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Hole in the plate under tension using Finite element analysis

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ABSTRACT

In this work described the results of a nonlinear static mode within **ELEXFEN**..A rectangular plate with a hole have initiate extensive practical a application in deferent file of engineering such as aerospace marine, automobile and mechanical and is well-known to most Engineer to predict the stress distribution an the stress concentration factor in a rectangular plate with a hole cut from the centre, subjected to a tensile loading along the ends Instructions are given on how to create a 2D model of the plate, apply constraints and a tensile loading.to predict the stress distribution and the stress concentration factor in a rectangular plate with a hole cut from the centre, subjected to a tensile loading along the ends . Instructions are given on how to create a 2D model of the plate, apply constraints and a tensile loading.

of circular holes. For the design of plate with a hole, proper knowledge of stresses and stress concentration factor (SCF) at the edge of hole under in plane loading are essential. In this project an attempt is made to review the investigations that have been made on the "stress analysis of a rectangular plate with circular hole ."

Finite Element simulations using Annoys have been done for stress analysis around the circular hole, made up of different materials. The materials considered are composite material i.e carbon / epoxy and also with mild.

1 Introduction

The objective here is to calculate stress concentration around a circular hole in the composite plate under longitudinal tensile load. The increasing use of composite materials in the design of structural parts with high mechanical performance requires a better understanding and modeling the behavior of these structures. Holes in composites will create stress or strain concentrations and hence will reduce the mechanical properties [1]. A ESPI technique has been used to study the strain concentration.[2] This paper illustrates how to set up a model within ELFEN to predict the stress distribution and the stress concentration factor in a rectangular plate with a hole cut from the centre, subjected to a tensile loading along the ends Instructions are given on how to create a 2D model .

2- Work definition

The work undertaken in this paper is a stress analysis of a finite rectangular plate which has a circular hole cut from the centre, as depicted in Figure 1. The plate is subjected to a uniform tensile load of 1N/mm at the ends of the plate which results in a stress concentration in the region of the hole.

The objective is to predict the stresses in the plate and the stress concentration factor, which is defined as the ratio of the stress in the region of the hole to the nominal stress in the plate.

As the geometry and loading of the plate is symmetrical about its longitudinal axis we can reduce the problem by considering a quarter of the plate[3] and placing suitable constraints along the continuous boundaries (Figure 2). A uniform tensile loading will be applied to the edge BC.

pTensile force of 1N/mm

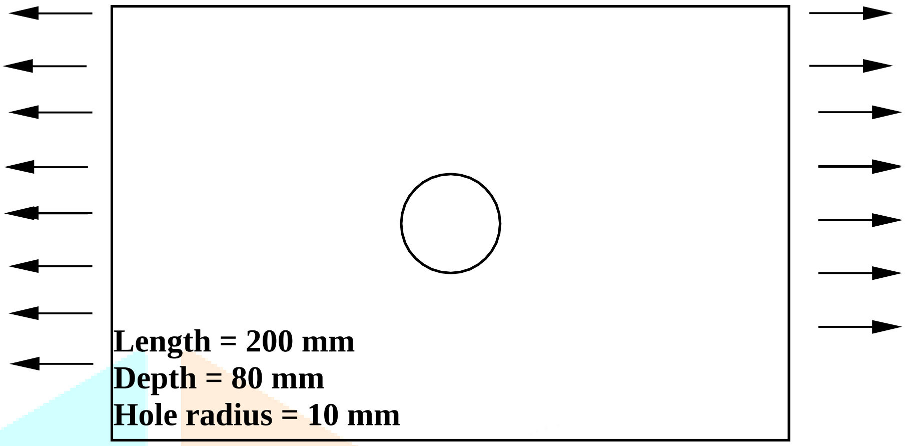

Figure 1 The geometry

4- Geometry

a rectangular plate with a hole cut from the centre, subjected to at ensile loading along the ends

