

The effect of welding line heat-affected-zone on the formability of tube hydroforming process

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Abstract. Tube hydroforming has been used as a lightweight design approach to reduce CO₂ emission for the automotive industry. For the high strength steel tube, the strength and quality of the welding line is very important for a successful tube hydroforming process. This paper aims to investigate the effect of the welding line's strength and the width of the heat-affected zone on the tube thinning during the hydroforming process. The simulation results show that both factors play an important role on the thickness distribution during the tube expansion.

1. Introduction

Tube hydroforming process has been applied extensively in the automotive body structure [1]. During the process, a tube is first put in the lower die cavity. After upper die closing, two cylinders are sealed on the both side of the tube. Then high pressure (>1000 bar) water is pumped into the tube to make tube expand to the die shape [2]. Most simulation studies focus on the thickness/wrinkle/burst prediction during tube-bending, preforming and hydroforming process [3-4]. Usually, in the finite element simulation model, a uniform mechanical property without considering the welding line's strength is assumed. However, during the tube making process and die-tryout, we found that the difference of mechanical property between the welding line and non-welding line area plays an important role in the tube thinning and accuracy of simulation prediction. In this study, we use finite element software PAM-STAMP 2G to investigate the effect of the welding line's mechanical strength and heat-affected-zone's width on the tube thinning behavior during hydroforming.

2. Model setup

An automotive chassis twist beam (see Figure 1) is selected as the simulation model in this study. In the middle is a V-shape section. On both end, the expansion ratio is around 11% by choosing a round tube of 113 mm outside diameter. The tube grade is 590 MPa thickness is 3.5 mm. The software Pam-Stamp 2G is used to build up the simulation model as shown in Figure 2. Young's modulus is 210 GPa and Poisson's ratio is 0.3. The total element number is 7056. The water pressure is multi-stage linearly increased from 0 to 1500 bar. The axial feeding distance is multi-stage linearly increased from 0 to 26 mm on both tube end.

During the electric resistance welding (ERW) tube making process, the mechanical properties of welding line will be changed by adjusting the heat treatment parameters. Usually, the strength of the welding line is higher than the other area of the material. In this study, we consider three different welding line's strength level during the simulation. Three cases of welding line are shown in Figure 3.



