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A Study of the Effect of Curvature of the Corner of Hole on Stress Concentration Caused by Uniform Heat Flux

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1-Introduction

Plates have extensive applications in the production of various structures. Plates have important practical applications in designing new steam and gas turbines, jet and rocket engines, and nuclear reactors. Components of such structures are subjected to thermal loading and this type of loading causes temperature gradients and unequal thermal expansion of various components. If the non-uniform thermal expansion in an elastic material cannot proceed freely, thermal stresses are created. When the uniform heat flux is disturbed by the presence of an insulated hole, local intensification of the stress around the hole is caused. Determining the amount and location of these stresses in modern engineering design process is essential to achieve accurate design and to predict the service life and reliability of structures.

In this study, stress field around a triangular hole in an infinite isotropic plate is discussed based on the steady-state two-dimensional theory of thermo-elasticity. A plate subjected to a remote uniform heat flux and thermal insulated condition along the hole boundary is assumed. The used method is the expansion of the Goodier and Florence's method. An infinite plate containing a noncircular cutout is mapped to a unit circle. In this paper, a conformal mapping function is proposed to study the effect of the bluntness of the cutout corners and cutout shape on the stress distribution around a hole.

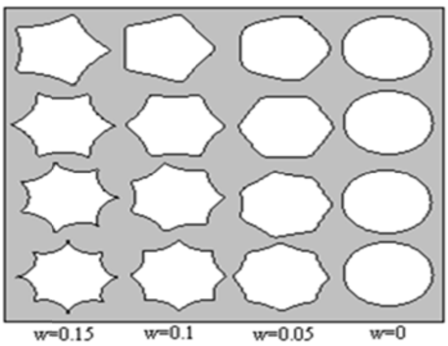

Fig. 1. The effect of bluntness of the cutout corners on its shape

Although a lot of research has been done on the study of perforated plate under the uniform heat flux, there is no article with a focus on the evaluation of the bluntness of the cutout corners. In the present study will try to investigate the influence of bluntness on the stress distribution around a hole. In Fig.1, the bluntness of the cutout corners (*w*) is shown.

2-Analytical Solution

An analytical solution method based on the complex variable method is used to investigate the effect of bluntness parameter. Florence and Goodier studied the stress distribution around a circular and elliptical hole by employing the analytical method. In order to apply this method to other hole shapes, establishing a relation between any hole and a circular hole is necessary. A special conformal transformation can be used to map the external area of different holles in the z-plane into the area outside the unit circle in the mapped plane. To verify the analytical results, the finite element method is implemented in the ABAQUS software. In the software, an infinite plate is modeled as a finite plate with length to the hole characteristic length equal to 20. The mechanical proprieties such as Young modulus, Poisson's ratio and thermal expansion coefficient are considered as a function of temperature. The upper and lower boundaries of the plate are exposed to a unit uniform heat flux while the lateral edges and the traction free edge of the hole are assumed to be thermally insulated.

In this paper the bluntness parameter is displayed with w. the variations of the dimension stress with w are shown in Figs. 2 to 4 for different shapes of hole.

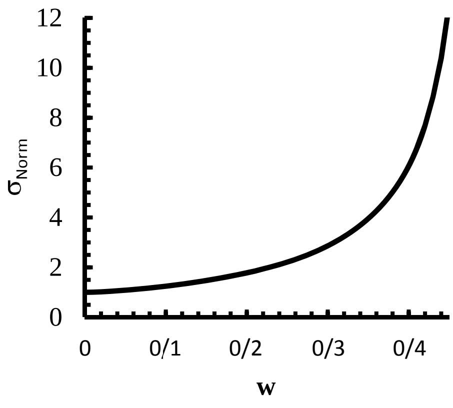

Fig. 2. Variation of dimensionless stress with bluntness parameters for triangular hole

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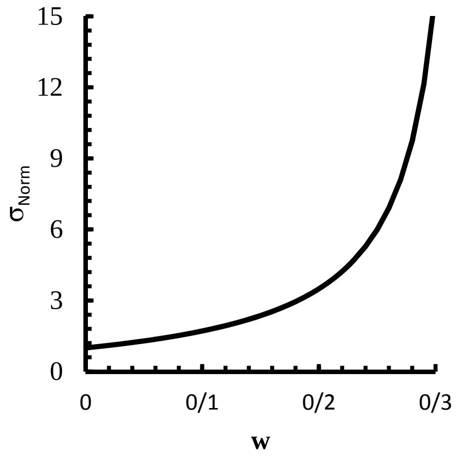

Fig. 3. Variation of dimensionless stress with bluntness parameters for square hole

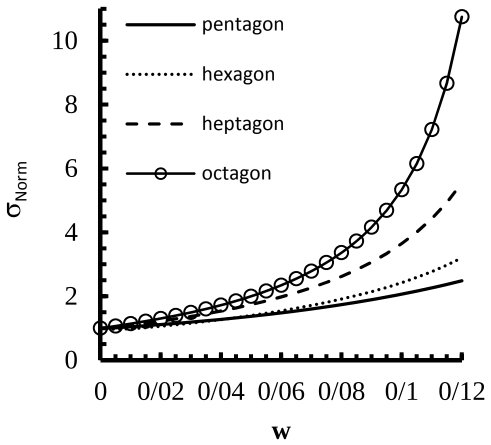

Fig. 4. Variation of dimensionless stress with bluntness parameters for n-gonal holes

3- Results

The main results are listed as follows, (*a*) the cutout shape and the bluntness of the cutout corners have significant effects on the maximum dimensionless stress. Moreover, the location of the maximum dimensionless stress depends on the cutout shape. (*b*) The greater curvature radius decreases the maximum dimensionless stress. (c) For some cutout shapes, such as hexagonal cutout, finding a *w* that causes the maximum dimensionless stress to be less than that of a circular cutout is possible. This means that the circular cutout is not always the best. For a certain noncircular cutout, a *w* may be found which leads to achieving a less maximum dimensionless stress in comparison with a circular cutout. For a hexagonal cutout, the maximum dimensionless stress for *w* up to 0.012 is less than that of a circular cutout (*w*=0) while it increases for *w* greater than 0.012. The least one equals to 0.996 when compared with circle cutout occurs for *w*=0.005.

4- Conclusion

In this study, the effect of bluntness parameters for different holes under uniform heat flux was studied. The results indicate that the hole curvature has a great effect on stress distribution around the different holes. In designing the perforated plates, effective parameters can be selected in order to achieve desirable stress. The results presented herein indicate that for a wide range of bluntness (*w*), the desirable stress holes is less than that of similar plates with a circular hole.