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Numerical evaluation of stress triaxiality at the top of notch for a specimen steel notched bi-S355

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Abstract: *The crack initiation in a mechanical structure is most often due to the presence of a notch. Harmfulness of notches generally depends on their size and their geometric parameters, such as radius and notch angle. We focus in this paper on S355 steel.*

The objective of our work is to establish a finite element numerical modeling of a tensile specimen with double notches using the computer code CAST3M 2009. This method finds its importance in the study and design of mechanical structures.

The results allow concluding the maximum stress which is located in σ_{Max} notch root. The numerical study also reveals that the maximum stress decreases gradually along the axis of specimen, over the range 0 to 2 mm, and then stabilizes at face value that corresponds to nominal stress. The stress concentration factor increases with the length of crack and the applied stress. That the local stress σx, parallel to the axis of the notch, is not up to the root of the notch (she even zero), reaching its maximum value by cons to a distance of 1 mm of the notch.

Keywords - *Notch, finite elements, maximum stress, stress concentration factor, nominal stress*

I. INTRODUCTION

The damage of the metal structures corresponds to an irreversible physical process often due to the presence of the defects [1]. Stage I of starting of a crack can represent up to 90% of lifespan for low levels of stresses [2]. But this percentage decreases appreciably as well as the total lifespan of the structure in the presence of defects. These defects are often accompanied by concentration of the stresses and can give rise to the starting of cracks and thereafter lead to the fracture of the structure [3,4]. Generally, the industrial structures contain defects of the microscopic cracks type, inclusions, cavities… etc In the field of the structures at the risk like the pressure vessels for example, in the presence of material defect or of crack and for obvious safety reasons, it is necessary to know in a precise way the degree of harmfulness of the defect. This helps the decision leading to stop or to continue the exploitation of the equipment and for how long. The economic issues and of safety can be important. To answer these problems, the numerical methods finite elements type, combined to the mechanic of fracture and fatigue are used by several authors.

Include the work of SAFFIH [5,8] on the numerical study of the harmfulness of the circumferential or axisymmetric semi-elliptic cracks in cylindrical shells with a thickness transition (the same internal diameter and different external diameters).

Based on the calculation of the stress intensity factors and the integral of contour J, he proposes an improvement of the simplified rules standard R6 or A16 for the transitions of thickness. EL HAKIMI [7] generalized the study with the hulls under cylindrical and spherical pressure. He proposes a step based on the stress intensity factors K_i and the integral J obtained numerically or by the simplified methods for semi elliptic internal or external, longitudinal or circumferential cracks. TOPPER and EL HADDAD [6] used the distribution of the stresses at the top of a short crack emanating from a notch, to provide the boundary conditions between the theoretical concentration factor of stress of a blunted notch and that of an acute notch.

RAHMAN and BRUST [9] showed that the integral J is the elastoplastic parameter of the mechanic of fracture which characterizes the initiation of the propagation and the instability of the cracks in ductile materials. All these works and much of others show the need to resort to the numerical methods sight the complexity of the stress field at the defects. These methods suffer from a lack of experimental validation. Our work proposes to undertake a numerical study. The specimens are of bi-notched tensile type.

II. METHOD USED

In this work, we consider a double-notch specimen side, stressed in tension (mode I), causing a crack opening. The specimen was discredited by finite elements.

The simulation is done using the computer code CASTEM 2009, including a calculation procedure described in steps of calculation described by a specific code and the results are validated by the results bibliographic [10]. The applied stresses are $\Delta\sigma$: 352 MPa, 282MPa and 248MPa.

The finite element method, used in this report, is suitable for a calculation of fracture mechanics. The area of the notch is finely refined.

The parameters to calculate the 3 dimensional geometric elements are cubic with 8 node elements. Numerical calculations in fracture mechanics can generate large sequences. This may cause an inability to solve these problems by means conventional computer, or get erroneous Model validation is established by comparisons with numerical results obtained by other authors; on cases where we have the analytical solution is compared with experimental results.

To validate our numerical results, we conducted a comparison with experimental results [10].

The study shows that the type of elements, the number of circles on cut and the mesh size directly affect calculation results.

III. EXPERIMENTAL SPECIMEN

The dimensions of notched tensile doubles specimens in S355 are shown in Figure 1 [10]. The section after machining these specimens is 221.9 mm2.

