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COMPARATION OF ANALITICAL AND EXPERIMENTAL RESULTS OF FLUID PRESSURE IN HYDROFORMING OF TUBES

E.Karabegović*, M.Jurković*, M.Mahmić*, M. Ficko**
***University of Bihac, Faculty of Technical Engineering of Bihac, B&H**
****University of Maribor, Faculty of Mechanical Engineering in Maribor, Slovenia**

ABSTRACT
Hydroforming is an advanced technological process of plastic forming which uses an incompressible fluid. A significant application of this technology is in plastic forming of tube parts. Research and investigation in this area have been particularly active during the last ten years. This paper provides an analysis of values for the internal fluid pressure in hydroforming of T-shape tubes. For the analysis, we have taken: material (steel, y alloy and brass), axial feeding (10-15-20 mm) and tube wall thickness (1-2-3mm). The results have been obtained by analytical and experimental methods.
Key words: hydroforming, tube, fluid, press, experiment

1. INTRODUCTION

The plastic forming process which uses fluids is mostly utilized in automotive industry for sheet metal and tube forming, It is significant that about 10% of manufacturing includes forming of tube parts. The purpose of the research in hydroforming is to achieve optimization and better techno-economic justification of the process. This paper presents an analysis of the process of T-shape tube hydroforming for three different materials, three wall thickness values and three axial feeding values. The analytic solution has provided results for the internal fluid pressure in tubes, and then these values have been compared with the values obtained by experimental investigation [1-9].

2. TUBE HYDROFORMING

In T-shape tube hydroforming, free bulging of tubes is prevented by a pressure-assisted die cavity, so that the flow of material is performed in radial direction, along the die cavity. To prevent the tube end destruction, the end of the blank is compressed by a ram cylinder, with the applied counter force F_2 (Figure 1).

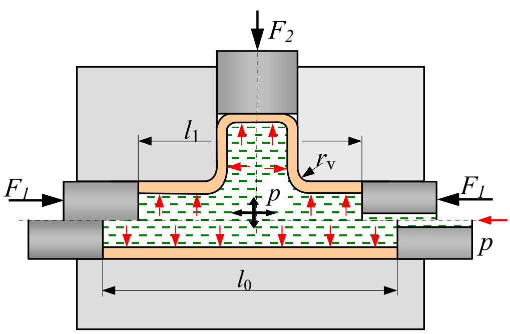

Figure 1. Scheme of T-shape tube hydroforming

The success of tube hydroforming depends on synchronized internal fluid pressure and axial feeding. The axial punches are necessary to seal the ends of the tube to avoid leaking of the fluid and to perform the defined axial feeding into the cavity. The application of the tube hydroforming process is justified by the possibility of generating complex shaped parts, Figure 2.

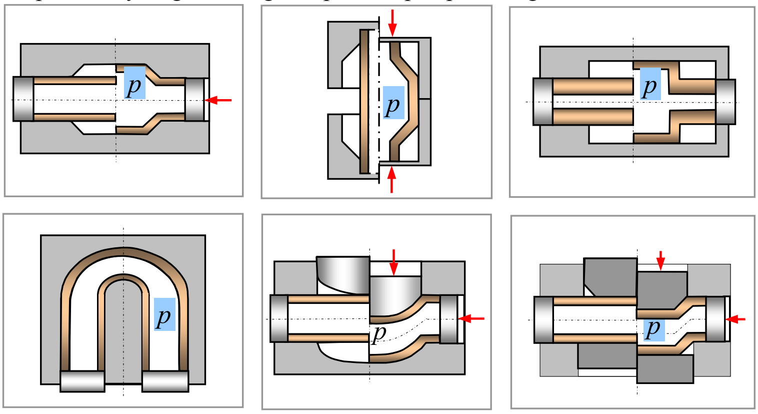

Figure 2. Various tube shapes generated by hydroforming

Some advantages of hydroforming are [4,5]:

- The process is simpler, relatively easily performed and reduces the production costs,
- Possibility of generating complex shape options and larger parts,
- A single machine tool corresponding to the defined shape of the finished product is required, which contributes to cost savings,
- Savings in the material and utilization of varied materials,
- Satisfactory fabrication quality,
- Automation of the process is simple and feasible (possible).

3. ANALYTICAL MODELLING

For the mathematical model of shapes [1,6]:

$$y = b_0 + b_1 x_1 + b_2 x_2 + b_3 x_3 + b_{12} x_1 x_2 + b_{23} x_2 x_3 + b_{13} x_1 x_3 + b_{123} x_1 x_2 x_3 \quad ...(1)$$

after determining the significance of coefficients (b_i), the polynomial shape of the mathematical model for internal pressure of the fluid in the tube is obtained:

$$y = 1.518,830 + 663,625 x_1 + 616,625 x_2 + 45,375 x_3 + 261,375 x_1 x_2 \quad ...(2)$$

The final shape of the mathematical model is obtained by substitution of coded values with numerical expresions (4.17) and performing mathematical operations:

$$p_{uc} = -162,577 + 56,56 s_0 + 0,757 \sigma_{0.2} + 9,075 \Delta l + 2,1081 s_0 \sigma_{0.2} \quad ...(3)$$

4. EXPERIMENTAL ANALYSIS

Experimental analysis has been done on the tube hydroforming machine in the laboratory of the Faculty of Technical Engineering of Bihac. Eksperimentalna analiza rađena je na uređaju za hidrooblikovanje cijevi u laboratoriji Tehničkog fakulteta u Bihaću. The measuring amplifier device *«Spider 8»* from *Hottinger Baldwin Messtechnik* (*HBM*), Germany, has been used for measuring the internal pressure of the fluid in the tube. The distribution of sensors for measuring the parameters of the hydroforming process is given in Figure x, where the positions for the measured values are the following [2-8]:

1- sensor for measuring the pressure of the fluid inside the tube,
2- dynamometer for measuring the axial force,
3- sensor for measuring axial feeding,
4- dynamometers for measuring the force applied for the removal of the finished part from the die.

