Abstract

The uniform crystallographic orientation and structure of turbine blades is crucial for their mechanical strength. During operation, turbine blades are subjected to enormous centrifugal forces, and crystallography heterogeneities lead to local stress concentrations, increasing the risk of crack initiation and propagation. This dissertation presents a comparative analysis of the spatial distribution heterogeneities of crystallographic orientation and dendritic, as well as *γ/γ'* phase structures, in the roots of single-crystal CMSX-4 and CMSX-6 nickel-based superalloy blades acquired with different withdrawal rate. Blade roots are particularly significant because crystallization defects in the roots are inherited by the airfoil, which crystallize later. Additionally, the selector periphery areas were analysed for their significant impact on the heterogeneities of root orientation and structure. These blades were produced using the directional solidification Bridgman technique at withdrawal rates of 1 mm/min and 3 mm/min.

For detailed characterization of the crystal structure of the superalloys, X-ray diffraction topography using a modified Auleytner technique and Ω-scan mapping of the *γ'* phase lattice parameter were employed, followed by scanning and transmission electron microscopy techniques, including EBSD and EDS.

The study demonstrated that the roots of CMSX-4 blades have a higher number of blocks and low-angle boundaries compared to CMSX-6, regardless of the withdrawal rates. Low-angle boundaries in CMSX-4 roots showed lower α values, indicating deviation from the blade axis, and lower β values, indicating dendrite precession, but higher γ values, indicating dendrite rotation, compared to CMSX-6. This implies that CMSX-4 roots exhibit lower primary, and higher secondary misorientation of dendrites at low-angle boundaries. This phenomenon coincides with the segregation of Re and W alloying elements to the boundaries and Ta and Al away from the boundaries, as confirmed by TEM chemical analysis.

Within the blocks of CMSX-4 roots, outside low-angle boundary areas, a statistically higher primary and secondary misorientation of adjacent dendrites, in comparison with CMSX-6 was observed. This increase includes the α, β, and γ misorientation components. In the selector periphery areas of CMSX-4 roots, primary α and β and secondary

γ misorientation were grater compared to CMSX-6, particularly at a withdrawal rate of 3 mm/min.

For CMSX-4 roots produced at a withdrawal rate of 1 mm/min, a reduction in the *γ'* phase lattice parameter near low-angle boundaries was observed. It was associated with the addition of Re and W, confirming their concentration near these boundaries. CMSX-4 roots exhibited a statistically smaller range of *γ'* phase lattice parameter variations compared to CMSX-6 roots. Furthermore, CMSX-4 roots showed an increased number of *γ'* crystallites in the second-order dendrite arm areas, where low-angle boundaries occur, with a distinct segregation of W to the *γ'* crystallites and less pronounced Re segregation. In the selector periphery areas, for both CMSX-6 and CMSX-4, no noticeable changes in the *γ'* phase lattice parameter (a_0) were observed for both withdrawal rates.

In the selector periphery areas of CMSX-4 roots, greater local changes in all misorientation components were observed at the most commonly used withdrawal rate in industry, highlighting the importance of high-quality selector-root connections and the geometry of this connection to minimize adverse crystallographic orientation heterogeneities.