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CAD-FEA STUDY ON THE INFLUENCE OF FILLET ON STRESS CONCENTRATION IN A PIPE T SHAPE

BY

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Abstract. Many mechanical systems include piping systems using frequently pipe T shapes, which represent stress concentration areas. The paper analyzes a possibility to reduce the stress concentration by use of the FILLET shape. The study was performed by use of Salome-Meca (EDF France) under Linux Xubuntu, used as CAD editor and also as pre/post processor for the FEA study. FEA processing was performed by use of Code-Aster, included in Salome-Meca. Salome-Meca has generated automatically the CAD model of a pipe T shape as a basic initial model. 8 alternative study cases were created. In each and every case a FILLET, varying within 5-40 mm, was added on the external edge resulted by the intersection of the main pipe with the incident pipe. A comparison between all the nine study cases is made considering the distribution of the von Mises stresses in order to analyze the stress concentration evolution.

Keywords: FEA; Salome-Meca; Stress concentration; FILLET; Pipe T Shape.

1. Introduction

Practical applications in the field of Mechanical engineering often include complex pressure vessels and piping systems. Their classical design is

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based on analytical formulas known from the theory of thin-walled vessels or thick-walled vessels (Boresi *et al*., 2003). The literature also presents practical methods using specific codes, (Moss, 2004), based on ASME Code, Section VIII, Division 1. Such a design procedure follows specific rules and does not implies a detailed evaluation for all stresses. Piping systems might have occasionally complicated shapes. For a rather limited number of cases, there were developed, (Young *et al*., 2002), specific formulas for the correct evaluation of stresses in the vicinity of the areas with a significant geometrical changes also known as stress concentrators. None of these cases include the intersection between pipes with rectangular axes. Usually such problems could be studied by use of Finite Element Analysis, FEA. The paper presents a Computer Aided Design, CAD and FEA study on the possibility of stress concentration reduction in a T-shape pipe by use of the FILLET shape.

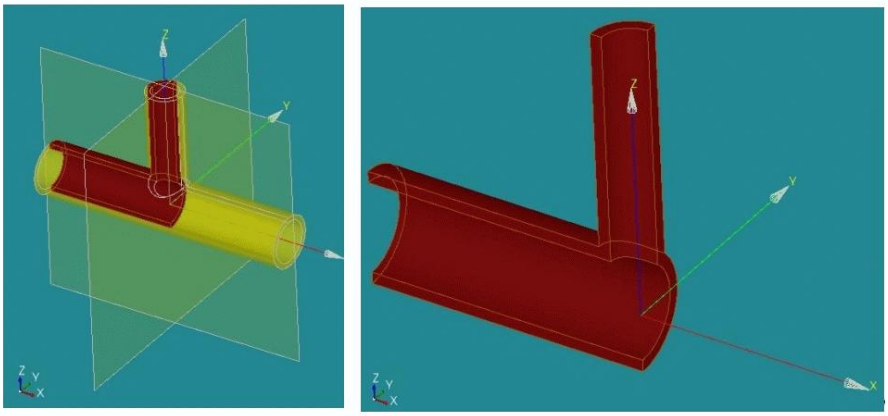

Fig. 1 − The initial CAD model: full model (left) and simplified model (right).

2. The CAD-FEA Study

The study was performed by use of the open-source system CAELINUX-2013 (*** *CAELINUX*, 2016) developed under Xubuntu. This package includes Salome-Meca (EDF, France), a CAD editor and pre/post processor, able to automatically define a T shape pipe. The initial model was created with the specifications defined within SALOME-MECA:

R1 – Radius of the main T-shape pipe = 80 mm
W1 – Thickness of the main T-shape pipe = 20 mm
L1 – Length of the main T-shape pipe = 960 mm
R2 – Radius of the incident T-shape pipe = 50 mm
W2 – Thickness of the incident T-shape pipe = 20 mm
L2 – Length of the incident T-shape pipe = 960 mm.

