Simulation of the Reconfigurable Tubes Hydroforming Technology

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ABSTRACT
Tube hydroforming (THF) has become a viable method for manufacturing complex automobile parts and an indispensable manufacturing technique in recent years. Coordination of the internal pressurization and axial feeding curves is critical in the tube hydroforming process to generate successful parts without fracture or wrinkling failure. In the paper are presented some comparative results about the tube hydroforming process of a symmetrical part, considering as the main parameter the presence or the absence of the axial feeding of the punches.
Key words: *tube hydroforming, metal forming, bulge forming*

1. Introduction

Tube hydroforming (THF) has become a viable method for manufacturing complex automobile parts and an indispensable manufacturing technique in recent years.

Coordination of the internal pressurization and axial feeding curves is critical in the tube hydroforming process to generate successful parts without fracture or wrinkling failure. The stress state at a given time and location varies with the process history and the design and control of the load paths. [1, 2]

Tube hydroforming has been well-known since the 1950's. Tube hydroforming has been called by many other names such as bulge forming of tubes (BFT's), liquid bulge forming (LBF) and hydraulic (or hydrostatic) pressure forming (HPF) depending on the time and country in which it was used. [3]

Hydroformed tube parts have improved strength and stiffness, lower tooling cost, fewer secondary operations, and closed dimensional tolerances compared to stamping processes, thus an overall reduced manufacturing cost.

Success of the tube hydroforming process depends on an appropriate combination of loading curve (internal pressure and axial feed at the tube ends), material properties and process conditions [4, 5]. One of the key concerns is to control the deformation process in order to maximize the expansion so that more complex shapes in various applications can be achieved. [6, 7]

Analogously, for a given shape a higher strength, lighter weight, less formable, or lower cost material can be adopted.[8]

2. Process Definition

The process cycle for a typical tube hydroforming operation follows the sequence illustrated in Fig. 1.

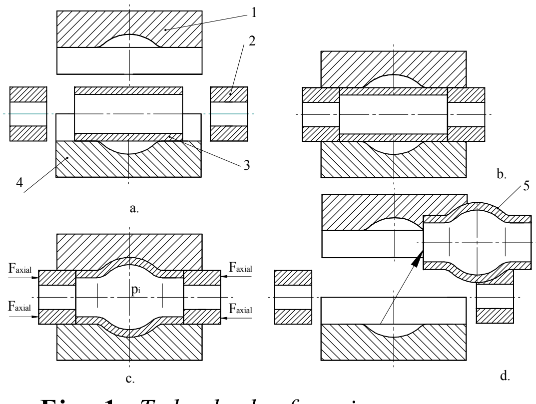

Fig. 1. *Tube hydroforming process: 1. superior die; 2. axial punches; 3. tube; 4. inferior die; 5. part*

First the tube is placed between the dies (figure 1.a). Clamping device is used to close the dies and to apply sufficient clamping force. Tube is filled with hydraulic fluid to provide necessary internal pressure. Axial punches are used to provide initial sealing to avoid any pressure losses (figure 1.b). Fluid pressure within the tube is increased after the die closes to cause necessary deformation with simultaneous application of axial feeding to push the material into the deformation zone (figure 1 c). The proper combination of axial feeding (F_{axial}) and internal pressure (p) are applied during the hydroforming process to improve hydroforming capabilities. Once the tube touches the die, the calibration phase starts. Axial feeding is not required during the calibration phase. Tube is subjected to large pressures to form corner radii. Finally, the bulged tube is taken out of the die (figure 1. d).

As it follows it will present some comparative results about the tube hydroforming process of a symmetrical part, considering as the main parameter the presence or the absence of the axial feeding of the punches.

3. Simulation Models Of Tube Hydroforming

Finite Element Analysis (FEA) is a powerful simulation tool for analyzing complex three dimensional sheet metal forming problems related to potential forming defects such as tearing, wrinkling and spring back. It can be used during the die design stage or as a troubleshooting tool in the production mode.

The DYNAFORM-PC solution package was developed to study the issues stated above and to assist the die designer and stamping engineer in meeting “rapid prototyping” requirements.

For tube hydroforming simulation two cases were developed: the deformation without axial moving of the punches and the deformation with axial moving of the punches, considering as the part, the one presented in figure 2.

