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REDUCTION OF STRESS INTENSITY FACTOR IN A UNIAXLALLY LOADED CRACKED PLATE

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Abstract.

This paper presents work in progress, concerning the reducing of stress intensity factor values for finite width plates by using auxiliary circular holes, the analysis is done by using the finite element method. To find the stress intensity factor "SIF", the ANSYS packages was implemented to evaluate the SIF by using th Finite Element of Fracture Mechanic. It had found out that the SIF is reduced to 56% by using the auxiliary hole in the plate, the dynamic load of unit step input had been test to show the validity of this method, which is better to prevent crack from propagation.

الخلاصة

في هذا البحث تم دراسة تقليل شدة الاجهادات في الالواح الحاوية على شقوق بواسطة ثقوب اضافية وقد تم التحليل بواسطة استخدام برنامج ANSYS الذي يستعمل طريقة العناصر المحددة لايجاد قيمة SIF وقد وجد ان نسبة تقليل شدة الاجهادات تصل الى نسبة 56% باستعمال الثقوب الاضافية ومن ثم تمت دراسة تاثير الحمل الديناميكي. ان فائدة هذه الطريقة تقلل من احتمال انتشار الشق داخل الالواح

1. Introduction

1.1 stress concentrations

There is extensive literature available on the study of stress concentrations around holes and many analytical, numerical, and experimental techniques have been developed for this study. Peterson [(2) D. BROEK] and Jindal [(5) Raamachandran J.(2000)] have summarized the results of this extensive study. Heuber and Hahn [(7) ZDENˇEK P. BAŽANT (2003)] have thoroughly reviewed the field of stress concentration in scientific research and engineering applications. The knowledge of stress concentration factors has prompted the designers to use higher factors of safety, leading to increase in the material required to manufacture machine components with holes. To effect a saving in material it is of prime importance that techniques for the reduction of stress concentration around holes be investigated.

1.2 Theoretical Analysis of stress intensity factor

Westergaard, Irwin , and Williams [(2) D. BROEK] were the first who write closed form solutions for the stress distribution near a crack. Their solutions were limited to very specific geometries and loading conditions. Their results, in the form of a series solution, showed that the stress varied with a distance r from a crack tip. It can be shown that, under linear elastic conditions, the first term of the series solution for the stress near a flaw in any body, under mode I, or opening, loading is given by [(3) M.A. Meggiolaro (2005)]:

$$\sigma_{ij}^{(I)} = \frac{K_I}{\sqrt{2\pi r}} f_{ij}^{(I)}(\theta) \quad 1$$

where *r* polar coordinates as defined in Figure (1), *fij* is a function dependent on the mode of loading, and *KI* is the mode I stress intensity factor. The sub- and super-scripts (*I*) denote mode I loading. Similarly, two other modes of loading can be defined as in-plane shear, mode II, and out-of-plane shear, mode III. The stress solutions for mode II and III loading are identical in form to Equation (1), but with all of the sub- and super-scripts *I* replaced with *II* or *III*.

To study the influence of auxiliary holes on the stress intensity around the crack. The auxiliary holes is put from distance(1.25 d) to(3d) where d being diameter of the auxiliary. The hole stress distribution around crack and auxiliary holes in plates under plane stress conditions have been determined numerically by the finite element methods [(4) M. B. Prime (1999)][(1) Cook, R. D.(1974)]. The dimensions of the specimens considered are (100 mm × 100 mm × 1 mm) thick with crack of (10 mm) in length. The dimensions of these specimens are purposely large in comparison with hole diameter so as to have negligible influence on plate width.

2. J-integral analysis

The fracture mechanics parameter, namely the stress intensity factor is used to quantify both the fatigue crack growth rate and fracture behaviors. The stress intensity factor (K) is a function of the applied stress, crack size and the geometry. The stress intensity factor (K) uniquely characterizes the stress field around the crack tip due to the external applied loading. It has the units of stress times square root of length.

The component of two-dimensional J-integral are defined as[(8) Zdenek Knesl (2007)] (see fig.(1))

$$J = \int_\Gamma W dy - \int_\Gamma \left(t_x \frac{\partial u_x}{\partial x} + t_x \frac{\partial u_y}{\partial y} \right) ds \quad 2$$

Where:

Γ = any path surrounding crack tip

W = strain energy density

t_x = traction vector along x axis

t_y = traction vector along y axis

n = unite outer normal vector path

u = displacement vector

s = distance along the path Γ

3. Numerical examples

In order to verify the validity of the proposed method, several numerical examples are considered, where the dimension, mechanical property, and the load of the plate are shown in table(1).

