of casting was systematically investigated by X-ray diffraction, light microscopy, energy-dispersive X-ray spectroscopy, and scanning electron microscopy.

Keywords: superalloy; René N5; aerospace; heat-resistant, microstructure

1 Introduction

Nickel-based superalloys are widely used in the turbine blades of modern aero-engines and gas turbines because of their excellent high-temperature mechanical properties, high creep and fatigue resistance, and very good corrosion resistance. The usefulness of Ni-based superalloys during long-term service at harsh conditions depends strongly on the alloying elements, their concentrations, and the morphology of the strengthening phases. In industrial practice, the Ni-based superalloy René N5 is used in a fully heat-treated condition. The solution treatment partially homogenizes the microstructure, and subsequent ageing allows a high-volume fraction of cube-shaped γ′ precipitates to be obtained. Therefore, getting more information on the superalloy microstructure and properties in the as-cast state is essential to design and control subsequent heat treatment properly. Solidification segregation of the elements between dendritic and interdendritic spaces induces the formation of non-equilibrium phases, such as carbides, eutectic phases, or other low melting point phases, which should be dissolved during homogenization [1-3].

2 Experimental procedure

René N5 is a second-generation SX superalloy developed by General Electric (Table 1). The presence of Re delays the coarsening of the γ' phase and increases the misfit between γ matrix and γ' precipitates. The superalloy is also strengthened by the effects of chromium, tantalum, and tungsten in solid solution. Additionally, aluminium and titanium contribute to its strength due to the precipitation-strengthening effects of the intermetallic γ' phase. Although the γ' phase is mostly responsible for improvements in thermo-mechanical properties, it also poses challenges during processing, making these alloys prone to crack formation and, consequently, expensive to cast and repair welding. The multi-scale microstructure characterizations were conducted to reveal the primary-dendritic structure, microsegregation, and morphology of γ′ phase and MC carbides. The samples for LM and SEM observations, cut from the casting, were ground, polished (diamond suspensions: 3 µm, 1 µm; colloidal silica: 0.25 µm), and chemically etched in No. 17 (25 mL water, 25 mL HCL, 25 mL HNO_3, 1,5 g H_2MoO_4) for 5 seconds. Initial characterization of morphology and distribution of precipitates was carried out on a Leica light microscope. For SEM-EDX analyses, 20 kV accelerating voltage was set on a Phenom XL apparatus equipped with Energy Dispersive X-ray Spectroscopy detector.

Table 1. Nominal chemical composition of René N5 superalloy, wt%

Ni	Cr	Co	Mo	Ta	Re
Bal.	7.0	8.0	2.0	7.0	3.0
W	Al	C	B	Hf	-
5.0	6.0	0.05	0.004	0.15	-

3 Result and discussion

The unetched cross-sections display the distribution of microporosity in the casting and the distribution of carbides (Fig. 1). A dendritic structure was revealed on chemically etched metallographic sections of the castings. The features of the primary structure of the superalloy are very clear. Dendritic areas (primary cores and secondary dendrite arms) are characterized by a relatively uniform two-phase γ+γ' microstructure, and the precipitates of the γ' intermetallic phase may vary in size. In the interdendritic spaces, in addition to carbides, there are also numerous γ-γ' eutectic islands.

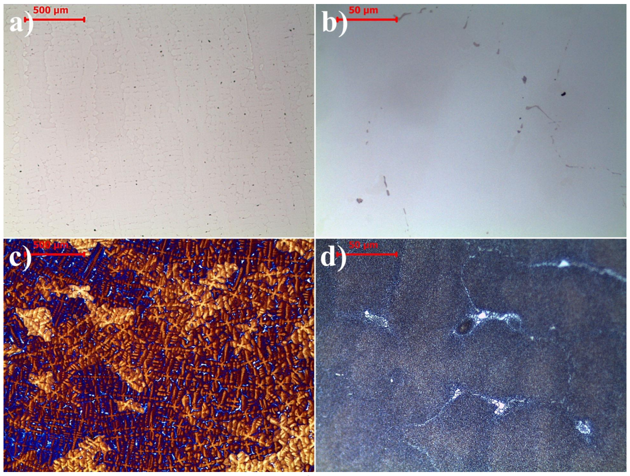

Figure 1. a-b) distribution of microporosity and carbides in unetched sample; c-d) dendritic structure in etched sample, LM

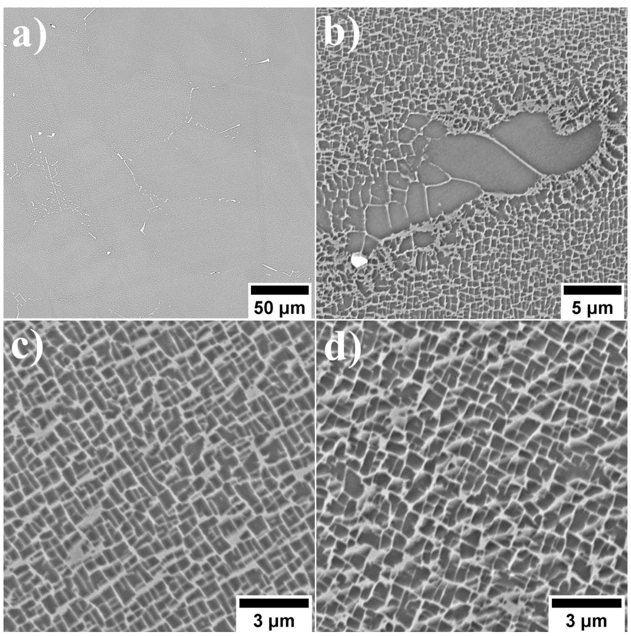

Figure 2. Morphology of precipitates in as-cast René N5: a) carbides; b) primary γ' phase; c) secondary γ' phase in dendritic region; d) secondary γ' phase in interdendritic space, SEM-BSE

Casting solidification is associated with alloying element segregation. This favors the formation of MC carbides near eutectic $\gamma-\gamma'$ islands (Fig. 2a-b). The observed carbides are characterized by complex morphologies, including blocky-shaped, sharp-edged parallelograms and Chinese script-like. The dominant component in the microstructure is the secondary γ' precipitates, which have a cube-like morphology (Fig. 2c-d).

4 Conclusions

This work focused on characterizing the as-cast microstructure and resulting properties of René N5. The obtained results allowed to draw the following conclusions:

-Local microporosity in interdendritic spaces was revealed in unetched samples.

-The types of precipitated phases mainly contain γ'-Ni_3Al phase, (Ta, Hf)C carbides, and eutectic $\gamma+\gamma'$ phase.

-The cube-like γ' precipitates in dendritic regions are finer compared to interdendritic regions.

Acknowledgments

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