This is considered the “case study 1”, or “no FILLET”, a reference model, Fig. 1, (left). The full model has two symmetry planes (xOz) and (yOz).

For an efficient use of the hardware resources during FEA processing, the FEA study uses a simplified model, Fig. 1, (right) which represents a quarter of the initial one.

Table 1

Basic Parameters of the FEA Study

Study case	FILLET R [mm]	Finite Elements, TETRA10 [Quadratic tetrahedrons]	Nodes	DOFs
1	No FILLET	136567	237371	740289
2	5	136111	236715	737913
3	10	136285	236991	739053
4	15	136162	236755	738545
5	20	135605	235872	735546
6	25	136306	236792	738332
7	30	136163	236575	738015
8	35	137219	238290	743426
9	40	138403	239941	748069

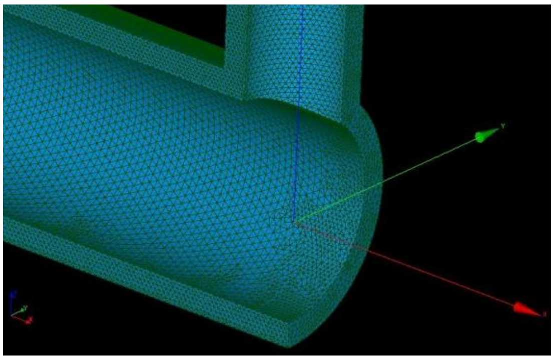

Fig. 2 − Mesh details of the FEA model (case study 1: no FILLET).

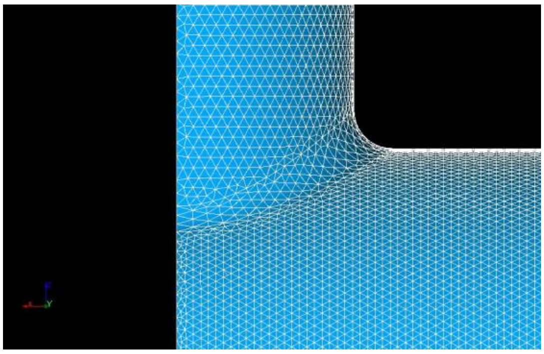

Fig. 3 − Mesh details of the FEA model (case study 4: R = 15mm).

The geometry resulted from the intersection between the main pipe and the incident pipe is very complex and could be considered a stress concentrator. The study analysed the possibility of reducing the stress concentration, considering eight additional study-cases, by use of the FILLET shape option. On the initial CAD model, “case-study 1”, there were applied FILLETS, within Salome-Meca, in the range 5-40 mm on the exterior edge generated by the intersection between the main pipe and the incident pipe. The corresponding study-cases and values of FILLETS are described in Table 1 and Table 2.

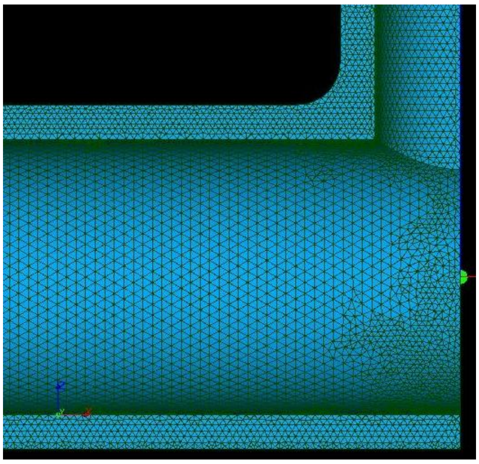

Fig. 4 − Mesh details of the FEA model (case study 6: R = 25mm).