Table(1) the dimension and mechanical property of the plates

W	L	R=a	d	σ	E	v
100 mm	100 mm	10 mm	10 mm	10 N/mm^2	210000 N/mm^2	0.3

3.1 Plate with crack edge

Consider a rectangular plate subjected to uniform uniaxial tensile stress with edge crack as shown in fig.(2) by using Ansys package the finite element mesh for the plate is shown in fig.(3) the stress contour is shown in fig.(6) the SIF = 66.5 Mpa (m)$^{0.5}$

To reduce the stress concentration and the stress intensity factor Consider the previous plate subjected to uniform uniaxial tensile stress with crack and auxiliary holes where putting in different location above and below the crack at distance equal to "d" as shown in fig.(4). For the symmetry the finite element mesh and the boundary conditions for the plate were shown in fig.(5). The stress contour is shown in fig.(6). While fig.(14) shows the variation of stress intensity factor with the distance of the auxiliary hole in plate with end crack

3.2 Plate with central crack

Consider a rectangular plate subjected to uniform uniaxial tensile stress with central crack as shown in fig.(8). For the symmetry the finite element mesh is shown in fig.(9) the stress contour is shown in fig.(12). the SIF = 58.4 Mpa $(m)^{0.5}$

To reduce the stress concentration and the stress intensity factor, Consider the previous plate subjected to uniform uniaxial tensile stress with central crack and auxiliary holes as shown in fig.(10) the finite element mesh and the boundary condition for the plate the is shown in fig.(11) the stress contour is shown in fig.(13). While fig.(15) shows the variation of stress intensity factor with the distance of the auxiliary hole in plate with end crack

3.3 Dynamic load consideration

The load time history of four plats are shown in fig.(16) while the respose of unit step dynamic load for cracked plate are shown in fig.(17,18). The holes on the cracked plates had great influence by reducing the stress intensity factor as shown in the previous figures since the stresses distrebution around the cracked had been reduced will cause to reduce the SIF

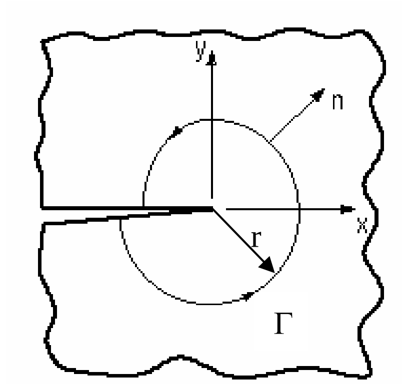
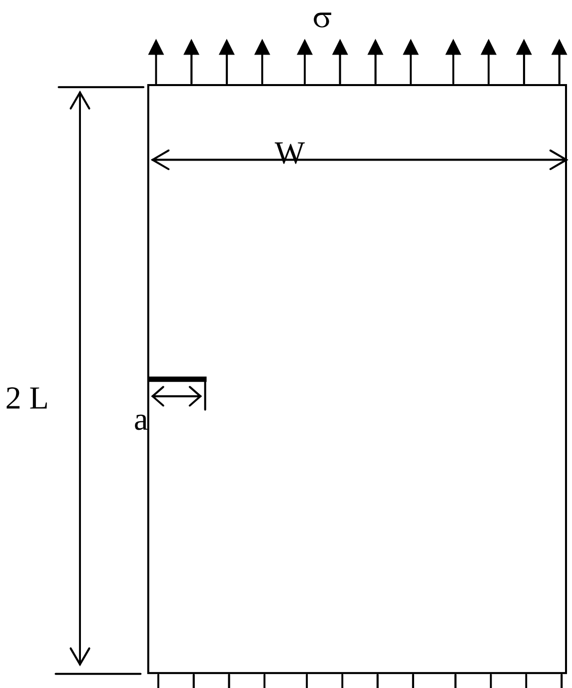


