ELASTIC FIELD EQUATIONS FOR BLUNT CRACKS WITH REFERENCE TO STRESS CORROSION CRACKING

Matthew Creager* and Paul C. Paris**

ABSTRACT

The elastic stress field equations for blunt cracks are derived and presented in a form equivalent to the usual sharp crack tip stress fields. These stress field equations are employed in analyzing a dissolution model for the arrest of stress corrosion cracking by crack tip blunting, which is often observed with the arrest of stress corrosion cracks.

Stress corrosion, the growth of cracks due to the combined and interrelated action of stress and environment, is a highly complex phenomena in all its aspects. In general, it involves the diffusion of an environment into a crack which, in some way, attacks the highly stressed material in the vicinity of the crack tip causing the crack to grow. There have been recent experimental observations in which the arrest of a stress corrosion crack was accompanied by the apparent blunting of the crack tip. See Figures 1 and 2. These observations suggest that an investigation of the

Figure 1: 12% Ni - 5% Cr - 3% Mo - Maraging steel in 3-1/2% NaCl solution at K_i equal to 9500 psi \sqrt{a}. Exposure time in excess of 300 hours. Courtesy of Floyd Brown, U.S. Naval Research Laboratory.

stability of the shape of the crack tip surface may be of great interest.

In order to attempt to relate the conditions of attack to the stress conditions for blunting, a very simplified mechanical view of the process si-

* Research Assistant, Department of Mechanics, Lehigh University, Bethlehem, Pennsylvania.
** Professor of Mechanics, Department of Mechanics, Lehigh University, Bethlehem, Pennsylvania.
milar to that of Charles and Hillig\footnote{1} will be adopted here. The usual continuum model of a crack is a planar void of material, and the corresponding mathematical model is a plane of discontinuity. However, since the chemical attack of a material by the environment at the crack tip is being considered, it is relevant to have as a physical model of the crack, a void that is not the usual plane ending with zero radius of curvature, but a narrow volume with a finite curvature at the tip. This type of blunt crack or notch is conveniently represented mathematically by an elliptical or hyperbolic cylinder, void of material, in which the radius of curvature at the tip is small in comparison to the major dimensions of the void.

It is then of interest to explore the nature of the stress distribution about this blunt crack or notch. As is usual in Fracture Mechanics, an elastic analysis will be attempted which may later be discussed in the light of the effects of nonlinear material behavior near the crack tip. Consequently, the elastic stress distribution in the neighborhood of elliptical holes and hyperbolic notches will be presented. Since regions near the crack tip are of special interest, it is advantageous to expand the expressions for the stresses as a power series in terms of radial distance from some point near the tip and to discard all the second order terms. This is most appropriately done by expanding the expressions for the stresses using the origin chosen in Figure 3, since certain simplifications result. Note that the origin is a distance of $\rho/2$ away from the crack tip, where $\rho$ is the radius of curvature at the crack tip. When $\rho/a$ (a is half the crack length) is small compared to one, the origin is to a very close approximation the focal point of the ellipse or hyperbola that represents the surface of the crack. The results of this expansion for both the elliptic hole and the hy-