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Hollow Structure

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Abstract. Some present requirements of the mechanical structures are high strength and lightweight. A solution is to adopt the hollow structure design. In mechanical engineering industry are commonly using hollow structural sections, surface – type and even three dimensional hollow parts. The final shape is usually the result of structural optimization in which smallest material quantity fulfil the strength requirements. In this paper the study considers a different distribution of the same mass, more exactly starting with a single whole and "splitting" its surface in smaller and smaller holes each iteration. The intuitive expected result in reducing equivalent stresses considering von Mises criteria was not achieved.

1. Introduction

Presently, one goal of a mechanical structure is to use less possible resources in order to achieve the imposed requirements, as von Mises stresses. This is done using, now common, structural optimization modules from CAE software. The classical solution for one dimensional elements are hollow structure sections, honeycomb shape [1], [2], [3], [4] for bidimensional parts and complex hollow shapes for three dimensional parts as brake calipers made by Porsche [5], Bugatti [6] and others [7], structures similar to autoclaved aerated concrete bricks used in civil engineering. In a mechanical structure, a hole is a stress concentrator, so, we have studied the effect of the same mass distributed in a such way that the a single hole is "split" in more smaller and smaller holes in each analysis.

2. The Hollow Structure

We analyzed a bidimensional structure. This type of structure is more simple than a three dimensional one and the results are easy to reveal and interpret.

The hollow general pattern of the hollow structure is presented in Figure 1.

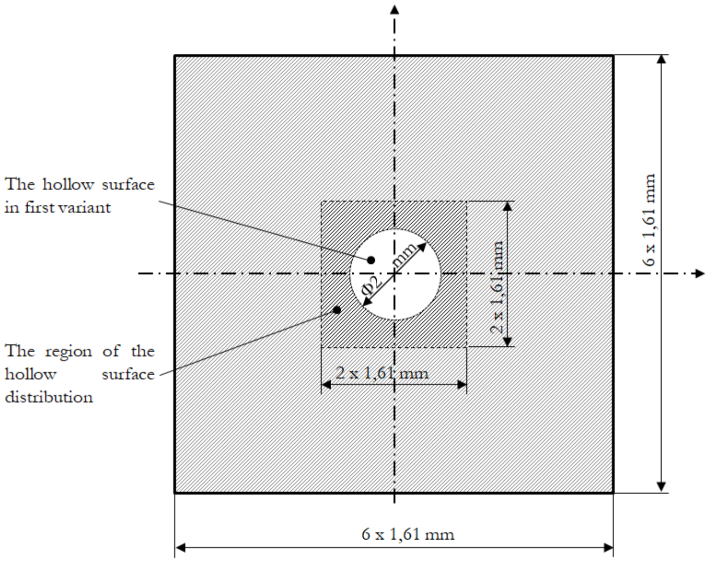


Figure 1. The General Pattern of the Hollow Structure

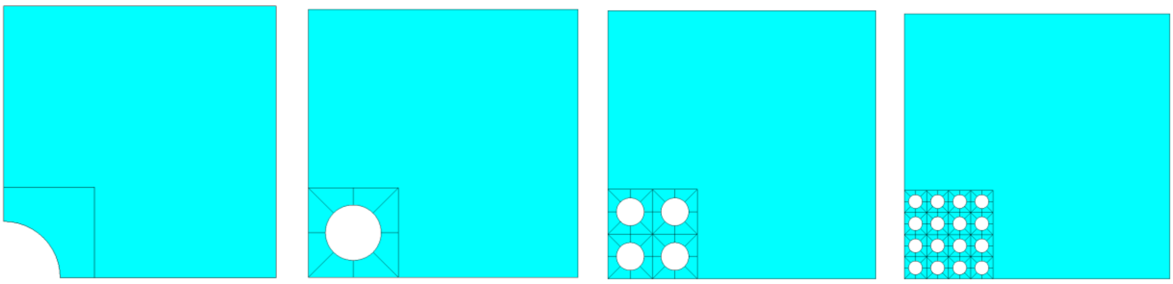
The empty surface has an area of a circular hole with the radius of 1 mm, distributed different in all four configurations. In the first one, the structure will have a single hole of a 1 mm radius – Figure 2, a. In Figure 2, b it is the second configuration with four holes with a ½ mm radius. In the third variant, the structure has 16 holes, with a radius of ¼ mm as Figure 2, c reveals. The last one considers the same initial empty area distributed in 64 holes with a radius of ¼ mm as it is Figure 2, d.

