INFLUENCE OF TRANSITION METALS ON THE SOLID SOLUTION STRENGTHENING AND CREEP BEHAVIOR OF NICKEL STUDIED BY ULTRA-HIGH TEMPERATURE NANOINDENTATION TESTING

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In recent years, nanoindentation systems have been developed which can operate at ever higher temperatures (up to 1000°C) [1]. This now allows to characterize individual phases of high temperature materials such as nickel-based superalloys at their operating temperature. The influence of rhenium on the mechanical properties of Ni alloys at room temperature and elevated temperatures has already been investigated by using nanoindentation testing [2, 3]. However, for the mechanical characterization at temperatures above 1000 °C, macroscopic test methods had to be applied until now.

Testing at these high temperatures present special challenges for the tip material used as well as the temperature stability of the system. Therefore, a new high temperature nanoindentation system with a maximum test temperature of 1100 °C was developed to overcome this limitation. The system is capable to perform tests at relatively high indentation depths due to the combination of a 1 N actuator and a comparatively high frame stiffness even at temperatures above 1000 °C.

In our study, the influence of rhenium, tantalum and tungsten on the solid solution strengthening of single crystalline nickel at temperatures up to 1100 °C were investigated by nanoindentation testing. In addition to experiments with constant strain rate, strain rate jump tests, creep experiments were also performed and compared with macroscopically determined data [3].

Furthermore, the principle of the recently developed Constant Contact Pressure (CCP) creep method is presented [4]. In contrast to conventional nanoindentation creep methods, the contact pressure instead of the load is kept constant. This avoids a simultaneous relaxation of hardness and strain rate and offers the possibility of performing long-term creep experiments.

References:

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