Implementing Axisymmetric Smoothed Finite Method (S-FEM) Element in ABAQUS to Analyze defective Pressure Piping

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Abstract

Pressure piping is the most productive way for large volume compressed natural gas (CNG) transportation. In pipeline constructions, the thickness of between two pipes joining together is often not consistent due to the miss-match in dimensions, and thus stress concentrations can often occur at the pipe joints, arising safety concerns. Therefore, it is of importance to accurately analyze the key influencing factors of dimensional miss-matching defects, providing theoretical basis for the preliminary design and post-repair of pipelines. This work uses the smoothed finite element method (S-FEM) that has been proven accurate in stress analysis compared with the traditional FEM. Since the geometry and the load of the pressure piping are both axisymmetric, a novel axisymmetric S-FEM element is firstly developed, coded and integrated in ABAQUS using the user-element-library (UEL). Intensive studies are then carried out to examine the effects of different level of miss-match in the thicknesses of two joined pipes and the effects of the radius of the transitional fillet used to bridge the miss-matches. It is found that the maximum hoop stress reduces as the radius of the transitional fillet increases. For the thinner section of the pipe, the maximum hoop stress is only affected by the thickness miss-match.

***Keywords*:** Pressure piping; Finite element analysis (FEA); Smoothed finite element method (S-FEM); Hoop stress; Transitional fillet

Introduction

As demand of compressed natural gas (CNG) is increasing, pressure piping is widely used for long distance CNG transportation. However, leaks and explosions of pressure piping could cause huge property losses even threaten people's life safety. There are many possible sources of defect such as production defect, installation error, fatigue, etc. [1-3]. But there is very little research has been done about defect of different level of miss-match in the thicknesses of two joined pipes caused by production process. Since it is an important kind of reason for pressure piping's failure, it's necessary to analyze the defective piping under working condition providing theoretical basis for the preliminary design and post-repair.

In general, finite element analysis (FEA) [4-5] is the most common way for model simulation as its high efficiency and low cost. For this study, as geometry and load of the pressure piping are both axisymmetric, two-dimension (2D) axisymmetric elements is selected to discrete the problem domain. Relate large mesh density should be applied at the defective section to compute more accurate results. Nevertheless, for current FEA software packages, it's hard to control the most suitable mesh density at defective sections. If mesh density is too small, it's impossible to compute accurate maximum stress for stress concentration issue. On the contrary, overlarge mesh density will cause computing inefficiency and heavily distorted elements will occur between dense and sparse mesh regions. Therefore, smoothed finite element method (S-FEM)[6-[8] is processed to analyze models instead of the traditional FEM. It has been proved that S-FEM computing more accuracy results and quicker convergence speed compared with traditional FEM. In addition, models with distorted mesh condition can be calculated by S-FEM with accuracy results.

For pressure piping in this study, the defect of different level of miss-match in the thicknesses of two joined pipes is analyzed by S-FEM in ABAQUS. In general, at the stagger sections of interconnected piping, transitional fillet is applied to reduce the stress concentration. Examining the effects of different level of miss-match in the thicknesses of two joined pipes and the effects of the radius of the transitional fillet for the pressure piping.

Effect of thickness difference and transition fillet size on hoop stress

In this section, Pressure piping with the defect of thickness difference and transition fillet size have been studied. And the model of thickness difference at both inner surface and outer surface are all analyzed with S-FEM. Finally, the effect of the thickness difference and the size of the transition fillet on the maximum hoop stress is obtained.

We firstly analyzed a 500mm pressure piping with thickness difference at middle of the inner surface as shown in Fig. 1. The pressure piping can be divided into two parts. For the lower part, inner and outer radius are fixed to 230mm and 250mm, respectively. But for the upper part, the outer radius is fixed to 250mm, the inner radius is changed from 230.5mm to 234mm, and the increment is 0.5mm. Meanwhile, the radius of transition fillet is also changed from 0.5mm to the maximum thickness difference, and the increment also is 0.5mm.

