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APPLICATION OF TENSION CONCENTRATORS FOR STRESS RELIEF

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Abstract. *The technological advance in the mechanical industry gives rise to the need for increasingly precise and reliable techniques in the manufacture of components. It is essential for the engineer to know the mechanical properties of the materials that will be used. In the study, the objective is to make an analysis of the behavior of the material on traction, being the material a steel plate of square cross section, evaluating its behavior from the presence of tension concentrators. Three different plate configurations were evaluated, one without hole, one with a hole in the center and the last configuration with a hole in the center and holes in the sides of the central hole. The side holes were applied in order to relieve the tension of the central hole. Based on the results obtained and the evaluation performed, it was possible to notice the influence of the application of these side holes to relieve the tension concentration of the central hole. There was an increase in the resistance and rupture limits after the lateral holes were applied.*

Keywords: *Tension suppressors, Tension concentrators*

1. INTRODUCTION

Technological advancement is constantly improving the processes and techniques used in the manufacture of mechanical components. Despite these enhancements, some of these components still require elements like holes, notches, and so on. These components act negatively on the project by concentrating the tension in specific places. During the use of components that are subject to the application of forces it is possible to occur faults that can cause economic losses and risk the integrity of the operators. The need to increase equipment safety and resistance has increasingly required the development of techniques that alleviate this concentration at specific points. One way to explain the occurrence of the tension concentration problem is through the concept of power lines, which is presented by YOUNG (2002, apud FRANQUETTO, 2007, p.25), which can be used for the qualitative determination of the possible points of tension. For a component subject to a given load and that is in equilibrium, it can be said that all the stresses that are applied in one region of the component, pass through other regions, the component being the path through which the lines of force pass. Fig. 1 shows the appearance of power lines through some components subjected to tension and bending.

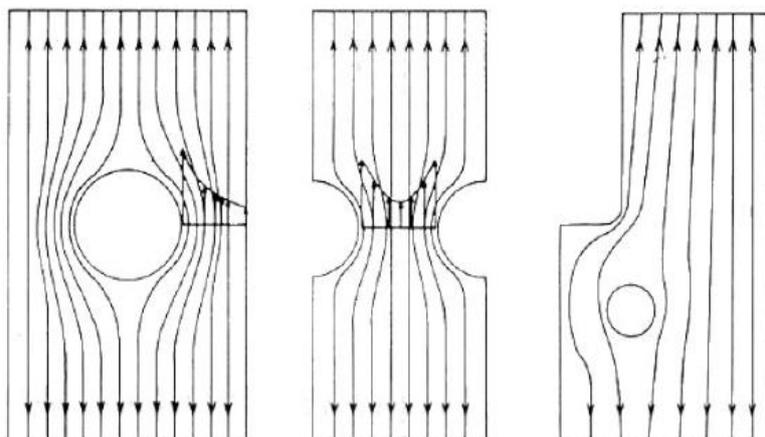


Figure 1: Power lines in components under tension

2. FRACTURE AND TENSION

The failure of materials applied in engineering is an undesirable event, as, besides jeopardizing human life and safety, it can lead to loss of materials among other reasons. In this way the study of the possibilities of the occurrence of failures becomes quite important so that they are understood and thus avoided.

According to Dieter (1981), fracture is the separation in two or more parts of a solid body, under the action of a tension, where this process is constituted in two parts, beginning of crack and propagation of the crack.

Dieter (1981) states that in engineering we can divide fracture types into two: ductile fracture and fragile fracture. Callister (2002) states that the classification of the fracture type is based on the ability of the material to undergo plastic deformation.

One of the main concepts in the study of the mechanics of solids is the concept of tension.

Norton (2013) states that tension can be defined as the force per unit area with units in psi or MPa.

Norton (2013) states that a body subjected to some forces will have tension generally distributed according to a continuously variable function within a continuous portion of the material. Every infinitesimal element of the material can conceivably experience different stresses at the same time, thus, it becomes necessary to analyze the stresses acting on extremely small elements within the body.