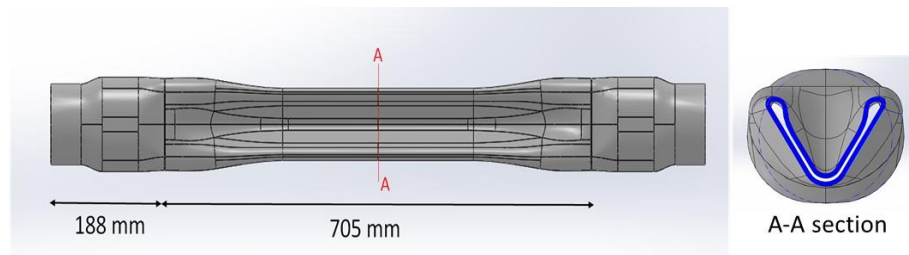


Figure 1. Automotive chassis twist beam structure

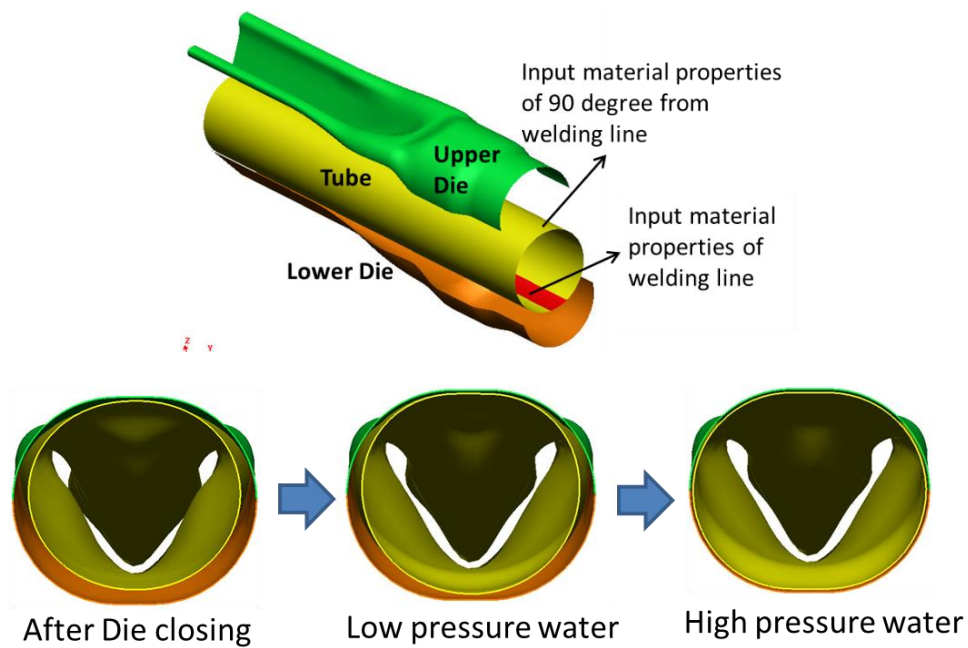


Figure 2. Tube profile change during hydroforming

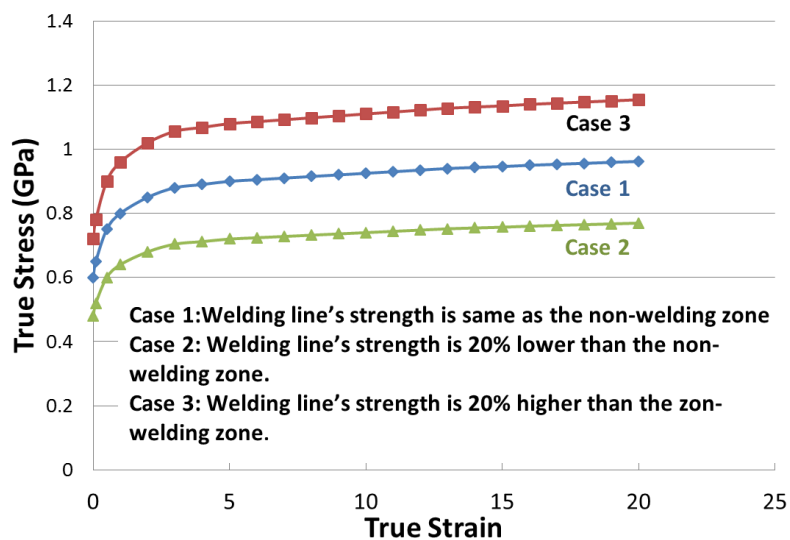


Figure 3. Flow-Stress curves for different welding line's strength

3. Simulation results and discussions

During the tube making process, the welding line's strength and the range of heat affecting zone (HAZ) will be affected by using different online annealing parameters. In the following, we discuss how the welding line's material property and the width of HAZ affect the tube thinning during hydroforming.

3.1. The effect of welding line's material property on the tube thinning

Figure 4(a) shows the material thinning of the welding line after hydroforming when we consider different strength of the welding line. The welding line including the HAZ is assumed to be 25mm. Case 1 is the case when we incorporate a uniform material property (i.e. welding line's strength is same as the non-welding line material). It could be observed that the thinning is very uniform through the width of the welding line, ranging from 4.8% to 6.5%. If the strength of the welding line is 20% lower than the non-welding line area, during hydroforming the thinning of the welding line become more significant as shown in Figure 4(b). Thinning of the welding line increases to range from 19.2% to 26.1% because now the welding line is a soft zone compared to the non-welding area. Figure 4(c) is the case when the welding line's strength is 20% higher than the non-welding line material. It could be observed that the thinning of the welding line is further improved compared to the case 1 and case 2. The main reason is that during tube expansion, the soft area of the tube will be mainly stretched. This result shows that during the heat treatment of tube making process, the mechanical property of the welding line plays an important role in the tube thinning and fracture location. A local thinning on the welding line during hydroforming should be avoided.

