ESRF	**Experiment title:** **Ni-based superalloys : Elastic properties, lattice parameters and creep behaviour. An 'in situ' study.**	**Experiment number:** ME554
Beamline: ID15A	**Date of experiment:** from: 08 October 2003 to: 15 October 2003	**Date of report:** 27 feb 2005
Shifts: 18	**Local contact(s):** Thierry D'ALMEIDA	*Received at ESRF:*

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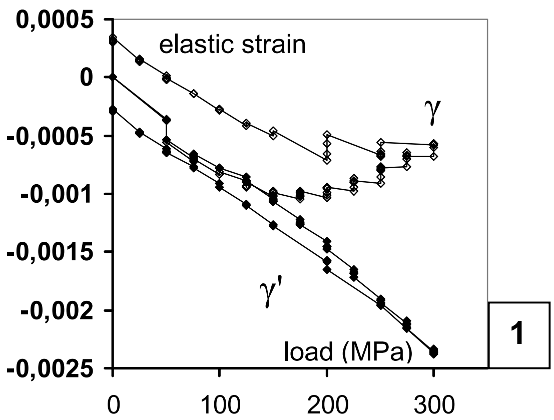
Report:

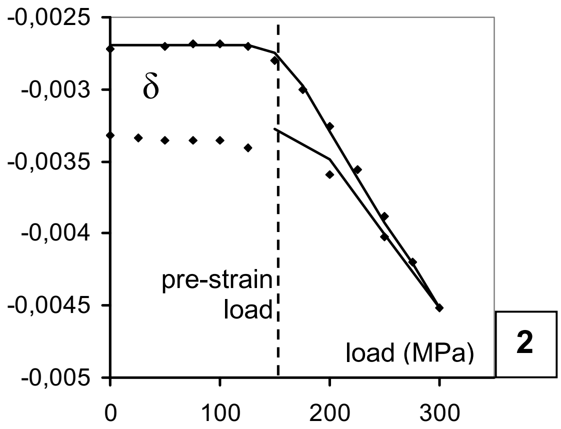
Due to their good mechanical behaviour at high temperature, Ni based single crystal superalloys are used to manufacture aircraft engine turbine. They are diphasic materials with ordered γ' precipitates inside a fcc γ matrix. Their creep behaviour is correlated to their microstructure and the early evolution the γ' precipitates morphology from cuboïds to platelets (rafting) results in the transition from the initial stage I of creep to a second stage with a minimum creep rate (stage II). A key parameter of the mechanical behaviour is the "lattice mismatch" $\delta = ½(a_{\gamma'} - a_{\gamma})/(a_{\gamma'} + a_{\gamma})$ due both to the difference in the "natural" lattice parameters and to the difference between the plastic strains of both phases. This lattice mismatch introduces internal stresses which play a key role in rafting, and later in the mechanical behaviour of the material.

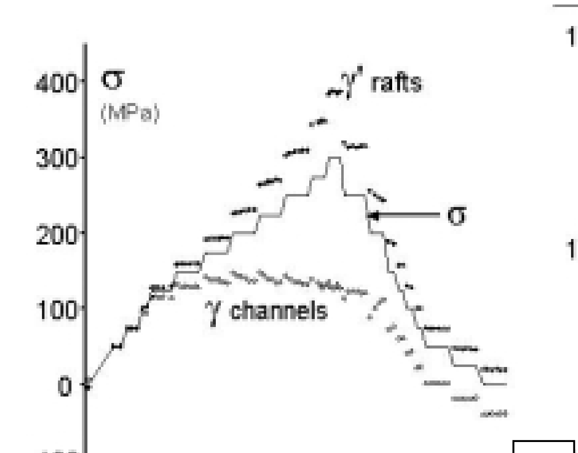
Former experiments done at the ESRF had shown that the actual (measured) value of the mismatch could vary during a creep test : from energetic considerations, we expected it to remain constant at low stresses, and then to increase linearly with a slope depending on the elastic constants (Young modulus and Poisson coefficient) of both phases . The aim of experiment ME 554 was thus to test this prediction and to study the response of the lattice mismatch to load variations. This part of the experiment was successful. However, a reanalysis of the data showed that the method could give far more interesting results.

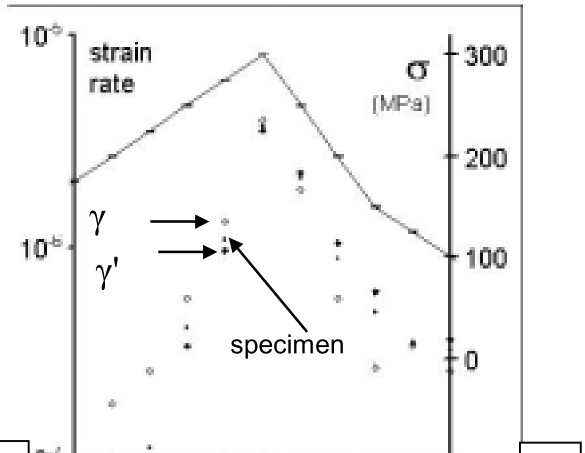
Three specimens of the AM1 superalloy were pre-strained in the laboratory at respectively (1080°C, 150 MPa), (1080°C, 120 MPa) and (1000°C, 200 MPa) until the beginning of stage II in order to obtain a raft microstructure. The specimens were then tested at ID15 under various loads, and the variations of the lattice parameters of the γ and γ' phases were recorded in the raft plane (perpendicular to the tensile axis) using the Triple Axis Diffractometer. (Figure 1). They were used to evaluate the Young modulus of both phases, and the equilibrium values of the mismatch (Figure 2) vary as expected: the mismatch remains constant as long as the stress is lower than the pre-strain stress, and then decreases linearly. As long as the plastic strain rate of the γ' phase remains low, the measured slope is within 5% of its expected value.

Taking these data, it is now possible to calculate the **effective stress** acting on dislocations in the two phases: We can see in Figure 3 that the effective stress in the γ phase saturates at 130 MPa, while the load on the γ' phase reached 400 MPa in this experiment, under a 300 MPa load. As we know the plastic strain of the whole specimen and the difference between the strains of both phases ($\varepsilon_{\gamma} - \varepsilon_{\gamma'} = -2\delta$), we can now calculate the average plastic strain rate **of each phase** during a loading step. (Figure 4), and begin to build a constitutive law. We are currently working on the modelling of these results.









Figures 1 and 2: Variations of the lattice parameters and of the lattice mismatch vs. load. Figure 3: Applied load (continuous curve) and effective stresses (diamonds) in both phases vs. time. Figure4: Strain rates of the specimen, γ phase (empty diamonds) and γ' phase (full diamonds) during loading steps.