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FEA STUDY ON THE INFLUENCE OF FILLET ON STRESS CONCENTRATION ON EDGES

BY

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Abstract. FILLET shape is frequently used in Computer Aided Design, CAD design of parts used in Mechanical engineering in order to reduce the stress concentration. The paper presents a Finite Element Analysis, FEA study on the influence of the FILLET applied on the edges of a through-the-thickness hole concentrator in a plate. FEA study is performed by use of open source packages: Salome-Meca and Code Aster. For the initial case, in the absence of FILLET, results are compared with the theoretical case: infinite plate subjected to biaxial stress with a through-the-thickness hole, a problem with analytical solution. FEA study determines the variation of the stress concentration coefficient versus the radius of the FILLET.

Keywords: CAD; FEA; Edges; FILLET; Stress concentration.

1. Introduction

The edges of the components used in Mechanical Engineering are sometimes stress concentration areas. CAD design frequently uses, when possible, geometrical solutions to optimise the shape in these areas in order to improve the stress distribution.

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FEA studies, (Aignătoaie, 2010; Aignătoaie, 2011; Aignătoaie, 2014), make possible to evaluate the influence of a specific shape on the stress concentration.

The theoretical problem of an infinite plate subjected to a biaxial stress field with a through-the-thickness hole concentrator, has an analytical solution, usually used in the study of the residual stresses (Bârsănescu *et al*., 2004).

The test case study is a plate with a through-the-thickness hole, Fig. 1.

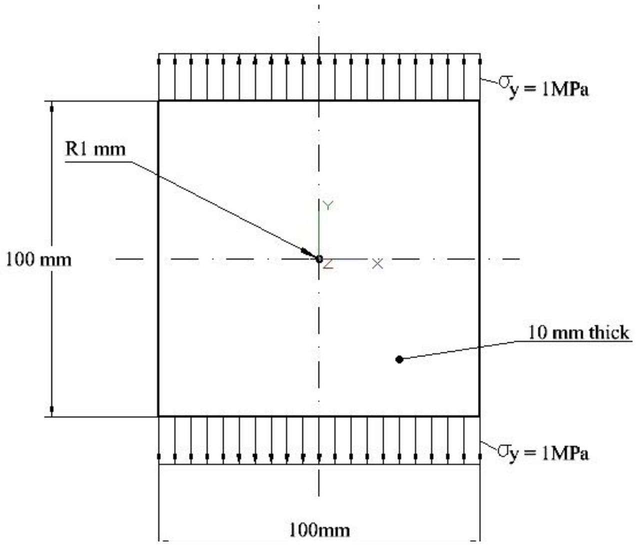

Fig. 1 − Test case study: finite plate with monoaxial load.

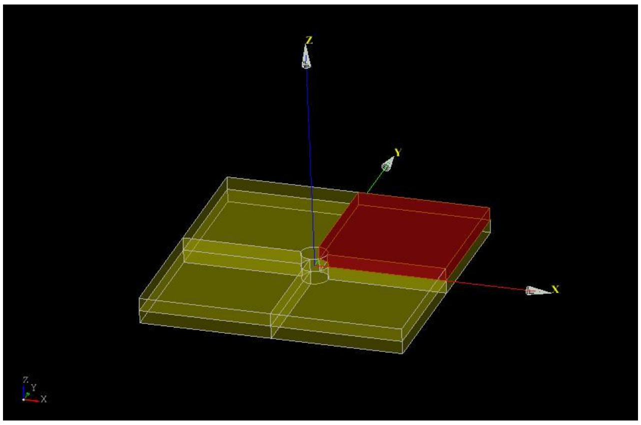

Fig. 2 − Simplified CAD model for FEA study.

2. The FEA Study

Due to symmetry properties, the model for FEA study could be reduced to 1/8 from initial shape, Fig. 2. The supports conditions implied roller conditions in any symmetry plane: the DOF (Degrees Of Freedom) are FREE in the plane and BLOCKED normal to the plane.

The plate is from steel with medium content of Carbon: E = 2.1 10^5 MPa and υ = 0.3.

The FEA study was performed by use of the Open Source packages Salome-Meca (pre/post-processor) and Code Aster (processor), as parts of CAELINUX 2013, (Caelinux).

The study has considered 4 test cases for which *R*, the radius of the FILLET, took the values 0 (without FILLET), 1, 2, 3 mm. Details of the meshes are included in Table 1 and Figs. 3, 6, 9, 12.

