Determining of Optimum Location of Added Hole on Perforated Plate and Numerical Analysis of Its Effect on the Stress Concentration

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Abstract: The aim of this work was to investigate Stress Concentration Factor (SCF) variations induced by adding of holes in a perforated base plate subjected to uniaxial tension load, using Finite Element Method (FEM). Analyses were applied in 2D for different diameters, orientation angels and distances of added holes from the base hole. A parametric model in ANSYS finite element software was used to calculate the SCFs and the differences between SCFs have been shown in various graphs. To investigate the variation of SCF in perforated base plate, two holes with the same diameter were located symmetrically to the longitudinal axis with different angles and distances from the base hole. The results showed that by adding holes with a proper diameter, orientation angles and distances from the base hole, the SCFs can be reduced. Using the obtained graphs and corresponding to the base hole diameter the most adequate diameter and its position was determined. Obtained results for special statuses had a good agreement with the graphs of Peterson's stress concentration factors.

[Rahmani A, Khalili A, Soleimani R. **Determining of Optimum Location of Added Hole on Perforated Plate and Numerical Analysis of Its Effect on the Stress Concentration**. *Life Sci J* 2013;10(3s):512-514] (ISSN:1097-8135). http://www.lifesciencesite.com. 80

Keywords: Stress concentration, perforated plate, Finite Element

1. Introduction

Presence of a hole in mechanical joints such as fasteners, rivets, pins and also in path of cables and wires is unavoidable. Creating of a hole in plate as a geometrical discontinuity leads to local stress concentration around the hole. Stress Concentration Factor (SCF) is defined as the ratio of the peak stress in the body to a reference stress. Usually the stress concentration factor is K_{tg}, for which the reference stress is based on the gross-sectional area (Eq.1).

$$K_{tg} = \frac{\sigma_{max}}{\sigma} \quad (1)$$

Infinite stressed perforated plate case is one of the important classical problems in mechanical engineering and because of its wide range application in industry it has widely been noticed by engineers. Importance of this subject leads to complete elasticity solving of the problem with applying of Airy function [1]. By solving the related equations, stress field can be defined around the hole. According to the stress distribution at around the hole it is found that maximum axial stress at edge of the hole is three times larger than that of gross stress and therefore SCF=3. Based on the importance of this subject, many researches such as *Peterson* [2] have obtained special graphs for determining the elastic stress concentration factor, using analytical methods and experimental tests. However, it should be noticed that application of these factors has been restricted to statically loading of elastic materials. Many researchers have studied SCF in different types of holes in structures and some methods have been introduced for its reduction. The results show that using several methods, such as; adding extra holes to element, changing profile of the hole, using fillets and any methods which can smooth the stress distribution, SCF can be reduced [3-6].The aim of this work was to determine the optimum diameter, location and orientation of symmetric added holes to find a minimum SCF in an infinite axial loaded perforated plate. The parametric finite element model in ANSYS has been used for calculating of SCFs in different statuses.

2. Finite element modeling

To analyze the SCF variations in modified infinite perforated plate (Fig.1), two holes with the same diameters in parametric FE model were added symmetrically respect to x-x axis onto the base perforated plate. The reason why the added holes were considered symmetrically was to avoid the bending stresses. In the FE model variables were dimensionless d/D, L/D and θ

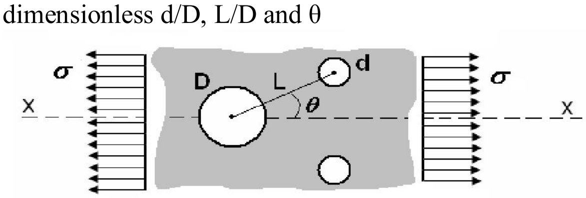

Fig. 1. Modified infinite perforated plate

Loading was in plane and uniaxial which leads the calculations to be done in plane stress state.

By considering the fact that the base model is symmetric respect to x-x axis, only half of the model was considered for FE modeling (Fig.2). As it can be seen in Fig. 2, down horizontal line in y direction and left vertical line in x direction have been fixed and uniform stress in x direction has been applied to right vertical line. Elastic modulus (E) and Poisson's ratio (v) have been considered 210GPa and 0.3, respectively. For meshing of the model, Plane8node82 element, which is suitable for irregular shapes without as much loss of accuracy, has been used (Fig.3).

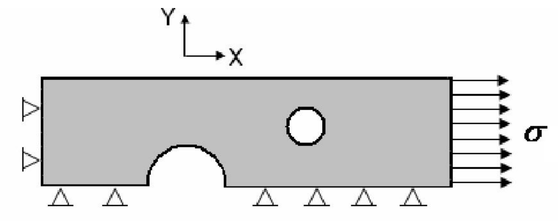

Fig.2. Half of the model

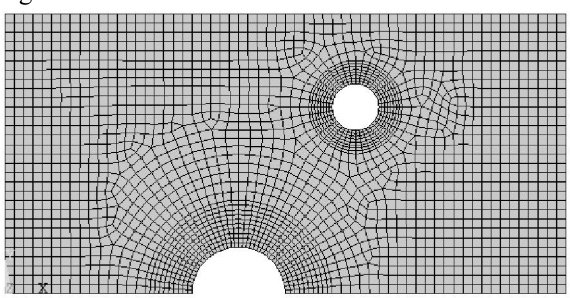
Fig. 3. Meshed plate

3. Results and Discussion

The result of analyzed stress concentration factor in a perforated plate with an added equal hole with semi directional loading (θ=0) is shown in Fig. 4. The results of *Peterson* SCFs method ([2] p.282) is also shown in this figure for comparison and validation of the results.

