Theoretical Study for Plate with Holes Under Distributed Load Using Finite Element Method

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Abstract

The study represents a numerical investigation onto the behavior of a plate with hole, or number of holes by finite element method. The investigated specimens are subjected to a direct tension stresses acting parallel to the axis of the plate.

Initially the plate contain one hole at the center of plate, the diameter of this hole was changed to study the effect of this variation on stress concentration.

Also , the effect of number of holes onto the stress concentration were studied by taken a plate with one hole, two holes, three holes and four holes distributed along the plate axis. In each study all the holes had the same diameter.

Finally the effect of the distance between the centers of holes were studied by taken a plate with four holes at the same distance each other, then these distances varied uniformly.

All results were obtained using a program called *ANSYS*.

الخلاصة

يقدم هذا البحث دراسة نظرية حول سلوك وتصرف نماذج من نوع **(Plate With Holes)** باستخدام طريقة العناصر المحددة **(Finite Element Method)**.

النماذج المستخدمة في هذه الدراسة كانت معرضة إلى اجهادات شد باتجاه الطول وتحتوي على ثقب يقع في مركز الصفيحة.تم تغيير قطر الثقب لدراسة تأثير هذا التغيير على تمركز الاجهادات **(Stress Concentrations)**

أيضا تم دراسة تأثير عدد الثقوب على تمركز الاجهادات عن طريق أخذ صفائح تحتوي على عدد من الثقوب مرة بثقب واحد وأخرى بثقبين ثم بثلاث ثقوب وأخيرا صفيحة بأربع ثقوب مع تغيير أقطار هذه الثقوب لمعرفة السلوك تحت هذه التغييرات.

وأخيرا تم دراسة تأثير المسافة بين مراكز الثقوب على تمركز الاجهادات عن طريق أخذ صفيحة تحتوي على أربع ثقوب وعلى مسافات متساوية،ثم تغيير هذه المسافات مع المحافظة على تساويها بين الثقوب.

النتائج تم الحصول عليها عن طريق استخدام برنامج يسمى ***ANSYS*** وهو برنامج متخصص للحل بواسطة العناصر المحددة.

Introduction

A thin planar body subjected to plane loading on its edge surfaces said to be in plane stresses. here stresses σ_z ,τ_{xz} , and τ_{yz} are set as zero [3].

$$\varepsilon_x = \frac{1}{E}(\sigma_x - \upsilon\sigma_y)$$

$$\varepsilon_y = \frac{1}{E}(\sigma_y - \upsilon\sigma_x)$$

$$\varepsilon_z = -\frac{\upsilon}{E}(\sigma_x + \sigma_y)$$

$$\gamma_{xy} = \frac{2(1+\upsilon)}{E}\tau_{xy}$$

For plane stress situations, assuming isotropic materials,

$$\begin{bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{bmatrix} = \frac{E}{1-\upsilon^2}\begin{bmatrix} 1 & \upsilon & 0 \\ \upsilon & 1 & 0 \\ 0 & 0 & \frac{1-\upsilon}{2} \end{bmatrix}\begin{bmatrix} \varepsilon_x \\ \varepsilon_y \\ \gamma_{xy} \end{bmatrix}$$

Which is used as $\sigma = D\varepsilon$

In engineering practice, the actual stress distribution does not have to be determined. Instead, only the maximum stress must be known, and the member is designed to resist this stress when the axial load P is applied.

Stress concentration factor K is defined as a ratio of the maximum stress to the average stress acting at the smallest cross section, i.e., [5]

$$K = \frac{\sigma_{\max}}{\sigma_{avg}}$$

$$\sigma_{avg} = \frac{P}{A}$$

Where A is the smallest cross sectional area, section a-a in figure (1)

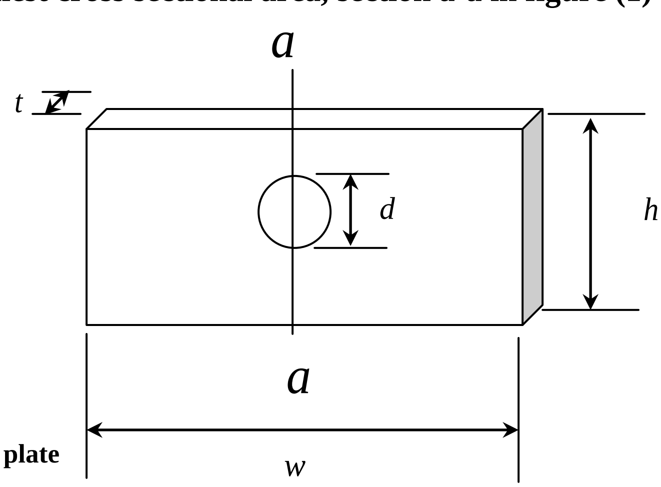

Figure (1) Dimension of plate

$$\sigma_{avg} = \frac{P}{(w-d)*t} = \frac{\sigma*t*w}{(w-d)*t} = \sigma\frac{w}{w-d}$$

Where σ is the direct tension stress effect on the plate

Problem Modeling and Boundary conditions

A plate with such a loading as shown in figure (2) can exist any where in space. The dimension and properties of the plate are listed below:

w=300 mm
h=200 mm
t=10 mm
E=200 GPa (Steel alloys Structural A36)
ν=0.32 (Steel alloys Structural A36)
σ=3 MPa (Arbitrary)

The symmetry of the geometry and symmetry of the loading can be used effectively. Let x and y represent the axis of symmetry as shown in figure (2). The nodal displacement components are those in the x and y directions, denoted by u_x and u_y respectively. Both variables are independent on the z direction. The suggests that the part which is one quarter of the full area, with the loading and boundary conditions as shown below is all that is needed to solve the problem.

