	Experiment title: "In situ" study of the lattice parameter mismatch of the MC-NG new generation superalloy during a creep test at high temperature	**Experiment number**: ME 372
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Report:

Due to their good mechanical properties at high temperature, Ni based superalloys are used to manufacture aircraft engine turbine blades. The improvement of the turbine performances goes through an increase of the gas temperature at the turbine entrance. For this aim, a superalloy of a new generation, containing Rh and Ru, named MC-NG is under development at the ONERA. As the previous superalloys, it is a diphasic compound with ordered gamma prime precipitates inside a FCC gamma matrix. The creep characterisation of this new material shows a significant increase of the life duration before rupture compared to the superalloys of the previous generation (AM1, MC2). But the shape of the creep curves differs significantly from that of the previous generation. Previous studies by scanning electron microscopy (SEM) allow to correlate the creep characteristic to the microstructural evolution of the gamma prime precipitates. Among the parameters which control this evolution, the lattice parameter mismatch between the γ and the γ' phases is one of the most important. The aim of this study is to determine the evolution of the lattice parameter mismatch of this new superalloy during a creep test, as a function of time and therefore of deformation, in order to understand the microscopic mechanisms at the origin of the differences between the two generations of superalloys.

Using the Triple Crystal Diffractometer (TCD) installed on the high energy beamline ID15A which allows “in situ” bulk measurements, we measured the evolution of the lattice parameter mismatch of a MC-NG sample during a creep test. Before the experiment, the specimen received the standard heat treatments which led to a cuboïdal precipitate morphology with a cube edge of 0.45 µm. It was submitted to a tensile creep test at 1100°C under 150 MPa up to rupture which was reached in 56 hours. During such a creep test, the precipitates evolve from cuboïds to rafts perpendicular to the applied stress before to dislocate during stage III of the creep curve. In a previous experiment (ME 188), the evolution of the lattice parameter mismatch was measured for the reflection (200), so for lattice plane parallel to the applied stress corresponding to a mismatch determination along a direction parallel to the rafts appearing during the creep deformation. During the present experiment, the lattice parameter mismatch was measured for the reflection (002) corresponding to a mismatch determination along a direction perpendicular to the rafts.

The aims of these measurements were a comparison with similar measurements performed on the AM1 superalloy (1) in order to check the differences between these two alloys. Indeed, as shown for the AM1 superalloy (2), it is mainly this type of measurements which allows to understand and to model the creep behaviour of the material. So we expect to determine the mechanism at the origin of the better performance of the new superalloy (3).

The obtained results show some similarities with those of the AM1. Same qualitative evolutions of the lattice parameter mismatch are observed during the different stages of the creep test, but the kinetic and the amplitude of these evolutions differ significantly. For MC-NG, the splitting of the diffraction peak, which corresponds to the first stage of the deformation curve, takes more time, showing that the stability of the cuboïdal precipitates is stronger. But the evolution of the misfit during stage two is faster than that of the AM1 showing that the rafted precipitates dislocate faster than in AM1. The misfit evolutions at the transition between stages I and II are strongly enhanced in the MC-NG superalloy, the amplitude of the misfit variations are stronger. Using the model developed for the AM1 superalloy (4), this will allow us to apprehend the origin of the difference in the mechanical properties at high temperature.

Two other experiments were also performed on the superalloy AM1 in order to check their feasibility. The first one was a test to measure independently the Young modulus and the Poisson ratio of each phase when the raft structure is developed. These quantities are important for quantitative simulations of the behaviour of the different superalloys. The test was made at 1050°C and the obtained results are conclusive. It is the first direct measurement on the diphasic material. A systematic study as a function of temperature will be performed in a future experiment. The second one concerns the mismatch evolution under applied stress for a rafted microstructure. Indeed dislocation networks depending on the rafting conditions develop at the γ-γ' interfaces and block the misfit value. The stress threshold where the misfit begins to change informs us on the value of internal stresses which act on the dislocations. The results of this test look also very promising and support request for a new experiment.

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