Fig.(1) integration contour



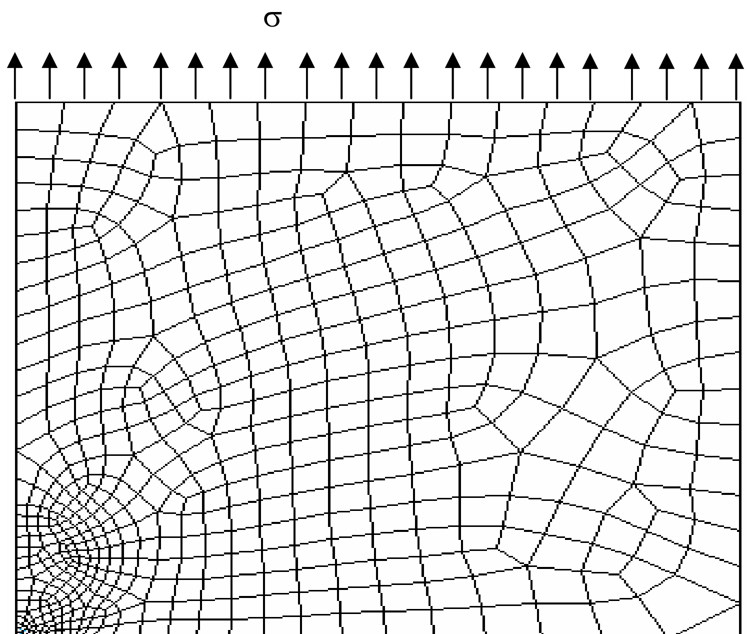


Fig.(2) geometry and loading for plate

Fig.(3) FE meshes of half plate

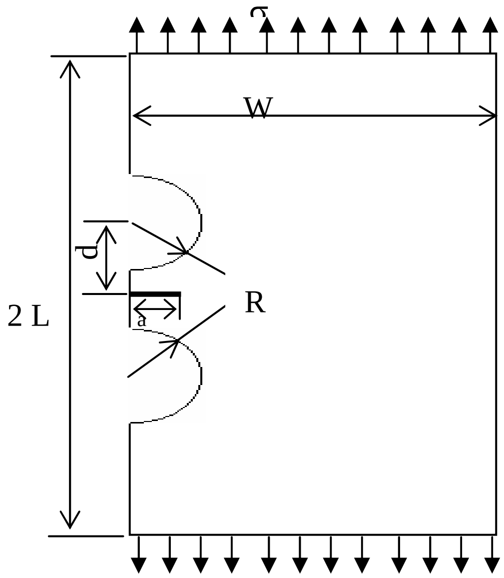
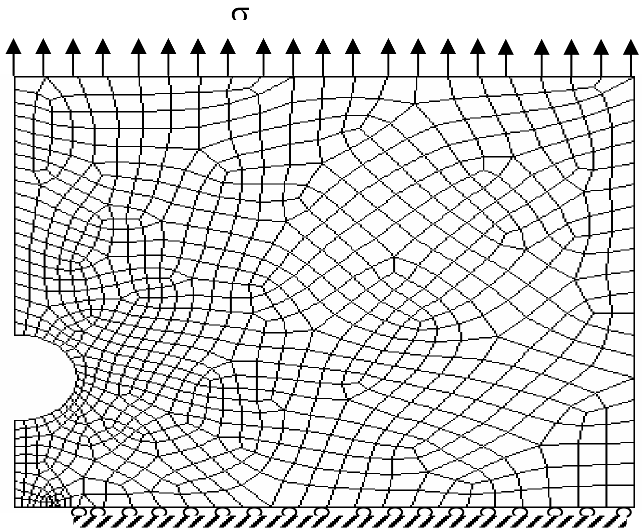


