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ANALYSIS OF PERFORATED SHEET METALS WITH SQUARE AND HEXAGONAL HOLES USING FINITE ELEMENT METHOD

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ABSTRACT

Since the manufacturers and users of sheet metal parts are aiming at reducing the weight of the component, some components are made out of perforated sheet metals. As the use of perforated sheet metals is wide, its behavioural study is important. An attempt is made here to study its structural behaviour. Finite element analysis is used to analyze the deformation behaviour of perforated sheet metals. After the modelling of perforated sheet metal plate having square and hexagonal perforation, uniaxial tensile load is applied. The FEA is carried out using commercial FE software ANSYS to find its structural behaviour with respect to relative density and the results obtained are compared with literature. Sheet metals with hexagonal perforations are found to have better load bearing capacity and higher stiffness for particular relative density and hence they are better than square perforations at higher factor of safety.

Keywords: *Perforated Sheet Metals, Effective Stiffness Ratio, Effective Yield Strength Ratio, Relative Density, Stress Distribution Profile, FEA and Factor of Safety.*

1. Introduction

The perforated sheet metal is sheet metal in which perforations have been blanked out of the metal. Perforated sheet metal allows for a verity of standard designs, making it easy to use for a number of purposes. Perforated plate is an industrial product with numerous practical uses. Its production is simple and complex at the same time, simply to say holes are punched in a raw metal plate just doesn't do it justice. Plate can be perforated using a standard punching process, that is, a punch and die, in material up to 1 inch thickness. The applications of perforated sheet metals include Ceilings, Walls, Floors, Conduits, Stairways, Grills, sieves in shakers, Strainers in dying industries etc.

2. Literature Survey

Baik et.al. [1] studied the deformation behaviour of perforated sheet metals with round holes of varying diameter using two dimensional and three dimensional finite element methods under uniaxial tension. Ochsner et.al. [2] examined the elastic-plastic behaviour of Aluminium sheets in relation to the relative density. Litewka [3] presented the results of experimental study of the overall plastic behaviour of the perforated plates with circular holes in square and triangular pattern. Rens.et.al. [4] studied the mechanical behavior of perforated plates which was simulated by the analysis of homogenized (unperforated) plates. Kormi.et.al. [5] developed a general methodology using finite element method to calculate effective elastic constants by isolating a unit module from the whole plate. IPA [6] handbook gives guide lines to design perforated sheet metals like number of holes, diameter of holes, open area etc. Chen.et.al [7] developed a boundary element alternating method (BEAM) to study the stress concentration of a two-dimensional (2D) perforated plate.

3. Finite Element Modelling

The perforated plates are modeled, both in square and hexagonal holes, as per the guidelines of industrial perforators association (IPA). Figures 3.1 and 3.2 show the modeling of the perforated sheet metals with square and hexagonal holes respectively. The figure 3.3 shows the finite element modeling using the ANSYS software. The boundary conditions are applied which is explained in the Table 3.1. Element selected for the analysis is SOLID 95. This element has compatible displacement shapes and is well suited to model curved boundaries. It can tolerate irregular shapes without as much loss of accuracy.

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It is defined by 20 nodes. The material selected is INVAR and its Young's modulus, Poisson's ration and maximum yield strength are 151 GPa, 0.28 and 725 MPa respectively. Baik et.al. [1] have studied the deformation behaviour of perforated sheet metals with round holes, made from INVAR, using both experimental and FEM techniques. That is the reason for choosing the same material in our study to compare the results. Also as deformation behaviour of round holes already studied, square and hexagonal holes are taken in this study. Figures 3.4 and 3.5 show the deformation of perforated sheet metals with square and hexagonal holes respectively.