The tricky part in this operation is to achieve a root radius notch sharpest possible, in order to initiate a fatigue crack at low stresses. The machining process using slitting saws was executed in several phases.

Machining with a roughing cutter of the V shaped notch. This produces a flat bottomed notch about 0.5 mm.

Finishing the notch root with a well sharpened cutter to fit the angle of 60°. The radius is less than 0.1 mm.

The notch root radius is verified by the microscope at a magnification of 280.

The cuts have obtained a radius of about 0.05mm.

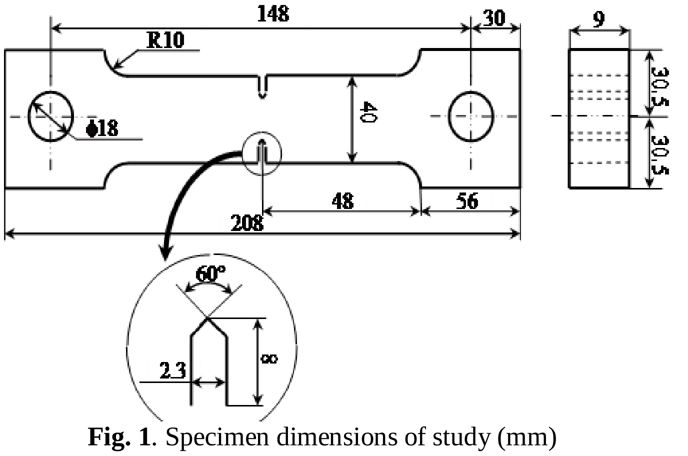

Fig. 1. Specimen dimensions of study (mm)

3.1. Material

The material in our computer code is the Steel S355 (EN 10020). Its mechanical characteristics are summarized in Table 1.

Table 1. Mechanical properties of steel S355

Specification	Properties		
S355	σ_u (Mpa)	σ_e (Mpa)	E (Gpa)
	621	372	200

σ_u: Stress at break
σ_e: yield
E: Young's modulus

Its chemical composition is reported in Table 2.

Table 2. Chemical composition of steel S355

	Composition (%)					
S355	**C**	**Mn**	**P**	**S**	**Si**	**Cu**
	0,29	0,80-1,20	0,09	0,05	0,15-0,30	0,20

Figure 2 shows the curve of conventional experimental evolution of the stress as a function of material deformation. The general shape of this curve showed a ductile behavior.

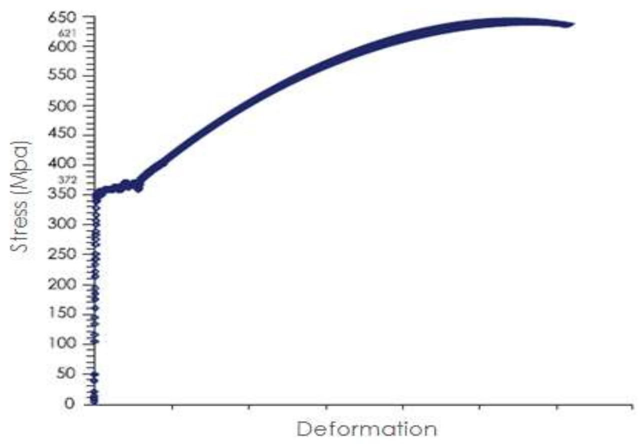

Fig. 2. Diagram of traction [10]

Values main mechanical characteristics of the material, obtained by tensile tests are given in Table 1.

3.2. Mesh and boundary conditions

In this part of study, we modeled by finite elements include the tensile test of bi-notched. This problem has two planes of symmetry, and therefore only a quarter of the specimen is modeled.
The mesh of the specimen is shown in Figure 3a. The mesh is refined notch root (Figure 3b).

The model includes 4980 elements of the cubic type to 8 nodes

The tensile force is applied to the specimen via a rigid triangle indicated by arrow. This ensures that the effort is perfectly aligned.