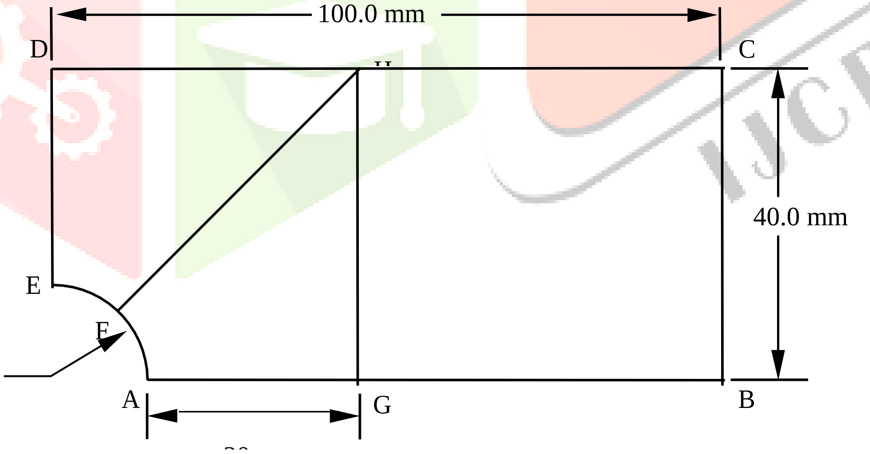

Figure 2 Idealization of the Reduced Geometry

- **Simulation with Coarse Structured Mesh of Quadrilateral Elements**

Material Properties

The material properties used asx owns in the table below:

Table 1 material pvro.p/certbis

Property	*Value*
Young's Modulus	200,000N/mm^2
Poisson Ratio	0.3

Finite element mesh

A structured mesh of linear quadrilateral elements as shown in figs3.

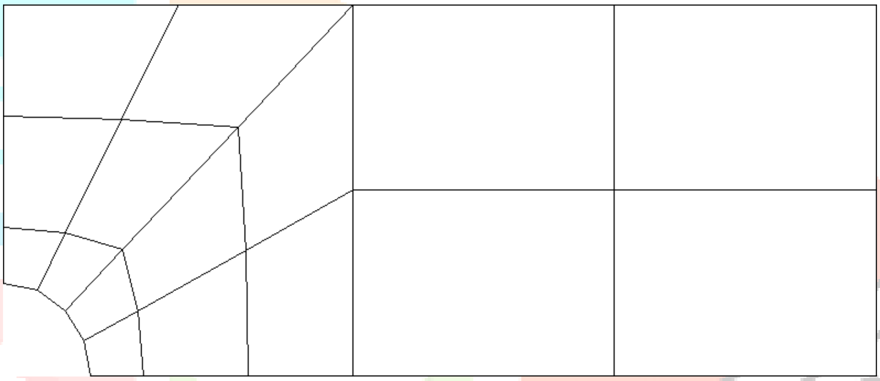

Figure 3 of Coarse Structured mesh

Analysis

The direct stress σXX contours should appear as displayed in Figure 4 ", and the un-averaged contours of σXX should appear as in Figure 9. It can be seen from Figure 5