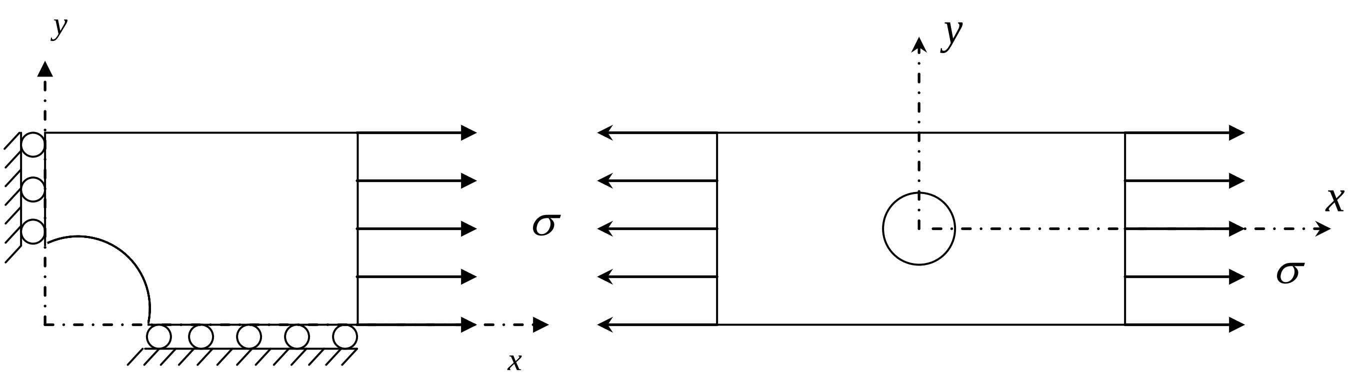

Figure (2) Axis of Symmetry for Plate with Hole

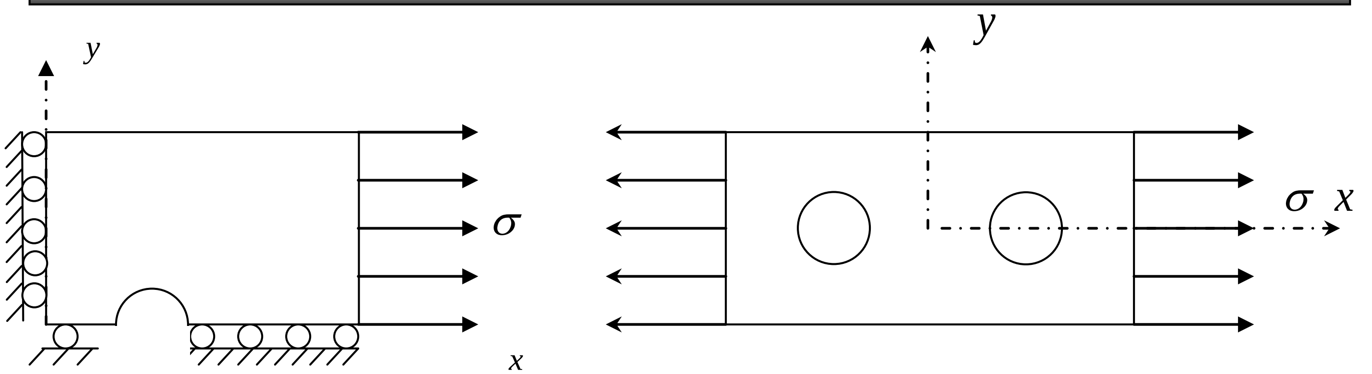

Figure (3) Axis of Symmetry for Plate with Two Holes

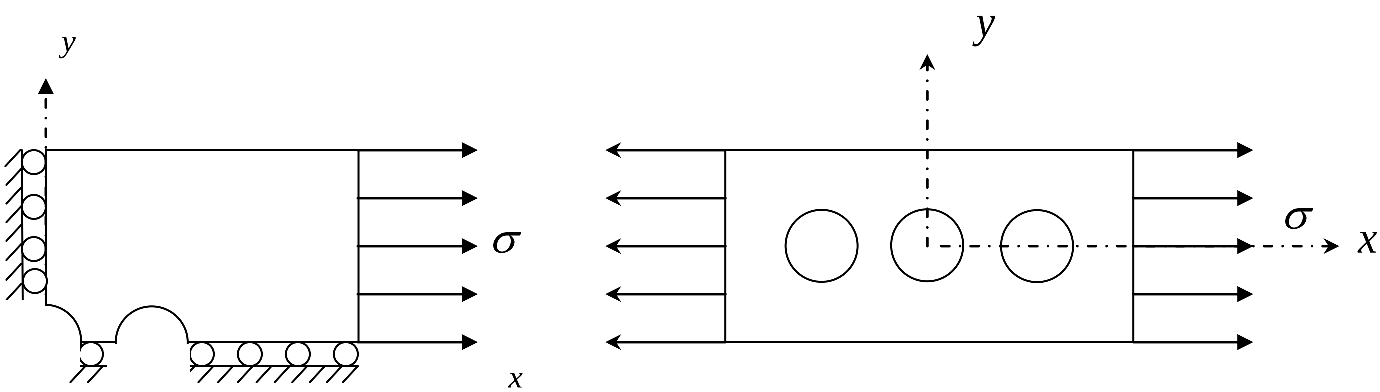

Figure (4) Axis of Symmetry for Plate with Three Holes

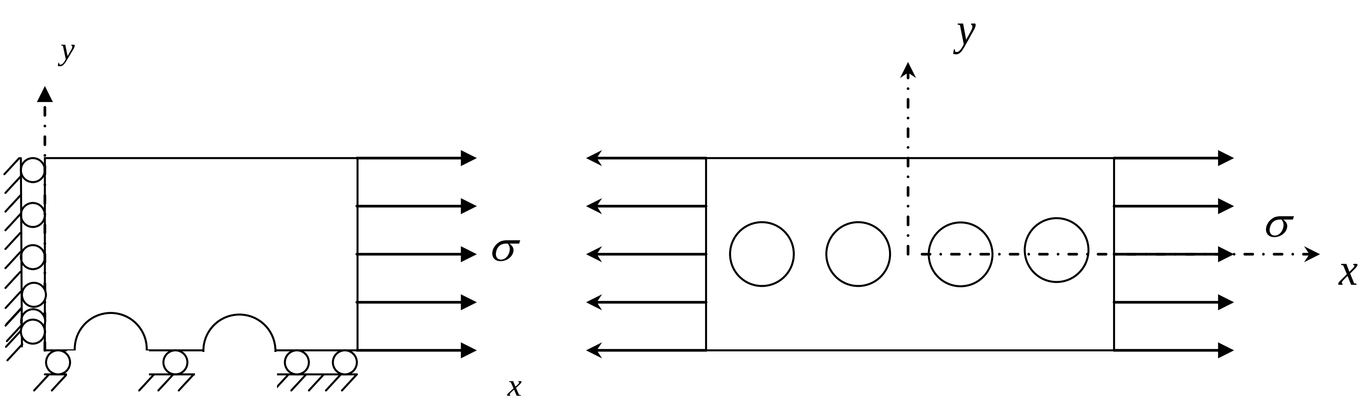

Figure (5) Axis of Symmetry for Plate with Four Holes

The points along the x-axis move along x direction only, so u_y=0. The points along the y-axis move along y direction only therefore u_x=0.

In this research some variables which effect on the stress concentration was studied like the diameter of hole, by taken 5 plates each plate contain one hole in the centre of plate with five diameters 0.015,0.02,0.025,0.03 and 0.035 m as shown in figure (2). Also the above study taken for a plate with two holes, three holes, and four holes to study the effect of the number of holes on the stress concentration as shown in figures (3),(4), and (5).