The equations used in the design of mechanical components are usually formulated from the hypothesis that it has its constant cross-sectional area, but the cross-sectional area can be altered with the presence of notches, holes, among other elements. According to Norton (2013) any of these changes in geometry will cause localized tension concentrations and states that these geometric changes are called stress concentrators.

Shigley (2005) states that any discontinuity in a part of a machine alters the stress distribution in the circumference, so that the elementary stress equations no longer describe the state of tension of the part at those locations. These discontinuities are referred to as tension concentrators, and the regions in which they occur are known as areas of tension concentration.

Norton (2013) considers that tension concentrators should be avoided or at least minimized as much as possible in designing a project. Unfortunately it is not practical to eliminate all tension concentrators since they are required for coupling as well as provide functional shapes to the parts.

Through the observation of Fig. 1 it is possible to obtain a better understanding of the effect of tension concentration, as it is shown in the same that the tension trajectories are uniform in all places, except in the vicinity of the voltage concentrator; in him, however, these lines of force have to bend to turn around. Voltage concentration is a highly localized effect.

One way to explain the occurrence of the tension concentration problem is through the concept of power lines, which is presented by YOUNG (2002, apud FRANQUETTO, 2007, p.25), which can be used for the qualitative determination of possible points of stress concentration of a component. For a part subjected to a given load and in equilibrium, it can be said that all the tension that are applied in one region are withdrawn by another region, through which the lines of force pass.

Franchetto (2007) states that these lines can be approximated by stretched wires, indicating the trajectory of the force through the component, from its entry to the exit. Finally, it can be said that in points where the lines of force are closer to the tension in that place will be greater when compared to regions where the lines are parallel, generating regions of occurrence of tension concentration.

The presence of tension concentrators in designs is almost always inevitable, but there are several ways to reduce the concentration of tension.

According to Franchetto (2007) one of the ways of reducing the tension concentration factor is the addition of relief elements around the tension concentrator as shown in Fig. 2, where the hatched holes are holes for tension relief.

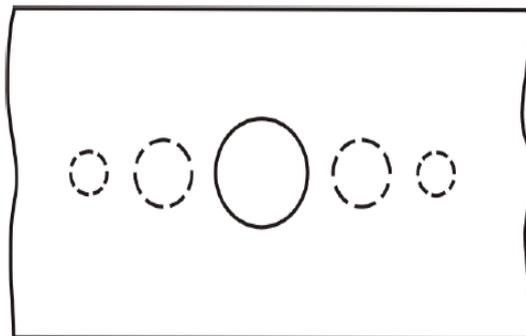


Figure 2: Holes for tension relief.

2.1 Traction test

According to Callister (2002) the traction test basically consists of deforming a sample, generally until its fracture, by an upward traction load that is applied uniaxially along the longest axis of the specimen (specimen).

Norton (2013) states that during the traction test the test specimen is slowly extended in traction until it breaks, while the force and the distance between the marks of the measurement length are continuously monitored. The result is the tension-deformation diagram of the behavior of the material under tension.

After a test specimen is subjected to a traction test, the test machine provides a graph showing the relationship between the force applied and the deformations occurring during the test.

Through the use of this graph it is possible to determine the mechanical properties of the material. It is also important to note that this graph takes into account engineering stress and deformation, considering the fact that it does not relate the reduction of area in the region of the peeling.

2.2 Experimental procedure

Initially, specimens were fabricated from a 3 meter long, 1/8 "thick and 1 1/2" wide bored bar that was cut into several pieces of 200 mm each. At the end of the cut-off phase, holes were drilled in some specimens in order to obtain the configurations and quantities specified in Table 1. It is possible to observe in Fig. 3 the finished samples.

