[MS20-P12] Structural and elastic properties of pseudo-single crystal CMSX-4 and LEK94 up to 1523 K

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Today pseudo-single crystals of nickel-base superalloys are widely used as blade materials in gas turbines and jet engines. The pseudo-single crystals of superalloys are characterized by an oriented coherent intergrowth of two different cubic phases, the more γ-phase with fcc structure and more γ'-phase (around 1 µm) with Ni_3Al structure [1, 2]. This particular microstructure results from a controlled exsolution process at high temperatures and causes the high mechanical strength at high temperatures [3]. Dendrites are a larger scaled microstructure (around 200-300 µm) in this material. Heavy elements like tungsten and rhenium are concentrated in the dendritic area; in contrast to this light element e.g. aluminum and tantalum are accumulated in the indendritic area. This segregation can be reduced by a special heat treatment [1]. However, the extreme operation conditions (high temperatures, corrosive atmosphere and high mechanical stresses) in gas turbines and jet engines may cause irreversible changes of the microstructure and thus of the relevant mechanical properties of the turbine blades. Therefore, a better understanding of the mechanical properties of pseudo-single crystal superalloys as a function of temperature, mechanical stresses, composition and microstructure is crucial for the optimization of these materials in respect to their use in harsh environments. To this end we combine macroscopic creep experiments and studies of elastic properties using resonant ultrasound spectroscopy (RUS) with structural and microstructural characterizations including reciprocal space mapping, electron diffraction techniques (SEM, TEM), electron microprobe analysis, atomic force microscopy (AFM), optical microscopy and finally dilatometer measurements.

The temperature development of the elastic constants shows a more pronounced softening of c11 and c12 in the as-cast nickel-base superalloy (CMSX-4). In contrast to this the decrease of the shear stiffness (c_{44}) is in the as-cast and heat treated sample nearly the same. Strong ultrasound dissipation effects develop above about 1200 K, this could indicate an increasing number of point defects or increasing mobility of grain boundaries. This coincides with the dissolving of the more γ'-phase, because this effect starts also at around 1100 K. The dendrite structure has no influence on the dissipation effect, because in both samples the same phenomena can be observed. Furthermore a change in the microstructure is observed by AFM, SEM, and TEM pictures. The TEM pictures show an increasing number of dislocations, this leads to a stress relaxation in the more γ-channels. This observation is confirmed by x-ray investigations, because the creep experiments induce changes in the misfits due to effects like annihilating of dislocations. In addition to that more more γ-phase is formed during the creep experiments and contributes also to a relaxation in this material. Finally the results measured by dilatometer show, that the more γ-phase has a higher thermal expansion than the more γ'-phase.

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Keywords: Metal alloys; mechanical properties of crystals; metallurgical single-crystal X-ray diffraction