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FEA STUDY ON THE INFLUENCE OF FILLET ON NATURAL MODES OF VIBRATION OF A PIPE T SHAPE

BY

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Abstract. Piping circuits are common components of products from all fields of activity. A pipe T shape is an example of structure with stress concentration in the vicinity of the intersection area between pipes. Previous CAD FEA studies have determined the influence of the fillet on the stress concentration factor. The paper presents a FEA evaluation on the influence of the fillet on the natural frequencies of the same T shape structures. The FEM (Finite Element Method) simulations were performed with Salome-Meca and Code-Aster (developed by Electricité de France), included in the package CAELINUX. Two study cases were considered: the standard model (the T-shape pipe with no fillet) and the same geometry including fillet R=50 mm (the radius of the fillet) in the area where the two pipes intersect. The study finally determined and compared the first 12 natural modes of vibration for the considered study cases.

Keywords: FEM; CAELINUX; Natural frequencies; Fillet; Pipe T Shape.

1. Introduction

The classical design of pipes uses analytical calculus defined by the Theory of Elasticity, (Boresi and Schmidt, 2003). Alternative solutions, (Moss,

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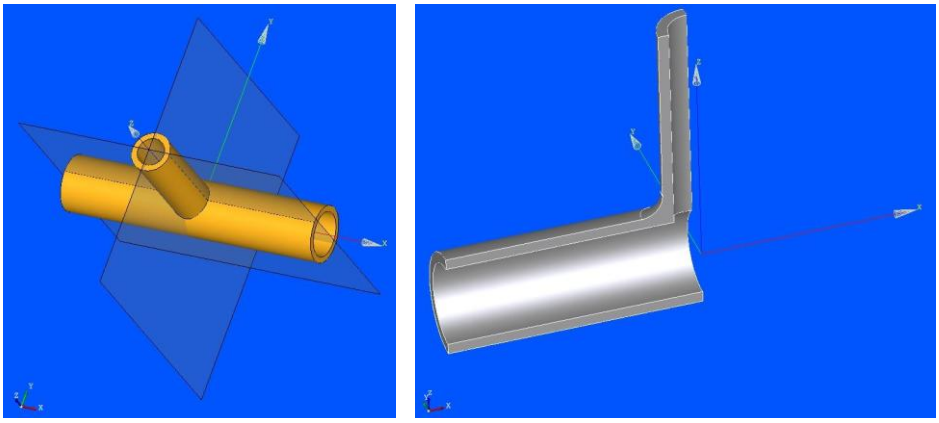
2004), reference the ASME Code, Section VIII, Division 1. The applied procedure does not imply an evaluation in detail of the stress gradient. The modern design of piping systems is imposed for many practical applications, including the T shape pipes. In the early stages of the design the study of the system is often conducted with FEM. A previous study (Aignătoaie, 2016) has evaluated the influence of fillet shape on the stress concentration in the area of intersection between pipes with rectangular axes. The fundamental elements for the study of structures operating under vibrations are described by (Piersol and Paez, 2010). The present paper describes a FEM study on the influence of the fillet shape on the natural frequencies of vibration of a T shape pipe.



a *b*

Fig. 1 – Geometric models: *a* – the model; *b* – simplified model with fillet.

2. The FEA Study

The CAD-FEA study uses Salome-Meca and Code-Aster (owned by Electricité de France) components of the open-source engineering package CAELINUX, (*** *CAELINUX*, 2019).

Two basic CAD models -identical with those used in (Aignătoaie, 2016) - were studied:

1. Standard model (a T-shape pipe without fillet)

2. Fillet R=40 model (the structure described at paragraph 1, but with the fillet parameter: R=40 mm).

The present paper has determined by use of FEA the first 12 natural frequencies for both two study cases described above.

Both CAD models have two symmetry rectangular planes, Fig.1*a*. The FEA study could be performed on a simplified model, Fig.1*b*.

All the studied structures were manufactured of AISI 1010 steel with the basic characteristics: the Young's modulus: E=205 GPa, Poisson's ratio: ν=0.29, density: ρ=7.87 g/cc.

Some details of the FEM mesh study are included in Table 1.

