STRESS AND STRAIN DISTRIBUTION IN PERFORATED PLATE LOADED IN MEDIAN PLANE

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1. Introduction

As is well known, the distribution of stresses in thin planar plates with circular holes and loaded by forces situated in the median plane of the plate can be determined using by analytical, numerical and experimental methods. Analytical solutions [1], [2] are typically obtained for simple cases by using complex variable functions and conforming transformations. In the case of complex structures, their analytical solution is rather difficult, the solutions being somewhat complicated.

As for the numerical methods, they allow for an approximation of any problem of static analysis, but in some cases the results obtained are not covert, the values obtained are often undervalued and sometimes these results are affected by very high errors (bigger then 15-20%).

From the experimental methods that can be used to determine the stress distribution pattern in a thin planar plate with circular holes, is the photoelasticity method. In the present paper is presented a comparative study between the experimental study, using the photoelasticity method, on plates with 7 circular holes having the same diameter, holes arranged in zig-zag, thus determining the state of tension on the perimeter of the holes and the values of the stress concentration coefficient, respectively the results obtained by numerical analysis, by the finite element method, for the same types of structures.

2. Experimental study

The perforated plates studied in this paper had 7 zig-zag holes in two configurations, as shown in figure 1.

For the experimental study, the plates were made from polycarbonate with a thickness of 4 mm. For a first plate, the diameters of the circular holes have 14 mm, and the distance between centers of two neighboring holes is 20 mm in the horizontal direction and in the vertical direction. For the second plate we increase the diameter of holes at 18 mm, keeping the same distance between centers of two neighboring holes in vertical direction and horizontal direction.

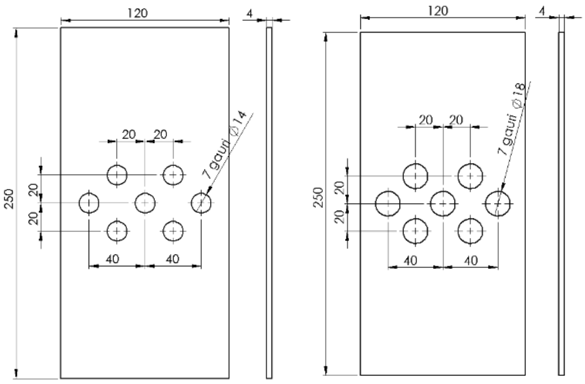

Fig. 1. Dimensions of perforated plates.

The plates thus obtained were solicited at uniaxial traction (in the direction of the Oy axis, with a uniformly distributed load (p = 5 N/mm^2) over the entire width of 120 mm of the plate and analyzed in monochromatic light, observing and photographing the distribution of isochromatic lines The applied load was chosen so as to obtain an isochromatic line field suitable for stress state analysis [3].

On the perimeter of the holes, where the stress has the maximum value, the stress is determined using next relation:

$$\sigma_{max} = N \cdot f_{\sigma} \quad (1)$$

where: N is the value of the order of isochromated line (fringe) line, and f_σ is the photoelastic constant of the photoelastic material used (polycarbonate) determined using calibration method with compressed disk ($f_\sigma = 0.766$ MPa/fr).

The stress concentration factor in one point from perimeter of holes can be calculated with next relation [4]:

$$\alpha_k = \frac{\sigma_{max}}{\sigma} \quad (2)$$

where: σ is stress in one point from unperforated plate.

Figure 2 shows the mode of distribution of the isochromate lines for the plate with seven circular holes of 18 mm diameter.

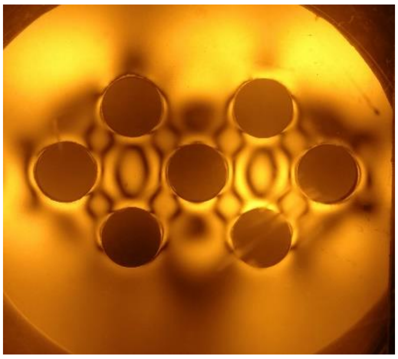

Fig. 2. Distribution of the isochromate lines.

3. Numerical simulation

Considering the geometric symmetry and loading of such a perforated plate, to shorten the time for the finite element analysis it was modeled, using the Abaqus 6.14 software package, only a quarter of the plate applying symmetry conditions to the left side respectively to the bottom side of the plate, and we apply a distributed load by the top of the plate (p = 5 N/mm^2).

For meshing the plates, we use shell element type (S4R - a 4-node doubly curved thin or thick shell, reduced integration, hourglass control, finite membrane strains). In figure 3 are presented a model of quarter of the plate meshed, with applied symmetry conditions and loads.

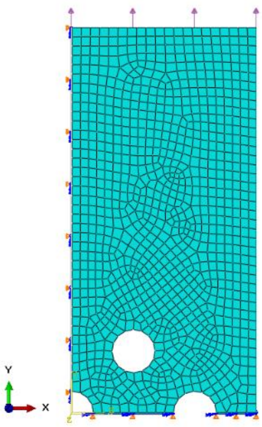

Fig. 3. Model of perforated plate meshed and loaded.

After or meshing the plates, we use shell element type (S4R - a 4-node doubly curved thin or thick shell, reduced integration, hourglass control, finite membrane strains) with approximate global size 3 mm. In figure 3 are presented a model of quarter of the plate meshed, with applied symmetry conditions and loads.

In the next figures are shows the results obtained after we are running the numerical simulation. Thus, in figure 4 are shows the Von Mises stress distribution for both case (14 mm and 18 mm diameter of holes).

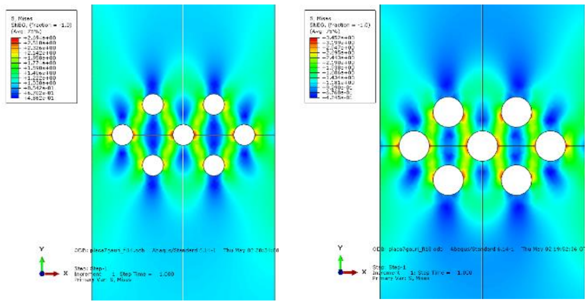

Fig. 4. Von Mises stress distribution.

Figure 5 shows distribution of first 5 isosurface obtained after we are running the numerical simulation for plate with seven circular holes of 18 mm diameter.

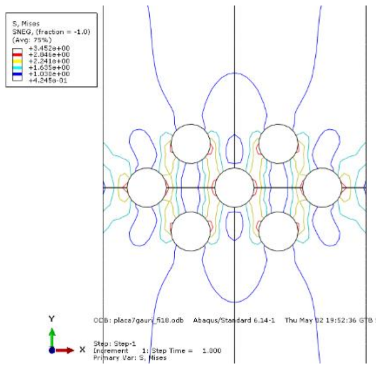

Fig. 5. Distribution of the isochromate lines.

4. Conclusions

By comparing the results obtained experimentally with those by the finite element method one can observe a good similarity between the distribution of stress in perforated plate.

References

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