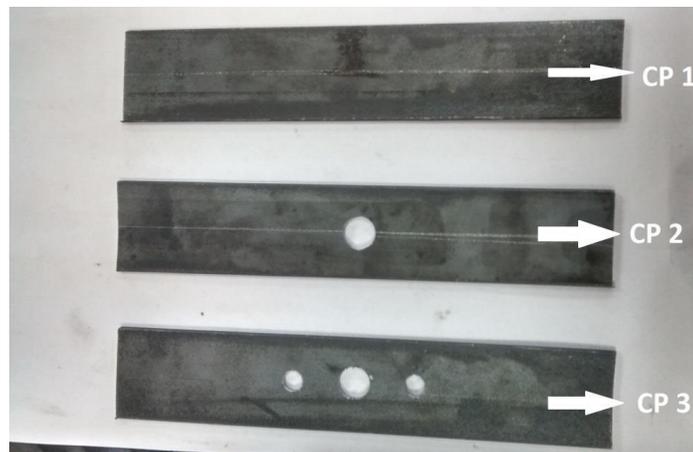


Figure 3. Completed test bodies.

In Fig. 4 it is possible to observe the dimensions of the specimens in millimeters.

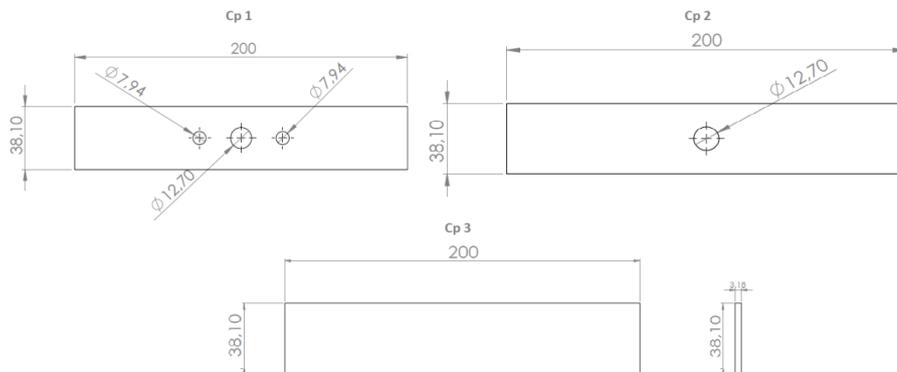


Figure 4. Design of test pieces.

Table 1. Dimensions of the holes of the test pieces used in the test.

Cp's	Diameter of central hole (mm)	Diameter of side holes (mm)	Amount
Type 1	-	-	3
Type 2	12.7	-	3
Type 3	12.7	7.935	3
Total			9

At the end of the Drilling stage, the test specimens were submitted to the tensile test to determine the rupture limits of each test specimen.

The tensile tests were performed in the UFERSA mechanical test laboratory.

All the bodies were properly adjusted in the test machine and tested until their fracture. It is possible to observe one of the fitted bodies in the machine claws and the fractured specimen, respectively, in Figures 5 and 6.



Figure 5. Test bodies set in test machine claws.



Figure 6. Test bodies after fracture.

With the help of the TESC software, the data on the test specimen and the parameters for performing the test were provided to the system, obtaining the data with the results that will be analyzed next. It was also used EXCEL (spreadsheet), where it was possible to plot some graphs that will also be discussed. In Table 2 it is possible to observe the parameters of the test.

Table 2. Test parameters.

Useful length (mm)	100
Deformation rate (mm / mm.s)	10^{-3}
Speed (mm / s)	0.05
Characterization of the area	Rectangular area
Strength limit	100 KN
Chart plotted	Tension x Deformation
End of test	Rupture of the body of evidence

2.3 Results

The tension x deformation diagrams obtained for the test specimens without tension concentrator can be observed in Fig. 7.