Fig.(4) geometry and loading for plate



Uy = 0

Fig.(5) FE meshes of half plate

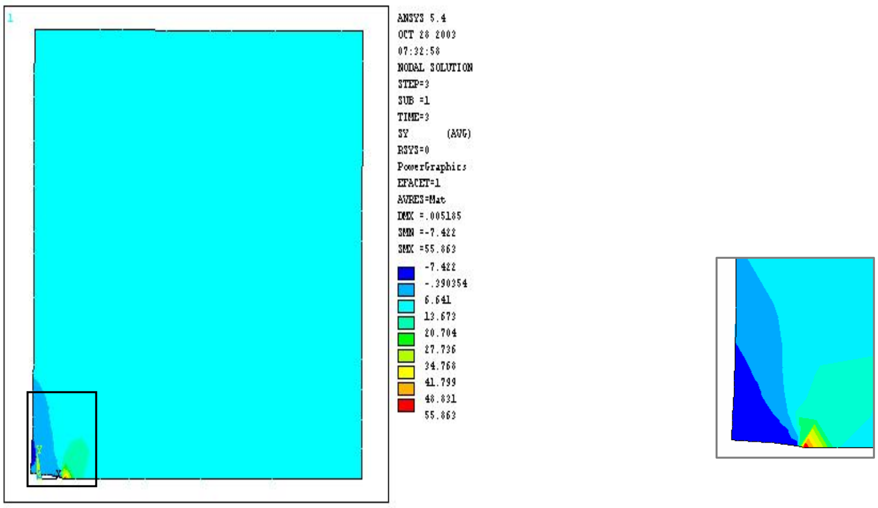


Fig.(6) stresses contour around the crack

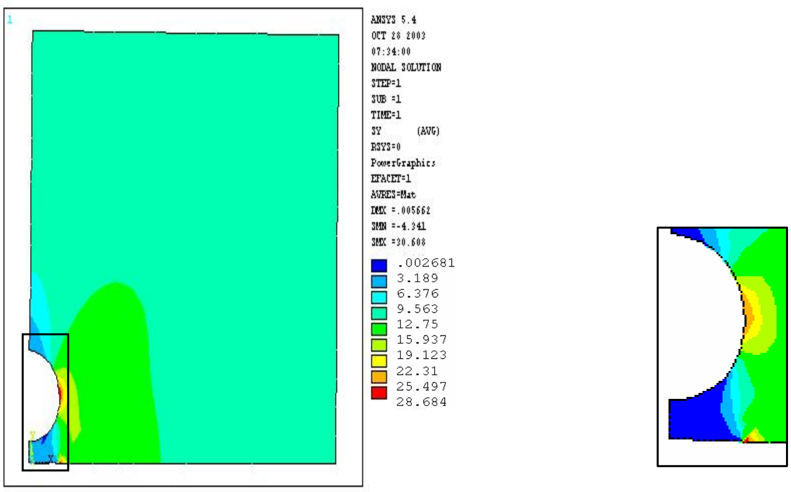


Fig.(7) the reduction of stresses around the crack

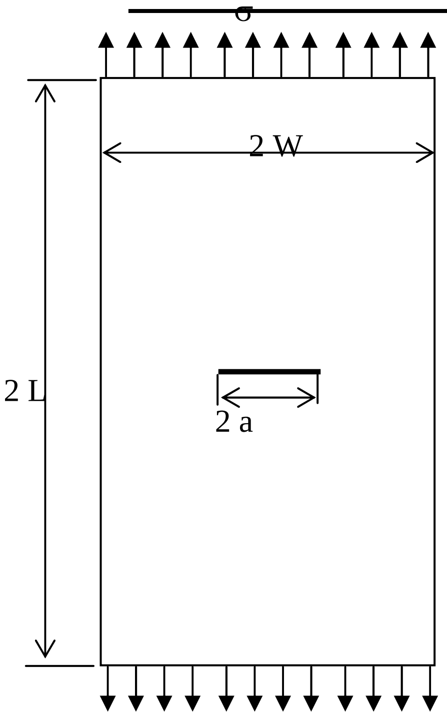


Fig.(8) geometry and loading for plate

