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High-temperature precipitate microstructure and misfit in Inconel-type superalloy

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Nickel base superalloys are a natural composites consisting of γ'precipitates (L12) with an ordered structure coherently embedded in a γ solid solution (fcc) matrix. The critical parts of turbines made of Ni-based superalloy are subjected to cyclic elastic-plastic straining as a result of heating and cooling during start-up and shut-down periods. Consequently, low-cycle fatigue at operating temperatures (up to 900℃) is an important factor in the evaluation of the service life. The thermo-mechanical exposure during low-cycle fatigue is connected with a change of its microstructure, namely the size and distribution of precipitates. Moreover, an important parameter for the characterization of microstructural changes in nickel base superalloys is misfit - the relative difference between lattice parameters of γ matrix and γ´ precipitates.
Nickel base superalloy IN738LC has been studied after low-cycle fatigue by small-angle neutron scattering (SANS) and neutron diffraction (ND) at SINQ (SANS-II and POLDI facilities).
Samples subjected to high-temperature low-cycle fatigue were annealed at various temperatures to change the size and the distribution of precipitates. Ex- and in-situ SANS and high resolution TEM studies were performed. It was found that additional precipitates are produced either during slow cooling from high temperatures or after reheating above 570℃. Their size and distribution were evaluated. The precipitates arise regardless the application of the mechanical load. Nevertheless, these small precipitates influence low-cycle fatigue resistance. From the SANS data, it can be also deduced that the equilibrium volume fraction of γ' -precipitates at temperatures from room temperature to 825℃ is significantly higher than 45%. The kinetics of formation of small and medium-size γ'precipitates at 700 and 800℃ was determined as well.
Misfit in IN738LC superalloy was examined at POLDI TOF neutron diffractometer both ex-situ and in-situ at elevated temperatures. A careful out-of-furnace measurement yielded the lattice parameters of both γ and γ' phases at room temperature (aγ= 3.58611(10) Å, aγ´= 3.58857(17) Å) as well as misfit (equal to 6.9(6)×10-4). The in-situ measurement at elevated temperatures determined the temperature dependence of lattice parameters of γ (up to 1120℃) and γ'(up to 1000℃). Using these data, evolution of the misfit with temperature was calculated. The misfit decreases with increasing temperature until it reaches zero value at temperature around 800℃. Above 800℃, it becomes negative.
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