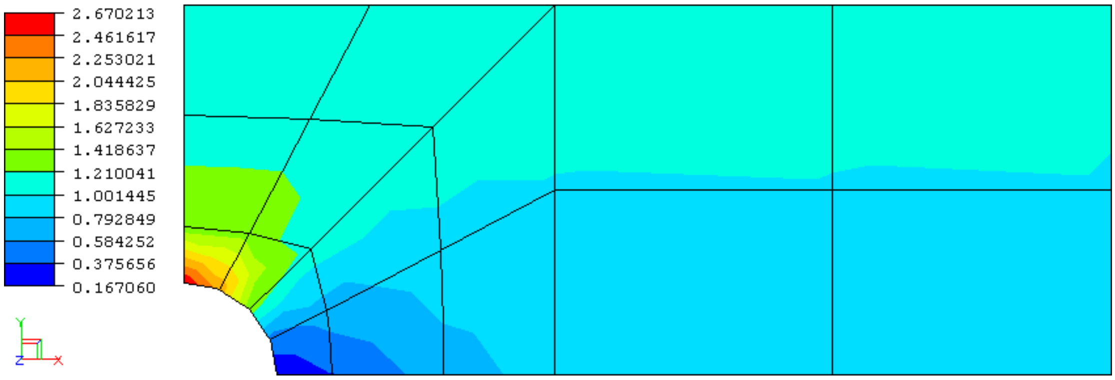

Figure 4 Direct Stress σxx Contours on the Surface of the Plate

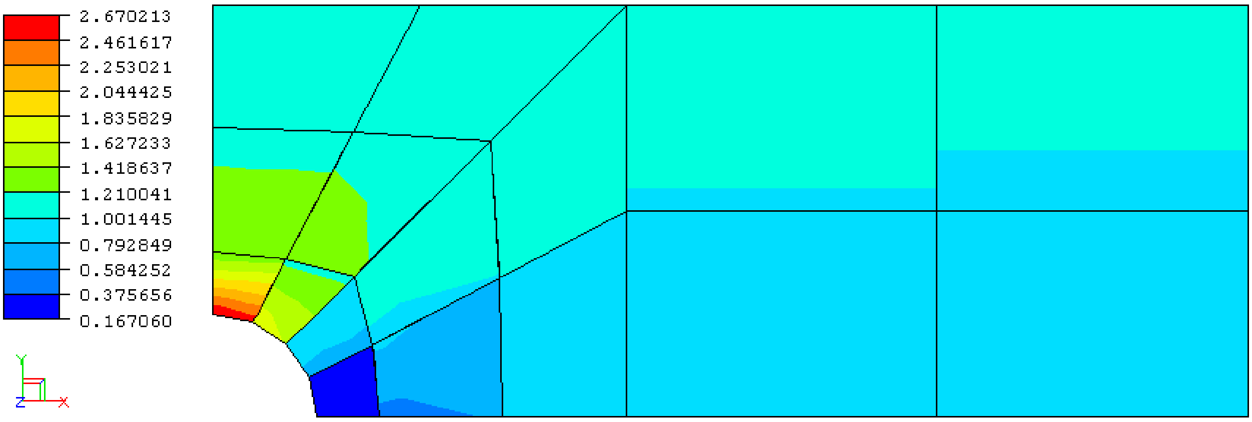

Figure 5 Un-averaged (Discrete) Contours of σxx on the Surface of the Plate

- **Simulation With Fine Structured Mesh of Quadrilateral Elements**

Finite Element Mesh

A structured mesh of linear quadrilateral elements is shown fig6

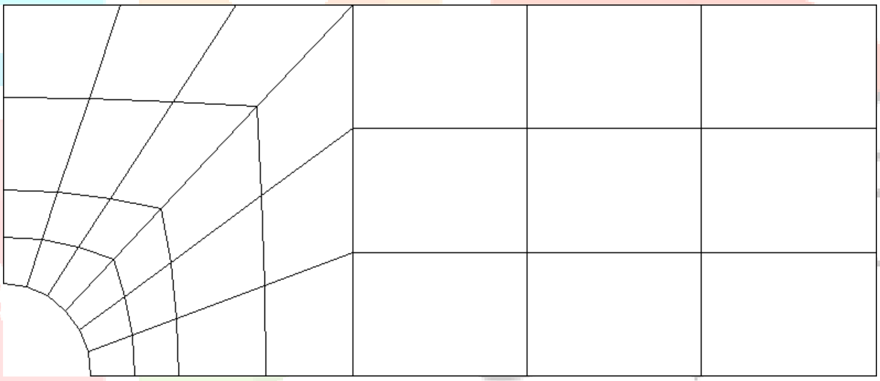

Figure 6 Fine Structured Mesh

Finite element analysis

The direct stress σ XX contours should appear as displayed in Figure7 and the un-averaged (discrete) contours of σXX should appear as in Figure 7. It can be seen from Figure 8 that the difference across neighboring elements is less than for the coarse mesh, indicating that the solution quality has improved. Also note that the stress values obtained have increased slightly.