Finally a plate with four holes at the same distance were studied, then these distances are varied to study the effect of the distance between holes centre on the stress concentration as shown in figure (6).

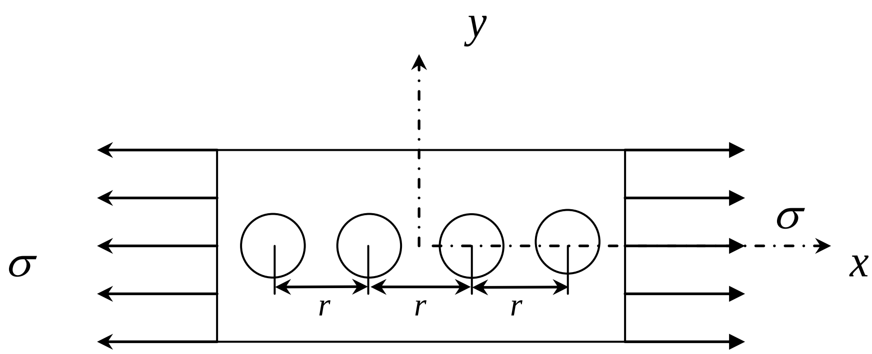

Figure (6) Plate with Four Holes at r Distance between Holes Centre

The Results

By taking advantage of symmetry planes, only one – fourth of the specimen needed to be modeled, this minimized the model size. The two dimensional quadrilateral structural solid p-element were used. The element is defined by eight nodes having two degrees of freedom at each node. The mesh make around the hole or holes to provide greater accuracy near the area of stress concentration as shown in figures (7), and (8).

