The Raymond D. Mindlin Lecture

Department of Civil Engineering & Engineering Mechanics, Columbia University
Engineering Mechanics Committee, ASCE Metropolitan Section
Engineering Mechanics Institute, ASCE

Modeling Ductile Fracture Toughness and Fracture Surface Roughness

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313 Fayerweather Columbia University

Abstract: Two fundamental questions in the mechanics and physics of fracture are: (i) What is the relation between observable features of a material's microstructure and its resistance to crack growth? (ii) What is the relation between observable features of a material's microstructure and the roughness of the fracture surface? An obvious corollary question is: What is the relation, if any, between a material's crack growth resistance and the roughness of the corresponding fracture surface? I will discuss results of 3D finite element calculations of mode I ductile crack growth aimed at addressing these questions. In the calculations, ductile fracture of structural metals by void nucleation, growth and coalescence is modeled using an elastic-viscoplastic constitutive relation for a progressively cavitating plastic solid. A material length scale is introduced via a discretely modeled microstructural feature, such as the spacing of inclusions that nucleate voids or the mean grain size. Connections between quantitative measures of crack growth resistance and quantitative measures of the statistics of the fracture surface roughness are investigated and related to the nature of the ductile crack growth process. Possible implications for designing more fracture resistant material microstructures will be discussed.

Biosketch: Professor Alan Needleman completed his Ph.D. in Engineering at Harvard University in 1970. He then spent five years in Applied Mathematics at MIT before moving to Brown University where he became Florence Pirce Grant University Professor in 1996. He retired from Brown in June 2009 and moved to the Materials Science and Engineering Department at the University of North Texas (UNT). In January 2015 he left UNT and became TEES Distinguished Research Professor in the Department of Materials Science and Engineering at Texas A&M. His contributions include the development of a ductile fracture computational methodology, the development of cohesive surface methods for fracture analysis and creation of a framework that enables using discrete dislocation plasticity to solve general boundary value problems. Professor Needleman was awarded a Guggenheim Fellowship in 1977, and is a member of the National Academy of Engineering and of the American Academy of Arts and Sciences. He has been awarded the Prager Medal by the Society of Engineering Science, the Drucker and Timoshenko Medals by the American Society of Mechanical Engineers and has been recognized by ISI as a Highly Cited Author in both the fields of Engineering and Materials Science. Professor Needleman also holds honorary doctorates from the Technical University of Denmark and Ecole Normale Superior de Cachan (France) and is an Honorary Professor of Dalian University of Technology (China).

The Department of Civil Engineering and Engineering Mechanics established the Mindlin Lecture to honor the pioneering contributions of Prof. Raymond D. Mindlin to the field of applied mechanics. His research encompassed photoelasticity and experimental mechanics; classical three-dimensional elasticity (e.g., Mindlin's problem); generalized elastic continua (strain-gradient and couple-stress theory); frictional contact and granular media; waves and vibrations in isotropic and anisotropic plates (Mindlin's Plate Theory); wave propagation in rods and cylinders; theory of electro-elasticity and piezoelectric crystal resonators, and crystal lattice theories.
A member of the National Academy of Engineering and the National Academy of Sciences, Prof. Mindlin received the National Medal of Science for applied mechanics and mathematics in 1979. He had been awarded the Medal for Merit in 1946, by President Harry S. Truman, for his work in developing the radio proximity fuse, a detonator for weapons used in offensive warfare that was a significant factor in World War II. ASCE created the **Mindlin Medal** in 2009.

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