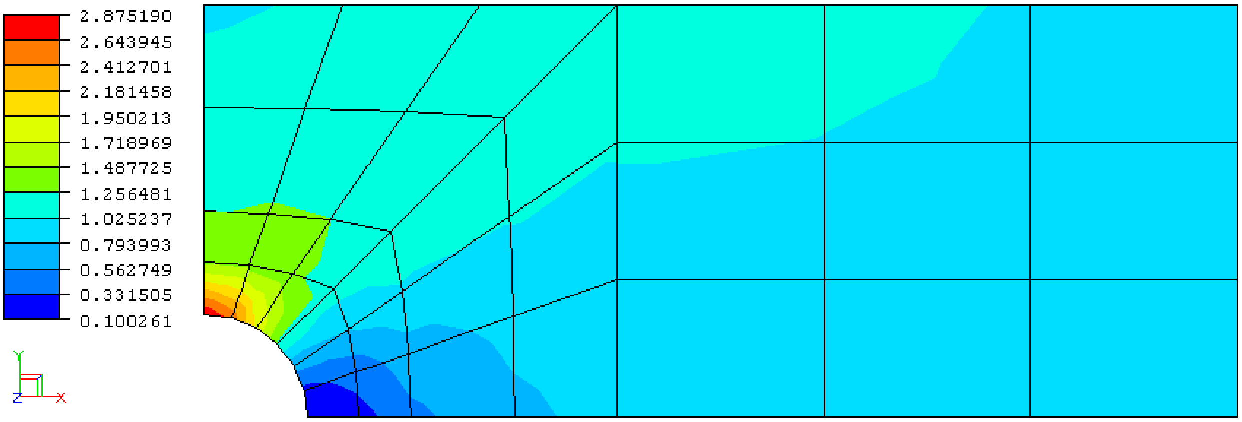

Figure 7 Direct Stress σxx Contours on the Surface of the Plate

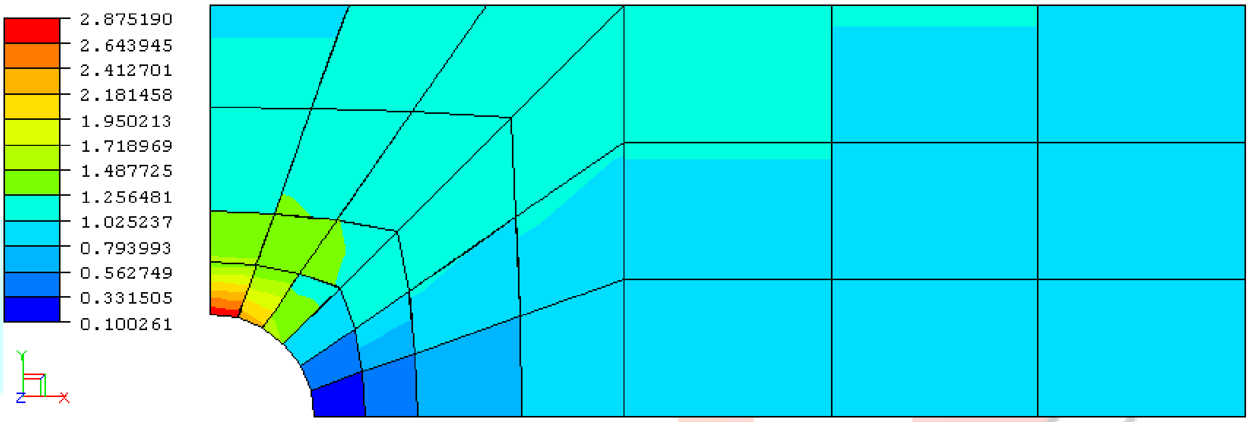

Figure 8 Un-averaged (Discrete) Contours of σxx on the Surface of the Plate

- ## Simulation With Coarse Unstructured Mesh of Triangular Elements

Finite Element Mesh

An unstructured mesh of linear triangular elements is shown in fig 9

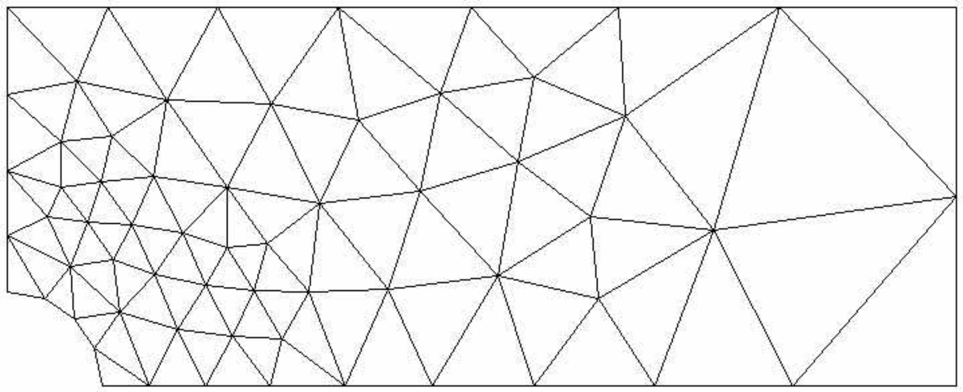

Figure 9 b Coarse Unstructured Mesh

Finite element analysis

The direct stress σXX contours should appear similar to those displayed in Figure 10 and the un-averaged (discrete) contours of σXX should appear similar to those in Figure 11. Note that as unstructured meshes vary, the contours may not be identical to those shown. It can be seen that the stress values obtained are lower than both sets of results using structured meshes, and also that there is a large change across element boundaries around the hole, indicating a poor quality of solution.

