MODELING STRESS INTENSITY FACTORS OF CRACKS EMENATING FROM A CENTERED CIRCULAR HOLE IN A TUNGSTEN-CARBIDE RECTANGULAR PLATE UNDER UNIAXIAL COMPRESSION

Yitzchak Yifrach*

Department of Mechanical Engineering, Braude College of Engineering, Karmiel, ISRAEL

Abstract

Crack propagation under load is different than displacement controlled. The displacement controlled loads usually cause stable propagation. This paper evaluates the mode I Stress Intensity Factors (SIF) of a crack emenating from a centered circular hole in a square plate under compression. Such a geometry is similar to square cutting tool insert .The plate is made from tungsten carbide (WC+Co). Two types of compression loads are considered: pressure truction and normal displacement. Linear 3D static analyses are conducted with the aid of a commercial software (Abaqus/CAE 2020). The SIFs for various crack lengths are obtained using the J integral and verified by analytic expansion of the crack's normal gaps. The results show that displacement load causes lower SIFs and a more stable propagation. For some loads the crack might come to a halt even for truction load.

1. Introduction

A brittle material such as tungsten carbide have no yield strength, and involves fracture without any appreciable plastic deformation. We are interested in understanding the propagation of a crack emenating from a centered circular hole in a square plate under compression as shown in Fig. 1a. This geometry simulates a square insert cutting tool as shown in Fig. 1b.

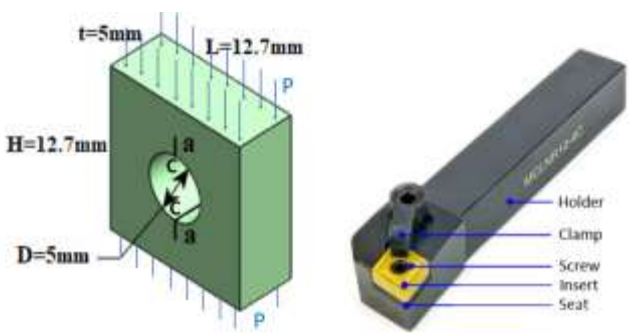

Fig. 1: a. A crack (a) emenating from a circular hole (D) of a rectangular tungsten-carbide plate (H,L,t) under compression P. b. Tool holders for a Common square single cutting tool insert

Seven crack lengths were modeled numerically (a = 0.5 , 1.0 , 1.5, 2.0 , 2.5 , 3.0 , 3.5mm) under pressure (P = 705 MPa) and normal displacent (d = -25.689 μm). These compression loads create the same circumferential tension stress for a = 0 at point C (figure 2b) at the middle of the plate (t_m = 2.5 mm) where plane strain conditions prevaile. Linear 3D static analyses were conducted using Abaqus/CAE 2020.

2. Results

Due to symmetry only 1/8 of the geometry shown in figure 1a was modeled numerically. The numerical mesh used quadratic hexahedral elements of type C3D20. A typical mesh is shown in Fig. 2a for a = 0.5 mm. The mesh was made locally denser near the crack tips having seed size of 62.5 μm. All meshes were checked for numerical convergence.
The two cases of loading (P = 705 MPa and d = -25.689 μm) were first apllied for a = 0 (no crack). The tensional cicumferential stress σ_{xx} between points C and E is shown in Figure 2b. It can be observed that the stress at point C due to both load cases is equal : $\sigma^*_{xx} = 1.807$ GPa . The fact that both normal stresses

variations become negative (compression) at ~ 2.3 mm indicate that for crack lengths greater than 2.3mm, the cracks might become stable (will not advance). The insert within Fig. 2b show the contour map of σ_{xx} indicating that the strees is higher within the plate than on the free face.

A Comparison of the normalized K_I^* versus normalized crack length a^* is shown in Fig. 2c. The mode I SIFs where calculated using J integral. The SIFs due to pressure load where verified by using expansion of the crack face normal gaps using 3 terms of the analytic asymptotic expansion. The maximum relative difference was less than 3.7% for $0.5\,mm \le a \le 3\,mm$ which confers reliability to the results. The SIF was normalized by $K_I^* = K_I / K_I^0$ where $K_I^0 = 1.12\sigma_0\sqrt{\pi a_0}$ which is the solution of an edge crack in semi-infinte region subjected to tension. A short crack $a_0 = 50\ \mu m$ is assumed and $\sigma_0 \equiv \sigma_{xx}^* = 1.807$ GPa. The normalized crack length is $a^* = 2a/(H-D)$. It can be observed that $\partial K_I^* / \partial a^* < 0$ for application of constant displacement and becomes negative for constant pressure at crack length $a^* = 0.4$.

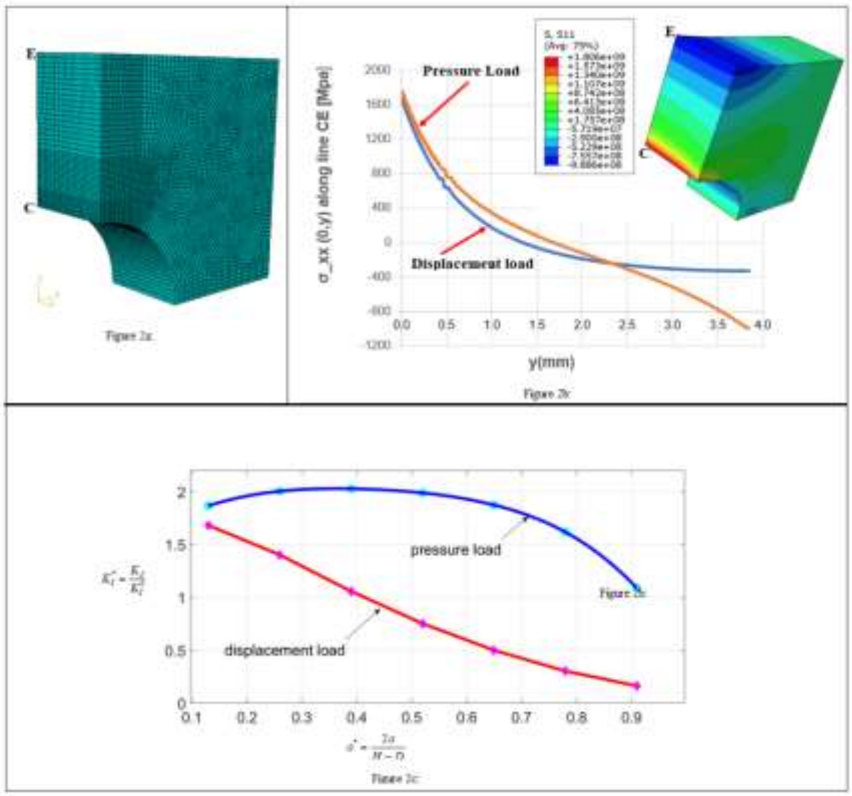

Fig. 2: a. A typical mesh for a = 0.5 mm. b**.** Comparison of normal stress along the line CE for constant pressure and and constant displacement load without cracks. c. Comparison of normalized SIF (K_1*) versus normalized crack lengths (a*) due to constant pressure load and constant displacement load.

3. Conclusions

a. Constant displacement is preferable type of load because $\partial K_I^* / \partial a^* < 0$ for all a* which lead to stability.

b. Even a crack loaded by pressure control might became stable for long cracks because $\partial K_I^* / \partial a^* < 0$ for $a^* \ge 0.4$.

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