Fast finite element stress and deformation prediction for large thick-wall welded cylinder with angle-inserting elbow†

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KEY WORDS: (Large thick-wall) (Fast prediction) (Stress evolution) (Roundness change) (Simplified models)

1. Introduction

During thick-wall vessel welding, due to the serious uneven heating on the thick-wall vessel during welding, larger deformation easily occurs on the joint during welding and cooling. It is necessary to make prediction of the characteristics of structure stress and deformation.

In the numerical calculation of large thick-wall structure welding, the calculation workload can be effectively reduced by appropriate simplification, as in reference [1-2].

Three predictor models based on software ANSYS with simplification of bead, moving heat source, and both of them respectively are presented. As a result, the characteristics of stress and deformation have been predicted fast.

2. Finite element modeling

As shown in **Fig. 1,** thick-wall welded cylinder with angle-inserting elbow is composed of two parts, the wall thickness of both structures are 125mm. The temperature input imposed during each bead is showed in **Fig. 2**. All parts of the joint are carbon steel 20G, whose properties are shown in **Fig. 3**. The specific process parameters are shown in **Table 1**. The 3D finite element mode is shown in **Fig. 4**.

Table 1 Technological parameter

Parameter	Value
Welding speed / cm/min	16
Average time for single welding / min	100

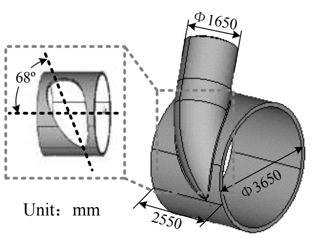


Fig.1 Structure and groove of welded cylinder with angle-inserting elbow

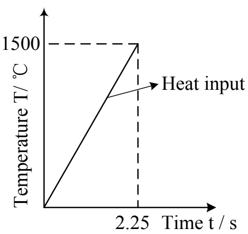
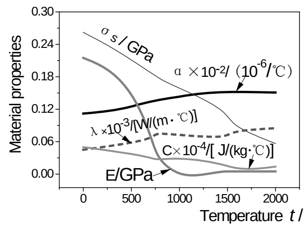


Fig.2 Heat input and their duration



α: Linear expansion coefficient; σ_s: Yield strength; E: Elastic modulus; C: Specific heat; λ: Thermal conductivity; ρ(Density)=7.89×106kg/m³

Fig.3 Material property

3. Comparison of simplified model

Three simplified models are established. The welding order and weld size after the beads is simplified to be 5 and are described as shown in **Fig. 5**. The simplification methods are given in **Table 2**.

The stresses of point A at different locations along the depth direction of the weld are compared as shown in **Fig. 6**. It can be known that, the stress distribution under model A is most close to the typical description of stress distribution of thick-wall vessel in other reference [3].

Stresses of region B at different locations along the vertical direction of weld are compared as shown in **Fig. 7.** It can be known that the method of simplified bead is obviously better than that of simplified moving heat source when studying the stress within the same bead plane.

The regions where the equivalent residual stress under 3 simplified models is up to 80%, 60% and 50% respectively are compared as shown in **Fig. 8**. It can be seen that the methods of bead and moving heat source simplified have little effect on the overall stress of joint.

In order to explain the effect of simplification method on the stress evolution of joint, the process stress under 3 simplified models of point A at different moments are compared as shown in **Fig. 9**.

4. Fast prediction

Under the Model C, the computing time under this simplified model can be shorten significantly. Therefore, Model C whose bead and moving heat sources are both simplified is selected for fast prediction of joint stress in this article.

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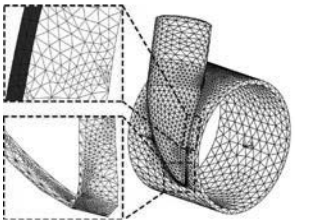


