New approach to understanding cracks

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Could engineers have known ahead of time exactly how much pressure the levees protecting New Orleans could withstand before giving way? Is it possible to predict when and under what conditions material wear and tear will become critical, causing planes to crash or bridges to collapse? A study by Weizmann Institute scientists takes a new and original approach to the study of how materials fracture and split apart.

When force is applied to a material (say, a rock hitting a pane of glass), a crack starts to form in the interior layers of that material. In the glass, for example, the force of the striking rock will cause the fracture to progress through the material with gradually increasing speed until the structure of the glass splits apart. The path the forming crack follows and the direction it takes are influenced by the nature of the force and by its shape. As cracking continues, microscopic ridges form along the advancing front of the crack and the fracture path repeatedly branches, creating a lightning bolt or herringbone pattern.

Physicists attempting to find a formula for the dynamics of cracking, to allow them to predict how a crack will advance in a given material, have faced a serious obstacle. The difficulty lies in pinning down, objectively, the fundamental directionality of the cracking process: From any given angle of observation or starting point of measurement, the crack will look different and yield different results from any other. Scientists all over the world have experimented with cracking but, until now, no one has successfully managed to come up with a method for analyzing the progression of a forming crack.

Prof. Itamar Procaccia and research students Eran Bouchbinder and Shani Sela of the Chemical Physics Department set out to find a way of analyzing data from experiments in cracking that would avoid the direction problem. First, they divided the cracks' ridged surfaces up into mathematically-determined sectors. For each sector they were able to measure and evaluate different aspects of the crack's formation and to assign it simple directional properties. After some complex data analysis of the combined information from all the sectors, the team found their method allowed them to gain a deeper understanding of the process of cracking, no matter which direction the measurements started from. The team then successfully applied the method to a variety of materials – plastic, glass and metal.

From the concrete in dams and buildings, to the metal alloys and composites in airplane wings, to the glass in windshields, many of the materials we depend on daily are subject to cracking. The team's method will give engineers and materials scientists new tools to understand how all of these basic materials act under different stresses, to predict how and when microscopic or internal, unseen fractures might turn life-threatening, or to improve these materials to make them more resistant to cracks' formation or spread.

Source: American Committee for the Weizmann Institute of Science

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