Table 1
Details of the FEM Simulation

Models	Nr. of finite elements, Type: TETRA10 [Quadratic tetrahedrons]	Nr. of nodes	Nr. of DOFs
1.Standard model	136567	237371	740289
2. R=40mm model	138403	239941	748069

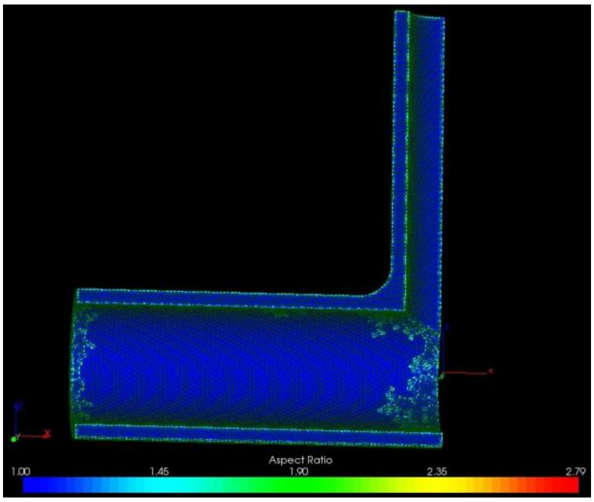


Fig. 2 – The Aspect Ratio Face distribution for the R=40 mm model.

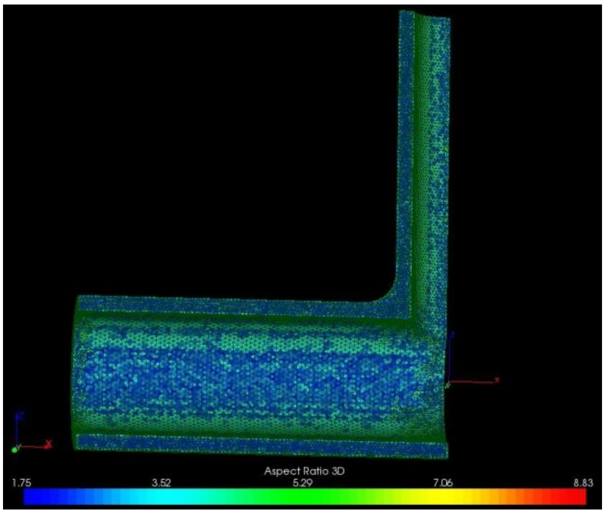


Fig. 3 – The Aspect Ratio 3-D distribution for the R=40 mm model.

Salome-Meca investigates the quality of the mesh using specific procedures: Aspect ratio 2-D face, Fig. 2 and Aspect ratio 3-D, Fig. 3.

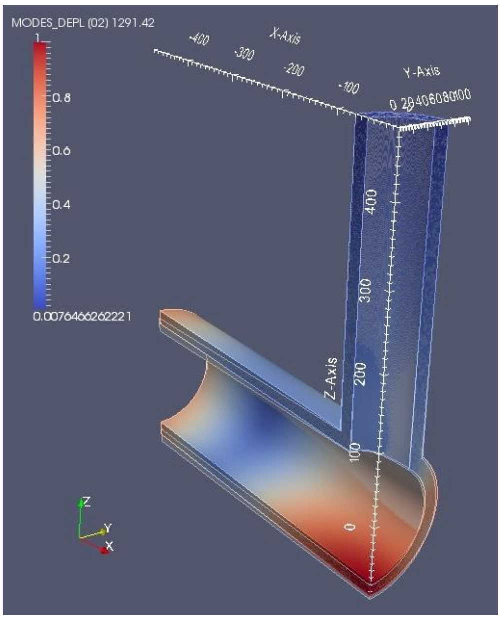


Fig. 4 – Mode shape 2, for the standard model:.

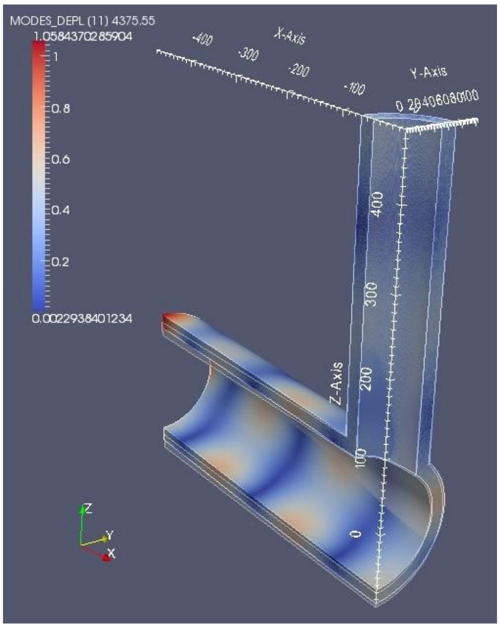


Fig. 5 – Mode shape 11, for the standard model.

