EXPERIMENTAL AND NUMERICAL INVESTIGATION OF THE EFFECTS OF HOLE DIAMETER ON THE TENSILE STRENGTH OF STEEL PLATE

MEHMET ŞAHBAZ1

[1]Department of Mechanical Engineering, Karamanoğlu Mehmetbey University, Karaman, Turkey, mehmetsahbaz1@gmail.com, ORCID: 0000-0001-6379-8345

ABSTRACT

Plate materials are used in many industrial areas by drilling holes on it for different reasons (mounting, fastener like bolt or pin etc.). This situation affects the strength of the material. In this study, the effect of hole diameter on the stainless steel plate material on the tensile strength was investigated experimentally and numerically. The work pieces were prepared with a gauge length of 32 mm, a width of 18 mm and a thickness of 1.5 mm. Then they were divided into groups of three, and holes were not drilled in the first group, but holes were drilled in the centers of the others with a diameter of 4,6 and 8mm. Then, these work pieces were subjected to the tensile test at room temperature at a speed of 16mm/min (strain rate is 0.008 sec-1). The test results were determined by taking the average of each group and the results were compared within themselves. As expected, the applied tensile force and elongation decreased as the diameter increased, whereas the tensile strength was nearly the same for all cases. In this study, a correlation was obtained between the decrease in tensile force and elongation and the increase in hole diameter. In addition, tensile test simulation was performed with numerical analysis for all cases and similar results to the experiment were obtained. In the numerical analysis results, it was found that the stress concentration increased when approaching the hole from the edge, confirming the theoretical information.

Keywords: *Elongation, Stress Concentration, Tensile Strength.*

1.INTRODUCTION

In the developing industrial technologies, the use of sheet and plate materials has become widespread in many areas, and they are used where needed by being brought into different forms. During this shaping, assembly, joint, etc. Due to the reasons, holes of different diameters are drilled on the materials. These applications on the material cause stress concentration in that area of the material and affect the strength of the material. In order to prevent the negative consequences of this situation, different studies have been carried out for materials exposed to different situations. Some of these will be briefly summarized below.

Erim and Uyaner investigated the stress distributions and stress concentration coefficients in a simple beam with a circular hole under the effect of constant bending moment. In this study, a beam with a circular hole on its transverse axis was investigated by the Finite Element Method under the effect of simple bending. The hole is displaced along the aforementioned axis and both isotropic (steel) and orthotropic (Graphite-Epoxy) materials are used for the beam [1].

Çelik et al. on the other hand, the stress concentrations in the welding of different metals (iron and steel) were investigated in their study [2].

Bulut examined the thermal stresses around a hole in the composite (including steel and stainless steel) materials used in the reactor body. He supported his work with finite element analysis and analytical methods [3].

Çelik and Turan investigated the damage behavior of notched composite plates in their research. Eight layers of glass fiber braided and epoxy resin filled composite sheets were used as materials. They examined the effect of notches and holes drilled on the edges and middle of the plate on the tensile strength [4].

In this study, three different diameter holes were drilled on the stainless steel plates and tensile tests were performed for four different situations, one without holes, and the effects of hole diameter on stress, strain and displacement were investigated. In addition, the study was supported by finite element analysis (FEA).

2. MATERIAL AND METHODS

The work pieces were formed from steel plates with a length of 70 mm and a width of 18 mm, 1.5 mm thick. Four groups of three work pieces were formed, the first group was left unperforated, and the others were drilled with 4mm, 6mm, 8mm diameter holes. Some of these samples are shown in the figure below (Fig.1). Then, a tensile test was applied to all these work pieces with a gauge length of 32mm. In addition, the stresses in the material were determined by finite element analysis and the results were compared with the experimental. The results obtained are given both visually and graphically in the results section.

