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Survey of Fracture Toughness Test Methods

For aircraft and space applications, materials are utilized at stress levels close to their maximum capability; consequently, these requirements have given impetus to numerous research studies on high strength materials. One such study which has been developed rapidly over the last decade is fracture mechanics.

In the simplest terms, the fracture toughness of a material determines how large a crack the material is able to tolerate without fracture when loaded to a level approaching that at which crack-free material would fail by excessive plastic deformation. For example, how large a crack can be tolerated in the wall of a pressure vessel manufactured from Brand X steel when the nominal hoop stress is raised to 90 percent of the yield strength?

Naturally, every reasonable effort would be made to avoid having any cracks or like defects in the structure. But experience indicates unmistakably that it would be quite unrealistic to depend upon the total absence of crack-like defects. If something fairly quantitative about the crack tolerance of materials were known, more realistic and more effective measures could be taken with regard to inspection, quality control, proof testing, and avoidance of development of cracks in service.

The most direct way of evaluating the crack tolerance of a material apparently would be to test a series of specimens provided with cracks of graded sizes to determine an empirical relation between strength and crack size. But the problem is not simply a matter of crack size. In addition, crack shape, bulk of the member (i.e., thickness of a plate), orientation of the crack in relation to the fibering of the material, temperature, and rate of loading all may affect the fracture strength of a structural member of a given material. To take into account all these factors in a purely empirical test program would require very large numbers of specimens for each material evaluated. The burden of testing can be considerably reduced, however, by applying knowledge of the mechanics of fracturing, best represented at the present time by linear elastic fracture mechanics.

A comprehensive survey has been prepared which presents current methods of fracture toughness testing that are based on linear elastic fracture mechanics. General principles of the basic two-dimensional crack stress field model are discussed in relation to real three-dimensional specimens. The designs and necessary dimensions of specimens for mixed mode and opening mode (plane strain) crack toughness measurement are considered in detail. Methods of test instrumentation and procedure are described. Expressions for the calculation of crack toughness values are given for the common types of specimens.

Notes:

1. Details of this survey are contained in: NASA Technical Note D-2599, *Fracture Toughness Testing*, by J. E. Srawley and W. F. Brown, Jr., Lewis Research Center, Cleveland, Ohio, January 1965. Copies of TN D-2599 are available from, and inquiries concerning this survey may be directed to:

   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B68-10046

(continued overleaf)

2. Supplementary information on this subject is contained in ASTM-NASA STP 410: *Plain Strain Crack Toughness Testing of High Strength Metallic Materials,* by W. F. Brown, Jr., and J. E. Srawley, 1967. Copies are available from:

   American Society for Testing
   and Materials
   1916 Race Street
   Philadelphia, Pennsylvania 19103

Patent status:

No patent action is contemplated by NASA.

Source: J. E. Srawley, M. H. Jones, and W. F. Brown, Jr.
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