USING SIMULATIONS TO INVESTIGATE THE APPARENT FRACTURE TOUGHNESS OF MICROCANTILEVERS

Steffen Brinckmann, Max-Planck-Institut für Eisenforschung, Germany
brinckmann@mpie.de
Kurt Matoy, Infineon Technologies Austria AG, Austria
Christoph Kirchlechner, Max-Planck-Institut für Eisenforschung, Germany
Gerhard Dehm, Max-Planck-Institut für Eisenforschung, Germany

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In the past decade, micrometer cantilevers were frequently used to evaluate the fracture toughness of single phases and the fracture toughness of particular grain and phase boundaries. The calculation of the fracture toughness relies on the cantilever geometry and the experimentally determined maximum force. To quantify the toughness, the geometry and force enter analytical models, which are based on simulations that use an isotropic elastic material, perfect beam geometry and in many cases a two-dimensional configuration. However, the vast majority of materials have a limited amount of plasticity and are anisotropic. Moreover, the intentionally prepared pre-crack is seldom straight due to the focused ion beam (FIB) production method. This study uses thousands of 3D finite element method (FEM) simulations to investigate the influence of anisotropy, imperfect pre-crack shape and plasticity on the apparent fracture toughness of the material.

Initially, we will discuss the influence of anisotropy on the apparent fracture toughness. To that end, the ratio of anisotropy between the cantilever axis and the transversal axis is varied to establish the effect on the fracture toughness. More, we investigate the influence of Poisson's ratio and beam geometry because these values interact with the anisotropy. We find that typical metals with an anisotropy ratio less than 3 and typical cantilever geometries with an l/h ratio of more than 4 are only slightly affected by the anisotropy. We present view-graphs that allow the user to determine the influence of anisotropy for other cantilevers and highly anisotropic materials. Secondly, we investigate the influence of material bridges that are frequently used to ensure straight pre-cracks at the start of crack propagation. Additionally, we investigate the influence of pre-crack front rounding, i.e. the material bridges are omitted. We varied the geometry of the material bridge and crack front rounding to establish the influence of the geometry on the apparent fracture toughness. We discuss the difference between load controlled experiments with an internal feedback loop and displacement controlled experiments. We argue about the geometric requirements to ensure stable crack growth and the optimal experiments.

We close with a discussion on the influence of plasticity on the fracture toughness and the applicability of the plastic zone size according to Rice for microcantilever experiments.

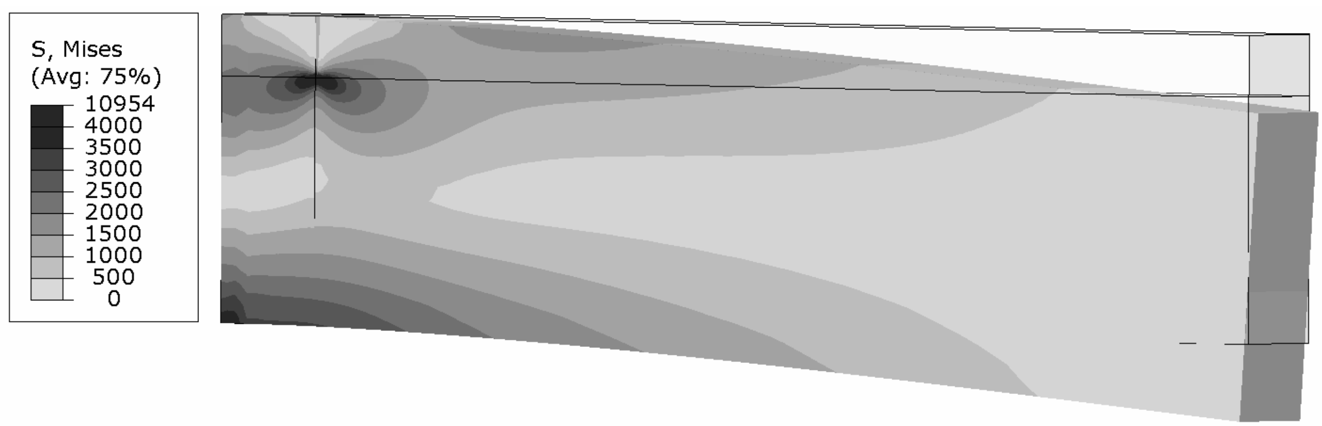

Fig 1: Mises stress distribution in the deformed reference cantilever: the pre-crack length is a/l = 1/5 and the anisotropy ratio is 2.

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