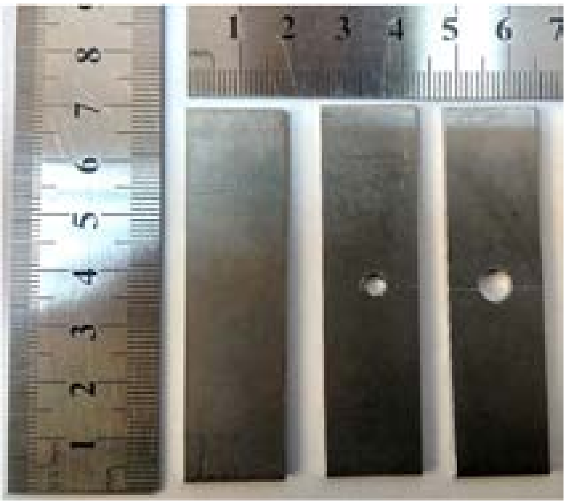

Figure1. Energy harvesting system

3. RESULTS AND DISCUSSION

Three tensile tests were repeated for each case, and the resulting Force-Displacement and Stress-Strain graphs are given below. As seen in Figure 2, the applied Force, and Displacement decreased as the hole diameter increased. Figure 3 shows the stress-strain graphs obtained from the tensile tests. As can be seen from this graph, there was a proportional decrease in the area and force with the increase in the hole diameter, and the tensile strength was not affected much by this situation. However, the strain value was negatively affected by this situation and showed a decrease similar to the Displacement.

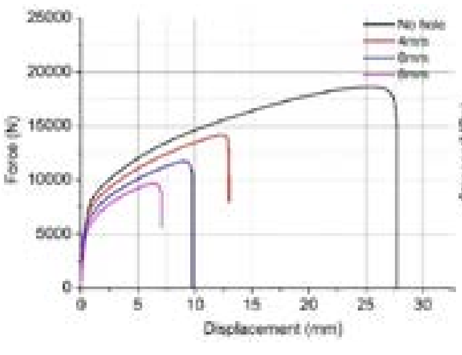

Figure 2. Force-Displacement tensile graphs

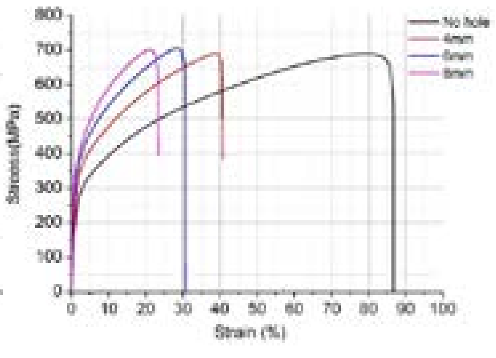

Figure 3. Stress- Strain tensile graphs

Table 1. Force-Displacement and Stress-Strain values

	Force (N)	Displace-ment (mm)	Stress (MPa)	Strain (%)
No hole	18627	27,75	688,7	86,7
4 mm	14188	12,93	689,4	40,4
6 mm	11764	9,79	705,1	30,6
8 mm	9680	7,04	700,7	23,4

In the figure below (Fig. 4), displacement, strain and force curves are given for the having hole work pieces and it is observed that they show an almost linear behavior. This showed that there is a linear relationship between the hole diameter and these values.

