MM 49: Topical Session: Fundamentals of Fracture - Novel Experimental Techniques I

Time: Thursday 10:15–11:30 Location: H4

Topical Talk MM 49.1 Thu 10:15 H4

How crystals break - crack initiation and propagation, experiments and atomistic calculations — •Dov Sherman — Technion, Haifa, Israel

The fine details of the way brittle crystals break are still not well understood. Continuum elastodynamics based Freund energy-speed relationship suggests crack initiation at Griffith energy and propagation speed that ranges 0<V<CR. Massive atomistic computer calculations have been employed in the last two decades to resolve the fundamentals of crack initiation and propagation in brittle crystals. New effects were suggested which are not in accord with the continuum approach. The lack of sufficient experimental evidences for the theory and described effects prevent the final approval of both.

Our cleavage fracture experiments of silicon crystal show crack propagation at low speed with energy-speed relationship that apparently obeys Freund equation of motion. These findings, in addition to the fine details of the crack front, have yielded a new type of atomistic computer calculations that were able to ascertain the experimental results.

We will describe the past and present theories and phenomena associated with fracture in brittle crystals, present the fine details of the experimental results and the new atomistic calculations, and suggest a new paradigm for crack propagation sequence and energy consumption mechanisms not consider before.

MM 49.2 Thu 10:45 H4

Development and verification of an approach for determining fracture mechanical properties from tests on small size specimens — •Michael Mahler and Jarir Aktaa — Karlsruhe Institute of Technology (KIT), Institute for Applied Materials (IAM), 76344 Eggenstein-Leopoldshafen, Germany

In general, fracture mechanical properties will be identified on standard-sized specimens. Therefore special standard specifications are in use to determine J-R curves for ductile or fracture toughness for brittle fracture.

To determine fracture mechanical properties of sub-sized specimens an evaluation procedure based on finite element simulations of the crack propagation process will be used. The fracture process zone will be described by using a cohesive-zone-model (CZM). This surface based approach is able to describe the fracture mechanism in the ductile and brittle regime selecting proper law for the constitutive traction separation. The first of the two parameters for the CZM will be experimentally determined by notched tensile tests to identify the cohesive stress. The second parameter will be found by fitting the force-deflection curve of experimental three point bending tests to the simulated one. The geometry of the sub-sized specimen is 27x3x4 mm^3 with side grooves. The applicability of the evaluation procedure will be verified on the ferritic martensitic steel T91. Therefore a comparison between standard- and sub-sized specimens is considered. The objective is to establish small size testing technology for the determination of fracture mechanical properties.

MM 49.3 Thu 11:00 H4

Micro Cantilever Bending Tests and Nanoindentation on NiAl Bond Coats and SX-NiAl — •Ralf Webler, Steffen Neumeier, Karsten Durst, and Mathias Göken — Lehrstuhl Allgemeine Werkstoffeigenschaften, Department Werkstoffwissenschaften, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Deutschland

Typically, turbine blades in aero engines and stationary gas turbines are coated with bond coats or environmental barrier coatings that are based on beta-NiAl. NiAl is an attractive intermetallic compound due to its high melting point and high Al content, which provides supreme oxidation resistance. A drawback, however, is that beta-NiAl is very brittle below the ductile to brittle transition temperature. The mechanical behavior of bond coats depends on their chemical composition, particularly important is the Al content of beta-NiAl based coatings. During service, these coatings are exposed to thermal cycling, their chemical composition changes and the mechanical properties accordingly. To determine the influence of chemical composition on hardness, Young's modulus and especially fracture toughness, bond coats with different Ni and Al content in the as-coated and thermally cycled state as well as SX-NiAl were investigated with nanoindentation and new small scaled methods. Micro cantilevers were cut by employing focused ion beam milling and subsequently in-situ bending tests were performed. This method allows to study fracture mechanics on a local scale of individual phases present in bulk materials. Results show an increase of Young's modulus with Al content and a higher hardness and fracture toughness is found in off-stoichiometric NiAl compared to binary NiAl. Furthermore, fracture surfaces differ significantly between high Ni and high Al containing samples which shows a clear influence of composition on the fracture behavior of NiAl.

MM 49.4 Thu 11:15 H4

Study on the fracture properties of NiAl single crystals by in-situ micro-cantilever bending experiments — •Johannes Ast, Karsten Durst, and Mathias Göken — Institute of General Material Properties (WW1) , Erlangen, Germany

In order to to study fracture mechanical properties on a small length scale and to understand the relation between micron-scale fracture toughness and the one of the bulk materials, in-situ and ex-situ micro-cantilever fracture tests were carried out on anisotropic NiAl single crystals. This material system offers two interesting fracture systems consisting of the soft <110> and the hard <100> orientation. The macroscopically determined fracture toughness for these two orientations is around 3-4 MPa$\sqrt{m}$ and 8-9 MPa$\sqrt{m}$ respectively. Beams of different sizes in the micron regime were prepared by Focused-Ion-Beam (FIB) machining. An AFM-based force measurement system mounted inside a Scanning Electron Microscope (SEM) was used for the in-situ experiments and a Nanoindenter XP was chosen for the ex-situ experiments. The experiments were evaluated by means of elastic-plastic fracture mechanics using the J-Integral and the crack tip opening displacement (CTOD). The discussion is focusing on the size of the plastic zone ahead of the crack tip where strong strain-gradients are formed and size effects in the flow stresses occur due to the small sample dimensions. TEM investigations and EBSD measurements of the fractured cantilevers provide detailed insights into the processes leading to fracture.