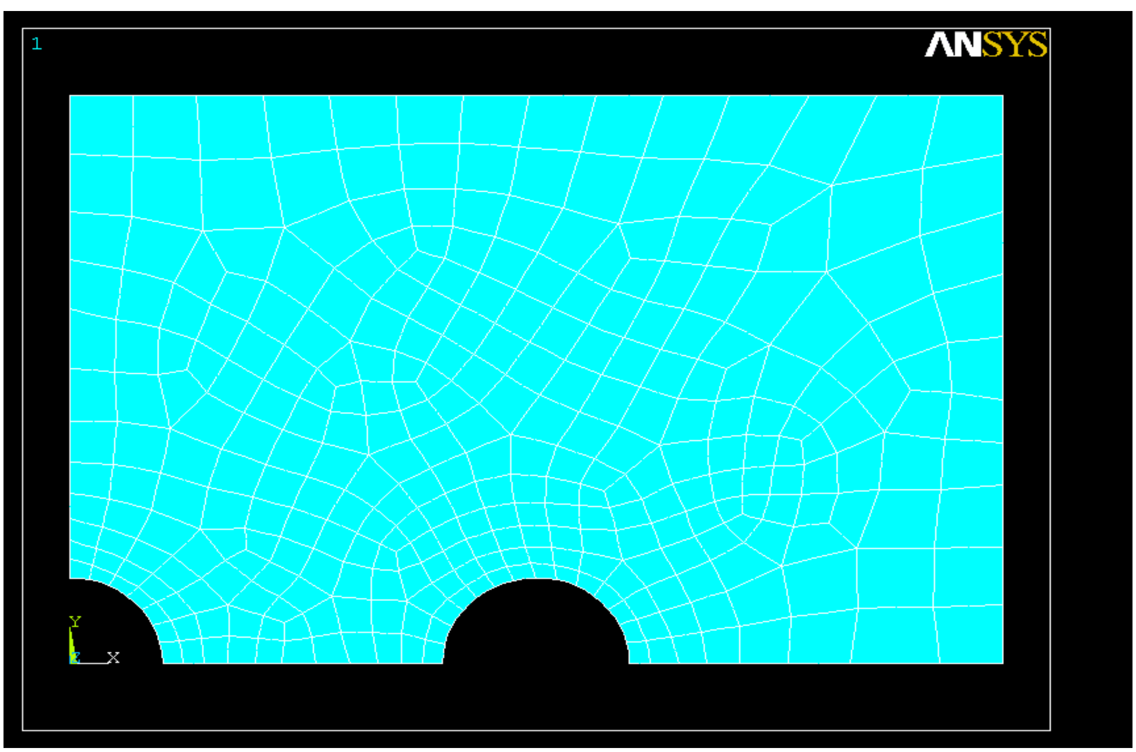

Figure (7) Mesh of Plate with Three Holes

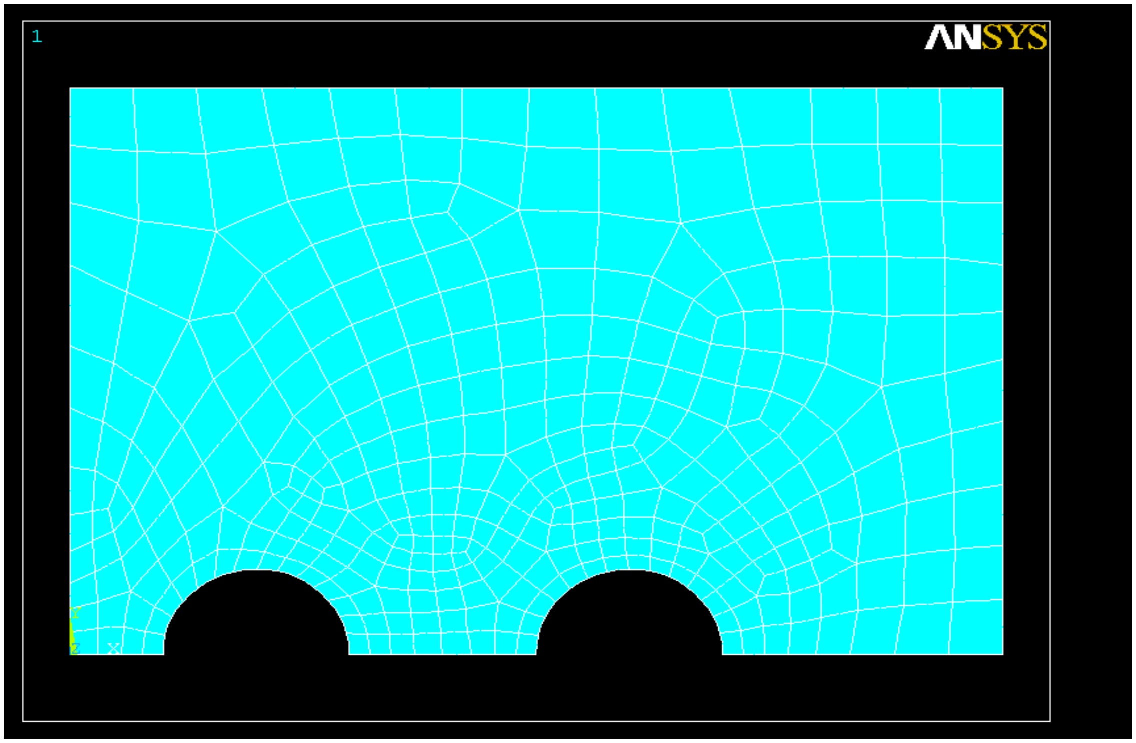

Figure (8) Mesh of Plate with Four Holes

***ANSYS* program will be utilized to provide finite element analysis of a plate with hole or holes to determine the maximum stress, strain and their locations. The findings of this study are summarized in the tables (1), (2), (3), (4)**

Table (1) Results for plate with one hole under tension stress

d(m)	σ_{max}(MPa)	ε_{max}
0.015	9.06	4.53×10^{-5}
0.02	9.06	4.53×10^{-5}
0.025	9.13	4.57×10^{-5}
0.03	9.26	4.63×10^{-5}
0.035	9.36	4.69×10^{-5}

Table (2) Results for plate with two holes under tension stress

d(m)	σ_{max}(MPa)	ε_{max}
0.015	8.92	4.47×10^{-5}
0.02	8.96	4.47×10^{-5}
0.025	8.96	4.47×10^{-5}
0.03	9	4.50×10^{-5}
0.035	9.03	4.52×10^{-5}

Table (3) Results for plate with three holes under tension stress

d(m)	σ_{max}(MPa)	ε_{max}
0.015	8.87	4.43×10^{-5}
0.02	8.88	4.43×10^{-5}
0.025	8.88	4.43×10^{-5}
0.03	8.89	4.44×10^{-5}
0.035	8.96	4.48×10^{-5}

Table (4) Results for plate with four holes under tension stress

d(m)	σ_{max}(MPa)	ε_{max}
0.015	8.85	4.42×10^{-5}
0.02	8.79	4.40×10^{-5}
0.025	8.71	4.35×10^{-5}
0.03	8.78	4.42×10^{-5}
0.035	8.89	4.49×10^{-5}

Table (5) Stress concentration factor (SCF) for plate with different holes

		1hole	2 holes	3 holes	4 holes
d(m)	Average stress(MPa)	SCF	SCF	SCF	SCF
0.015	3.243243243	2.7935	2.750333	2.734917	2.72875
0.02	3.333333333	2.718	2.688	2.664	2.637
0.025	3.428571429	2.662917	2.613333	2.59	2.540417
0.03	3.529411765	2.623667	2.55	2.518833	2.487667
0.035	3.636363636	2.574	2.48325	2.464	2.44475