Fig.4 Finite element model of joint

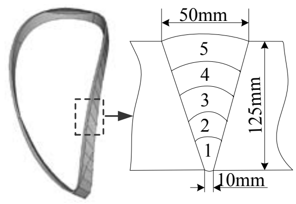


Fig.5 Welding process and size description for 5 bead

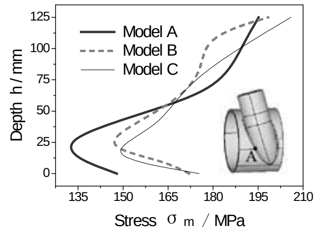


Fig.6 Equivalent stress in depth at point

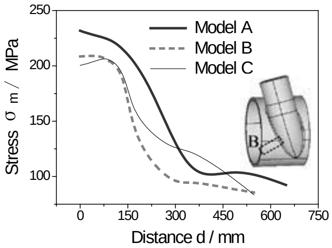


Fig.7 Stress with distance to the welding center at region B

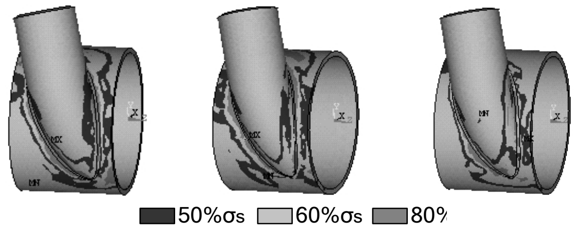
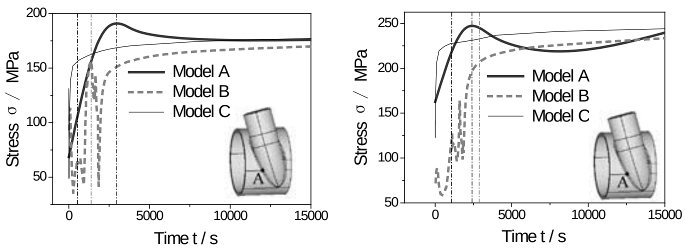


Fig.8 Equivalent stress with three simplified standards

Table 2 Simplified methods

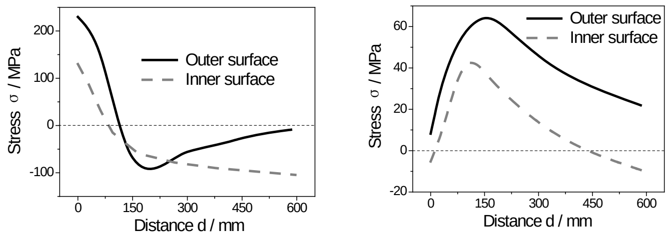
Model	Bead	Moving heat source
A	5	No
B	1	Yes
C	1	No

Figure 10 shows the longitudinal and transverse stress distribution on the internal and external surface of region B at different locations along the vertical direction of weld. It can be known from the figure, the stress on the external surface of the weld is obviously higher than that on the internal surface.



（a）Internal surface （b）External surface

Fig.9 Stress cycle on the internal and external weld at point A



（a）Longitudinal residual stress （b）Transverse residual stress

Fig.10 Stress of the weld with distance from the centerline

For the analysis of deformation characteristics of joints, the roundness change of the left and right ends on the cylinder, the roundness change of weld curve, and the displacement of elbow outer contour are analyzed, the research area is shown as in **Fig. 11**.

Figure 12 shows the relative displacement of all points on the elbow outer contour at different moments. At the beginning of welding, elbow is far from the cylinder, finally the distance between elbow and cylinder is smaller and the axis curvature of elbow is larger.

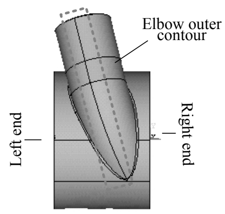


Fig.11 Research region of displacement

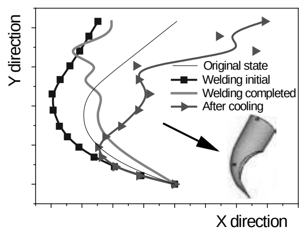


Fig.12 Displacement schematic diagram of elbow axis

Figure 13 shows the roundness change at the two ends of left and right on the cylinder. During cooling, the roundness change of the cylinder is just opposite to that in the stage of welding. The elliptic deformation of circle at the left of the cylinder is smaller than that of the circle in the right.

Figure 14 expresses the displacement of all the points on the weld at different moments. It can be seen that the angle between the symmetrical axis of weld and the axis of cylinder has an important influence on the deformation of the weld.

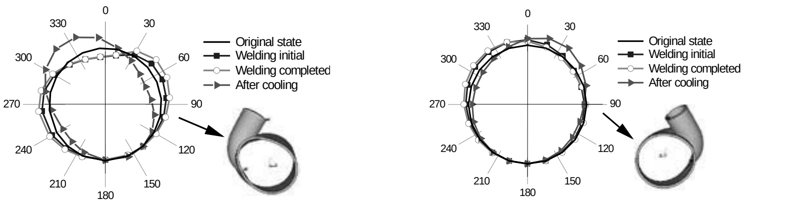


Fig.13 Displacement schematic diagram of point on both ends of thick-wall cylinder

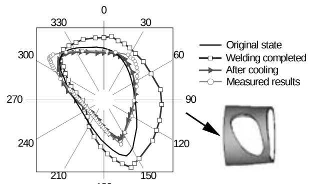


Fig.14 Displacement schematic diagram of point on bead

5. Conclusions

(1) The process peak stress increases in case of simplified moving heat source model, and the process stress of the joint with many beads or a very long welding time is affected more significantly by the simplified bead model.

(2) Under the model whose bead and moving heat sources are both simplified, the distance between elbow and cylinder as well as the roundness change of the cylinder, are in a reverse state during welding and cooling.

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