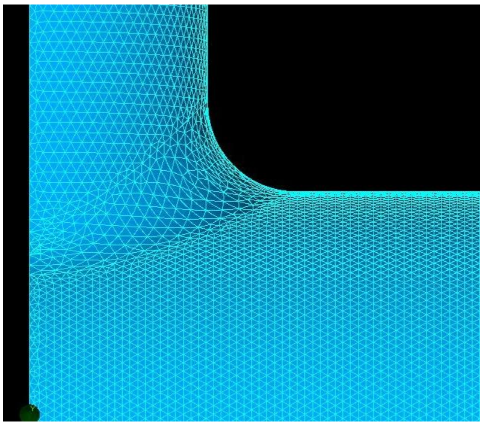

Fig. 5 − Mesh details of the FEA model (case study 8: R = 35mm).

The boundary conditions for the simplified FEA model implies free Degrees Of Freedom, DOFs within each and every symmetry plane and blocked DOFs normal to these planes. The most important meshing parameters for all the studied models are presented in the Table 1. The FEA model was loaded with a pressure p = 10 MPa, uniformly distributed on all the interior faces of the T shape pipes.

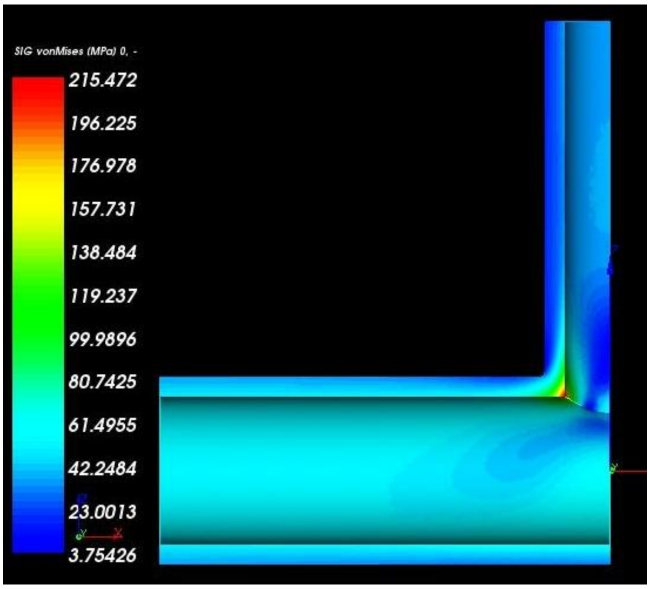

Fig. 6 − Details of $\sigma_{\text{von Mises}}$ distribution (case study 2: R = 5).

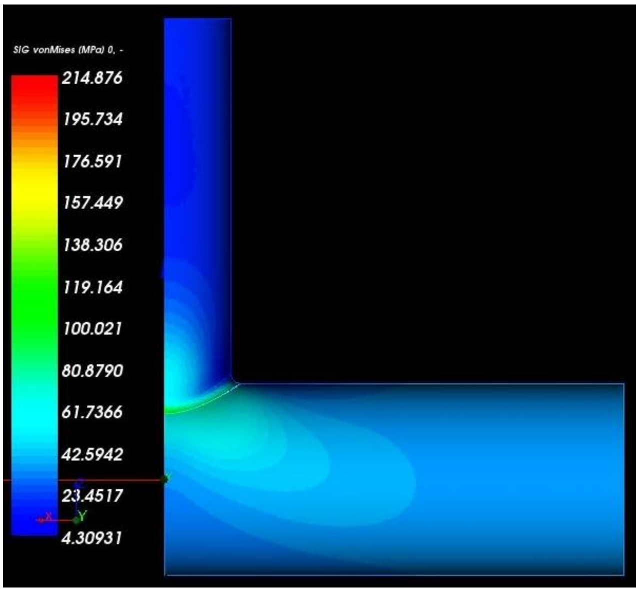

Fig. 7 − Details of $\sigma_{\text{von Mises}}$ distribution (case study 3: R = 10).