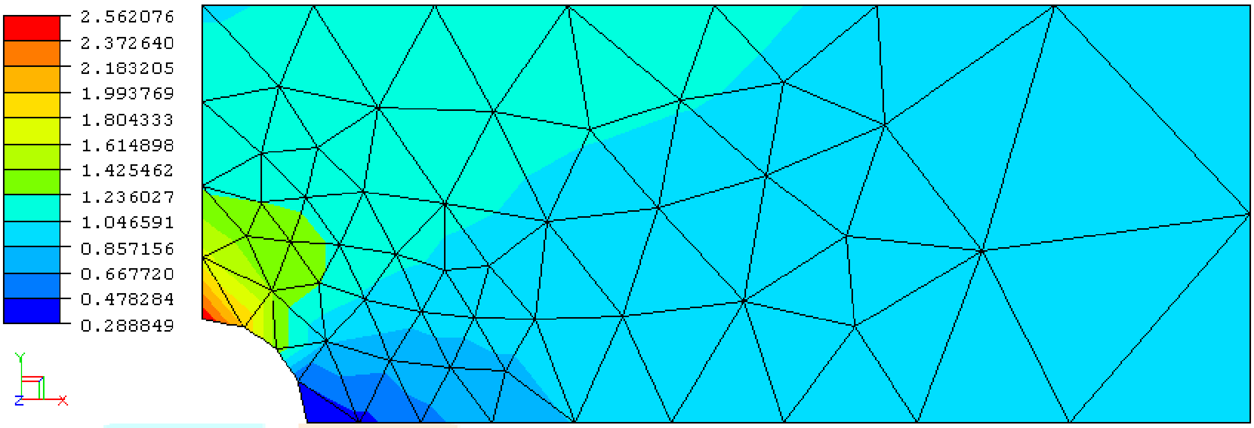

Figure 10 Direct Stress σxx Contours on the Surface of the Plate

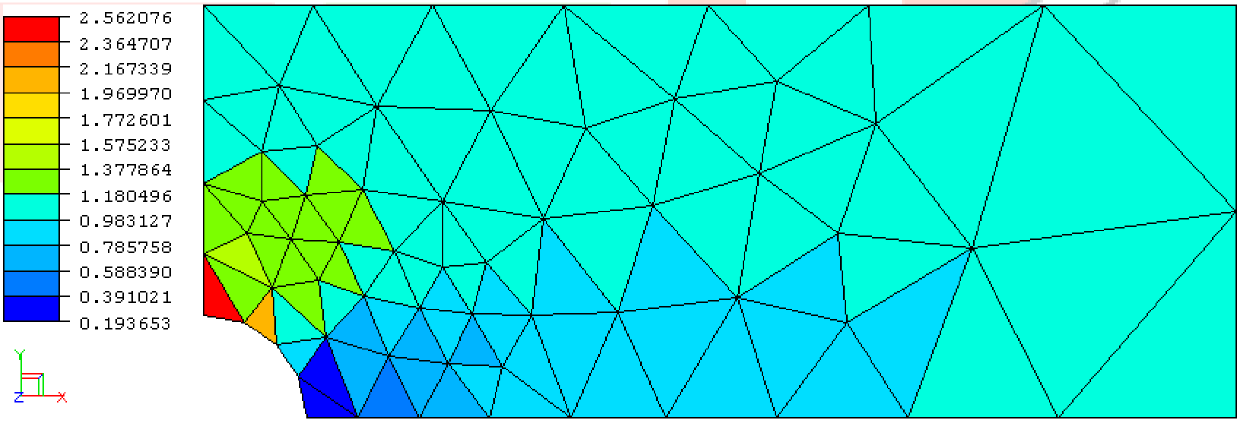

Figure 11 Un-averaged (Discrete) Contours of σxx on the Surface of the Plate

- **Simulation With Fine Unstructured Mesh of Triangular Elements**

Finite Element Mesh

An unstructured mesh of linear triangular elements is to be adopted is shown in fig 12

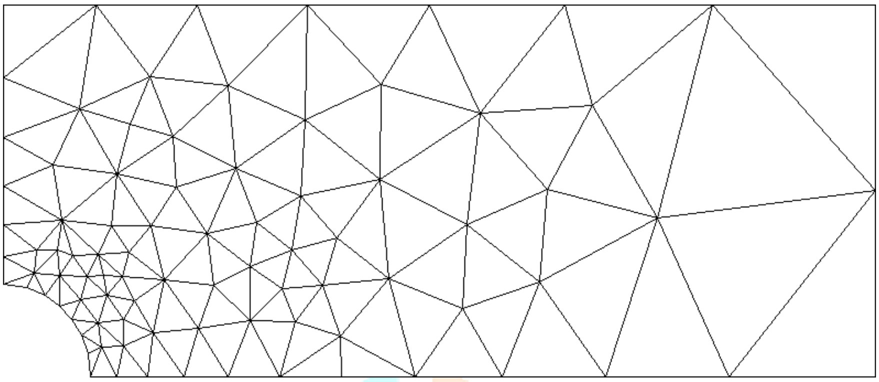

Figure 12 Fine Unstructured mesh

Finite element analysis

The direct stress σ_{xx} contours should appear similar to those displayed in Figure 13 and the un- averaged (discrete) contours of σ_{xx} should appear similar to those in Figure 14. Note that as unstructured meshes vary, the contours may not be identical to those shown.

Note that the stress values have increased, but the difference between the averaged and the un- averaged stresses has decreased. The change across element boundaries has also decreased, indicating an improvement in solution quality. It is also apparent that the finer unstructured mesh describes the hole geometry much more accurately than the coarse one..