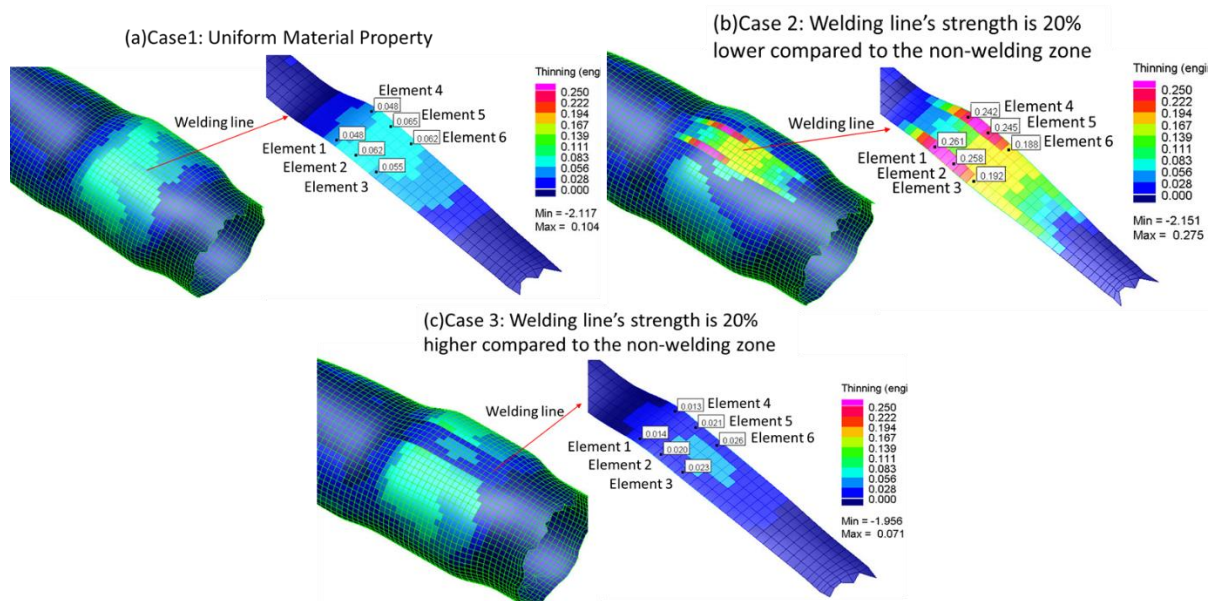


Figure 4. The effect of welding line material property on the tube thinning

3.2. The effect of width of heat-affected-zone on the tube thinning

In this section, we discuss the effect of the width of heat-affected-zone (HAZ) on the tube thinning during hydroforming. Three different cases (HAZ=25, 45, 60 mm) are considered in this study and we all assume the welding line's strength is 20% higher than the non-welding area. When the HAZ is 25mm, after tube expansion the thinning of the HAZ's edge is between 7.4~9.5% as shown in Figure 5(a). When the HAZ is increased to 45 mm and 60 mm, the thinning at the same element has been changed to the range of 6% to 8.1% and 5.4% to 7.3%, respectively. This result indicates that with the increasing of the HAZ, the local thinning of the welding line could be improved, thus lower the risk of bursting during hydroforming.

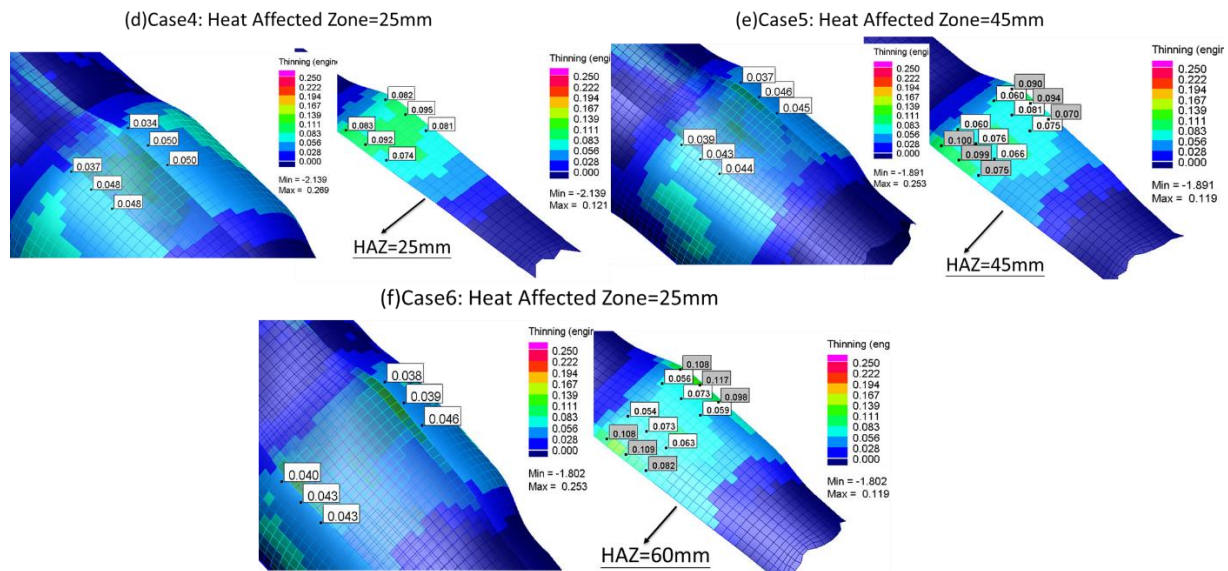


Figure 5. The effect of width of heat-affected-zone on the tube thinning

4. Conclusions

In this paper, we investigate the effect of welding line's mechanical properties and the width of heat-affected-zone on the tube thinning during hydroforming. The simulation results show that the local thinning of the welding line could be improved by (1) Increase the strength of the welding line and (2) Increase the range of the heat-affected-zone. The results also suggest that in the finite element simulation, a model incorporating the welding line and non-welding's line's material properties should have a better prediction of the tube thickness distribution.

References

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