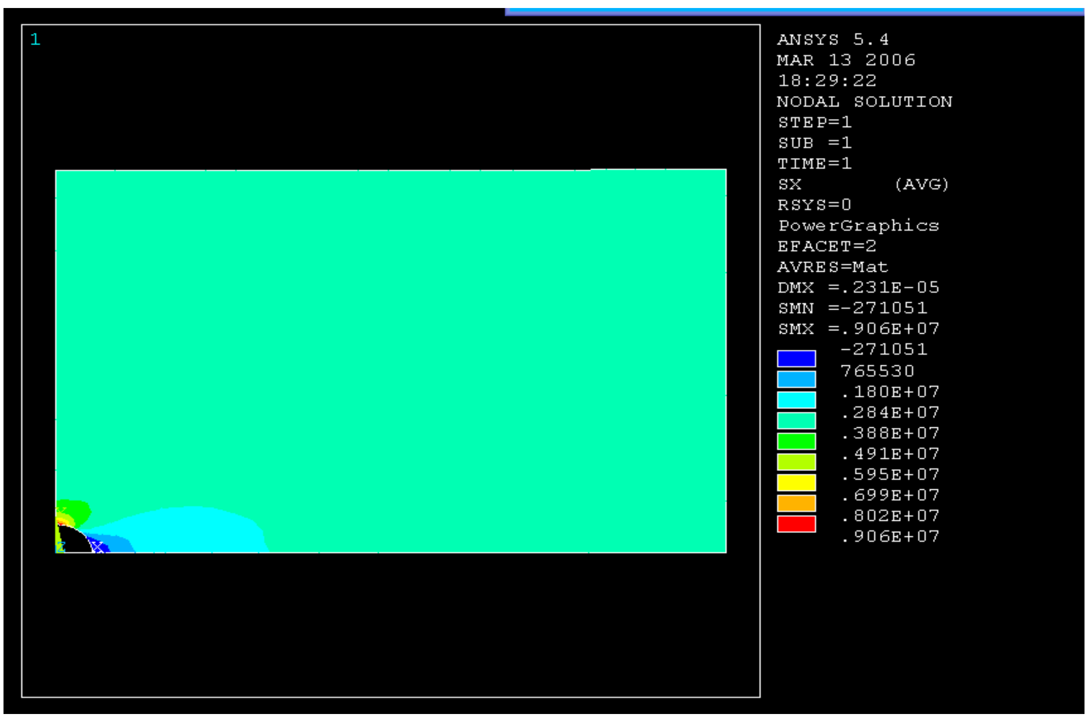

Figure (9) Stress concentration for plate with one hole, d=0.015 m

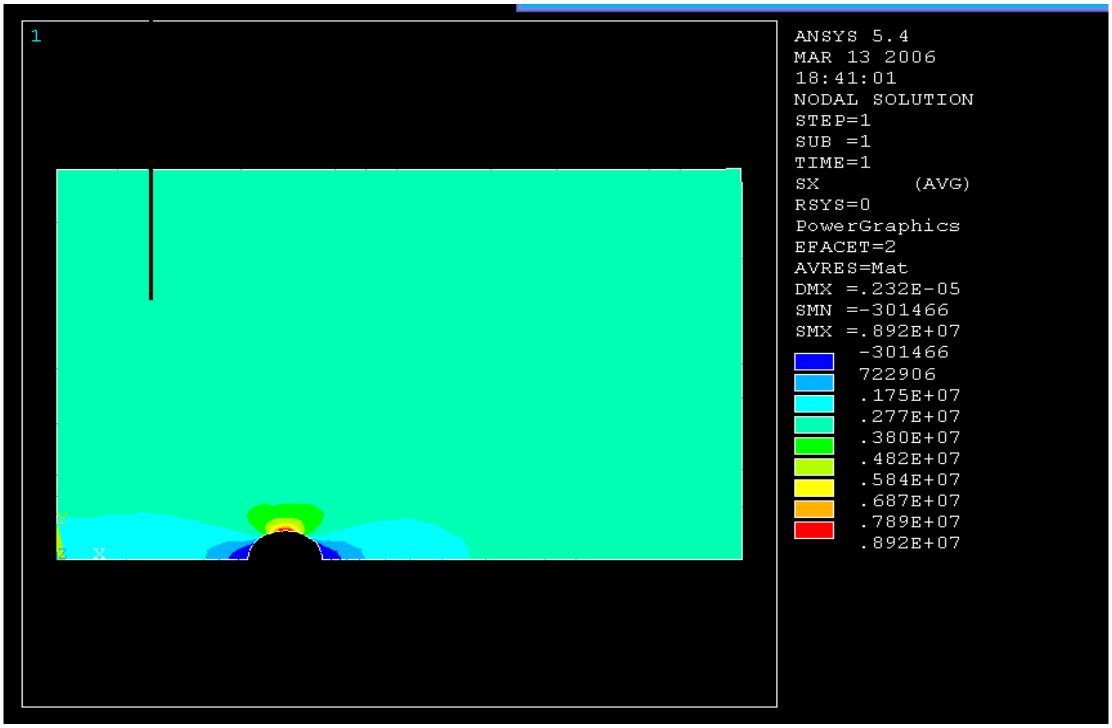

Figure (10) Stress concentration for plate with two holes, d=0.015 m, the distance between center of holes r=0.1 m