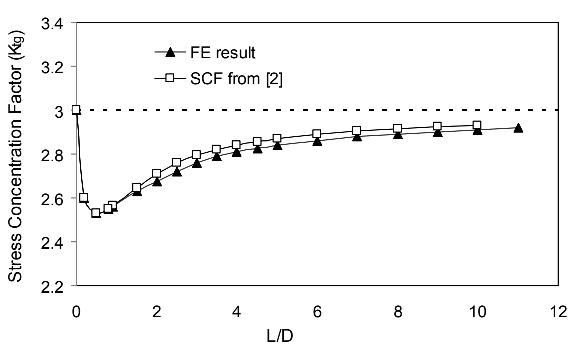

Fig. 4. FE results and SCF results from [2]

In this figure L/D is a dimensionless factor that indicates the location of added hole respect to the base hole. This figure shows that the obtained results using the parametric finite element model have a good agreement with *Peterson* SCF.

By adding the holes to element, SCF can be reduced, due to the smoothing of the stress distribution. Decreasing of SCF leads to reduction of created local stress and as a result considerably increases the strength of the structure. For more information, the analysis were also applied with variable hole diameter in θ=0, in addition of distance of added hole respect to the base hole. In this case SCF is a function of two variables, diameter of the hole and its distance from the base hole (Fig.5). It is obvious in Fig.5 that SCF reduces by adding a hole with any diameter. The results also show that to gain the lower SCF at higher hole diameters (d/D), the distance of the added hole from the base hole (L/D) should be decreased.

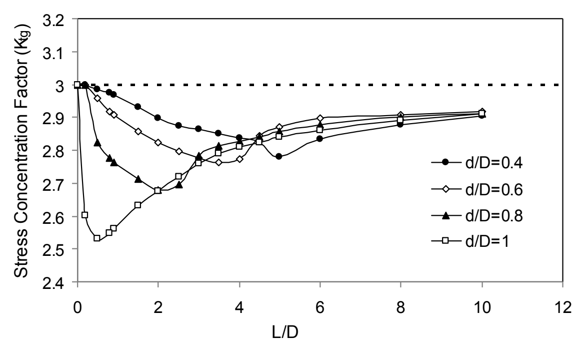

Fig. 5. SCF in different L/D and d/Ds.

In fact minimum SCF occurs in d/D=1 and near the base hole. It should be mentioned that inordinate increasing of the distance of the added hole with any diameter doesn't have a considerable effect in SCF reduction. In general, the added holes may have an orientation respect to the base hole. In this case SCF is a function of three variables, diameter of the holes, distance and orientation of the added holes respect to the base hole. FE results have been shown for d/D=0.4 and 0.8 in Figs.6 and 7, respectively. With reference to the results of Figs.6 and 7 it can be concluded that by adding a hole with d/D<1 in orientation angles below 30^0, SCF can be reduced respect to primary state.

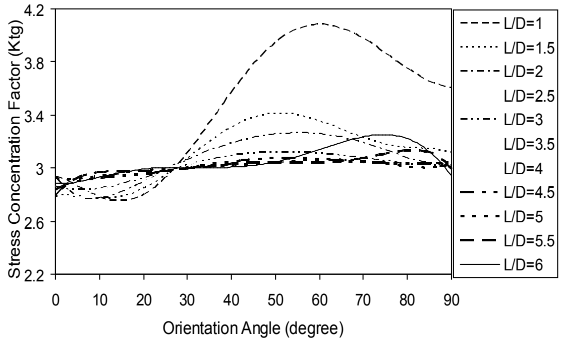

Fig. 6. SCF for d/D=0.4 and various L/D and θ

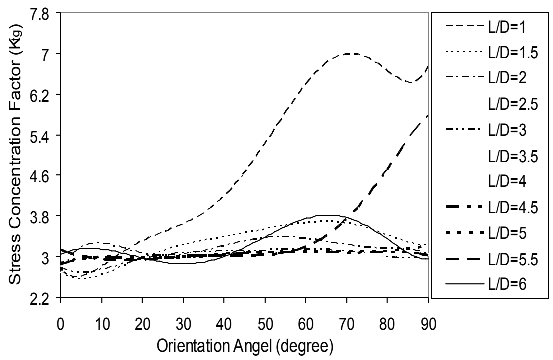

Fig. 7. SCF for d/D=0.8 and various L/D and θ

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4. Conclusions

By application of a FE model to find of SCFs in a perforated plate with added holes, it was shown that by adding of holes with a proper diameter and designed location and orientation, SCF can considerably be reduced respect to primary state.

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