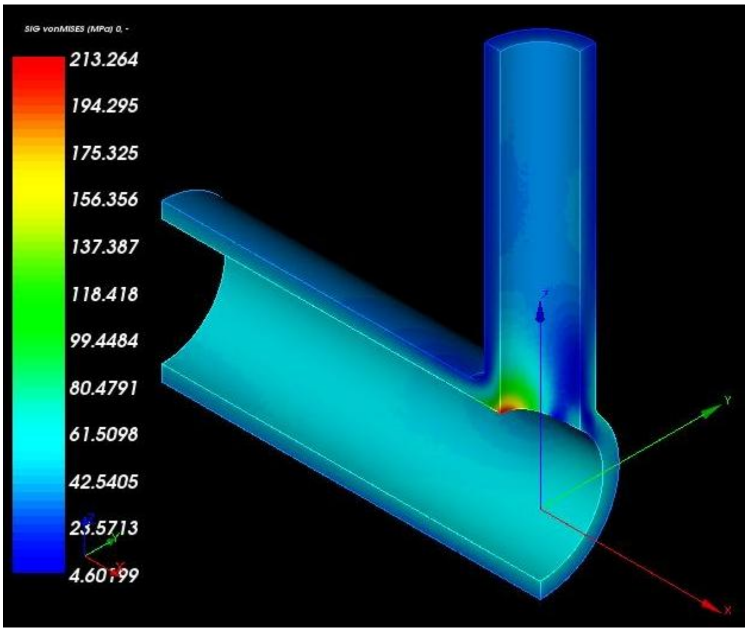

Fig. 8 − Details of $\sigma_{\text{von Mises}}$ distribution (case study 5: R = 20).

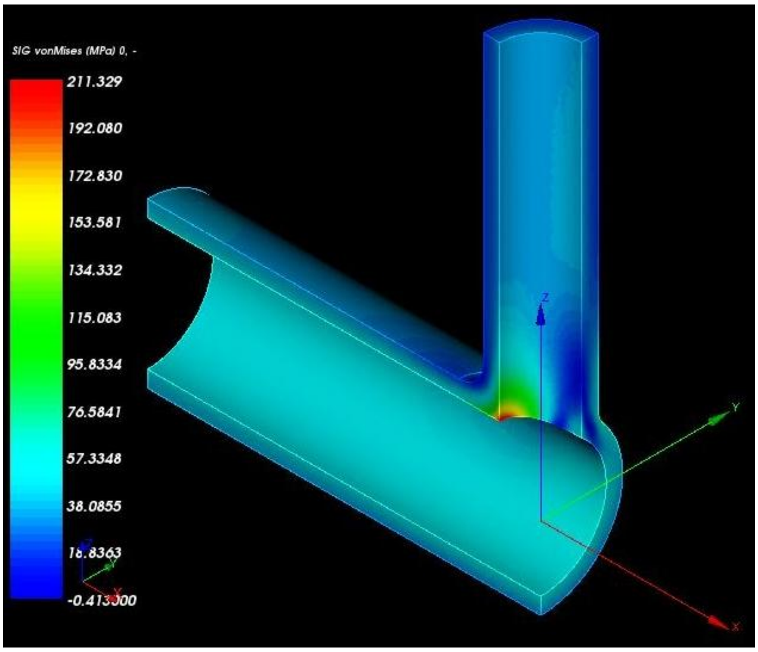

Fig. 9 − Details of $\sigma_{\text{von Mises}}$ distribution (case study 7: R = 30).