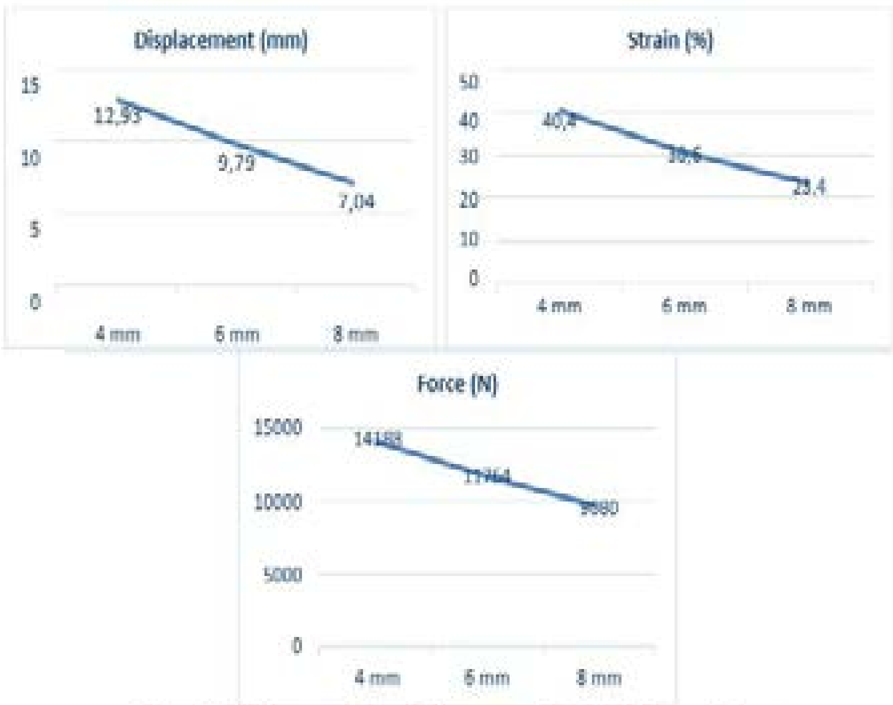

Figure 4. Displacement, Strain and Force curves for having hole work pieces

In Figure 5, there are examinations of the images of a perforated plate after it has been subjected to the tensile test. In Figure 5a, the elliptical structure of the hole on the work piece after drawing and the tears on its edges can be seen. In Figure 5b, the deformation at the edge of the hole is seen more closely, while in Figure 5d this situation is shown in 3D. In Figure 5c, the stress concentration formed around the hole after the finite element analysis (FEA) is seen and it is similar in shape to the experimental one. In addition, it has been shown both experimentally and numerically that the first tear is at the edges where the stress is most intense.

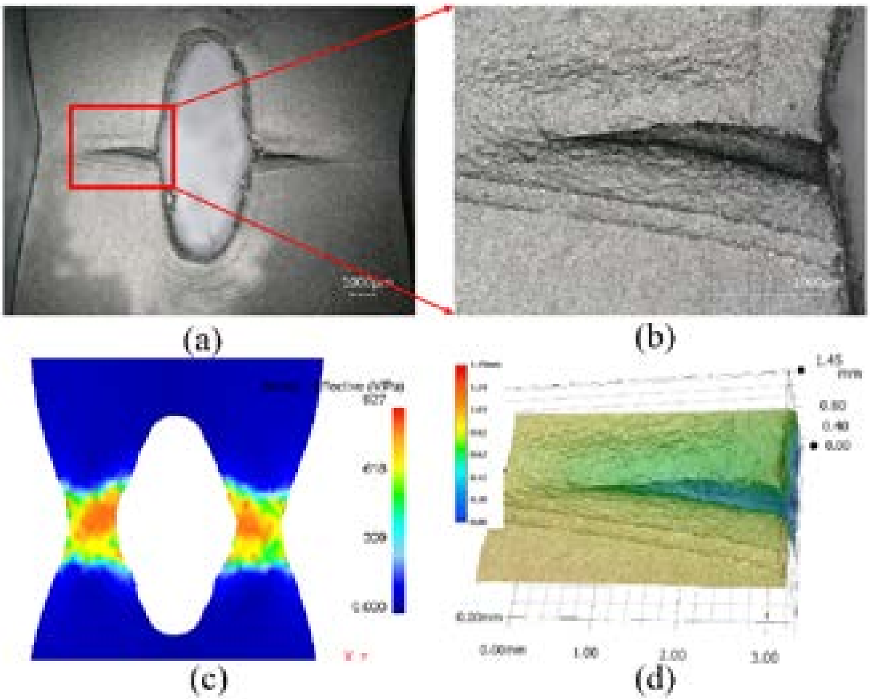

Figure 5. (a) Having hole plate with tensile test, **(b)** close-up view of deformation, **(c)** FEA results of stress concentration view, **(d)** 3D view of deformation

4. CONCLUSION

In this study, the effect of hole diameter on the steel plate on the tensile strength of the material was investigated by experimental and numerical methods. It has been observed that there is a proportional decrease in displacement, strain and force values with the increase of hole diameter and this situation is shown graphically. In addition, with the finite element analysis performed, the stress concentration due to the tensile force in the material was observed and it was observed that the deformation occurred in this region.

REFERENCES

[1] S. Erim and M. Uyaner, "Stress distributions and stress concentration factors in a simple beam with a circular hole subjected to constant bending moment," *Model. Meas. Control B*, vol. 67, no. 1, pp. 65–78, 1999.

[2] A. Çelik, A. Özel, and S. Karadeniz, "Farklı metallerin kaynağında gerilme yığılmalarının incelenmesi,"*Pamukkale* Üniversitesi *Mühendislik Bilim. Derg.*, vol. 2, no. 1, pp. 55–60, 1996.

[3] O. Bulut, "The thermal stress analysis around the cavities in composite plates used for the body of reactors,"*J. Fac. Eng. Archit. Gazi Univ.*, vol. 34, no. 2, pp. 1077–1086, 2019, doi: 10.17341/gazimmfd.460504.

[4] A. ÇELİK and K. TURAN, "Çentikli kompozit levhaların hasar davranışlarının incelenmesi," *Dicle* Üniversitesi *Mühendislik Fakültesi Mühendislik Derg.*, vol. 6, no. 2, pp. 73–82, Dec. 2015, Accessed: Oct. 05, 2021. [Online]. Available: https://dergipark.org.tr/en/pub/dumf/312812.