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FRACTURE MECHANICS AND POLYMERS

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The study of fracture mechanics is concerned with the fundamental aspects of fracture – with such basic questions, for example, as: What are the parameters that influence fracture?

Materials used for these studies may range all the way from metals, to polymers like rubber and plastics, fiberglass laminates, and even rocks.

In the past five years there has been a concerted effort at Caltech to study the fracture mechanics of polymers – first, because there is little information available on the strength properties of these materials; secondly, because they have a direct relation to the fracture of solid propellant rocket fuels. Solid propellants are compounds made up of about 25 percent rubber, with the remaining 75 percent consisting of oxidizer (such as ammonium perchlorate) and some metallic additives.

Because researchers at Caltech cannot work with explosives, they have chosen to use pure polymers for their studies. These materials have many of the basic properties of other viscoelastic materials such as solid propellants and airplane or automobile tires. The basic difference between polymers and metals at ordinary temperatures is that polymers have time-dependent properties, while metals have essentially static properties. However, when metals are heated to elevated temperatures, they may react in much the same way as do many polymeric compounds in their mechanical response, and they begin to flow and undergo large deformations under load.

Polymers can be viewed as a group of materials that form the transition between rigid materials and liquids. There is, therefore, great incentive to study the fracture behavior of these materials, because the findings are potentially applicable to a large class of other materials.

A special characteristic of viscoelastic fracture is that the material properties change while fracture occurs. Also, the material properties depend on the *rate* of fracture progression. This is generally not true in the case of metals.

Two major problems had to be faced when work was started at Caltech on fracture studies of polymers: (1) There was a lack of knowledge of the mechanical properties of these materials; (2) The materials that were available from industry were generally not uniform enough for use in a careful research program. During the past four years, therefore, considerable effort has been devoted to the material characterization, and to the mathematics to incorporate these material properties in engineering stress calculations.

Research in the field of fracture mechanics in Caltech's Graduate Aeronautical Laboratories is scarcely more than ten years old, but one indication

Wolfgang Knauss, research fellow in aeronautics, uses a sheet-straining device to measure the amount of energy that is dissipated when a fracture occurs in polymeric material.

of the state of its health is the fact that it keeps spawning subsidiary research efforts. Thus, during the past year, the GALCIT work on the basic material parameters of polymers has resulted in a new field of study being set up in Caltech's W. M. Keck Laboratory of Engineering Materials – polymer science.

This endeavor has as its main purpose the investigation of the physical behavior of polymers from the molecular viewpoint. As part of the study, researchers are now trying to select or develop a polymer for standardization purposes.

While there are many groups working in this area of polymer research, both here and abroad, all of them are using different materials, so that comparisons of results are difficult to make. If all groups could be encouraged to use the same material, this problem would be simplified. The Caltech researchers are therefore interested in standardizing this material, and making it available from a central source, for use by industry and other research laboratories.

One of the possibilities for such a material is a polyurethene polymer, compounded with castor oil, which is clear, permitting easy observation of fracture-initiation and growth. Because it is also stress-optically very sensitive, it permits the experimental determination of structures which are hard to analyze theoretically. Thus, it is useful in the study of fracture mechanics, where complex geometrics occur. The stress-optic fringe pattern in the picture above, for example, can be used to determine the stresses at the tip of an advancing crack. Finally, and most important, the material behaves visco-elastically like solid propellants when at 0° C.

The Caltech research on fracture mechanics of polymers is under the direction of Max L. Williams Jr., professor of aeronautics. The polymer fracture research is guided by W. G. Knauss, research fellow in aeronautics, and is supported by the National Aeronautics and Space Administration. A grant from Edwards Air Force Base, California, is making possible the development of the Keck materials science program.