VIII International Conference on Computational Plasticity
COMPLAS VIII
E. Oñate and D. R. J. Owen (Eds)

INFLUENCE OF THE HEAT AFFECTED ZONE ON HYDROFORMING WITH TAILOR-WELDED TUBULAR BLANKS

André P. Roque [*], Renato M. Natal Jorge [*], Marco P.L. Parente [*],

Robertt A. Fontes Valente [†], António A. Fernandes [*]

[*] IDMEC-Polo Porto
Faculty of Engineering, University of Porto
Rua Dr Roberto Frias 4200-465 Porto, Portugal
e-mail: andre.roque@fe.up.pt, web page: http://paginas.fe.up.pt/wwwidmec/

[†] Department of Mechanical Engineering
University of Aveiro
Campo Universitário de Santiago 3810-193 Aveiro, Portugal

Key words: Numerical Simulation, Tubular Hydroforming, Tailor-Welded Tubes, Weld Line.

Summary. *The hydroforming process represents an alternative production method when complex geometry components are required. Considering the cost per unit as a critical value, hydroforming shows up as a competitive production method. In this work a case study is presented where the initial part, two tubes with different thicknesses and joined with a butt-weld, is hydroformed. Simulation analyses are presented using the Finite Element Method. A particular focus will be carried out on the characterization of the Heat Affected Zone (HAZ), namely geometry and mechanical properties.*

1 INTRODUCTION

Tube hydroforming is widely used in the automotive and the aircraft industries [1-5]. This process has become a viable method for mass production once it can be used with pressures up to 15,000 Bar, and due to the advancements in computer power to help controlling the process. Tube hydroforming technology leads to better properties compared to conventional stamping. Some of the advantages include: less parts involved in the process therefore less operations and lower costs; more complex geometries can be obtained with implications on weight and mechanical properties (structural strength and stiffness); fewer secondary operations are needed; reduced dimensional variations; better surface finish due to the reduced friction and reduced scrap. This process, however, has some important disadvantages, such as: larger cycle times; the need for expensive equipment and a lack of extensive knowledge base for process and tool design [6].

Originally, a tailor-welded blank process consists of two or more sheets that have been welded together in a single plane prior to forming [7, 8]. The sheets can be identical, or they can have different thickness, mechanical properties or surface coatings. Various welding processes can also be used to join them. This type of blanks has several advantages, namely a low cost; reduction in part weight and flexibility in mass production. Especially in the laser-welding process, since high strength, hardness of the weld zone and a narrow weld bead can be ensured, it is possible to manufacture parts with superior quality.

By merging these two technologies there are important issues that have to be studied. This includes tube preparation, pre-form design, part design for hydroforming, tooling design, process sequence (with emphasis on pressure and axial feeding steps) and Heat Affected Zone characterization. Numerical simulation of hydroforming, altogether with tailor-welded blanks, can help to improve the process.

2 NUMERICAL ANALYSIS

The simulations in the present work were carried out using ABAQUS/Standard software, where static implicit non-linear analyses were made. The studies have consisted in inserting the part inside the tooling, filling it with an incompressible fluid, through the use of F3D3 and F3D4 elements. Alternately, internal pressure is imposed in the fluid, along with axial displacement in the upper end of the part, together with the upper surface of the fluid. For the blanks modeling, C3D8 solid elements were used. Finally, the tool was modeled with R3D4 rigid shell elements.

In this work several simulations are presented, based on a tubular part originally studied by Ahmetoglu *et al.*[9]. The part is initially a cylindrical tube with one butt-weld. The final configuration consists on a cylindrical tube with an axisymmetric bulge. The weld line is placed perpendicular to the axis of the tube. Two methods will be considered relating the representation of the weld line. The first method is to model the weld line accurately. In this situation the shape of the weld line and its mechanical properties are taken into account. This approach requires fine element meshing in the weld seam area. In the second method, only the geometry of the weld line is taken into account, and in this case the weld line and heat affected zone (HAZ) mechanical properties are considered to be identical to the base material.

