New computer program predicts crack initiation in 3-D

March 26 2020

Credit: Akira Hojo

Most structures and materials have defects, and if the conditions are right, these defects can lead to the initiation and propagation of cracks. Finding out where and with what orientation a surface crack is most likely to initiate is a critical part of analyzing and designing a structure. An important quantity to compute in this type of analysis is the energy release rate, which is the energy available for crack propagation. The energy release rate is compared to the fracture toughness, a material property that describes the energy required for a crack to propagate.

Calculating the energy release rate for the infinite potential locations and orientations of a surface crack in a 3-D structure using conventional methods is an exhaustive task because a detailed analysis needs to be performed for every crack location and orientation. A new method developed by researchers at the University of Illinois at Urbana-Champaign can pinpoint the location and direction of a critical crack in a structure with a single analysis.

"This new method allows us to simplify the analysis tremendously, because instead of having to do an analysis for every single potential location of a crack along the surface of a certain structure, we perform a single analysis of the uncracked domain, which is much cheaper and faster to solve. This reduces the amount of computational work by orders of magnitude," said Philippe Geubelle, a professor in the Department of Aerospace Engineering.

To get a precise estimate of the energy release rate, the current method requires a numerical analysis with a very fine grid to discretized the structure, especially in the vicinity of the crack. Geubelle said this new method uses topological derivatives to get an estimate of what the energy release would be if a crack showed up at any location and with any this orientation along the surface of a 3-D structure.

"Using this technique, we can immediately pinpoint the location and orientation that corresponds to the highest energy release rate—meaning the highest energy available for crack propagation. If the energy release rate is smaller than the fracture toughness, the crack won't propagate. However, if the energy release rate approaches the value of the fracture toughness, then the structure will need a redesign."

The new method can be combined with commercial finite element software packages such as Ansys, Abaqus, and Nastran.

"What this method allows us to do is to say, 'give me a complicated shape and complex loading conditions, and we will tell you the most probable location where a surface crack is going to start.'" Geubelle said.

The study, "Energy Release Rate Approximation for Small Surface Cracks in Three-Dimensional Domains Using the Topological Derivative," was written by Kazem Alidoost, Meng Feng, Philippe H. Geubelle, and Daniel A. Tortorelli. It appears in the *Journal of Applied Mechanics*.

More information: Kazem Alidoost et al. Energy Release Rate Approximation for Small Surface Cracks in Three-Dimensional Domains Using the Topological Derivative, *Journal of Applied Mechanics* (2019). DOI: 10.1115/1.4045793

Provided by University of Illinois at Urbana-Champaign