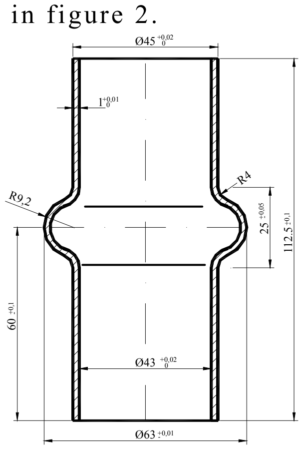

Fig. 2. *Part considered for obtaining by tube hydroforming*

The general model of tools for deformation is presented in figure 3. The difference, between two models is the presence of the two plates at the ends of the tub in the case of the deformation with axial moving of the punches. These plates simulate the hydraulic ends of the axial pistons, which are in contact with the tube and are moving axially.

The blank is a tube (Φ45x127x1mm) made from steel, having a behaviour type power:

$$\sigma = K \cdot \varepsilon^n \qquad (1)$$

where: K is the constant of the material, K = 546.9 MPa; n – strain hardness coefficient, n= 0.19

The material is caracterized by the following anisotrophy coefficients r_{00} = 1.65; r_{45} = 1.25; r_{90} = 1.80.

For simulation we choose as finite element, one element of type Belytschko-Tsay, with 5 integration points. The friction coeficient was equal to 0.125.

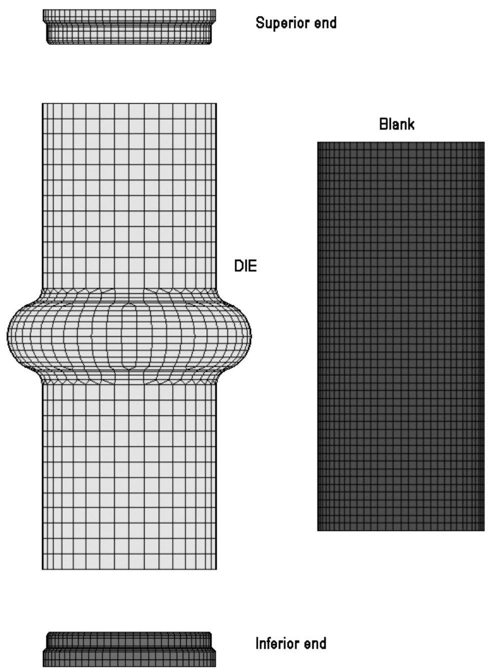

Fig. 3. *Tools model in tube hydroforming process simulation*

The number of finite elements used is: 1840 for the die; 3400 for the blank; 1830 for the two ends.

The pressure used, in the case of the deformation without axial moving of the punches, was of maximum 50 MPa, and the variation of this in time is presented in figure 4. The pressure results after some simulation tests.

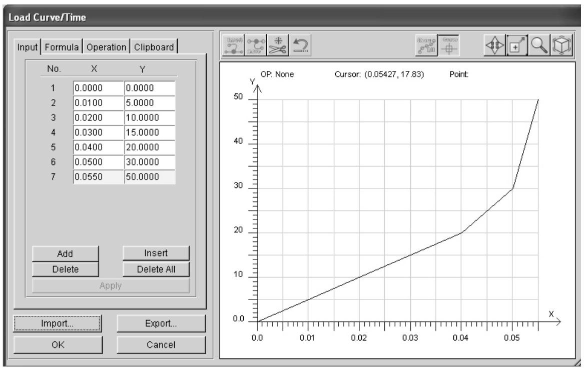

Fig. 4. *Pressure-time variation for deformation without axial punches moving*

In the case of the deformation with axial moving, the pressure used was of maximum 40 MPa, and the variation of this in time is presented in figure 5. The pressure results after some simulation tests. Secondly, in this case it must define the speed of the two ends. This was choosing of 149 mm/s for both ends.