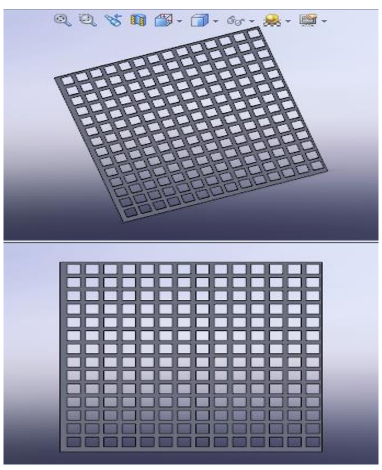

Fig. 3.1 PSM – Square Holes

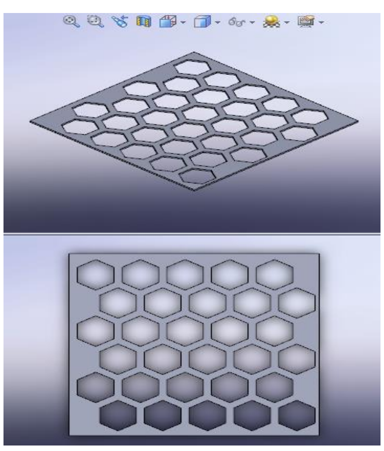

Fig. 3.2 PSM – Hexagonal Holes

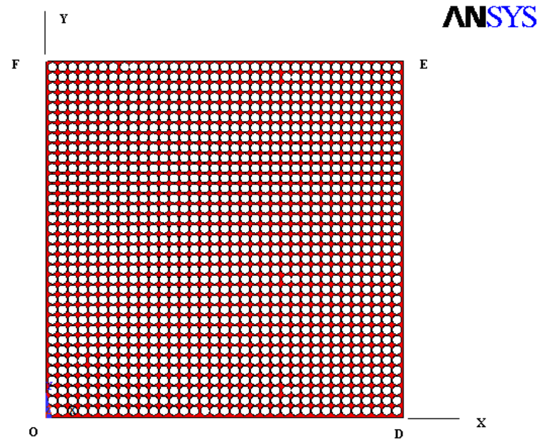

Fig. 3.3 FEM of PSM

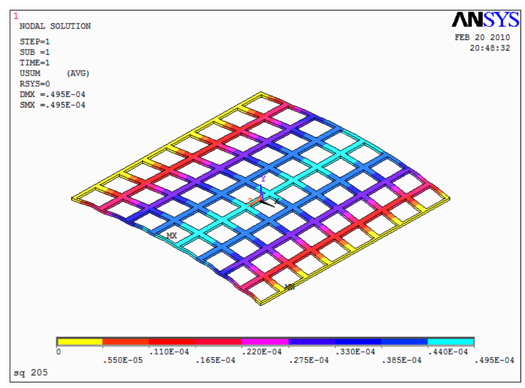

Fig. 3.4 Deformation Distribution – Square Holes

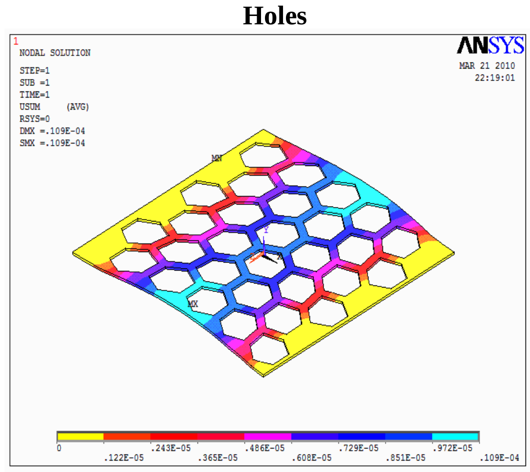

Fig.3.5 Deformation Distribution – Hexagonal Holes

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Table: 1 (Also refer Fig.3.3)

Tension direction	$\overline{OD}$	$\overline{DE}$	$\overline{EF}$	$\overline{FO}$
x-direction	Uy=0	Ux= X	_	Ux=0
y-direction	Uy=0	_	Uy= Y	Ux=0

4. Results and Discussions

Figure 4.1 shows the stress - strain graph of the perforated sheet metal. The experimental result [1] is compared with the present model. The sheet with hexagonal holes sheet is taken for the comparison. Elastic limit is same for both the model where as there is a small variation in the elastic-plastic region. The present model gives a little higher stress in that region than the experiment. Also it was observed during the analysis that the plate with square holes shows a higher stress value for a given relative density for a constant load as compared to that of plate with hexagonal holes. This shows that the hexagonal profile of the holes play an important role in decreasing the level of stresses and has a higher load bearing capacity than the square plate for the same amount of deformation.

