

# **Comparison of the Concentration Factor of Stresses on Flat Sheets with Two Holes with Low and High Speed Voltage Test**

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## **Abstract**

The research seeks to determine whether the stress concentration factor for flat plates with two stressed holes varies according to the application speed of the load. The research was developed using the experimental method, with two types of tests, one called low-speed load application and the other called high-speed load application. The behaviour of the theoretical stress concentration factor  $K_t$  has been studied on long flat plates with two holes under tension and made of isotropic material, with axial direction for the application of the vertical load. Different values were taken from the centre distance of the holes and it was found that the value of the stress concentrator  $K_t$ ; for the two tests always tends to values greater than 3.8. A comparison was made between the results obtained and it was determined that there is variation between the values of the  $K_t$  factor according to the speed with which the load of the voltage test is applied, with the highest being the  $K_t$  with high speed test.

**Keywords:** Stress concentrator, Strain gauges, Low speed load, High speed loading

## 1 Introduction

Material mechanics is a branch of applied mechanics that deals with the behaviour of solid bodies and has as its main objective to determine the stresses, deformations and displacements in mechanical elements when they are subjected to different types of loads. In order to determine the stresses and deformations it is necessary to know the physical properties of the materials as well as the laws and theoretical concepts that describe the conditions in which a given element is found. [1]. Among the main physical properties used in material mechanics is the stiffness module, and the Poisson ratio  $\nu$  [2]. Theoretical analysis and experimental studies play equally important roles in material mechanics. It is through these studies that formulas and equations are obtained to predict mechanical behavior, but it is not possible to use these formulas and equations unless the physical properties of the materials are known.

When designing a mechanical element, in addition to defining the mechanical properties of the material, it is important to make a correct geometric sizing; it is at this stage of the design when the conditions that determine the distribution of forces are defined. The concept of the stress concentrator is then introduced as any geometrical change that presents a part or mechanical element, be it a slot, a change of section, a hole, a threading, etc.

This paper presents the research done to obtain the value of the  $K_t$  stress concentrator for long plates with two holes using strain gauges; this value is obtained by means of the  $C/r$  relation, where  $C$  is the distance between centers and  $r$  is the radius of the holes.

## 2 Description

The research was developed using rectangular carbon steel plates, this method is valid for any material with isotropic characteristics, because theoretically the value of  $K_t$  is only influenced by the geometric characteristics of the plate and not by the properties of the material. [3]. Several plates subjected to the action of uniaxial tensile loads were brought to the laboratory, generating nominal stresses below the elastic limit of the material. The length and width of the plates have been taken sufficiently large in relation to the holes to ensure that variations in stress occur only in the vicinity of the holes and not in the vicinity of the material; under these conditions the geometry of an infinite plate is guaranteed, Figure 1.

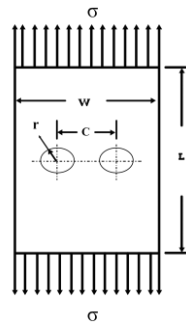


Figure 1. Illustration of the plates used for the test

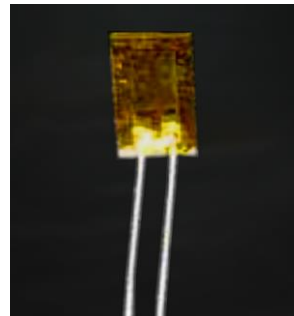


Figure 2. Strain gauge

One of the conditions that must be taken care of for the comparison of the results obtained in the low speed load application test and the high speed test is the machining that is done to the sheet in its preparation, since it is known that the machining processes can cause changes in the properties of the material and although they may be slight, they compensate the resistance of the material giving a small degree of uncertainty. [4].

Any discontinuity in a mechanical element alters the distribution of stress at the limits of the discontinuity so that the basic equations of stress calculation no longer describe the state of stress in the element. These discontinuities are called effort intensifiers, and the regions where they occur are called areas of concentration of effort. [5]. However, the ratio of the maximum value of the actual stress to the nominal value of the stress in the section of the area supporting the load is known as the stress concentration factor  $K_t$ . In this case, for flat plates with holes, the ratio is made between the maximum stress at the edge of the holes and the nominal stress of the plate without hole or remote stress.