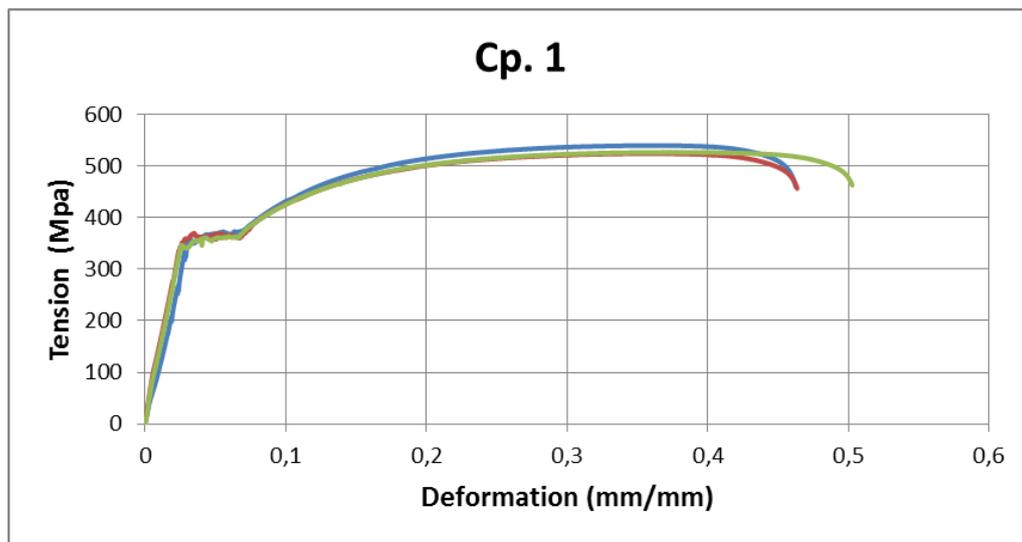


Figure 7. Diagram tension x deformation for the test pieces without holes.

Through the analysis of Fig. 7 it was possible to obtain the properties that can be observed in Table 3.

Table 3. Flow limits and tensile strength of non-drilled specimens.

Cp's	Flow limit (Mpa)	Limit of tensile strength (Mpa)
1.1	345,52	539,68
1.2	349,54	523,62
1.3	343,12	526,63
Average	346,06	529,98
Standard deviation	3,24	8,53

The tension x deformation diagrams obtained for specimens with a 12.7 mm diameter through hole can be observed in Fig. 8.

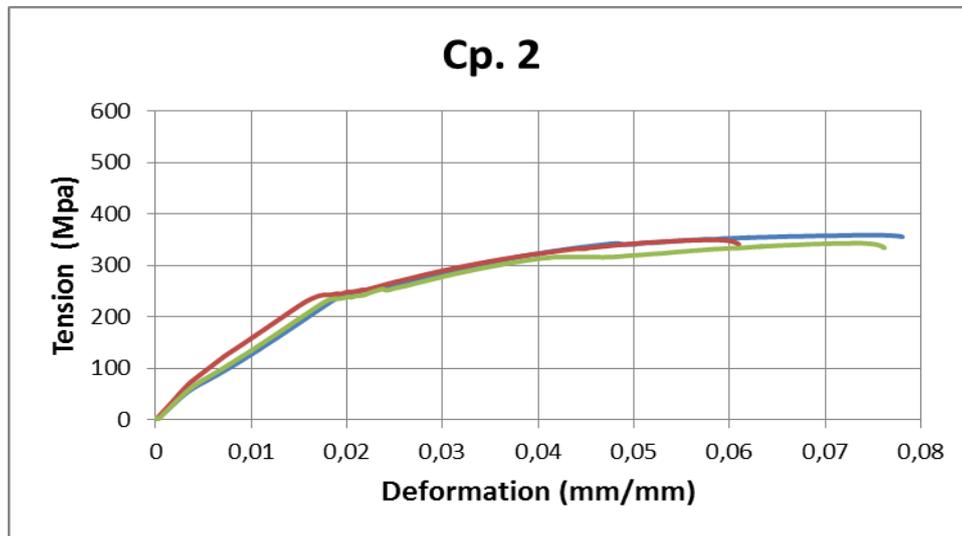


Figure 8. Diagram tension x deformation for the test pieces specimens with a 12.7 mm diameter through hole.

Through the analysis of Fig. 8 it was possible to obtain the properties that can be observed in Table 4.

Table 4. Flow limits and tensile strength obtained for specimens with a 12.7 mm diameter through hole.

Cp's	Flow limit (Mpa)	Limit of tensile strength (Mpa)
2.1	243,93	349,40
2.2	238,61	342,88
2.3	251,92	358,88
Average	244,82	350,39
Standard deviation	6,69	8,04

The tension x deformation diagrams obtained for specimens with a 12.7 mm diameter through hole and side holes of 7.935 mm in diameter can be observed in Fig. 9.

