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

BY

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Abstract. Piping systems are basic components of many mechanical systems. They frequently include pipe T shapes. The paper presents a CAD (Computer Aided Design) and FEA (Finite Element Analysis) study of such an element. The CAD model of the pipe T shape is generated automatically by use of Salome-Meca pre/post processor (EDF-France). The FEA processor Code-Aster, included in Salome-Meca, evaluates the stress concentration. The paper studies a possibility of reduction of the stress concentration. The initial basic model was used to generate 4 different additional study cases. In each and every additional case a different CHAMFER was added on the initial CAD model, on the external edges generated by the intersection of the main pipe with the incident pipe. A comparison of the von Mises stress distribution is made in order to analyze the evolution of the stress concentration in the studied models.

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

1. Introduction

Many practical applications in Mechanical engineering include pressure vessels and piping systems. Their theoretical design is based on analytical

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formulas from the theory of thin-walled vessels or thick-walled vessels (Boresi, *et al*., 2003). There are also methods using specific codes, (Moss, 2004), based on ASME Code, Section VIII, Division 1. In this case the design follows specific rules and does not require a detailed evaluation of all stresses. Frequently the piping systems have complicated shapes. For a limited number of cases, the literature, (Young *et al*., 2002), recommends specific formulas for the correct evaluation of stresses in the vicinity of the stress concentrators: the areas with rapid geometrical changes. These cases do not include the intersection between two pipes with rectangular axes. For such situations the most popular and convenient recommended solution is FEA. The paper presents a CAD and FEA study for stress concentration reduction in a T-shape pipe.

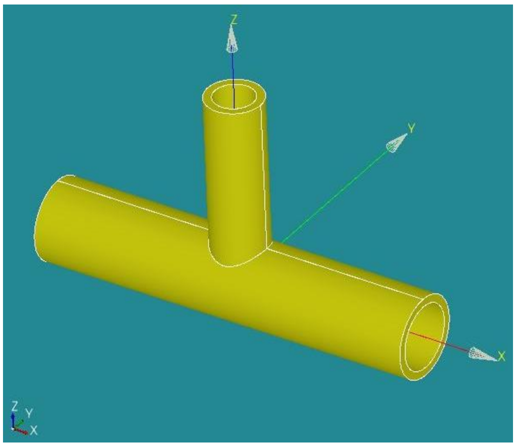

Fig. 1 − The initial full CAD model.

2. The CAD-FEA Study

The CAD model, Fig. 1, was automatically generated by use of SALOME-MECA (EDF, France), as part of the Open-source package CAELINUX-2013, (*** *CAELINUX*, 2016). SALOME-MECA was used as CAD editor for defining the geometry of the created models and also as pre/post processor for the FEA study.

The T shape pipe was created with the following 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.

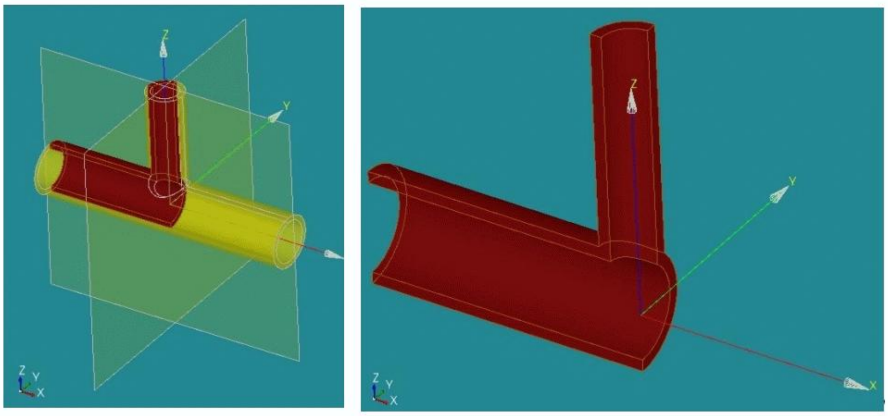

Fig. 2 − The definition of the simplified CAD model.

The initial CAD model, Fig. 1, has two symmetry planes (xOz and yOz), Fig. 2. For efficiency reasons of the FEA study it is more convenient to use a simplified model that is a quarter of the initial one, Fig. 2.

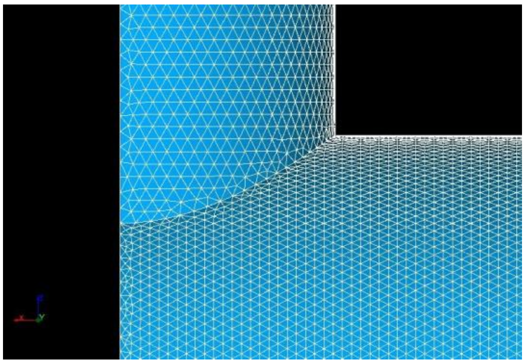

Fig. 3 − Mesh details of the FEA model (case study 1: no CHAMFER).