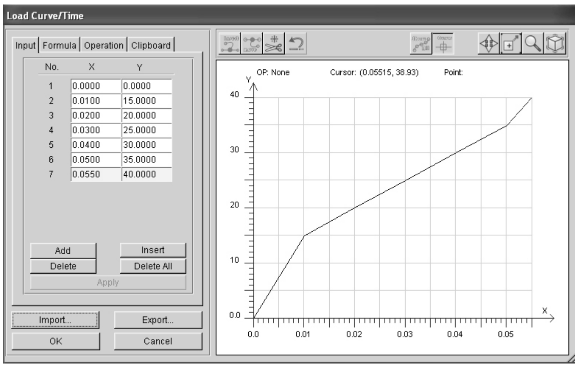

Fig. 5. *Pressure-time variation for deformation with axial punches movings*

3. Results And Discussions

From the results obtained, it could be made next observations:

a. Pressure exerted:
In the first case, the pressure was of 50 MPa to get the piece we are looking for.

The pressure exerted in the second case was 40 MPa.

b. Thickness:
In the first case, the tubular element is allowed to expand freely that is way the tube wall will thin and the radius will increase (figure 6).

We observe that the tube is thinner in the middle of the maximum deformation (less than 0.8 mm in comparison with the initial value of 1 mm).

In the second case the thickness variation is more constant in the deformation zone, because axial compression in the tube ends appears as a supplementary deformation which affects the material behaviour under pressure. The thickness in the tube ends is bigger (about 1.1 mm) because of the material axial compression.

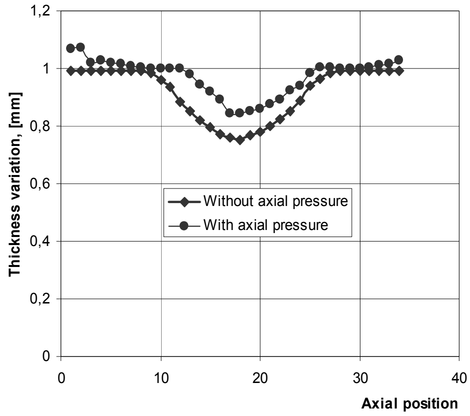

Fig. 6. *Thickness variations in tube forming process*

c. Plastic Strain:
In the first case, the plastic strain in the guiding zone is negligible (figure 7) and becomes maximum in expanding zone.

In the second case the plastic strain in the guiding zone is negligible (see also figure 7) and become maximum in expanding zone. Also in this case, in the edges of the tube the plastic strains had higher value because of axial compression.

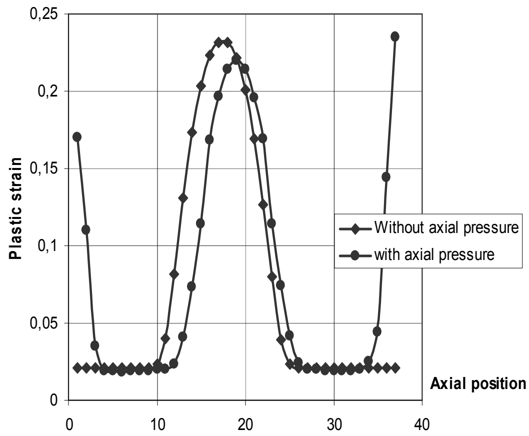

Fig. 7. *Plastic strain variations* in tube forming process

d. Sliding velocity:

We characterize this using the total velocity parameter. In the first case of deformation the variation of the total velocity is non uniform. In the second case the total velocity is almost constant and become bigger in the deformation zone.

There are big differences between the values of the total velocities in the two cases.

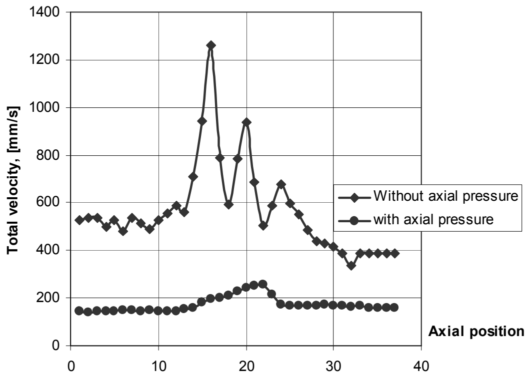

Fig. 8. *Total velocity variations in tube forming process*

e. Von Misses:

In the first case, the values of the maximum Von Misses stress (figure 9) show that the entire piece supports a plastic deformation. The value of this stresses no exceed the fracture limit. The upper value of 611 MPa is not bigger than the admisible breaking value of the material that is 700 MPa.

