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Thermo-Mechanical Processing Scheme to Obtain Micro-Duplex Structure Favoring Superplasticity in an As-Cast and Homogenized Medium Alloyed Nickel Base Superalloy

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Abstract : Ni-based superalloy with a nominal composition Ni-14% Cr-11% Co-5.8% Mo-2.4% Ti-2.4% Nb-2.8% Al-0.26 % Fe-0.032% Si-0.069% C (all in wt %) is used as turbine discs in a variety of aero engines. Like any other superalloy, the primary processing of the as-cast superalloy poses a major challenge due to its complex alloy chemistry. The challenge was circumvented by characterizing the different phases present in the material, optimizing the homogenization treatment, identifying a suitable thermomechanical processing window using dynamic materials modeling. The as-cast material was subjected to homogenization at 1200°C for a soaking period of 8 hours and quenched using different media. Water quenching (WQ) after homogenization resulted in very fine spherical γ' precipitates of sizes 30-50 nm, whereas furnace cooling (FC) after homogenization resulted in bimodal distribution of precipitates (primary gamma prime of size 300nm and secondary gamma prime of size 5-10 nm). MC type primary carbides that are stable till the melting point of the material were found in both WQ and FC samples. Deformation behaviour of both the materials below (1000-1100°C) and above gamma prime solvus (1100-1175°C) was evaluated by subjecting the material to series of compression tests at different constant true strain rates (0.0001/sec-1/sec). An in-detail examination of the precipitate dislocation interaction mechanisms carried out using TEM revealed precipitate shearing and Orowan looping as the mechanisms governing deformation in WQ and FC, respectively. Incoherent/semi coherent gamma prime precipitates in the case of FC material facilitates better workability of the material, whereas the coherent precipitates in WQ material contributed to higher resistance to deformation of the material. Both the materials exhibited discontinuous dynamic recrystallization (DDRX) above gamma prime solvus temperature. The recrystallization kinetics was slower in the case of WQ material. Very fine grain boundary carbides (≤ 300 nm) retarded the recrystallisation kinetics in WQ. Coarse carbides (1-5 μm) facilitate particle stimulated nucleation in FC material. The FC material was cogged (primary hot working) 1120˚C, 0.03/sec resulting in significant grain refinement, i.e., from 3000 μm to 100 μm. The primary processed material was subjected to intensive thermomechanical deformation subsequently by reducing the temperature by 50˚C in each processing step with intermittent heterogenization treatment at selected temperatures aimed at simultaneous coarsening of the gamma prime precipitates and refinement of the gamma matrix grains. The heterogeneous annealing treatment carried out, resulted in gamma grains of 10 μm and gamma prime precipitates of 1-2 μm. Further thermo mechanical processing of the material was carried out at 1025˚C to increase the homogeneity of the obtained micro-duplex structure.

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