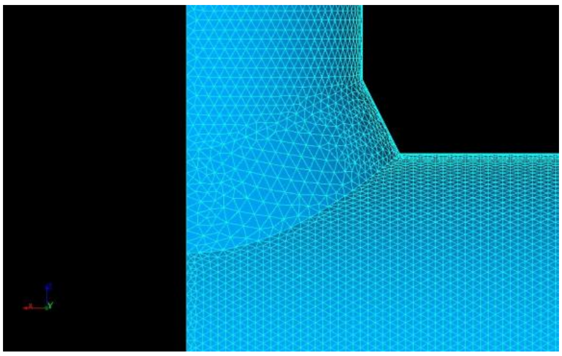

Fig. 4 − Mesh details of the FEA model (case study 3: H = 30; W = 15).

The area in the vicinity of the junction of the main pipe and the incident pipe, due to the rapid changes in form, represents a stress concentrator. In order to study the possibility of reducing the stress concentration four options of CHAMFER were considered. Salome_Meca CAD editor can automatically generate for Pipe T-Shape CHAMFERS defined by the parameters H, and W defined as:

H – Height of the chamfer along the incident pipe.

W – Width of the chamfer along the main pipe.

The CHAMFER options were applied on the exterior edge resulted from the intersection from the two pipes. The additional four study-cases and the corresponding values of the H and W parameters of the CHAMFER are indicated in Table 1 and Table 2.

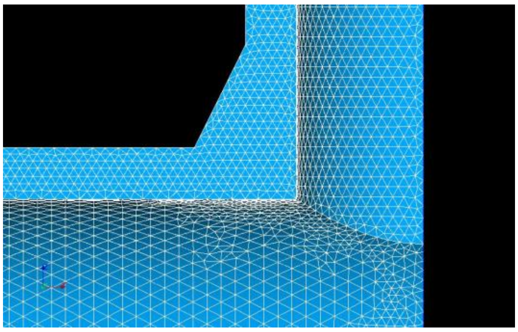

Fig. 5 − Mesh details of the FEA model (case study 4: H = 40; W = 20).

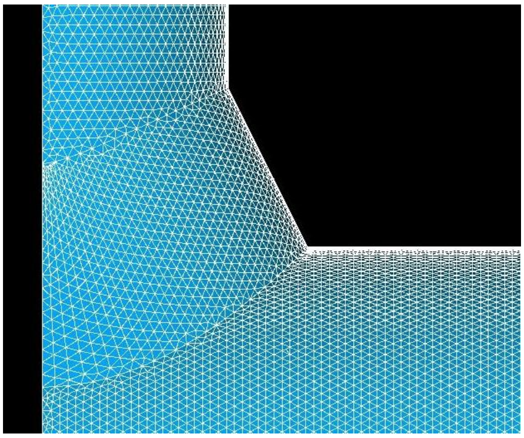

Fig. 6 − Mesh details of the FEA model (case study 5: H = 60; W = 30).

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

Table 1
Basic Parameters of the FEA Study

Study case	CHAMFER HxW [mm]	Finite Elements TETRA10 [Quadratic tetrahedrons]	Nodes	DOFs
1	No CHAMFER	136567	237371	740289
2	20x10	136993	238126	742476
3	30x15	138279	239947	748141
4	40x20	143528	247899	772167
5	60x30	144332	249087	776285

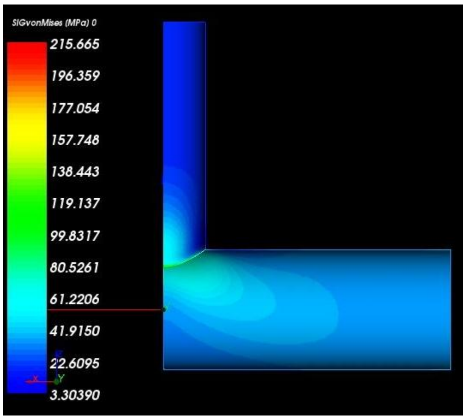

Fig. 7 − Details of $\sigma_{\text{von Mises}}$ distribution (case study 1: no CHAMFER).

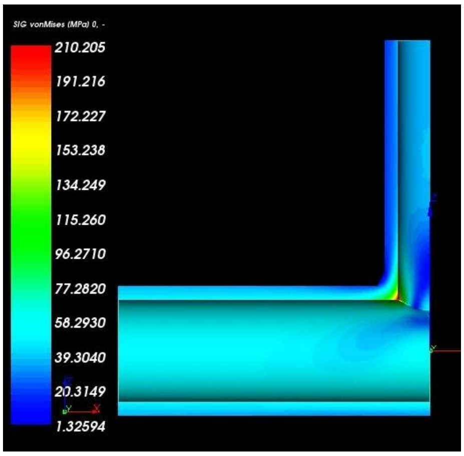

Fig. 8 − Details of $\sigma_{\text{von Mises}}$ distribution (case study 2: H = 20; W = 10).