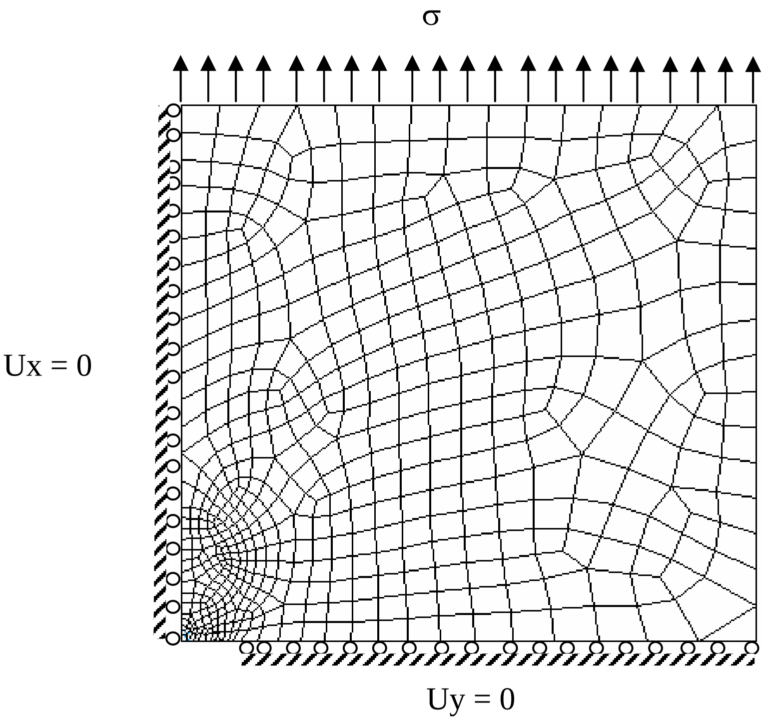


Fig.(9) FE meshes of quarter plate

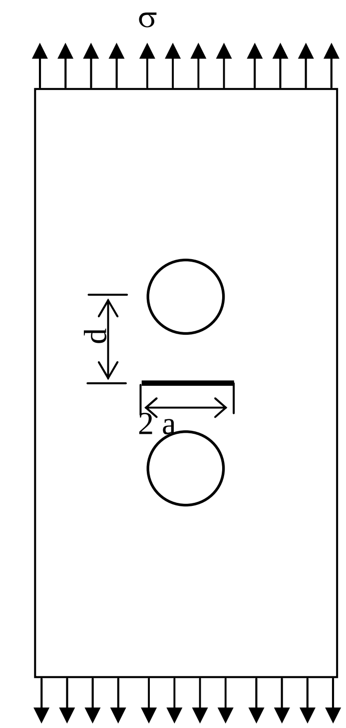


Fig.(10) geometry and loading for plate

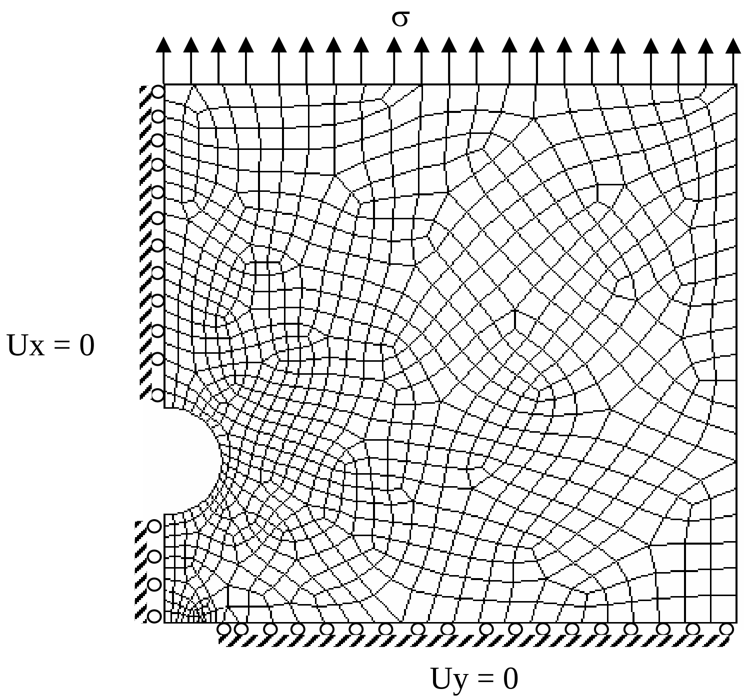


Fig.(11) FE meshes of quarter plate

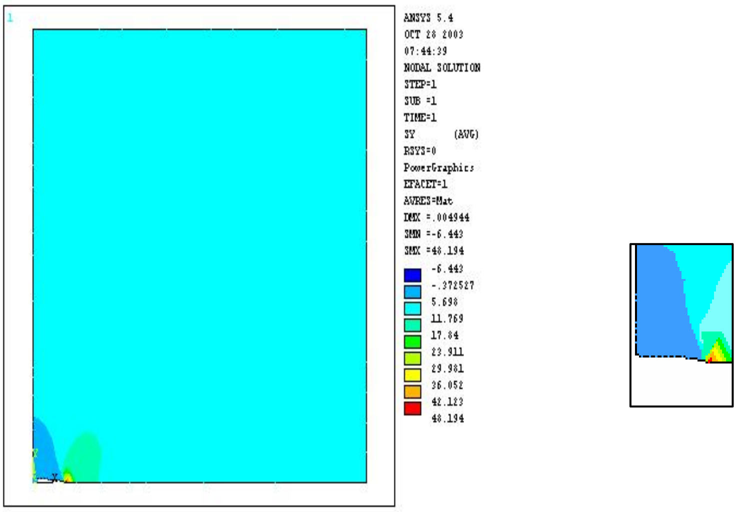


Fig.(12) stresses contour around the crack

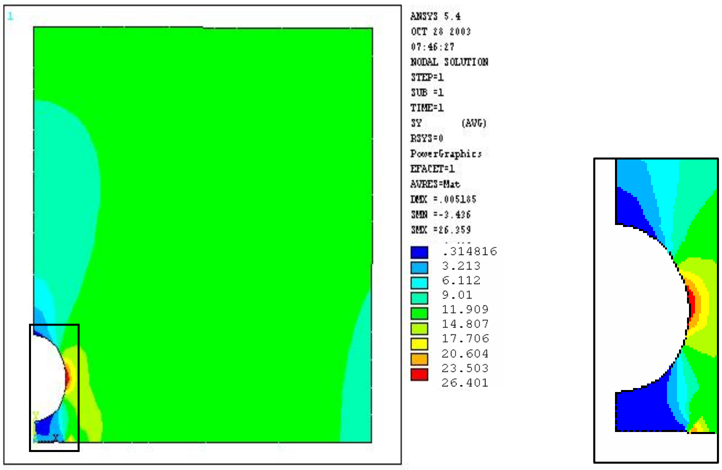