The material used in the simulations is based on the work of Reis *et al.*[8], which consists in low carbon steel.

Concerning the material for the welded region, its characterization is determined indirectly by means of the following relation between the yield stress of the welded region and the raw material:

$$\sigma_y^{weld} = \sigma_y^{tube} \frac{HV^{weld}}{HV^{tube}}. \tag{1}$$

in which HV represents micro-hardness measurements in welded and raw material regions. The obtained values for hardness are presented in Figure 1, based on the figure in the work by Reis *et al.*[8].

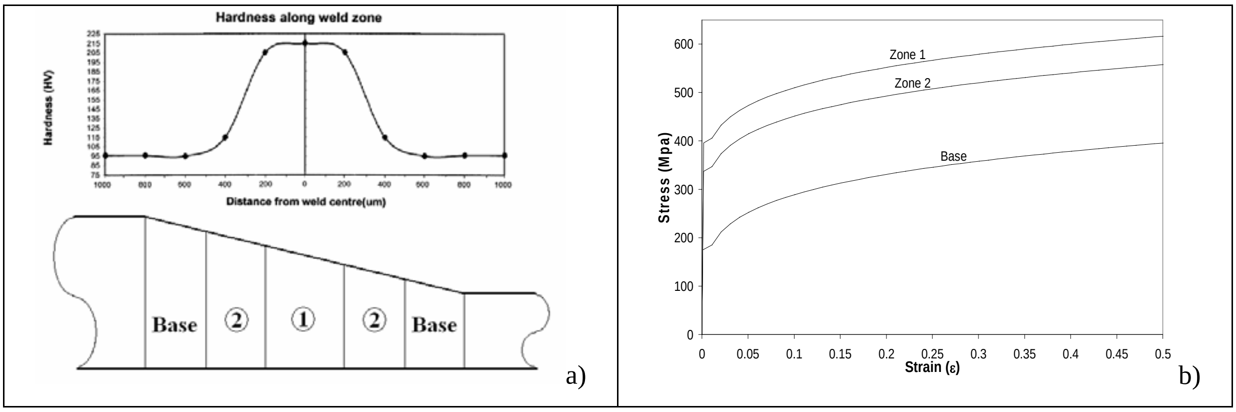

Figure 1 : a)Hardness along weld zone ; b) Stress-strain relations used.

The variation in hardening observed in the neighborhood of the weld centre is then used to obtain the values of the yield strength in this region. Equation (1) is also used to compute the plastic hardening. The stress-strain relations obtained for the different regions are indicated in Figure 1:b). For distances superior to 500 μm from the center of the weld the material is considered to be the base material.

Four different curves showing wall thickness variation are represented in Figure 2. As indicated in the legend, the first tube represents a 1.2x1.8 thickness tube in which the weld line properties where considered. The second line represents the same geometry but without consideration of properties variation in the welded region. The other two curves represent the result of welded tubes with single thickness. The thicknesses of these last two cases are those used to compose the 1.2x1.8 thickness tubes. For the examples where two thicknesses were used, the thick tube (1.8 mm) is on the left of the weld line and the thin tube (1.2 mm) is on the right of the weld line.