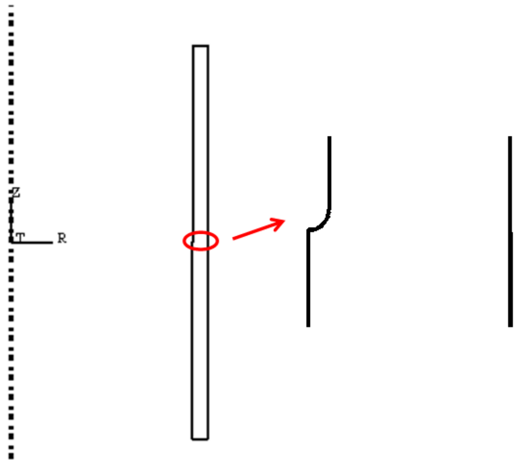
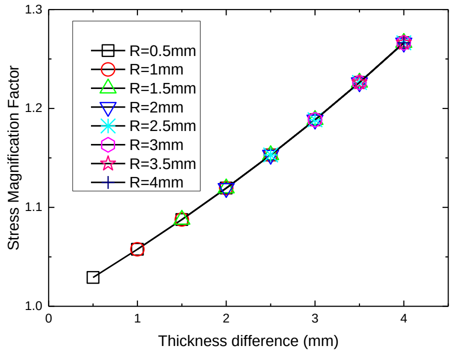
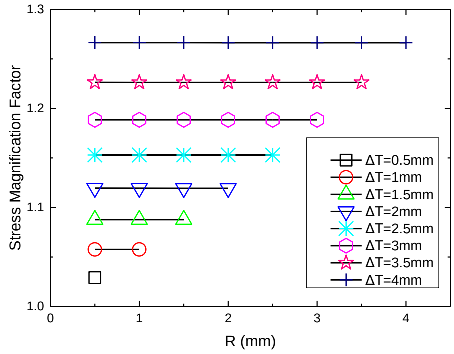


Fig. 1 Pressure piping with defect of thickness difference at inner surface

All the models are analyzed by the S-FEM in ABAQUS. Since the hoop stress is the largest among the stress components, the hoop stress is compared for each model. The maximum hoop stress is at the transition fillet, and there is also relatively larger hoop stress at the upper part because of the thin wall thickness. Therefore, the maximum hoop stress is compared at the transition fillet and upper part respectively for all the models. And the effect of thickness difference and transition fillet size on hoop stress can be obtained. The purpose of making convenient for results analyzing, the value of the maximum hoop stress of the defective piping is divided by that of the piping without defect. For the thin-walled part, the maximum hoop stress is only effected by the thickness difference rather than the size of the transition fillet as shown in Fig. 2 (a) and (b). And for the transition fillet part, the maximum hoop stress has linear relationship with the thickness difference as shown in Fig. 2 (c). In addition, keeping the thickness difference unchanged, the maximum hoop stress has quadratic function relation with the radius of the transition fillet as shown in Fig. 2 (d). For the case of thickness difference at the outer surface, the change rule of the maximum hoop stress for different size of thickness difference and radius of the transition fillet is the same as that of the defect at inner case.



(a)



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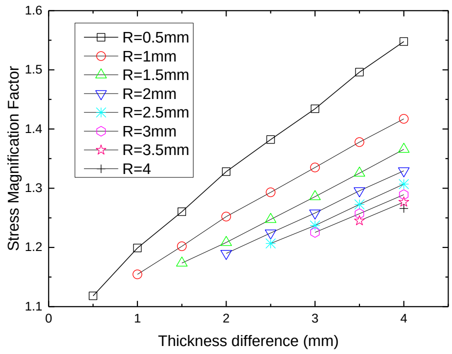
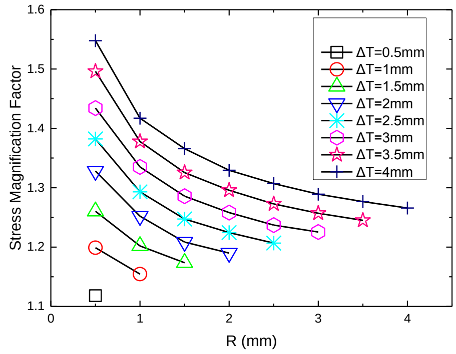


(c)



(d)

Fig. 2 The maximum hoop stress: (a) for different thickness difference at the thin-walled part; (b) for different radius of the transition fillet at the thin-walled part; (c) for different thickness difference at the transition fillet part; (d) for different radius of the transition fillet at the transition fillet part.

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