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Cracked elastic layer under compressive mechanical loads

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ABSTRACT

We consider boundary value problem in which an elastic layer containing a finite length crack is under compressive loading. The crack is parallel to the layer surfaces and the contact between crack surfaces are either frictionless or with adhesive friction or Coulomb friction.

Based on fourier integral transformation techniques the solution of the formulated problems is reduced to the solution of a singular integral equation, then, using Chebyshev's orthogonal polynomials, to an infinite system of linear algebraic equations. The regularity of these equations is established. The expressions for stress and displacement components in the elastic layer are presented. Based on the developed analytical algorithm, extensive numerical investigations have been conducted.

The results of these investigations are illustrated graphically, exposing some novel qualitative and quantitative knowledge about the stress field in the cracked layer and their dependence on geometric and applied loading parameters. It can be seen from this study that the crack tip stress field has a mode II type singularity.

1. Introduction

Stress concentration is often a critical concern because it affects the durability and reliability of structures and their components. Stress concentrators in structures can exist as a result of material composition imperfections (cavities, inclusions) or they can be caused by technological and structural needs (holes, cuts, etc.). In either case, analyzing the effects of stress concentrators is very important.

Stress concentrators in the form of cracks have been intensively studied in the literature. Since experimental observations indicate that crack growth is often in the form of opening mode crack growth instead of mixed mode or pure shear mode crack growth, the research reported in the literature on the subject of crack growth has mainly focused on mode I fracture (e.g. Erdogan and Sih, 1963; Sih, 1974; Bilby and Cardew, 1975; Cotterell and Rice, 1980; Hayashi and Nemat-Nasser, 1981; or Broberg, 1987).

In the majority of works in the literature it is assumed that the crack surfaces are not in contact. However crack surface contact can occur under compressive loading and such cracks can pose a potential risk just as cracks under tensile loading (e.g. Roy et al., 1999; Deng, 1993, 1995; Dhirendra and Narasimhan, 1998; Ghonem and Kalousek, 1988; Hallbfack, 1998; Hayashi and Nemat-Nasser, 1981; Hearle and Johnson, 1985; Isaksson and Stahle, 2002, 2003; Ishida and Abe, 1996; Hancock, 1999; Makaryan, 2006; Makaryan et al., 2009; Melin, 1986). Due to the elimination of crack surface opening, the growth of cracks with crack surface contact is in the shear mode (or mode II under in-plane loading conditions).

El-Borgi et al. (2004) considered the problem of a functionally graded coating bonded to a semi-infinite homogeneous medium with a crack embedded in the FGM layer and parallel to the free surface. The composite medium is subjected to a frictional Hertzian contact traction loading applied to the surface of the graded coating. The author's utilize a crack closure algorithm whenever the mode I stress intensity factors turn out to be negative under the action of compressive loads.

Broberg (1987) reported laboratory produced mode II crack growth in plates in experiments conducted in a combination of pressure and shear loads. Hearle and Johnson (1985) achieved shear crack growth in experiments performed on rail steels subjected to a moving point load. Ishida and Abe (1996) carried out rolling contact tests in a rail/wheel contact fatigue testing machine and reported sub-surface crack growth in mode II. More recently, the propagation of cracks parallel with a shear loaded surface (which are sub-surface horizontal cracks) due to surface traction caused by contact, have been analytically and numerically investigated by several researchers (e.g. Wong et al., 1996; Jayaraman et al., 1997, Komvopoulos and Cho, 1997). Melin (1987) concluded that mode II crack growth in an elastic material would be preferred over mode I only if the ratio between the critical stress intensity factors K_{IIc} and K_{Ic} is fairly low. The effect of crack surface friction

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