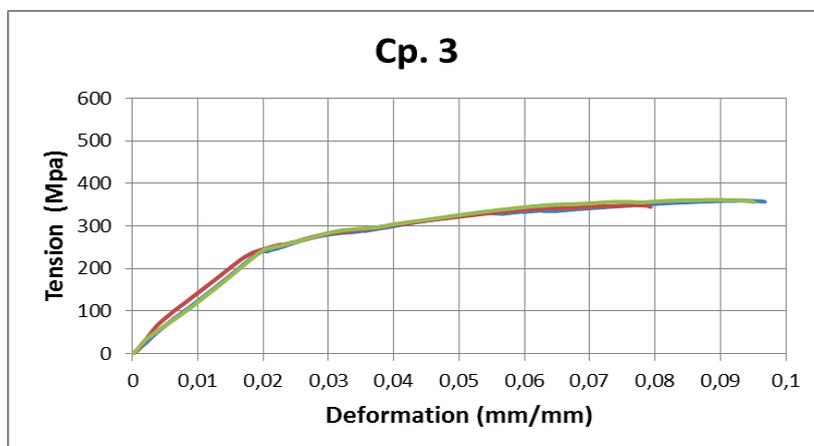


Figure 9. Diagram tension x deformation for the test pieces specimens with a 12.7 mm diameter through hole and side holes of 7.935 mm in diameter.

Through the analysis of Fig. 9 it was possible to obtain the properties that can be observed in Table 4.

Table 5. Flow limits and tensile strength obtained for specimens with a 12.7 mm diameter through hole and side holes of 7.935 mm in diameter.

Cp's	Flow limit (Mpa)	Limit of tensile strength (Mpa)
3.1	250,55	359,65
3.2	252,07	349,16
3.3	256,46	361,51
Average	253,03	356,78
Standard deviation	3,06	6,65

In Fig. 10 it is possible to observe a comparison between the three different types of specimens.

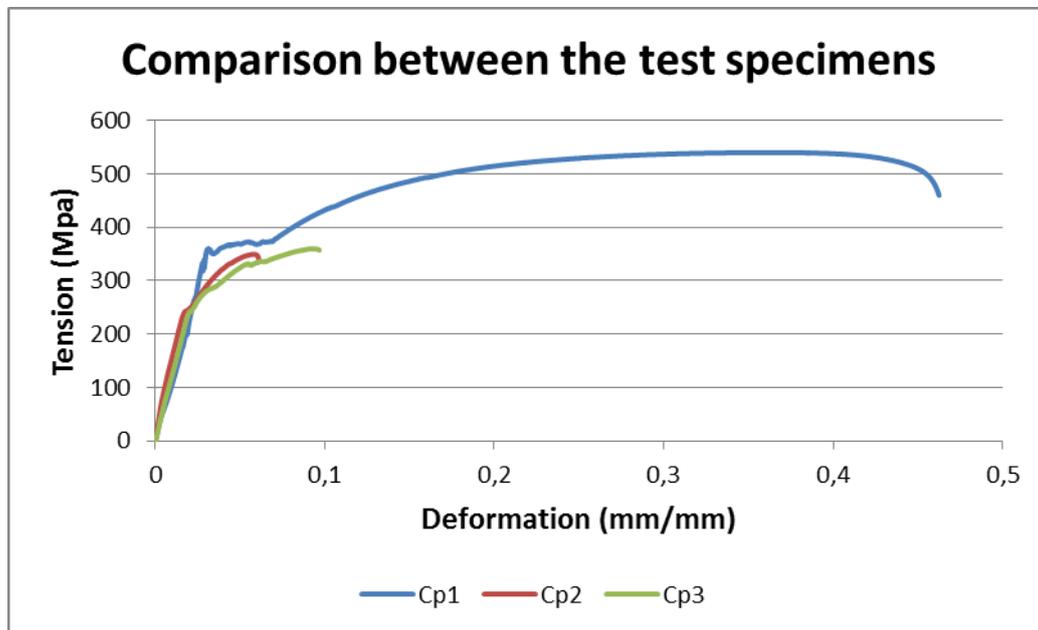


Figure 10. Comparison between the test specimens.