Fig.(13) the reduction of stresses around the crack

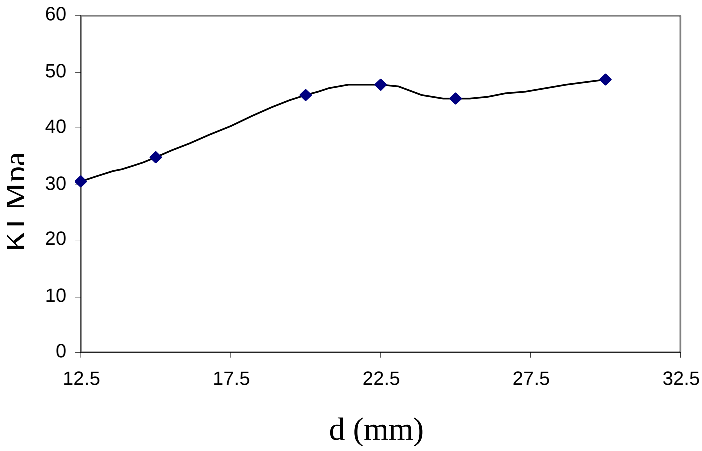


Fig.(14) variation of stress intensity factor with the distant of the auxiliary hole in plate with end crack

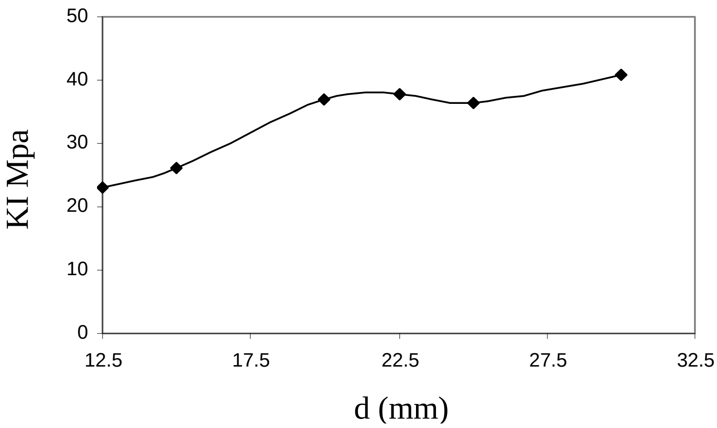


Fig.(15) variation of stress intensity factor with the distant of the auxiliary hole in plate with central crack