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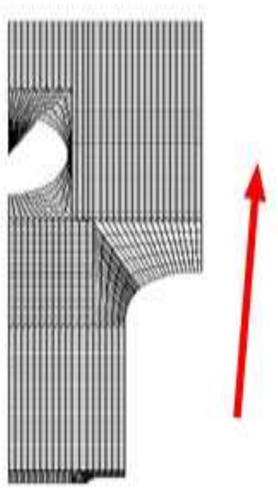


Fig. 3a. Mesh

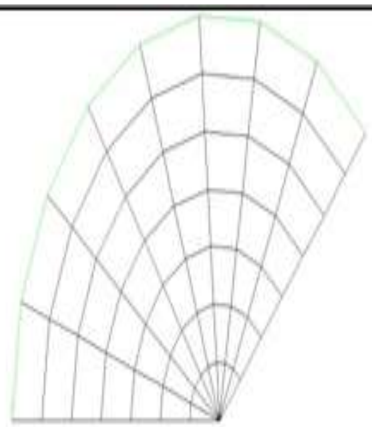


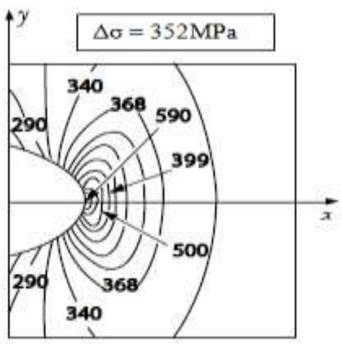
Fig. 3b. Mesh in the vicinity of the notch

From both sides of axes symmetry of the quarter of sample studied, we inhibited all displacements and rotations U = 0 and R = 0.

IV. THE ISOCONCENTRATION OF VON MISES STRESS

Any material present at the microscopic level, defects (in homogeneities, inclusions, manufacturing defects, etc...) And all parts may change section or surface states more or less perfect. However, since these conditions favor the occurrence of local stress concentrations and, consequently, cracks.

In Figure 3 we plotted the isoconcentration lines of Von constraint set. We made this layout for an element of 1.72 mm from the notch for the three levels of applied nominal stresses ($\Delta\sigma$ = 352MPa, 282MPa, 248MPa).



plan xy

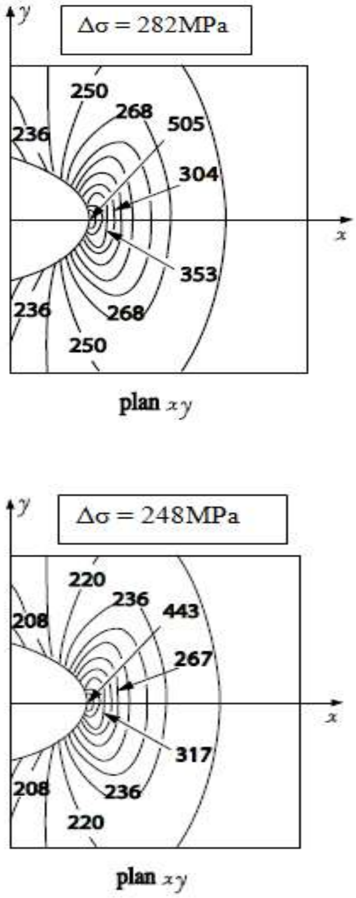
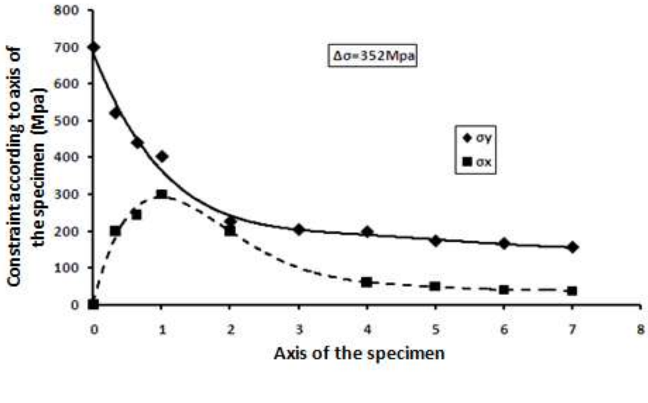


Fig. 4. Isoconcetration curve of von Mises stress in the xy plane

For all three cases, the numerical study reveals that the isoconcetration of von Mises stress is maximal near the notch root; this value follows a decrease when one moves away from the notch. For each isoconcetration of von Mises stress the value of von Mises stress increases with increasing nominal stress applied. Therefore the root of the crack value of von Mises stress exceeds the yield strength greater than 372=MPa) (for Δσ= 352MPa the value of von Mises stress = 590 MPa, for the value of Δσ = 282MPa 352MPa the value of von Mises stress 505MPa, for Δσ = 248MPa the value of the von Mises stress = 443 MPa, this reflects the influence of plastic behavior at this point.