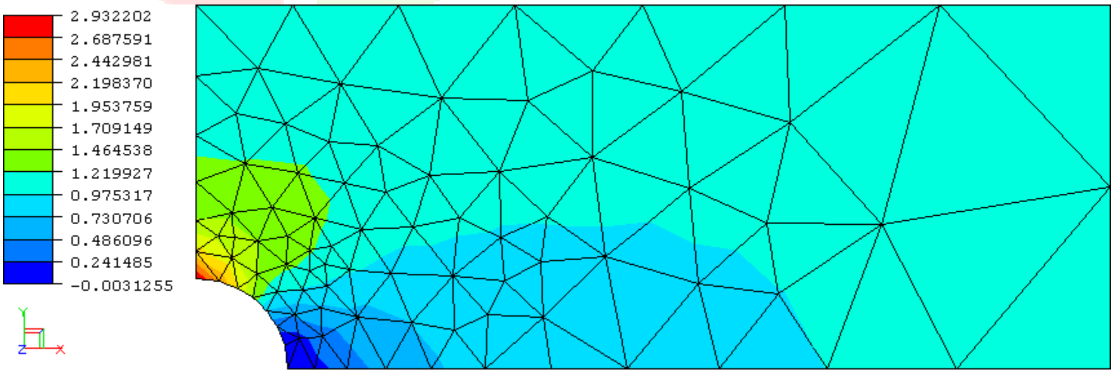

Figure 13 Direct Stress σxx Contours on the Surface of the Plate

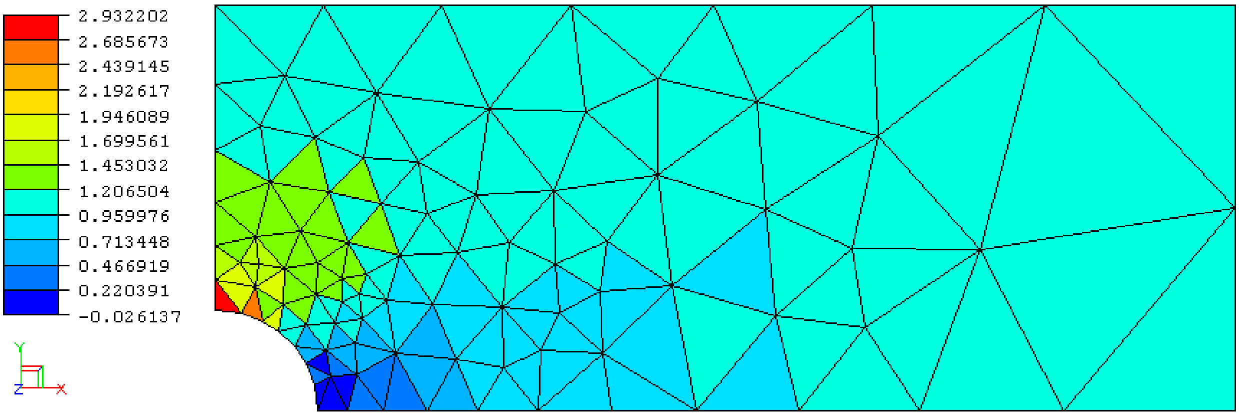

Figure 14 Un-averaged (Discrete) Contours of σxx on the Surface of the Plate

Dissection

The stress concentration factor is defined as the ratio of the stress at the stress raiser to the nominal stress in the body, calculated using the net cross-sectional area. Typical stress raisers are holes, notches and sudden changes of section, e.g. from round to square.

For a rectangular member with a circular hole at the centre, the stress concentration factory is given by† :

$$k = 3.00 - 3.13\,(2r/D) + 3.66\,(2r/D)^2 - 1.53\,(2r/D)^3$$

where *r* is the hole radius and *D* is the depth of the member. The nominal stress is given by:

$$\begin{aligned}\sigma &= \text{force} / \text{area}\\ &= P / [\, t\,(D - 2r)\,]\end{aligned}$$

where *P* is the nominal tension and *t* is the thickness of the member. For this example, the nominal stress is 1.333 N/mm^2, as we are using unit thickness.

The stress concentration factors from the four versions of this example (calculated as *max. stress / nominal stress*) and the value of *k* obtained from the formula above are listed below:

Project	**K**
PLATE 1	2.064
PLATE 2	2.157
PLATE 3	1.569
PLATE 4	2.199
Formula	2.422

All are underestimates, with **plate4** being the closest. It can be noted that **plate4** also has the least difference between the averaged and un-averaged stress values, which ranks it as the best of the four solutions.

Refining the mesh further will give a better approximation - using an unstructured size of 1 around the hole gives a *k* value of 2.39.

References

[1]. Pandit SD, Nishiyabu K, Verpoest I. Strain concentrations in woven fabric composites with holes. Compos Struct 2003;59:361–8.

[2]. Icardi U. Through-the-thickness displacements measurement in laminated composites using electronic speckle photography. Mech

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[3]. Marchetti E, Faraggiana R, Bonifacio P. A speckle interferometry survey of Bootis stars. A&A 2001;370:524–8.

[4]. Structural Composite Material by F.C. Campbell, ASM International (Text Book)