Details on the stress distribution in the vicinity of the concentrator are presented for σ_y, Figs. 4, 7, 10, 13, and $\sigma_{\text{von Mises}}$, Figs. 5, 8, 11, 14.

Table 1
Basic Parameters of the FEA Study

Study case	FILLET *R*, [mm]	Finite Elements [Quadratic tetrahedrons]	Nodes	DOFs
1	0	109281	173525	520575
2	1	115201	182723	548169
3	2	115627	183509	550527
4	3	117758	186506	559518

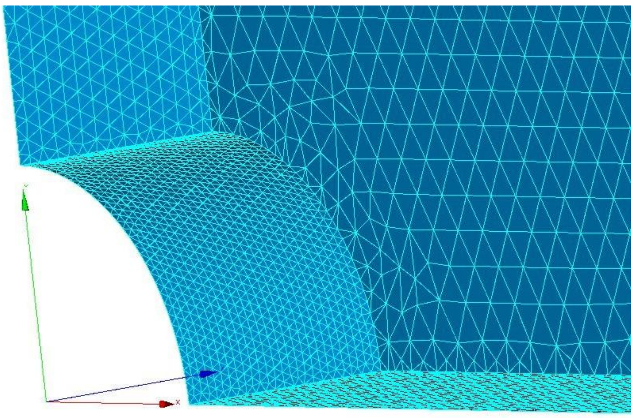

Fig. 3 − Case 1 (R = 0): Mesh details.

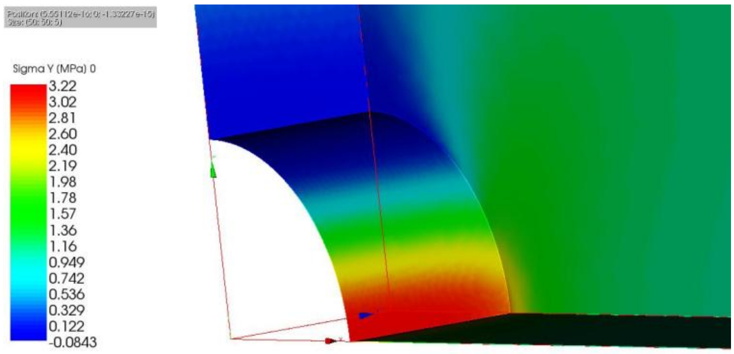

Fig. 4 − Case 1 (R = 0): σ_y, [MPa].

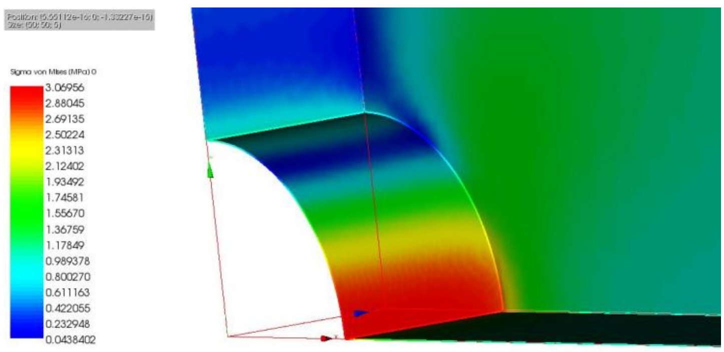

Fig. 5 − Case 1 (R = 0): $\sigma_{\text{von MISES}}$, [MPa].

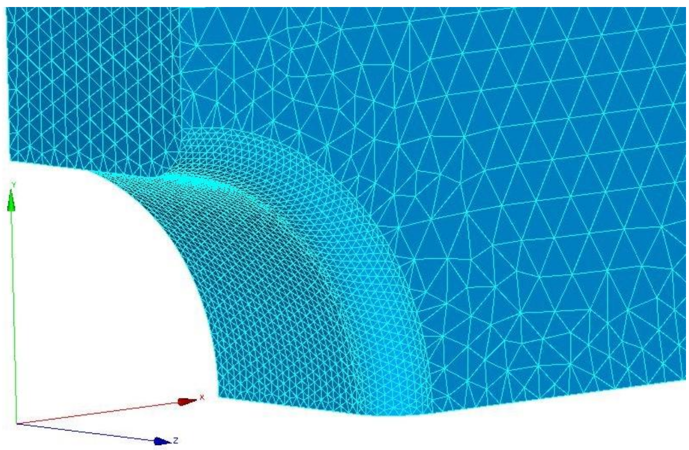

Fig. 6 − Case 2 (R = 1): Mesh details.

