INDENTATION CREEP TESTING OF SUPERALLOYS

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Great progress has been made over the last years in high temperature nanoindentation testing and quite reliable test systems are available to operate at temperatures up to 800°C. With such systems the high temperature strength is measured via the hardness of materials. However, for high temperature materials especially the creep strength is of interest and therefore also many attempts have been undergone to probe also the creep properties with high temperature nanoindentation. In most cases pointed indenters as Berkovich or conical indenters have been used for this. A major challenge, however, then is, how the nanoindentation data are converted into uniaxial creep properties, i.e. those which are needed for constructional purposes. Although, it seems that the stress exponent can be derived quite successfully with such indenters, an evaluation of a full creep curve for materials with significant primary creep does not seem possible, since the strain a pointed indenter is inducing is fixed by the indenter shape and stays more or less constant during the whole test [1].

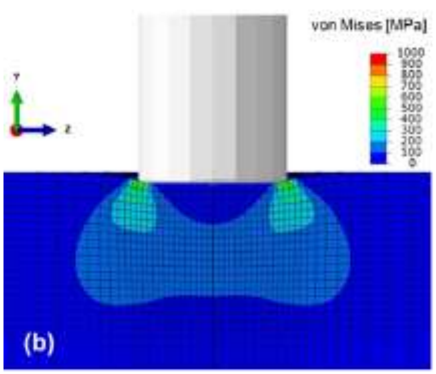

Fig. 1: Stress field underneath a flat punch indenter, from [3].

Therefore, flat-punch indenters are quite attractive, where this problem does not occur. In the literature many examples can be found, where indentation creep testing with a flat-punch indenter has been used successfully, going back to the early work of Yu and Li from 1977. However, in most cases flat-punch indenters with quite large diameters have been used, which do not allow local measurements. Recently, a new indentation creep testing approach has been developed which uses a flat punch indenter with a diameter of only 20 µm [3]. In the new set-up the creep experiments are performed inside a thermo-mechanical analyzer (TMA) which provides an excellent temperature stabilized environment for temperatures up to 1200°C and any possible drift effects can be completely neglected.

The method has been validated on single crystalline Ni alloyed with Re, Ta or W at a temperature of 650°C. Using crystal plasticity finite element modeling, the indentation creep response is converted into equivalent uniaxial creep properties. It is shown that the conversion parameters, evaluated for differently oriented single crystals, can be chosen independently of the creep rate exponent in the power law creep regime. It is found that the indentation creep results agree well with conventional uniaxial creep tests. Furthermore, the indentation creep testing setup has been used to study locally the creep rate of dendritic microstructures in Ni-base superalloys at 750°C. It is found that the creep strength in the dendrite core is significantly higher than in interdendritic regions, which corresponds with the enrichment of the most important strengthening element Re there.

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