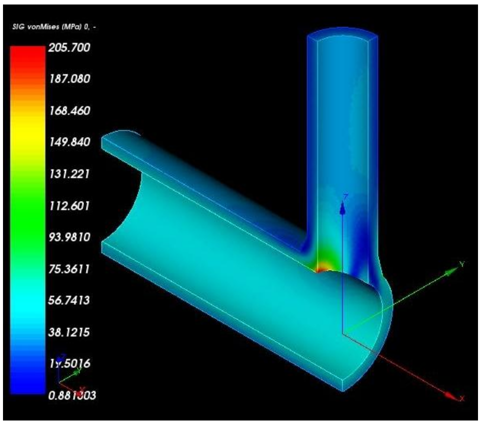

Fig. 9 − Details of $\sigma_{\text{von Mises}}$ distribution (case study 3: H = 30; W = 15).

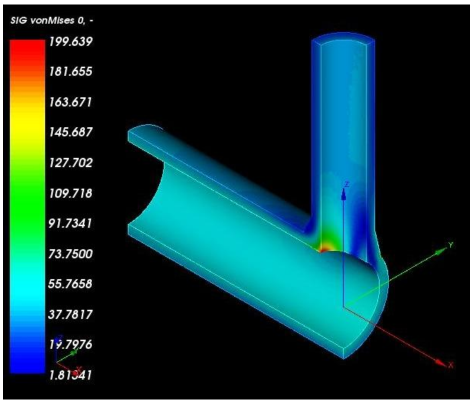

Fig. 10 − Details of $\sigma_{\text{von Mises}}$ distribution (case study 4: H = 40; W = 20).

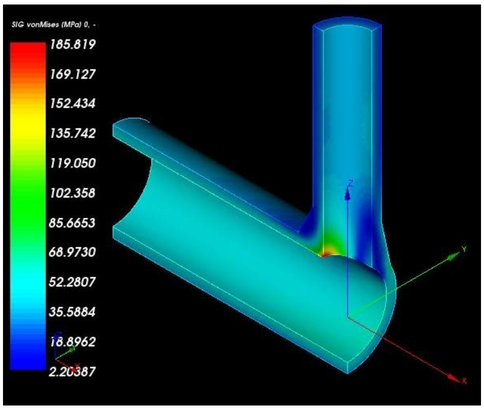

Fig. 11 − Details of $\sigma_{\text{von Mises}}$ distribution (case study 5: H = 60; W = 30).

Details of some meshed models are presented in Figs. 3-6. Figs. 7-11 show the distribution of the $\sigma_{\text{von Mises}}$ stresses in practically all the studied test-cases. Table 2 indicates $\sigma_{\text{von Mises}}$ stresses versus CHAMFERs used in the study.

Table 2

Maximum Value of the von Mises Stresses in Stress Concentration Area

Study case	CHAMFER HxW [mm]	$\sigma_{\text{von Mises}}$ [MPa]
1	No CHAMFER	215.665
2	H=20; W=10	210.205
3	H=30; W=15	205.700
4	H=40; W=20	199.639
5	H=60; W=30	185.819

3. Discussions and Conclusions

– The adopted values of 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. 7 and 8.

– The maximum stress concentration (evaluated by the $\sigma_{\text{von Mises}}$ stress) produces in all cases on the interior edge resulted from the intersection of the main and incident pipe, closer to the longitudinal symmetry plane xOz, Fig. 2.

– According to Table 2 $\sigma_{\text{von Mises}}$ was reduced in case study 5 with 13.83% by comparison with the initial, no CHAMFER case.

The use of CHAMFER might be an efficient solution for reducing the level of stress concentration.

The best decision should probably consider manufacturing costs versus the imposed safety conditions.

– Future studies could be extended to other solutions (classical or modern) for modifying 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 CHAMFER ASUPRA FENOMENULUI DE CONCENTRARE A TENSIUNILOR ÎNTR-UN SISTEM DE ŢEVI RAMIFICATE ÎN T

(Rezumat)

Sistemele de conducte sunt o componentă de bază pentru multe sisteme mecanice. În mod frecvent sunt folosite ţevi ramificate în T. Lucrarea prezintă un studiu Computer Aided Design, CAD- Finite Element Analisis, FEA a unui astfel de element. Modelul CAD a ţevii ramificate în T este generat automat cu ajutorul Salome-Meca, pre/post processor dezvoltat de EDF, Franţa. Evaluarea stării de tensiune a fost realizată cu ajutorul Code-Aster, processor FEA inclus în pachetul Salome-Meca. Lucrarea studiază o posibilitate de reducere a fenomenului de concentrare a tensiunilor. Modelul de bază iniţial a fost utilizat pentru a genera 4 cazuri de studiu suplimentare. În fiecare din aceste cazuri suplimentare, pe modelul iniţial CAD, pe muchiile exterioare rezultate din intersecţia dintre ţeava principală şi ţeava incidentă, s-au adăugat diferite valori pentru forma CHAMFER. Este realizată o comparaţie a valorii maxime a tensiunilor von Mises în toate modelele studiate, pentru a analiza evoluţia fenomenului de concentrare a tensiunilor.