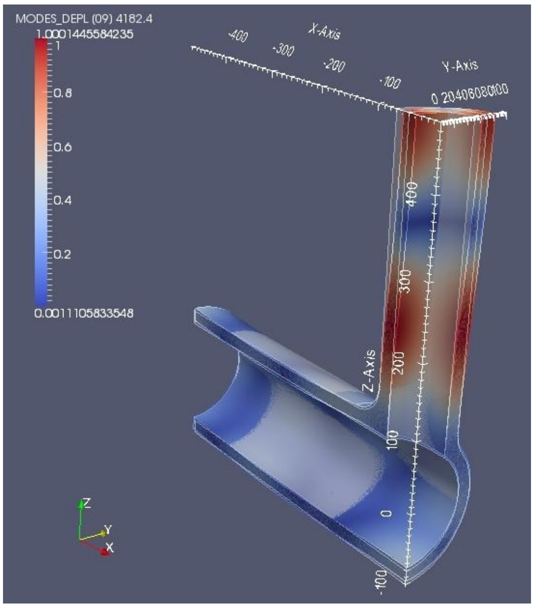


Fig. 6 – Fillet R=40 model, mode shape 9.

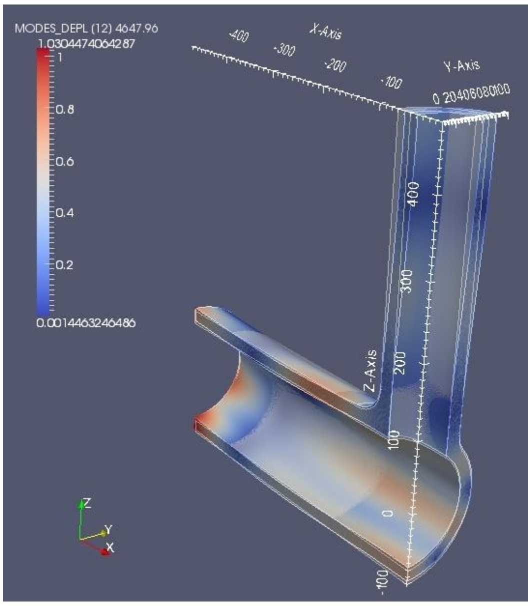


Fig. 7 – Mode shape 12, for the fillet R=40 mm model.

Figs. 4 and 5 present samples of the mode shapes for the standard model. Figs. 6 and 7 show 2 of the mode shapes determined for the fillet R=40 model. In all the figures presenting mode shapes the deformed image of the structure was superimposed with de non-deformed geometry set to a high level of transparency.

Table 2
The Influence of the Fillet Shape on the Natural Frequencies

Mode of vibration number	Frequency for standard model [Hz]	Frequency for Fillet R=40 model [Hz]	Influence of fillet shape [%]
1	524.681	554.686	5.718713
2	1291.420	1314.670	1.800344
3	1628.660	1631.870	0.197095
4	2062.670	2070.080	0.359243
5	2531.020	2559.320	1.118126
6	2812.280	2810.180	-0.07467
7	3516.640	3519.220	0.073365
8	3544.650	3556.950	0.347002
9	4144.410	4182.400	0.916656
10	4335.570	4337.920	0.054203
11	4375.550	4430.530	1.256528
12	4615.730	4647.960	0.698264

3. Discussions and Conclusions

Table 2 presents the all the data calculated and a comparison between the two studied models. The presence of the fillet produces a small increase (around 5%) of the initial frequency (mode 1). The rest are totally insignificant. The fillet does not influence practically the mode shapes.

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STUDIU FEA PRIVIND INFLUENŢA FORMEI FILLET ASUPRA MODURILOR PROPRII DE VIBRAŢIE PENTRU O ŢEAVĂ RAMIFICATĂ ÎN T

(Rezumat)

Reţelele de conducte sunt componente uzuale ale unor produse din multe domenii de activitate. O ţeavă ramificată în T este un exemplu de structură cu concentrare a stării de tensiune în vecinătatea zonei de intersecţie dintre cele două ţevi. Studii CAD FEA anterioare au determinat influenţa formei fillet asupra nivelului de concentrare a tensiunilor. Lucrarea descrie un studiu FEA privind influenţa formei fillet asupra frecvenţelor proprii de vibraţie ale ţevilor în T studiate anterior. Simulările MEF (Metoda Elementului Finit) au fost realizate cu pachetul Salome-Meca şi Code-Aster (dezvoltate de EDF, Franţa), ca părţi componente ale pachetului CAELINUX. Au fost considerate două modele de studiu: modelul standard (ţeavă ramificată în T, fără forma fillet) şi aceeaşi geometrie dar cu forma fillet R=50 mm (raza de racordare corespunzătoare). În final studiul a permis compararea frecvenţelor corespunzătoare primelor 12 moduri de vibraţie ale cazurilor considerate.