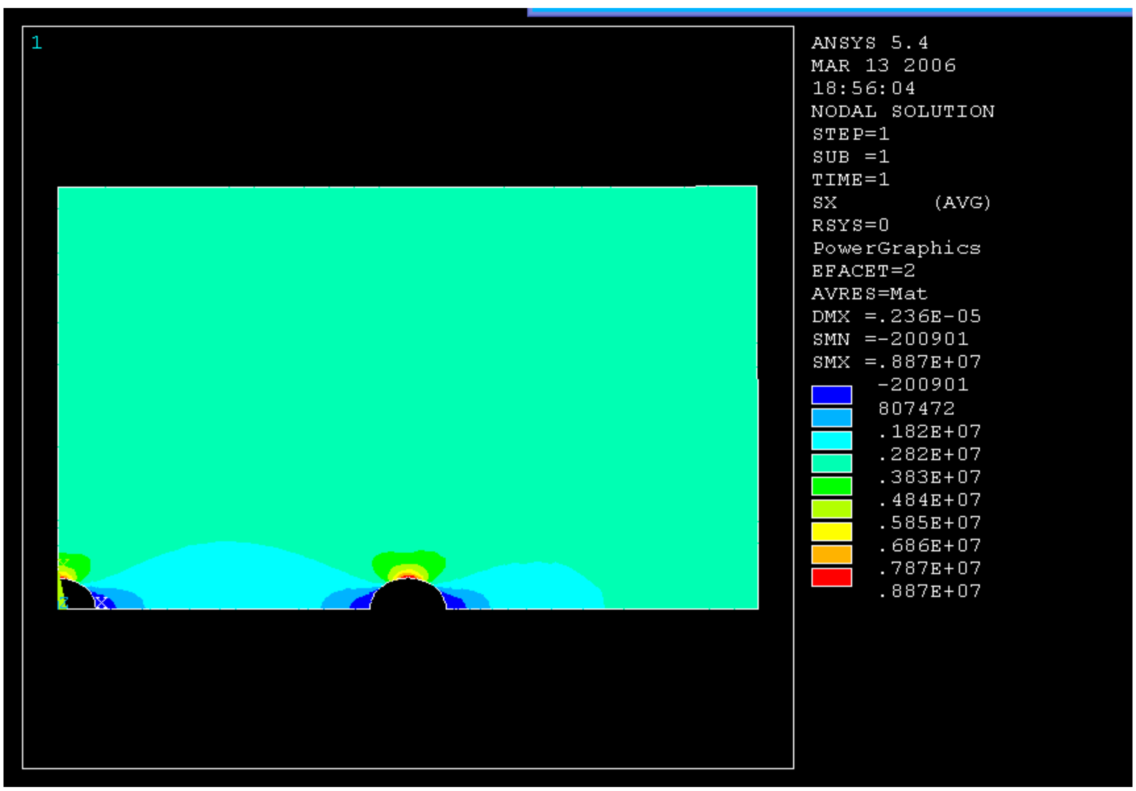

Figure (11) Stress concentration for plate with three holes, d=0.015 m, the distance between center of holes r=0.075 m