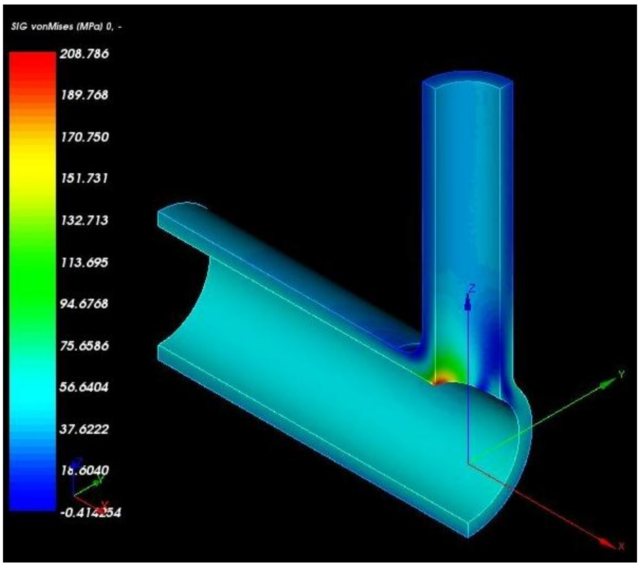

Fig. 10 − Details of $\sigma_{von\ Mises}$ distribution (case study 9: R = 40).

Table 2

Maximum Value of the von Mises Stresses in Stress Concentration Area

Study case	FILLET R [mm]	$\sigma_{von\ Mises}$ [MPa]
1	No FILLET	215.665
2	5	215.472
3	10	214.876
4	15	214.189
5	20	213.264
6	25	212.417
7	30	211.329
8	35	210.142
9	40	208.786

Details of some selected meshed models are presented in Figs. 2-5. Figs. 6-10, show the distribution of the $\sigma_{von\ Mises}$ stresses in some of the studied test-cases. Table 2 compares the maximal values for $\sigma_{von\ Mises}$ stresses in the stress concentration area versus FILLETs used in test case-studies 1-9.

3. Discussions and Conclusions

– The values for the L1/L2 parameters (the lengths for main/incident pipes) were sufficient large in order to avoid the influence of the boundary conditions applied at the end of the pipes on the stress concentration area, Figs. 6-10.

– The maximum stress concentration was evaluated by use of $\sigma_{von\ Mises}$ stress. The maximum values, in all cases, were observed on the interior edge resulted from the intersection of the main and incident pipe, within the area closer to the longitudinal symmetry plane xOz.

– According to Table 2 $\sigma_{von\ Mises}$ was reduced in case study 9 with 3.18% by comparison with the initial, no FILLET case.

The use of FILLET shape is probably not a very convenient solution for reducing the level of stress concentration. The manufacturing costs for generating such surfaces might also not be an advantage for adopting this solution.

– Future studies could be extended to other possibilities (classical or modern) for improving the shape of the edges in the stress concentration area.

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*** *CAELINUX*, www.caelinux.com, accessed 1.01.2016.

STUDIU CAD-FEA A INFLUENŢEI FORMEI FILLET ASUPRA FENOMENULUI DE CONCENTRARE A TENSIUNILOR ÎNTR-UN SISTEM DE ŢEVI RAMIFICATE ÎN T

(Rezumat)

Multe sisteme mecanice includ reţele de conducte care folosesc frecvent ţevi ramificate în T, care reprezintă zone de concentrare a tensiunilor. Lucrarea analizează posibilitatea de a reduce fenomenul de concentrare a tensiunilor prin utilizarea formei FILLET. Studiul a fost realizat cu ajutorul pachetului Salome-Meca (EDF Franţa) sub Linux Xubuntu, utilizat ca editor CAD dar şi ca pre/post processor pentru studiul FEA. Procesarea FEA a fost realizată cu ajutorul programului Code-Aster, inclus în Salome-Meca. Modelul CAD al unei ţevi ramificate în T a fost generat automat cu ajutorul Salome-Meca. Au fost considerate 8 cazuri de studiu, ca opţiuni alternative pentru reducerea fenomenului de concentrare a tensiunilor. În fiecare din aceste cazuri pe muchiile exterioare rezultate din intersecţia ţevii principale cu ţeava incidentă s-a aplicat opţiunea FILLET, valoarea acesteia variind în domeniul 5-40 mm. Este prezentată o comparaţie între valorile maxime a distribuţiei tensiunilor von Mises pentru toate cazurile studiate, pentru a analiza evoluţia fenomenului de concentrare a tensiunilor.