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Stress intensity factors for asymmetric branched cracks in plane extension by using crack-tip displacement discontinuity elements

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Abstract

Stress intensity factors are important in the analysis of cracked materials. They are directly related to the fracture propagation and fatigue crack growth criteria. Based on the analytical solution (Crouch, S.L., 1976. Solution of plane elasticity problems by displacement discontinuity method, Int. J. Numer. Methods Eng. 10, pp. 301–343; Crouch, S.L., Starfield, A.M., 1983. Boundary Element Method in Solid Mechanics, with Application in Rock Mechanics and Geological Mechanics, London, Geore Allon and Unwin, Bonton, Sydney) to the problem of a constant discontinuity in displacement over a finite line segment in the x, y plane of an infinite elastic solid, recently, the crack-tip displacement discontinuity element which can be classified as the left and right crack-tip displacement discontinuity elements are developed by the author Yan, X., (in press. A special crack-tip displacement discontinuity element, Mechanics Research Communications) to model the crack-tip fields to more accurately compute the stress intensity factors of cracks in general plane elasticity. In the boundary element implementation the left or the right crack-tip displacement discontinuity element is placed locally at the corresponding left or right crack tip on top of the ordinary non-singular displacement discontinuity elements that cover the entire crack surface and the other boundaries. To prove further the efficiency of the suggested approach and provide more results of the stress intensity factors, in this study, analysis of an asymmetric branched crack bifurcated from a main crack in plane extension is carried out.
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Keywords: Crack; Stress intensity factors; Crack–tip element; Displacement discontinuity

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1. Brief description of the present numerical method

In this section, a boundary element method is briefly described. It consists of the constant displacement discontinuity element presented by Crouch and Starfield Crouch and Starfield (1983) and the crack-tip displacement discontinuity element due to the author Yan (2004).

1.1. Theoretical foundation of constant displacement discontinuity element

The problem of a constant displacement discontinuity over a finite line segment in the x, y plane of an infinite elastic solid is specified by the condition that the displacements be continuous everywhere except over the line segment in question. The line segment may be chosen to occupy a certain portion of the x-axis, say the portion $|x| < a, y = 0$. If we consider this segment to be a line crack, we can distinguish its two surfaces by saying that one surface is on the positive side of $y = 0$, denoted $y = 0_+$, and the other is on the negative side, denoted $y = 0_-$. In crossing from one side of the line segment to the other, the displacements undergo a **constant** specified change in value $D_i = (D_x, D_y)$.

The displacement discontinuity D_i is defined as the difference in displacement between the two sides of the segment:

$$\begin{aligned} D_x &= u_x(x, 0_-) - u_x(x, 0_+) \\ D_y &= u_y(x, 0_-) - u_y(x, 0_+) \end{aligned} \tag{1}$$

Because u_x and u_y are positive in the positive x and y coordinate directions, it follows that D_x and D_y are positive as illustrated in Fig. 1.

The solution to the subject problem is given by Crouch and Starfield Crouch and Starfield (1983). The displacements and stresses can be written as

$$\begin{aligned} u_x &= D_x[2(1-\nu)F_3(x,y,a) - yF_5(x,y,a)] + D_y[-(1-2\nu)F_2(x,y,a) - yF_4(x,y,a)] \\ u_y &= D_x[(1-2\nu)F_2(x,y,a) - yF_4(x,y,a)] + D_y[2(1-\nu)F_3(x,y,a) - yF_5(x,y,a)] \end{aligned} \tag{2}$$

and

$$\begin{aligned} \sigma_{xx} &= 2GD_x[2F_4(x,y,a) + yF_6(x,y,a)] + 2GD_y[-F_5(x,y,a) + yF_7(x,y,a)] \\ \sigma_{yy} &= 2GD_x[-yF_6(x,y,a)] + 2GD_y[-F_5(x,y,a) - yF_7(x,y,a)] \\ \sigma_{xy} &= 2GD_x[-F_5(x,y,a) + yF_7(x,y,a)] + 2GD_y[-yF_6(x,y,a)] \end{aligned} \tag{3}$$

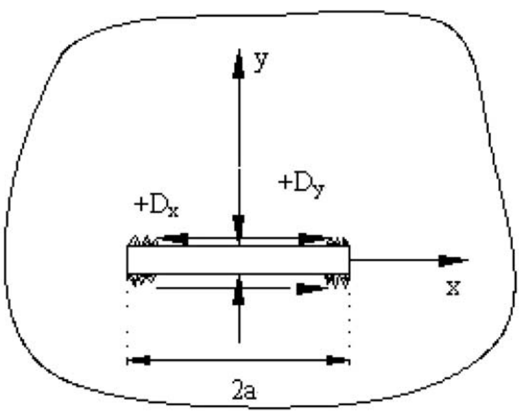

Fig. 1. Schematic of constant displacement discontinuity components D_x and D_y in infinite region.

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