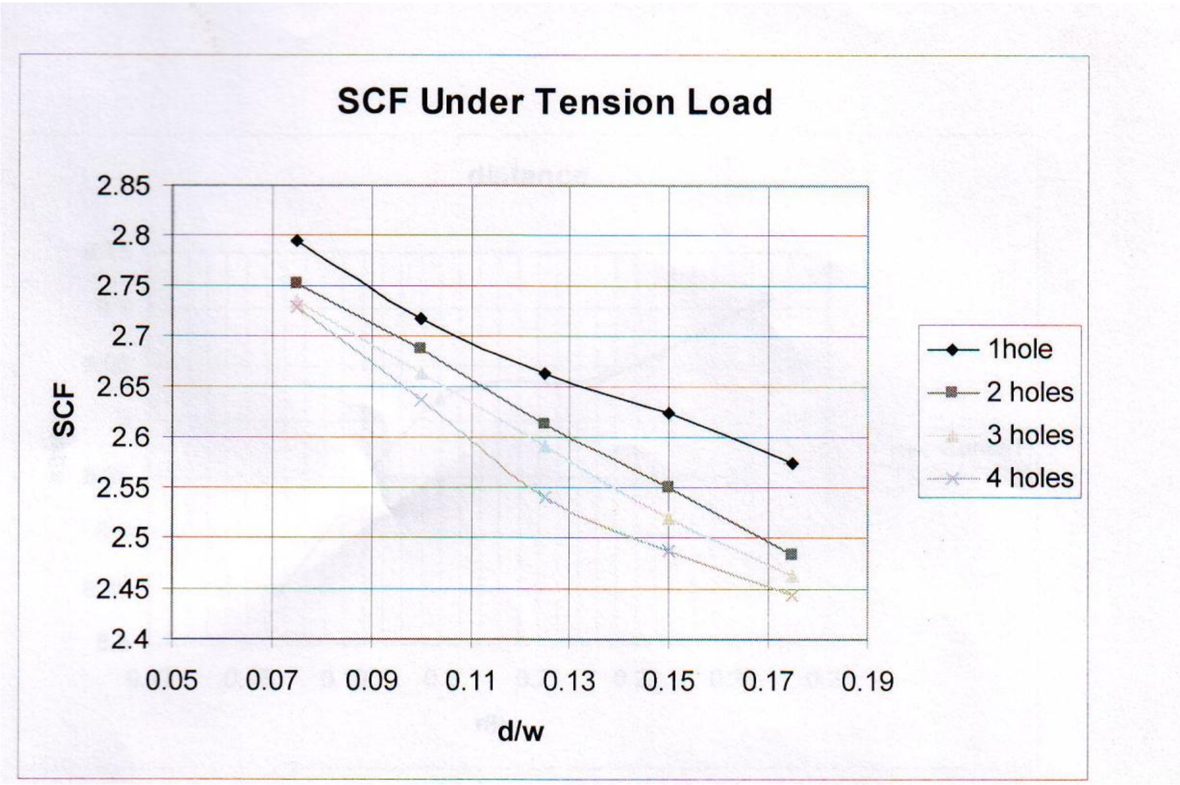

Figure (12) Stress concentration factor against d/w ratio under tension stress

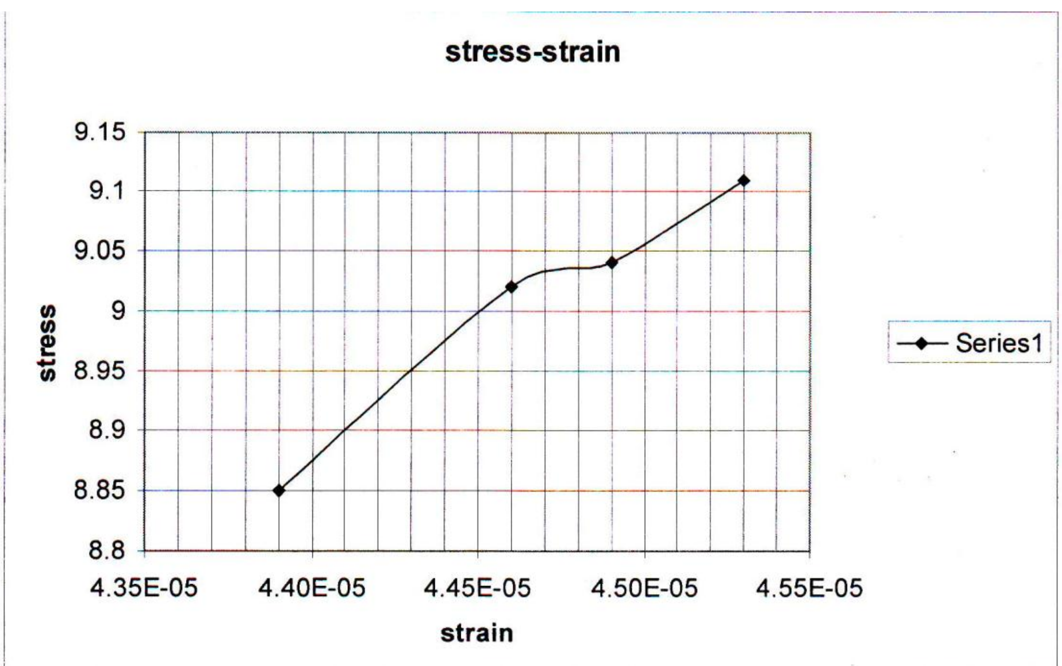

Figure (13) Stress strain relationship for a plate with different distance between holes

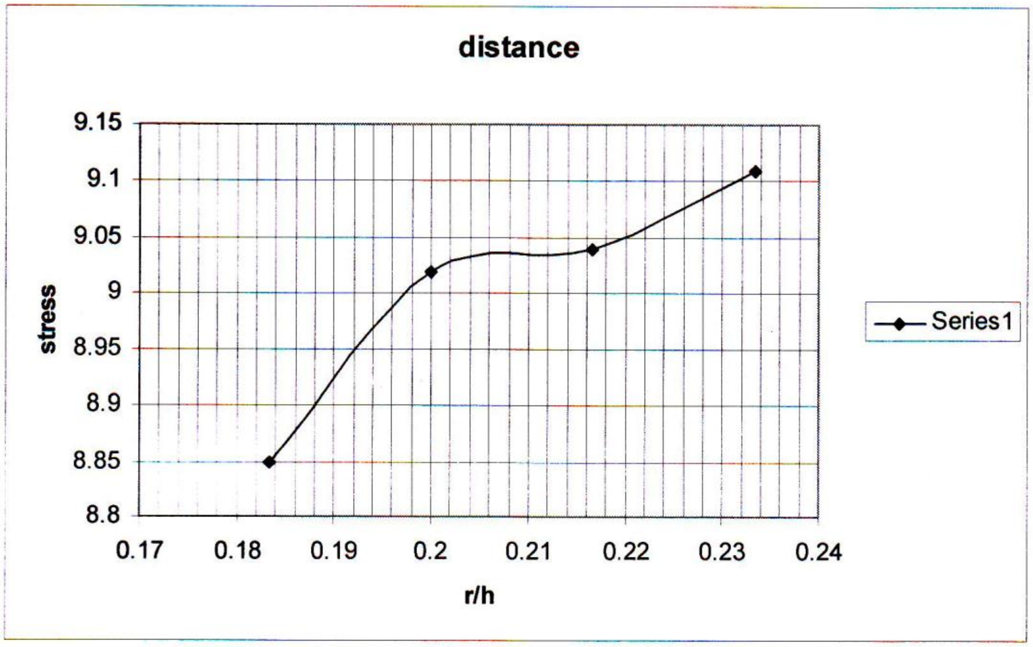

Figure (14) Maximum stress against r/h

Discussion

From the results listed above an important point of consideration in this study the concentration of the maximum stress around the hole, this caused by the absence of material at the hole.

Figures (9), (10), and (11) show that the maximum stress diminishes rapidly as we move away from the holes. At a distance from the end of the plate, the stress distribution is nearly uniform, and the maximum stress is only a few percent larger than the average stress. This observation is true for most stress concentrations, such as a plate with one hole, two holes, or more holes.

From tables (1), (2), (3), and (4) recognize that when the diameter of the holes increase the maximum stress in the smallest area increase, also these tables show the relationship between the number of holes and the maximum stress where the maximum stress is inversely proportional to the number of holes. From table (5) can note that the stress concentration factor decrease when the diameter of holes increase.

Figure (14) show that when the distance between the center of holes increase the maximum stress will increase also.

Conclusions

1- **Stress concentration factor decrease when the hole diameter increase, in this study if the hole diameter changed from 0.015 m to 0.035 m, the stress concentration factor varied from 2.7935 to 2.574 for plate with one hole.**

2- **Stress concentration factor decrease when the number of holes increase, for a plate with a constant diameter (d=0.015 m) of the holes the stress concentration factor decrease from 2.7935 to 2.72875.**

References

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