V. TAKING ADVANTAGE OF THE STRESS TRIAXIALITY AHEAD OF THE NOTCH

In this section we study the local stress exerted on the specimen. We find that the specimen is subjected to triaxial stress. For each applied stress we plotted the stress σx and σy along the horizontal axis of specimen.



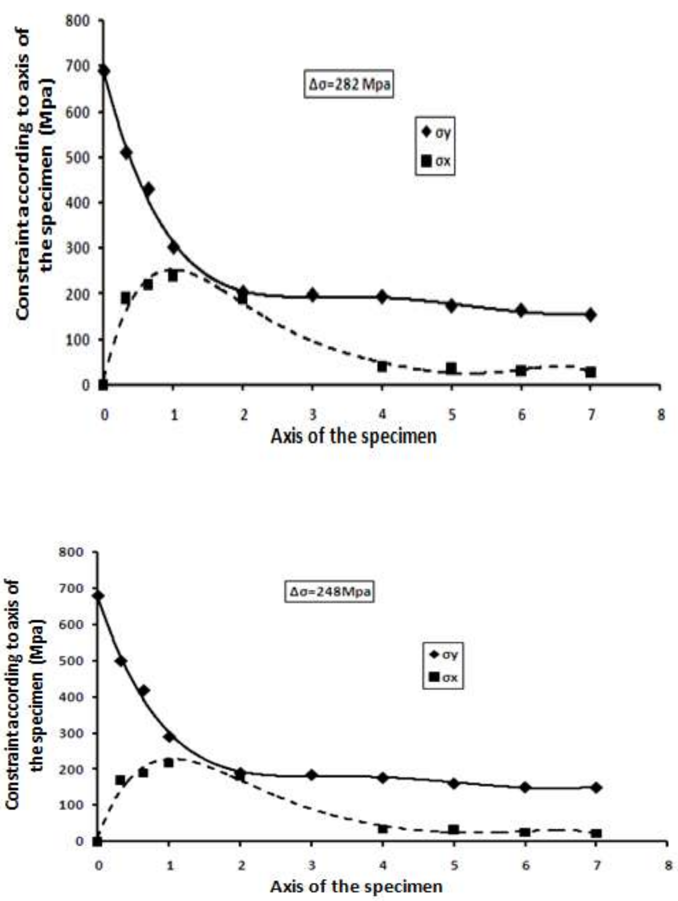


Fig.5. Variation of local stress σx and σy depending on the distance measured from the bottom of crack

For all three cases, we note that the constraint σ_y, parallel to the applied stress reaches its maximum value at the root of the crack. This constraint has then a parabolic trend over the range 0 to 2 mm to stabilize at the value of the nominal stress σ_{nom}. The maximum value is due to the localized plastic flow. The stress concentration in the vicinity of the notch causes a plastic deformation in that area, while the areas remote from the notch undergo only a purely elastic deformation.

Therefore, when σy at the root of the notch exceeds that of the strength of the material, we are seeing a local rupture of bonds and crack propagation. However, we find that the local stress σx, parallel to the axis of the notch, is not up to the root of the notch (she even zero), reaching its maximum value by cons to a distance of 1 mm of the notch.

VI. CONCLUSION

A finite element study using the software Cast3m doubly notched specimen of a mode I sought was conducted for three levels of nominal stress. The analysis shows that at the root of the crack the value of the von Mises stress exceeds the yield strength greater than MPa =372) (for Δσ= 352 Mpa the value of von Mises stress = 590 MPa for Δσ = 282MPa value of von Mises stress = 505MPa, for Δσ =248MPa the value of the von Mises stress is 443MPa, this reflects the influence of the plastic behavior at this point. then the constraint along the x axis and y axis , the stress σy is parallel to the applied stress, reaches its maximum value at the root of the crack. The maximum value is due to localized plastic flow. The stress concentration in the vicinity of the notch causes a plastic deformation in this area, while remote areas of the cut only undergo a purely elastic deformation. Therefore, when it exceeds the strength of the material, we are seeing a local rupture of bonds and crack propagation. However, we find that the local stress σx, parallel to the axis of the notch, is not up to the root of the notch (she even zero), reaching its maximum value by cons to a distance of 1 mm of the notch.

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