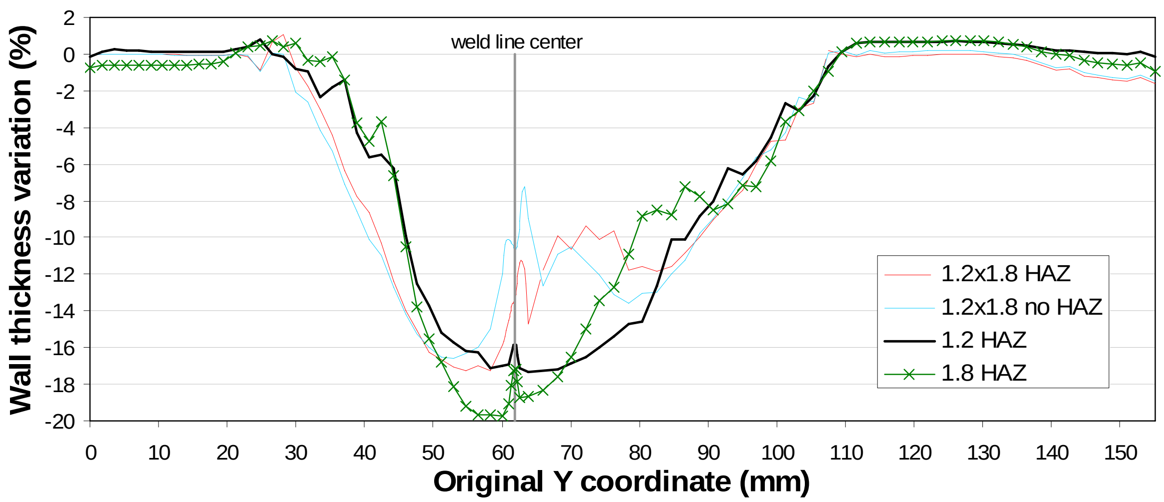

Figure 2 : Thickness distributions for the different configurations tested.

3 CONCLUSIONS

In this study, hydroforming process with a butt weld of two tubes with different thickness was simulated. Models were intended to compare different approaches in the modeling of the heat affected zone. For this purpose models with and without a heat affected zone were created. The presence of the heat affected zone clearly influences the results. In this study the difference between the thicknesses of the two parts of the tube was small. By increasing the difference between thicknesses, the presence of a well defined heat affected zone can have greater influence in the final results. Future work can be oriented in this direction.

Comparing different solutions obtained by numerical simulation is just a part of the work. This work can be then complemented by experimental studies in order to assess the importance of this numerical approach.

4 ACKNOWLEDGMENTS

The authors truly acknowledge the funding provided by Ministerio da Ciência, Tecnologia e Ensino Superior – Fundação para a Ciência e a Tecnologia (Portugal) under Grant POSI SFRH/BD/13013/2003; as well as the funding by FEDER/FSE, under Grant POCTI/EME/47289/2002.

5 REFERENCES

[1] R.A. Fontes Valente, R.M. Natal Jorge, R.P.R. Cardoso, J.M.A. César de Sá, J.J. Grácio, “Enhanced Strain Shell Elements for Simulation of Hydroforming Processes” in COMPLAS-2003, Barcelona, 2003.

[2] R.A. Fontes Valente, R.J. Alves de Sousa, M. Parente, R.M. Natal Jorge, J.M.A. César de Sá, J.J. Grácio, “Enhanced Assumed Strain Shell and Solid Shell-Elements: Application in Sheet Metal Forming Processes” in Numiform-2004, Ohio, USA, 2004.

[3] R.M. Natal Jorge, A.P. Roque, M.P.L. Parente, R.A.F. Valente, A.A. Fernandes, “Simulation of Tubular Hydroforming” in IV ECT, Lisbon, 2004.

[4] A.P. Roque, R.M. Natal Jorge, M.P.L. Parente, R.A.F. Valente, A.A. Fernandes, “Hydroforming of Tailor-Welded Tubular Blanks”, ESAFORM 2005, Cluj-Napoca, Romania, 2005.

[5] A.P. Roque, R.M. Natal Jorge, M.P.L. Parente, R.A.F. Valente, A.A. Fernandes, “Numerical Study of Hydroforming with Tailor-Welded Tubular Blanks”, accepted for publication on *Numisheet 2005*, Detroit, USA, 2005.

[6] S. Novotny, P. Hein, Journal of Materials Processing Technology 115, 65-69 (2001).

[7] Y. Choi, Y. Heo, H.Y. Kim, D. Seo, Journal of Materials Processing Technology 108, 1-7 (2000).

[8] A. Reis, P. Teixeira, J.F. Duarte, A. Santos, A. Barata da Rocha, A.A. Fernandes, Computers & Structures 82, 1435-1442 (2004).

[9] M. Ahmetoglu, K. Sutter, X.J. Li, T. Altan, Journal of Materials Processing Technology 98, 224-231 (2000).