Strain gauges, such as the one shown in Figure 2, are resistance strain gauges. This principle is based on the fact that metal and semiconductor materials undergo a change in their electrical resistance when they undergo a deformation. [6]. Resistance is related to the cross-sectional area, length and resistivity of the conductor.

The photo in Figure 2 is an actual picture of the gauge used in the experiment and has the properties described in Table 1.

## 2.1 Preparation of the sample

The test has been performed in accordance with ASTM A37, for structural steel sheets. For this purpose, a total of 50 standardized sheets have been machined as shown in Figure 3. Smooth steel sheets with a standardized dimension of 50 cm x 7 cm x 0.498 cm have been used. The Universal Tension Testing Machine was used for the test.

The test consists of a stress test to determine the stress concentrator  $K_t$  of the plates using a strain gauge in the centre of the specimen and in the centre of the two holes. This installation of the strain gauges is shown in Figure 4. When the

strain gauges are not well oriented on the sheet,  $K_t$  values are obtained, but these do not have a fixed value tendency, but vary as the experimental test progresses; therefore, the installation of the strain gauges and their orientation in a longitudinal way is very important for this test.

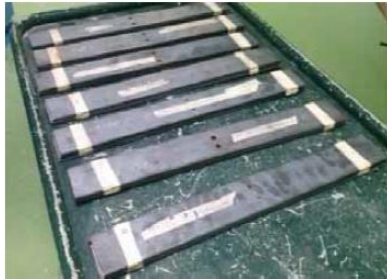


Figure 3. Slides with two holes



Figure 4. Gauges in the center of the holes

The cleaning of the plates and the installation of the gauges have been carried out in accordance with the guidelines and technical specifications given by the gauge supplier. The material must be properly prepared to create a clean surface, free from physical imperfections and chemically treated and appropriate [7] [8]. Table 1 presents the characteristics of the strain gauges used in this project.

Table 1. Properties of the strain gauge

Property	Quantity
strain gauge factor	2.14
Resistance	350 Ohm
reference	SGD-3/350-L Y 11

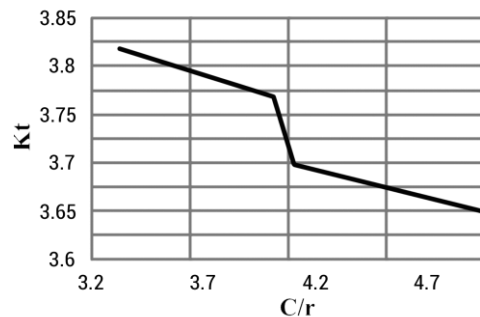
### 3 Results

Fifty (50) strain gauges corresponding to fifty (50) test specimens have been taken for the experimental study. It began by taking 25 specimens that have been loaded at a rate of 2 MPa/s, this test is called a low speed load test; posteriormente se repitió el proceso con las probetas restantes a las cuales se le ha aplicado carga a una velocidad de 6 MPa/s. The process was then repeated with the remaining specimens loaded at a rate of 6 MPa/s, is to say 3 times faster than the previous test and this test is called a high speed load test. Table 2 shows four specimens with the highest repetition of results from the total of 25 specimens used in the low velocity test. This table 2 shows the ratio  $C/r$  and the approximate value of the stress concentrator  $K_t$ , where  $C$  is the distance between the centres of the holes in the plates and  $r$  the radius of the holes.

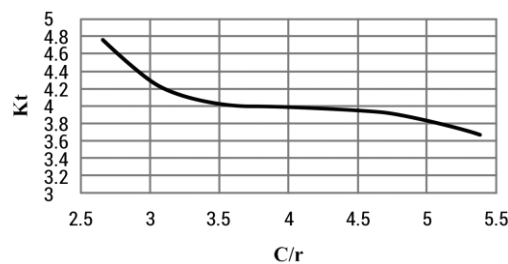
Table 2. Ratio  $C/r$  vs  $K_t$  in Low Load Speed Test

$C$ (mm)	$r$ (mm)	$K_t$	$C/r$
18,3	5,5	3,82	3,32
29	7,22	3,77	4,02
29,15	5,85	3,65	4,98
24,7	6	3,7	4,11

Figure 5 shows the results obtained in the low-speed test and the trend of the ratio of these results of the  $K_t$  stress concentrator to  $C/r$ .