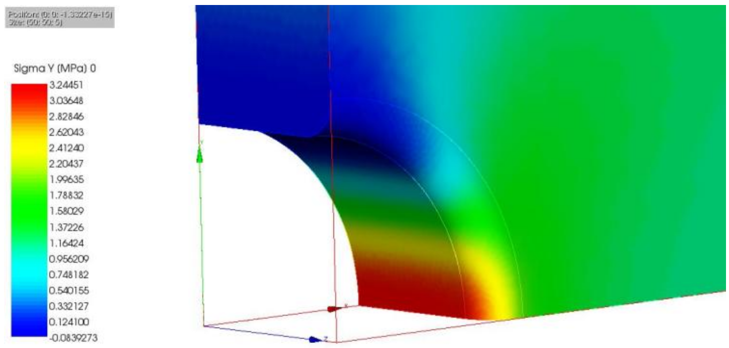

Fig. 7 − Case 2 (R = 1): σ_y, [MPa].

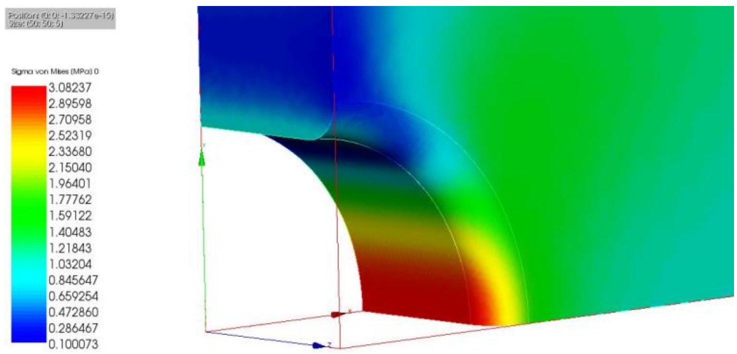

Fig. 8 − Case 2 (R = 1): $\sigma_{\text{von MISES}}$, [MPa].

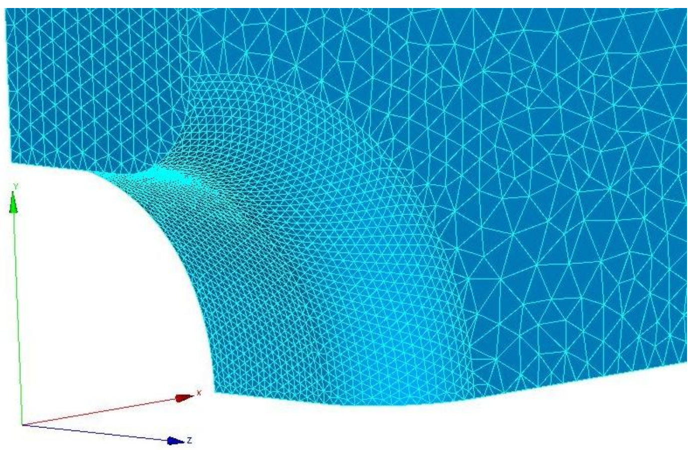

Fig. 9 − Case 3 (R = 2): Mesh details.

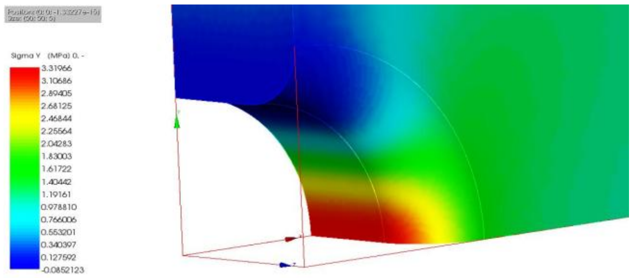

Fig. 10 − Case 3 (R = 2): σ_y, [MPa].

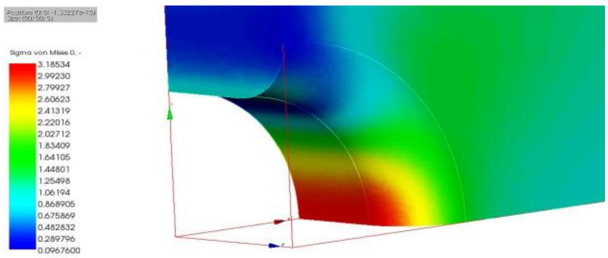

Fig. 11 − Case 3 (R = 2): $\sigma_{\text{von MISES}}$, [MPa].