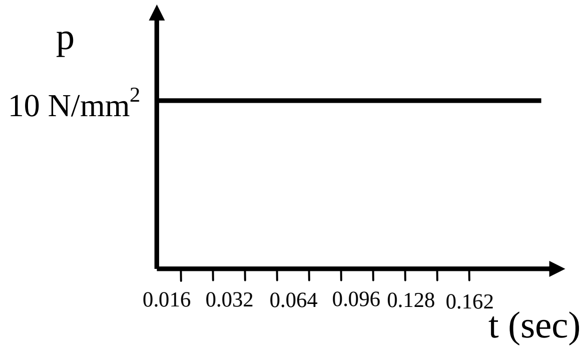


Fig.(16) variation of load history with time

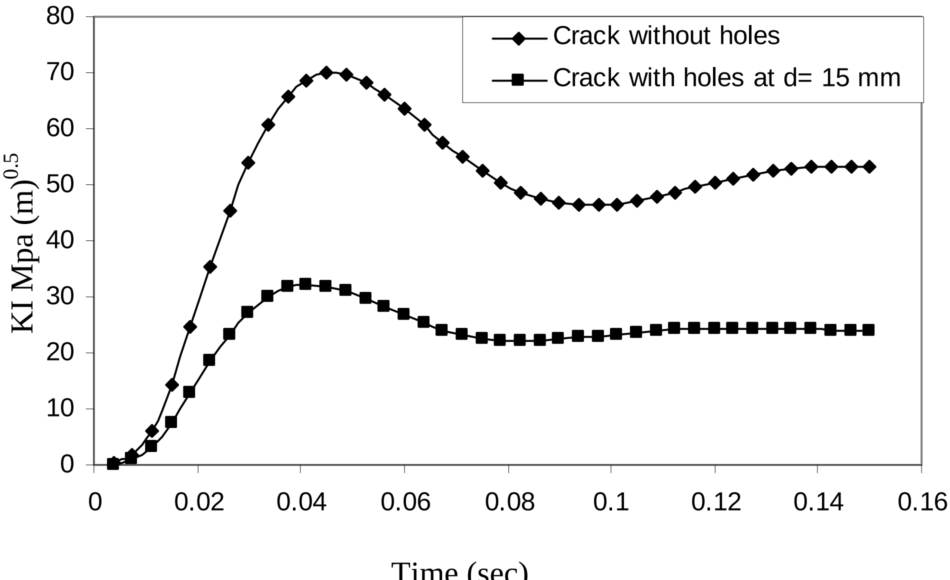


Fig.(17) variation of stress intensity factor with time (s) with end crack

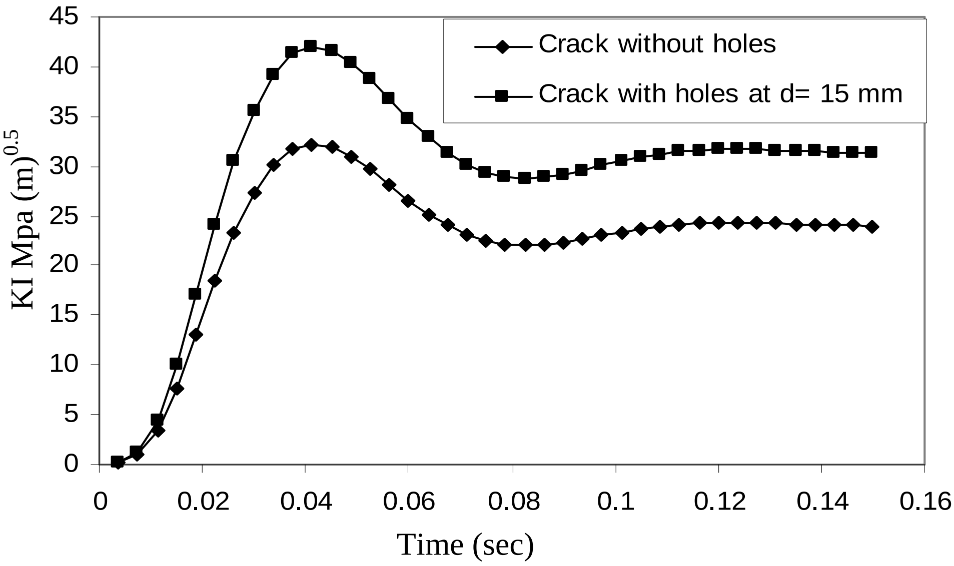


Fig.(18) variation of stress intensity factor with time (s) with central crack

4- CONCLUIONS

The results tabulated in figure (14) and (18) and the contours of stress distribution around holes (Figs 8 to 13) reveal that :

1- By introducing auxiliary holes in the direction of loading on either side of the crack , the SIF at the original hole on decreasing as the auxiliary holes come nearer the crack.

2- By introducing auxiliary holes in the direction of loading on either side of the crack , the variation of stress intensity factor with time will decrease as compare to the plate without hole.

3- The auxiliary holes in the had got effect in the dynamic results which is very important in the mechanical applications.

4- The dynamic result shows that the stress intensity factor have geart effect with the axuilary holes.

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