Micromechanical testing for mesoscale characterisations and macromechanical testing for microscale characterisations up to high temperatures

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This presentation gives an overview of recent experimental techniques developed in collaboration with different laboratories to identify (1) the mesomechanical behaviour of ultrathin materials, and (2) elementary deformation mechanisms at the microscale up to elevated temperatures.

(1) The evaluation of the thermomechanical properties within high temperature coated systems for aeronautical turbine applications motivated the concomitant developments of (i) preparation techniques to extract tens-of-micrometre-thick with centimetre-size specimens, and (ii) dedicated mechanical test rigs under highly controlled atmospheres to test them at elevated temperatures. Owing to the high "surface/volume" ratio of micromechanical specimens, a particular attention has been paid on the testing atmospheres in order to limit surface reactivity at high temperature. Freestanding coatings, interdiffusion zones and substrates constitutive of turbine blades were thus tested up to 1100°C to document the gradient of meso/macroscopic mechanical and thermal properties, and in particular, the brittle-to-ductile transition behaviour of the coating material. This recent high temperature micromechanical development enables a better evaluation of the plastic behaviour of coating materials in comparison with previous microtensile devices. Such a database is necessary for materials selection and for feeding numerical models predicting both the high temperature mechanical behaviour and the service life of coated structural components.

(2) In polycrystalline metallic materials, assessment of the plasticity in relation to the microstructure is necessary to understand the deformation processes during mechanical loading. High resolution digital image correlation (HR-DIC) techniques coupled with novel DIC codes have emerged as a quantitative tool to assess heterogeneous strain field at the microscale. *In-situ* and *ex-situ* scanning electron microscopy (SEM) and laser scanning confocal microscopy (LSCM) tensile testing were developed to characterize the continuous and discrete kinematics fields at the sub-grain level associated with non-localized deformation and slip events at room temperature. *In-situ* HR-DIC under SEM was capable to evidence elastic anisotropy of nickel-based superalloys at the grain scale. When irreversible deformation is concerned, {111}<110> slip systems identification using in-plane HR-DIC under SEM was possible. HR-DIC under LSCM added the possibility to measure the out-of-plane displacements and to fully quantify the slip activity, i.e. the local shear strain induced by individual slip bands. The validation of the HR-DIC technique at room temperature prompted its application at temperatures representative of service conditions for polycrystalline nickel-based superalloys. *Ex-situ* intermediate temperature HR-DIC tests under SEM were thus conducted to evaluate the local slip activity under macroscopic cyclic deformation in reactive atmosphere. Local oxide spikes were found to form under cyclic loading in grains where plastic deformation was observed to occur in the first cycles.HR-DIC clearly demonstrates the synergy existing between local slip activity at the microstructure scale and environment induced surface degradation.