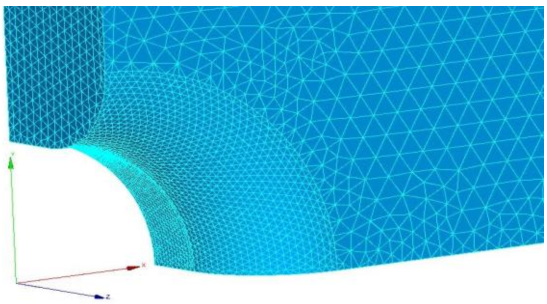

Fig. 12 − Case 4 (R = 3): Mesh details.

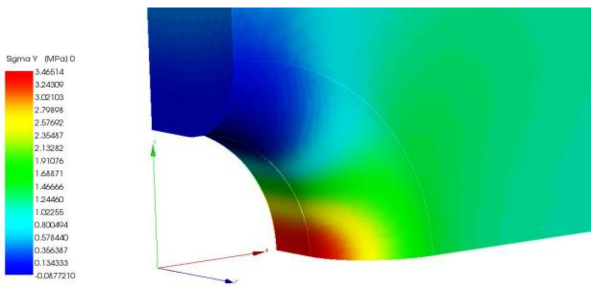

Fig. 13 − Case 4 (R = 3): σ_y, [MPa].

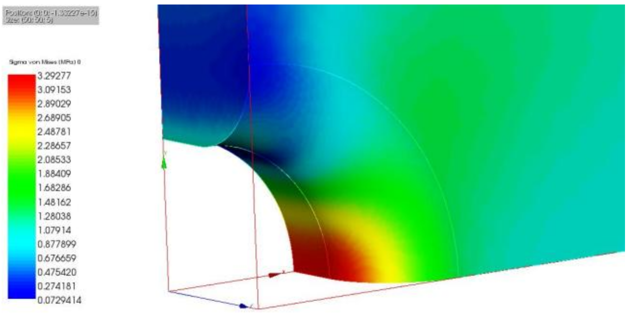

Fig. 14 − Case 4 (R = 3): $\sigma_{\text{von MISES}}$, [MPa].

The stress concentration factor, K, was calculated by use of Eq. (1):

$$K = \frac{\sigma_{\max}}{\sigma_{nom}} \tag{1}$$

where: σ_{nom} is the uniformly distributed stress in the plate: $\sigma_y = 1$ MPa; $\sigma_{\max}$ is the maximum value of the stress produced by the stress concentrator: $(\sigma_y)_{\max}$, determined analytically or by FEA.

Table 2
FEA Results

Study case	FILLET R, [mm]	σ_y [MPa]	$\sigma_{\text{von MISES}}$ [MPa]	K [Eq. (1)]
1	0	3.22	3.06	3.22
2	1	3.24	3.08	3.24
3	2	3.31	3.18	3.31
4	3	3.46	3.29	3.46

The analytical solution, (Bârsănescu *et al*., 2004), gives a theoretical concentration factor K = 3. The difference between theoretical value (K = 3) and the FEA study (K = 3.22) could be related with the two formulations: (infinite plate in 2-D space with analytical calculus) versus (finite plate in 3-D space with numerical calculus based on FEA).

3. Conclusions

– The increase of R reduces the area of the stress concentration zone, which moves towards the median plane of the plate, while stress gradient increases in value.

– The use of FILLET does not reduce the stress concentration in the stress concentrator. The variation of K versus R is not linear.

– Future researches for reducing the stress concentration could also try other geometry profiles on the edge or modifying the area in the vicinity of the hole.

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STUDIU FEA ASUPRA INFLUENȚEI UTILIZĂRII
FORMEI FILLET APLICATĂ MUCHIILOR ASUPRA FENOMENULUI
DE CONCENTRARE A TENSIUNILOR

(Rezumat)

Forma FILLET este utilizată frecvent în proiectarea CAD a unor elemente constructive utilizate în ingineria mecanică, cu scopul de a reduce fenomenul de concentrare a tensiunilor. Lucrarea prezintă un studiu AEF (Analiză cu Elemente Finite) privind utilizarea formei FILLET aplicată muchiilor unui concentrator de tensiune tip gaură străpunsă situat într-o placă. Studiul AEF este realizat cu ajutorul unor pachete Open-Source: Salome-Meca şi Code-Aster. Pentru cazul iniţial, fără FILLET, rezultatele sunt comparate cu problema teoretică cu soluţie analitică: placă infinită, cu o gaură străpunsă, solicitată biaxial. Studiul AEF determină variaţia coeficientului de concentrare a tensiunilor în funcţie de valoarea FILLET.