Figure 5.  $K_t$  vs  $C/r$  values with low velocity test at 2 MPa/s

From experimentation, Figure 6 is also obtained, as mentioned previously, has been carried out by applying a high-speed load of 6 MPa/s. Figure 6 shows the  $K_t$  vs  $C/r$  stress concentrator values of the high-speed test at 6 MPa/s. Figure 7 shows one of the eight numerical simulations that have been carried out according to the test in study indicated in Table 2 and Table 3, this in order to corroborate the experimental results of each test of the Universal Machine.

Figure 6.  $K_t$  vs  $C/r$  values with high velocity test at 6 MPa/s

From here we can see how the stress concentrator trend is greater than the value of the low speed test; we can also see that in a range of  $C/r$  values that varies between 3.5 and 4.5 we obtain a value close to the  $K_t$  equal to 3.8, which has been the final trend value of the low speed test.

Table 3 shows four specimens with the highest repetition of results from the total of 25 specimens used in the high-speed test.

Table 3. Ratio C/r vs Kt in high speed load test

C (mm)	r (mm)	Kt	C/r
15,5	5,85	4,75	2,65
32,8	3,75	4,09	3,28
29	6,3	3,93	4,65
18,9	2,5	3,67	5,4

The comparison of the two Figures and their behavior and their influence of the load application rate on the results of the stress concentrators is shown in this document below.

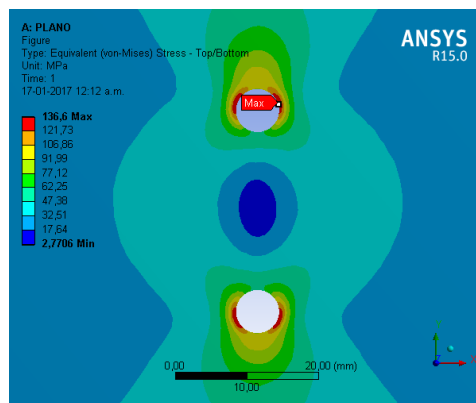


Figure 7. Numerical simulation of the sheets with two holes

#### 4. Comparison of results

When comparing the stress concentration factor Kt in flat sheets with two tensioned holes when applying load at low speed of 2 MPa/s and at high speed of 6 MPa/s, as shown in Figure 5 and Figure 6, if the two figures overlap, it becomes evident that the so-called high-speed test obtains higher Kt values compared to the so-called low-speed test, see Figure 8.

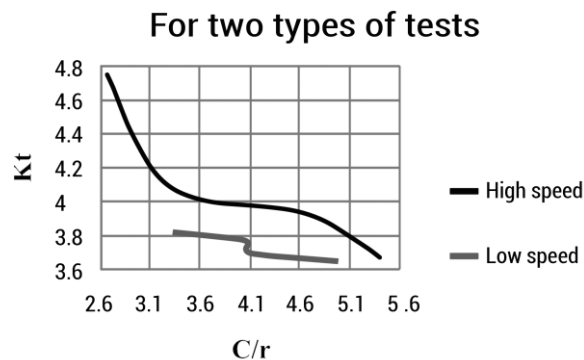


Figure 8. Comparison of Kt vs C/r values with low and high speed test

## 5 Conclusions

For tests where the load is applied at high speed, it is likely that the high speed in the test will overcome the energy possibly accumulated during the machining of the part and this phenomenon will occur, it is recommended to study further the phenomenon of why the stress concentrators vary in relation to the speed of application of the load.

From the previous study and as shown in Figure 5, the stress concentrator factor  $K_t$  tends to the value of 3.8 in low velocity tests with a value of 2 MPa/s.

When the sheet is subjected to high velocity loading, the  $K_t$  factor shows increases with a greater tendency 3.8 this is observed in Figure 6. The  $K_t$  value for the high velocity test tends to be greater than 4.8 as  $C/r$  tends to 6

**Acknowledgements.** Materials Resistance Laboratory of the University Francisco de Paula Santander. Colombia

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