The region in which we will evenly distribute the above mentioned empty surface, is a square with 2x1.61 mm. The 1.61 ratio is the golden one [8].

The hole structure is also a square with 6x1.61 mm. The thickness is 0.1 mm.

The structure has two axis of symmetry, so we will analyze the quarter of it.

In Figure 2 we have the quarters of the four variants with hole/holes distribution.



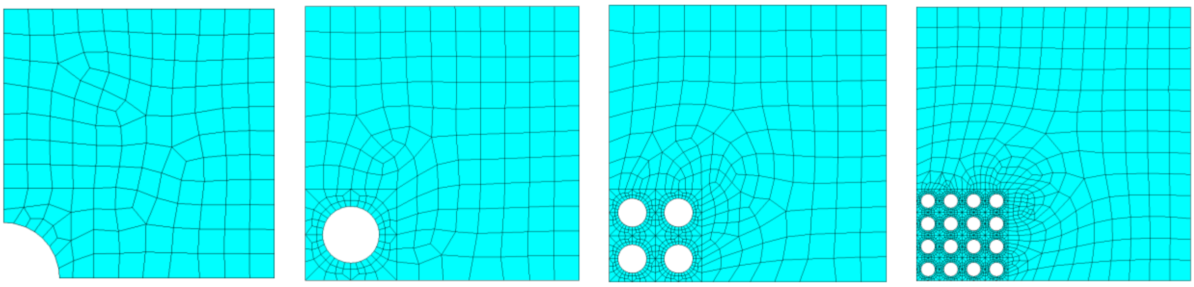
a b c d

Figure 2. The Four Variants of the Hollow Structure – Quarters

The material is OL37, with Young's modulus E=210000 MPa. The Poisson's coefficient is ν=0.3.

3. The Finite Element Model

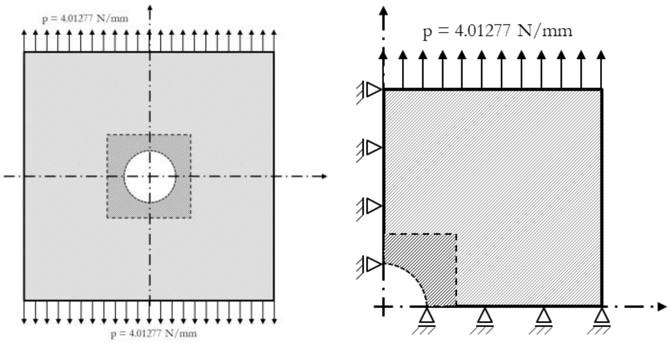
Due to symmetry around two axis, the analyzed model was a quarter of the real structure. The adopted finite elements are spatial shells, with four nodes, each with six degrees of freedom – three displacements and three rotations [9]. The mesh of all four variants is presented in Figure 3.



a b c d

Figure 3. The Finite Element Mesh of the Hollow Structure Variants

In all four cases the load was a linear distributed tensile pressure of p=4.01271 N/mm, as shown in Figure 4.



