MM 45: Topical Session (Symposium MM): Fundamentals of Fracture

Combining Experiments and Simulations, Multiscale Aspects of Fracture

Time: Wednesday 17:00–18:30 Location: TC 006

Topical Talk MM 45.1 Wed 17:00 TC 006

Fracture tougness of tungsten alloys — •Reinhard Pippan[1], Vladica Nicolic[1], Manuel Pfeifenberger[1], Daniel Scheiber[2], Lorenz Romaner[2], and Daniel Firneis[1] — [1]Erich Schmid Institut of Materials Science, Austrian Academy of Sciences, Jahnstrasse 12, 8700 and Department Materials Physics, Montanuniversität Leoben, Franz-Josef-Strasse 18 8700 Leoben, Austria — [2]Material Center Leoben Forschung GmbH, Roseggerstrasse 12, 8700 Leoben, Austria

We have performed in the last few years theoretical as well as experimental studies to investigate fracture relevant phenomena of tungsten. A summary of the result will be presented in this paper. The theoretical studies are based on density function theory analyses of dislocation mobility and the effect of impurities on decohesion energy. The experimental studies are mainly focused on the variation of the fracture toughness as a function of: temperature, in the temperature interval between the temperature of liquid nitrogen and 800°C; the effect of processing conditions, degree of deformation and effect of recovery and recrystallization etc.; the influence of alloying elements; the orientation dependence of fracture toughness, special attention was devoted to the effect of texture, grain size and grain shape, in order to improve the understanding of the brittle fracture process of tungsten alloys. In addition micro mechanical experiments have been performed to study in more detail the cleavage crack propagation process. .

MM 45.2 Wed 17:30 TC 006

Combined experimental and theoretical study of Fe_2AlTi/Fe-Al superalloys — •Martin Friák[1,2], Ivana Miháliková[1,2], Anton Slávik[1,2], Vojtěch Homola[2], Vilma Buršíková[2], Nadězda Pizúrová[1], Petr Dymáček[1], Ferdinand Dobeš[1], David Holec[3], Yvonna Jirásková[1], and Mojmír Šob[4,1,5] — [1]Institute of Physics of Materials, Academy of Sciences of the Czech Republic, Brno, Czech Republic — [2]Faculty of Science, Masaryk University, Brno, Czech Republic — [3]Department of Physical Metallurgy and Materials Testing, Montanuniversität Leoben, Leoben, Austria — [4]Central European Institute of Technology, CEITEC MU, Masaryk University, Brno, Czech Republic — [5]Department of Chemistry, Faculty of Science, Masaryk University, Brno, Czech Republic

Fe-Al-based superalloys containing sub-micron Fe_2AlTi cuboids coherently embedded into a disordered Fe-Al solid solution are intensively studied as materials for high-temperature applications. We focused on the $Fe_{71}Al_{22}Ti_7$ alloy composition for which the transmission electron microscopy (TEM) revealed the superalloy nano-structure and the energy-dispersive X-ray (EDX) technique detected the composition of individual phases. Subsequent quantum-mechanical calculations predicted these two phases to be elastically very different. The differences in the elastic response were detected also experimentally by room-temperature quasistatic nano-/micro-indentation and nano-scale dynamic mechanical analysis (nanoDMA). Regarding high-temperature macro-scale measurements, small-punch testing was performed and the data were analyzed using a rheological model.

MM 45.3 Wed 17:45 TC 006

Extraction of Information about Fracture at High Imposed Strain Rates from Ballistic Indentation Experiments — •Max Burley[1], Bill Clyne[1], Jimmy Campbell[1], and James Dean[2] — [1]University of Cambridge, UK — [2]Double Precision Consultancy, Cambridge, UK

Ballistic indentation experiments have been carried out, using high-speed photography to monitor projectile motion and stylus profilometry to record residual indent shapes. In addition, X-ray computed tomography has been used to capture the 3-D architecture of crack patterns in impacted samples. This experimental work has been coupled with iterative FE modeling of projectile penetration and rebound. Cermet spheres of 5 mm diameter were incident on cylindrical samples of pure Mg, with velocities in the range 50-200 m s-1. The strain rates operative during these experiments were ~104 - 106 s-1. In addition, quasi-static uniaxial compression tests were carried out, at several temperatures, to obtain the values of parameters characterizing the plastic deformation and its sensitivity to temperature. The Johnson-Cook formulation was then employed and ABAQUS software used for iterative simulation of the impact event. A Nelder-Mead convergence algorithm was then used to obtain best-fit values for the coefficient of friction and the J-C strain rate sensitivity parameter. Correlation was then established between the crack pattern and the stress field during the period of crack growth. It is concluded that the cracks are likely to have propagated largely under mode II conditions, with critical strain energy release rates that were considerably lower than those under quasi-static loading.

MM 45.4 Wed 18:00 TC 006

Towards physically-based fatigue design in ductile polycrystalline metals — •Christian Robertson[1] and Christophe Déprés[2] — [1]DEN-Service de Recherches Métallurgiques Appliquées, CEA, Université Paris-Saclay, Gif-sur-Yvette, France — [2]Laboratoire SYMME Université de Savoie74940 Annecy-le-Vieux, France

Actual components withstand in-service conditions involving many aggravating factors, including: multi-axial loading, variable amplitude and mean stress. These factors and the inherent data scattering due the microstructural material heterogeneities are usually addressed by adopting important (if not overly conservative) safety margins. In other words, none of the standard fatigue design approaches are truly predictive, missing out cyclic plasticity mechanisms involved during crack propagation, in actual poly-crystalline metals.

The fatigue response of ductile poly-crystalline metals involves dislocation motion and multiplication, at the scale of individual grains (1-100 *m, typically). Two-dimensional dislocation dynamics (DD) studies adapted to crack propagation have been conducted earlier and were able to capture several fatigue lifetime controlling mechanisms. Our goal in this paper is to further investigate fatigue crack propagation using DD simulations, including 3D boundary conditions adapted to face-centred cubic grains, in presence of both short (stage-I) and long (stage-II) cracks. The results are analysed quantitatively, with a view to develop advanced fatigue design criteria and concepts, accounting for typical complex loading conditions and material microstructural heterogeneities.

MM 45.5 Wed 18:15 TC 006

A multi-physics approach to investigate the effect of hydrogen on short fatigue crack growth — •Volker Schippl[1], Sven Brück[1], Hans-Jürgen Christ[1], and Claus-Peter Fritzen[2] — [1]Institut für Werkstofftechnik, Universität Siegen, 57068 Siegen, Germany — [2]Institut für Mechanik und Regelungstechnik - Mechatronik, Universität Siegen, 57068 Siegen, Germany

Hydrogen leads to a macroscopic embrittlement and under cyclic loading to increasing crack growth rate and a shorter fatigue life of mechanically loaded components. To address this problem, a better understanding of the hydrogen damaging mechanism is needed.

As the short crack propagation could dominate the whole fatigue life, a two-dimensional model is presented to simulate short crack propagation to get a better understanding of the fundamental mechanisms leading to failure. The model includes intergranular and transgranular crack growth and considers the plastic deformation along shear bands. The hydrogen concentration in the microstructure is calculated and the amount of the local hydrogen at the crack tip changes the crack growth mechanism. This multi-physics problem is addressed by using a sequential staggered BEM & FEM approach. At first, stresses and displacements are calculated by using a boundary element method. Based on the calculated hydrostatic stress field, the redistribution of hydrogen is determined using a finite element method. With this approach, it could be found that hydrogen leads to an increasing part of the irreversible plastic deformation at the crack tip which results in increasing crack growth rates and thus to shorter lifetime.