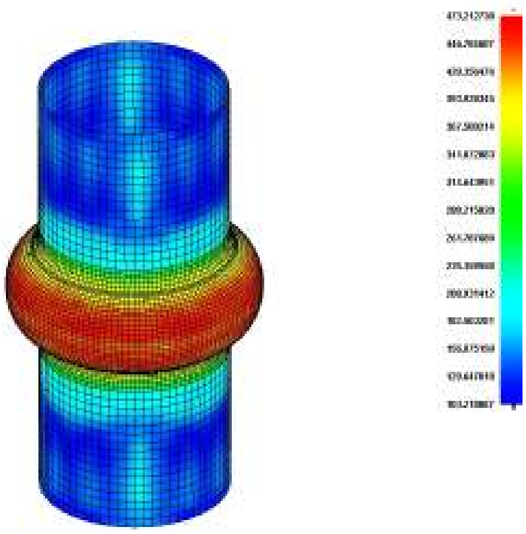

Fig. 9. *Von Mises stresses for deformation without axial punches movings*

In the second case of deformation, the upper value of 596 MPa Von Mises stresses is not bigger than the admisible breaking value of the material that is 700 MPa (figure 10).

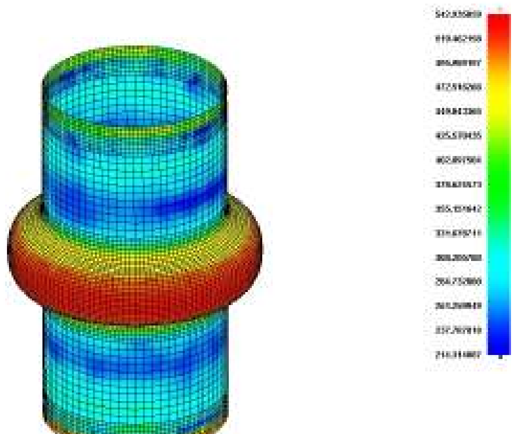

Fig. 10. *Von Mises stresses for deformation with axial punches moving*

4. Conclusions

In the case of the deformation with axial compression we obtain a more uniform stress – strain state. Also the thickness variation is more uniform having as a result a better quality of the part.

In the case of the deformation with axial compression, a supplementary deformation appears at the ends of the part, which will imply an addition operation of cutting.

The friction conditions are better in the case of the deformation with axial compression, which is reflected in the values of stresses.

The level of stresses is smaller in the case of the deformation with axial compression.

For industrial point of view the obtained results recommend the deformation with axial moving of the punches as the best method of manufacturing.

6. Acknowledgements

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Simularea tehnologiei reconfigurabile de deformare hidraulică a tuburilor

Rezumat

Hidroformarea tuburilor este o metodă viabilă în fabricarea reperelor complexe de automobil şi totodată o tehnologie de fabricație indispensabilă în multe alte sectoare industriale. Coordonarea presiunii interne cu avansul axial al poansoanelor este una din cerintele de bază ale procesului de hidroformare a tuburilor, coordonare care trebuie să garanteze obținerea unor repere fără ruperi sau cutări. În lucrare se prezintă câteva din rezultatele comparative ale hidroformării simetrice a tuburilor considerând ca principal parametru prezența sau absența avansului axial al poansoanelor.

Simulation Der Reconfigurable Innenhochdruckumformung Technologie

Zusammenfassung

Innenhochdruckumformung (THF) ist eine entwicklungsfähige Methode für komplizierte Automobilteile und eine unentbehrliche Produktionstechnik in den letzten Jahren herstellen geworden. Korrdination der internen Druckregulierung und der axialen einziehenden Kurven ist im Innenhochdruckumformungprozeß kritisch, erfolgreiche Teile ohne Bruch zu erzeugen oder Knitternausfall. Im Papier werden einige vergleichbare Resultate über den Innenhochdruckumformungprozeß eines symmetrischen Teils dargestellt und betrachten als der Hauptparameter das Vorhandensein oder das Fehlen dem axialen Einziehen der Durchschläge.