The mean values of the properties of the test specimens are contained in Table 6. In Fig. 11 a better observation is possible between the average values of the tensions.

Table 6. Average values of properties obtained.

Cp's	Flow limit (Mpa)	Limit of tensile strength (Mpa)
Cp. 1	346,06	529,98
Cp. 2	244,82	350,39
Cp. 3	253,03	356,78

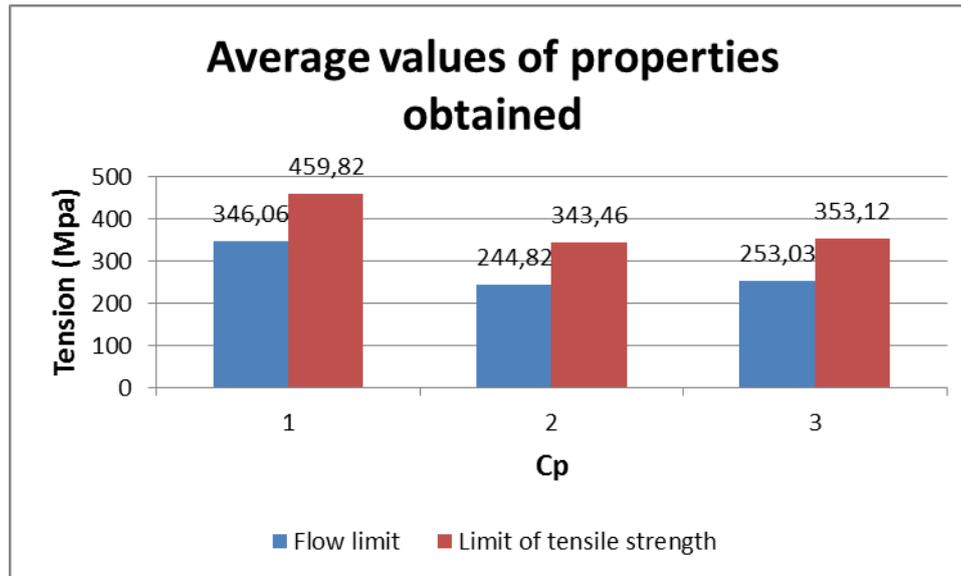


Figure 11. Average values of tensions.

Through the analysis of the mean values obtained with the tests, it was possible to observe:

- Reduction of the flow limit of the test piece without a hole for a test piece with a central through hole was 29.25%.
- The reduction of the flow limit of the test piece without a hole for a test piece with a central through hole and holes at the side of the central hole was 26.88%.
- The reduction of the tensile strength limit of the test piece without a hole to the central through-hole test piece was 33.8%.
- The reduction of the tensile strength limit of the test piece without a hole for the test piece of central through hole and side holes to the central hole was 32.6%.

3. CONCLUSIONS

By analyzing the tension and deformation graphs of the test specimens, it was possible to observe that, as expected, the test specimens with tension concentrators ruptured with a lower voltage than the test specimens without voltage concentrators, showing that when decreasing the area of the body of evidence when introducing the holes, the material reduces its plastic zone, because they were on higher tension values, breaking earlier and without much deformation of the body of evidence.

For the case where lateral holes were used to try to alleviate the tension concentration, it was found that the form of relief adopted possibly softened the power lines in the central hole, having an increase of 3, 35% of the flow limit value and 1.79% of the value of the tensile strength limit of the test piece with central bore thus improving the strength of the specimen.

An important aspect to be commented on is the cost of manufacturing the optimized parts, because as these need extra operations for the addition of tension relief holes in an assembly line can make the parts relatively more expensive, thus fitting the designer define the case that best suits your needs.

Considering the experimental conditions used in this work, the results obtained were in agreement with the expected one, being able to conclude the main objective of the work, which was to evaluate the application of holes (voltage concentrators) to relieve tension in an already existing concentrator (central hole).

4. REFERENCES

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