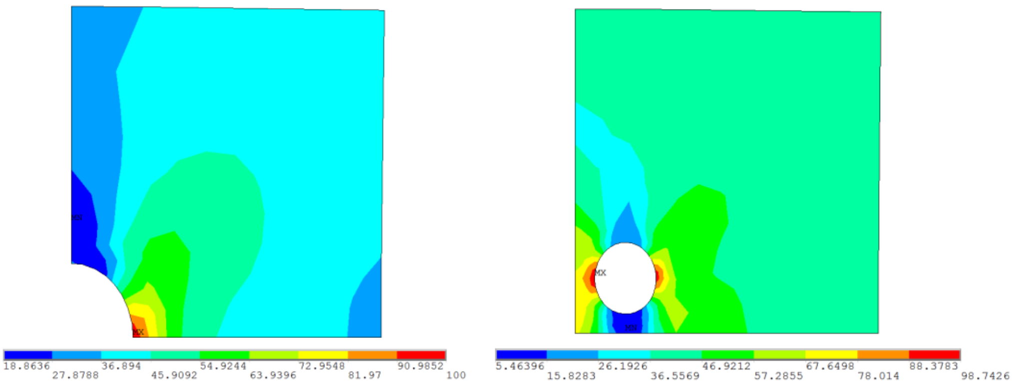
a b

Figure 4. The Load of the Hollow Structure

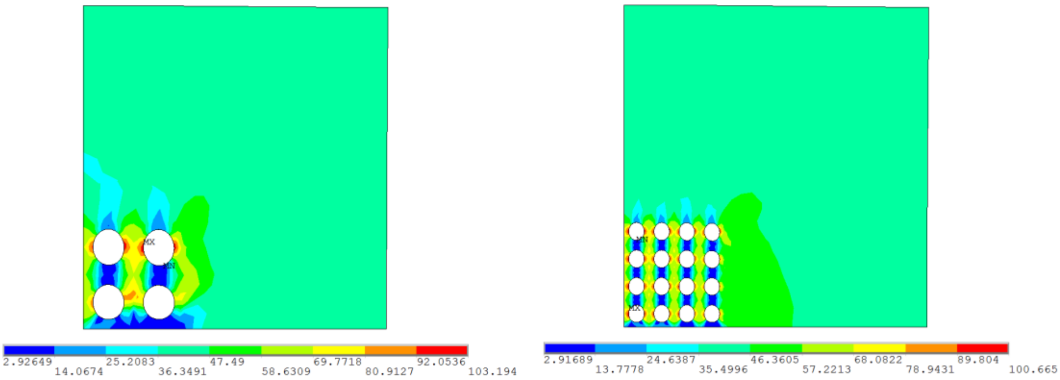
The analysis was linear static.

4. The results

The von Mises equivalent stress results are presented in Figure 5.



a b



c d

Figure 5. The equivalent von Mises Stress

The maximum values obtained are synthesized in Table 1.

Table 1. Maximum von Mises Stress for All Four Hollow Structure Variants

Variant/Hole number	a/One	b/Four	c/Sixteen	d/Sixty four
von Mises Stress [MPa]	100	98.742	103.194	100.665

5. Interpretation

After performing the analysis the next step is to interpret the maximum von Mises equivalent stress in four cases.

We will consider the first variant as the reference. Because it's maximum von Mises stress is 100 MPa, the absolute and relative deviation are the same. The deviations are presented in Table 2.

Table 2. Maximum von Mises Stress Absolute and Relative Deviations

Variant/Hole number	b/Four	c/Sixteen	d/Sixty four
von Mises Absolute and Relative Deviations [MPa], [%]	- 1.258	+ 3.194	+ 0.665

Placing the above values in a chart (Figure 6), we observe that the associated trend line oscillates around reference.

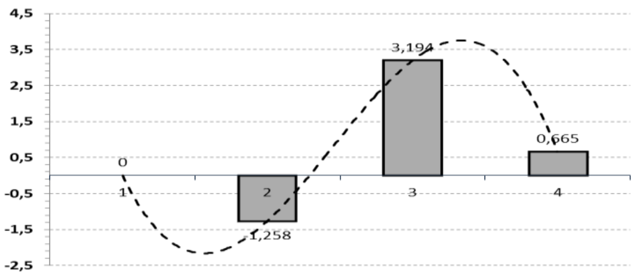


Figure 6. The Relative Deviation Trend

6. Conclusions

The assumption that distributing the material more uniform in the "hollow region" will decrease the maximum equivalent von Mises stress was not fulfil.

Considering the maximum deviation of approximately 3%, we can also conclude that the maximum equivalent von Mises stress remains on the same level.

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