The value of the internal pressure in the blank depends on: type of the material ($R_{0.2}$, R_m,), shape and dimensions of the workpiece, applied axial force, axial feed, etc. [2,3,5].

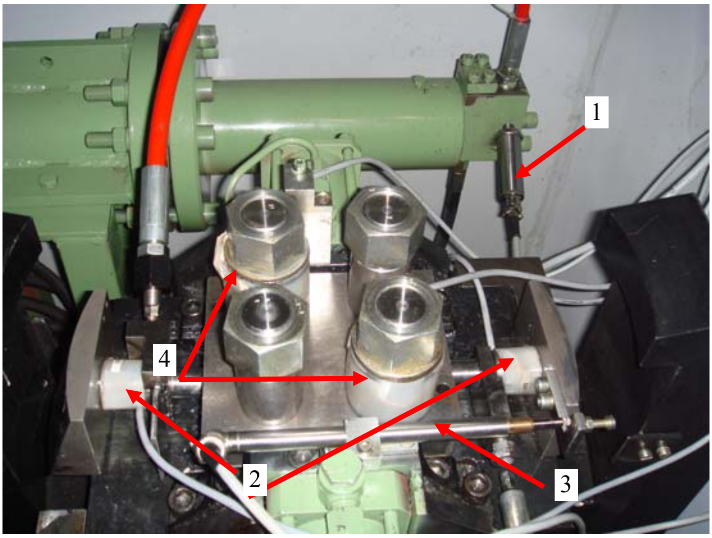

Figure 3. Measurement sensors in tube hydroforming

The fluid pressure in the blank, i.e. the internal pressure needed for hydroforming a T-tube with given shape and dimensions, has been measured with the sensor at position 1, Figure 4.

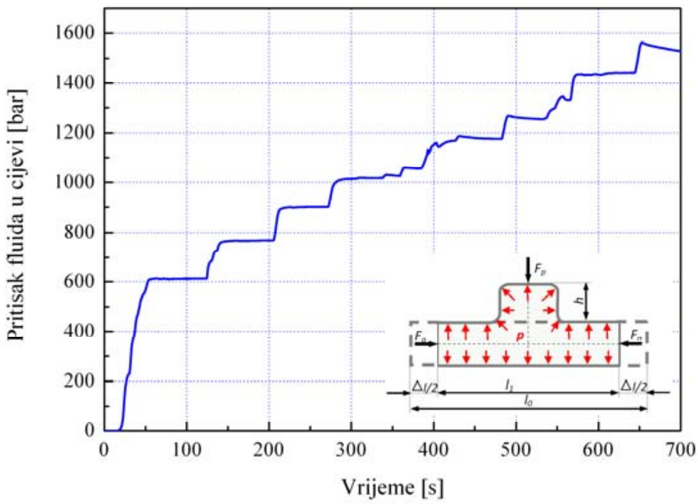

Figure 4. Experimental results for the fluid pressure in workpiece

The diagram shows the values of the fluid pressure in a steel tube with the flow stress ($\sigma_{0.2}$=290 N/mm^2), tube wall thickness (s_0=2 mm) and axial feed (Δl=15 mm).

5. COMPARISON OF THE RESULTS

With respect to the input parameters (tube wall thickness, flow stress and axial feed) the values shown in the table 1 have been obtained.

Table 1. Experimental and computational values of the fluid pressure in workpiece

Trial No	Natural values			Coded values			Eksperimental values	Computational values
	s_0	$\sigma_{0.2}$	Δl	X_1	X_2	X_3	$y_j^E = p_{uc}$	y_j^R
	mm	*N/mm²*	*mm*	-	-	-	*bar*	*bar*
1	1	164	10	-1	-1	-1	432	454,58
2	3	164	10	1	-1	-1	1.220	1.259,08
3	1	412	10	-1	1	-1	1.120	1.165,08
4	3	412	10	1	1	-1	2.940	3.015,08
5	1	164	20	-1	-1	1	477	545,33
6	3	164	20	1	-1	1	1.298	1.349,83
7	1	412	20	-1	1	1	1.210	1.255,83
8	3	412	20	1	1	1	3.090	3.105,83
9	2	290	15	0	0	0	1.570	1.518,83
10	2	290	15	0	0	0	1.590	1.518,83
11	2	290	15	0	0	0	1.610	1.518,83
12	2	290	15	0	0	0	1.645	1.518,83
						$\sum$	18.202	18.225,96
						$\bar{y}^E$	1.516,833	

The experimental values of the fluid pressure have been measured for three types of material (alluminum alloy, brass and steel).

6. CONCLUSION

Research relating to influence of process parameters to tube hydroforming has pointed out the important role of the analyzed parameters for the success of the process. One of the analyzed parameters is the fluid pressure during T-tube hydroforming. The analysis has shown that there is certain divergence of pressure values obtained by theoretic analysis of tube hydroforming from experimental values. The analysis done in this paper confirms the variation in fluid pressure values with respect to input data: three types of material, with different tube wall thickness, and three axial feed values. The reason for this is, undoubtedly, the influence of other contingent parameters and working conditions of the performed process.

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