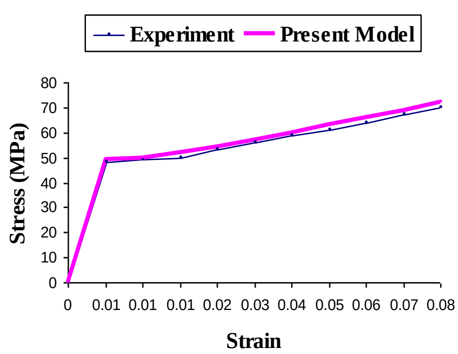

Fig. 4.1 Stress Vs Strain

Relative density is a ratio of density of perforated sheet metal to that of normal sheet metal (i.e. without perforations). The effective stiffness ratio (E^*/E_s) and hence the stiffness is found to be directly proportional to the relative density which is shown in figure 4.2. Initially the rate of increase is low but at higher relative density, the rate of increase is more. At lower values of relative densities i.e. relative density less than 0.5, it is found that the effective stiffness of plate with hexagonal holes is higher than that of the plate with square holes. As we approach higher values, the effective stiffness for both the plates approximately becomes equal. The present models are compared with the experimental model [2].

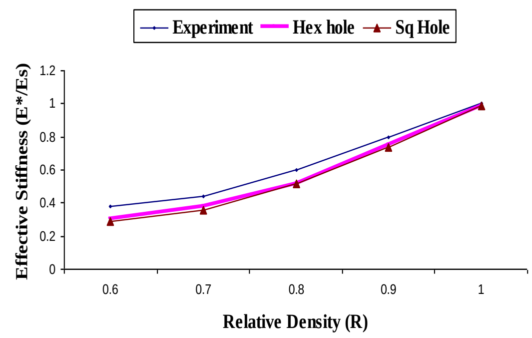

Fig. 4.2 Effective Stiffness Vs Relative Density

The effective yield stress is also found to be directly proportional to the relative density which is shown in figure 4.3. Here also at lower relative density, the rate of increase in effective yield stress is low but at higher relative density, the rate of increase is more. As we approach higher values, the effective yield stress for both the plates approximately becomes equal. It is understood from the figures 4.2 and 4.3 that the resistance to deformation will increase with the increase in relative density.

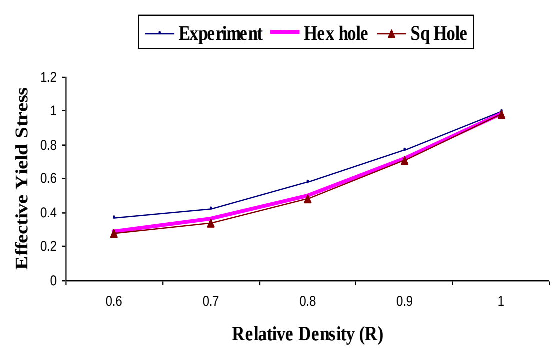

Fig. 4.3 Effective Yield Stress Vs Relative Density

5. Conclusion

The results obtained by the finite element analysis of perforated sheet metals with square and hexagonal holes under uniaxial tension are in good agreement with the results available in the literature. From the above discussions and graphs, the plate with hexagonal holes has better load bearing characteristics as it exhibits high stiffness, low stress for a particular relative density and low stress for the same deformation when compared to plate with square

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holes. Thermal analysis and modal analysis can be carried out for different perforated plates. Analysis of perforated plates made of composite materials using FEA can also be carried out.

6. References

1. *Seung Chul Baik, Kyu Hwan Oh and Dong Nyung Lee, (1996), "Analysis of the Deformation of a Perforated Sheet under Uniaxial Tension", Journal of Materials Processing Technology,Vol.58, 139-144.*

2. *Ochsner A, Winter W and Kuhn G (2001), "Elastic-Plastic Behaviour of Perforated Aluminium Under Tension and Compression", Technical Mechanics, Vol.21, 101-108.*

3. *Litewka A (1998), "Homogenization of the Elastoplastic Behavior of Perforated Plates", Nuclear Engineering and Design, Vol. 57, 417-425.*

4. *Van Rens B J E, Brekelmans W A M, Baaijens F P T (1998), "Experimental Study of the Effective Yield Surface of Perforated Materials", Computers and Structures, Vol.69, 537-545.*

5. *D. C. Webb, K. Kormi, S. T. S. Al-Hassani, (1995), "Use of FEM. in performance assessment of perforated platei subject to general loading conditions", International Journal of Pressure Vessels and Piping, Vol.64, 137-152.*

6. *Designers, Specifiers and Buyers (1993), "Handbook for Perforated Metals, "Industrial Perforators Association publication".*

7. *Chen K T, Ting K and Yang W S (2000), "Stress Analysis of Two-Dimensional Perforated Plates using Boundary Element Alternating Method", Computers and Structures, Vol.75, 515-527.*

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