Determination of the force required for the hydro-forming of al 99.5

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Abstract. In this paper the authors present the hydroforming of the tubular parts. It also presents the technology of the tubular parts' hydroforming. In this paper we determine the forces necessary for the hydroforming process. They are also presented the mechanical parameters of the material that are used in the deformation process. Also, the variation in wall thickness of the aluminium specimen is determined before the deformation process.

Keywords: Hydroforming, Aluminium, Force, Wall thickness

1 Introduction

Hydroforming is a manufacturing process that uses the pressure exerted by a hydraulic medium to produce deformations of a sheet or tubular blank.

Tube hydroforming is a method commonly used in the manufacture of complex components in the automobile resistance structure and a manufacturing technology that is being assimilated in many other industrial sectors (aerospace, household goods).

Coordinating the internal pressure with the plunger axial feed is one of the basic requirements of the tube hydroforming process, which must ensure that there are no defects (breaking or breaking the walls).

The process of hydroforming the tubes with high internal pressure is one of the newest manufacturing processes for tubular components. Prior to hydroforming, the tubes may be performed. During hydroforming, the material is inflated by increasing the internal pressure by means of two plungers acting on the ends of the tube. The plungers perform the pressure of the tube heads by introducing the pressurized fluid through the plunger holes.

The advantage of this method of hydroforming consists in:
• the hydrostatic pressure of the liquid uniformly presses the preform using plunging, preventing the formation of creases, stretching and thinning of the processed material;
• the stress and deformation state is more favourable in the case of the hydroforming and it is possible to obtain parts in a single operation;
• the economic efficiency of the hydroforming process by introducing the pressure of liquid is more obvious and more productive than other classical processes deformation, since the deformation is accomplished in a single operation.

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Reviewers: Róbert Čep, Jozef Pilec

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2 Calculations of pressure and forces required for hydroforming

2.1 Estimation of the hydroforming pressure

The maximum pressure of the hydroforming fluid can be determined by the relationship

\[
p_{\text{max}} = \frac{Rm \cdot s}{R} \, [N/mm^2],
\]

(1)

Approximate [Singh, Neugebauer]:

Where: \( Rm = 77.1 \, N/mm^2 \) is the maximum breaking strength of the material hydroformed (Al 99.5 ENAW 1050 H0 SR EN 10088-1: 2005);

\( s = 1.5 \, mm \) - nominal wall thickness;

\( R = 8 \, mm \) - the radius of connection of the vertical branch of the tube.

From the relation (1) results:

\[
p_{\text{max}} = 14.45 \, N/mm^2 = 144.5 \, \text{bar}.
\]

(2)

Consider the approximate character of the formula (1). Numerical simulation of the hydroforming process will allow verification that this maximum value of pressure hydroforming allows complete connection.

2.2 Determination of mould closing force

The force of closing the mould (exerted by the press ram) must balance the effect mechanical pressure acting within the tubular blank. Considering the fact that, in the case of the hydroforming process, the internal pressure increases extremely rapidly at the level maximum, the ram force can be calculated using the relationship:

\[
F_{\text{ram}} = p_{\text{max}} \cdot l_{\text{sfl}} \cdot d_{\text{sf}} = 144.5 \cdot 99.5 \cdot 35 = 503221.21 \, N = 503,22 \, \text{KN}.
\]

(3)

The maximum pressure was multiplied by the area of the horizontal projection of the inner surface of the still unreformed blank.

2.3 Determination of sealing force

The sealing force (exerted by the plungers that axially press the ends of the emissive) performs a double function: plasticizing the material by bringing it closer to the tear strength, respectively balancing the opening effect of the pressure acting inside the tube. By summing the forces corresponding to the two axial plunger functions, the sealing force is obtained:

\[
F_s = [\pi (d-s) \cdot s \cdot R_m] + [p_{\text{max}} \cdot \pi (d-2s)^2/4]
\]

\[
F_s = [3.14 \cdot (35-1.5) \cdot 2 \cdot 77.1] + [144.5 \cdot 3.14 \cdot (35-2 \cdot 1.5)^2/4] = 117371.1N = 117,37 \, \text{KN}
\]

(4)

In order to determine all these forces it was necessary to determine the parameters of the materials used in the actual hydroforming process.

3 Experimental determinations of material parameters

Figure 1 shows the state of stresses in the tube wall during the process and the following notations are inserted: \( R \) - outer tube radius, respectively \( s \) - thickness of the wall, \( \sigma_1 \) - represents a circumferential stretching stress, and \( \sigma_2 \) - represents an axial compression stress.

The two non-zero voltage components in the tube wall are: negative and acts in the axial direction (corresponds to the compressive force \( F \)) and the other is positive and acts in the...
circumferential direction (represents the effect of the pressure stretching p). The hydroforming process is based, for example, on the swelling of a tubular blank, accompanied by axial or radial compression [1-7]. This process typically consists of the following steps: expansion with compression, calibration [5]. Hydroforming is part of the cold processing industry.

The process is used for the construction of highly complex geometry cavities from high deformability tubes or boards.

**Table 1. Material Parameter of Al 99.5 ENAW 1050 H0**

| Parameter of material                              | Al 99.5   |
|---------------------------------------------------|-----------|
| Tensile strength Rm                               | 77.1 MPa  |
| Conventional Yield stress Rp0,2                   | 58.9 MPa  |
| Proportional elongation under maximum force Ag     | 13.5 %    |
| Total elongation below maximum force Agt           | 18.7 %    |

Figure 2 shows the curve of tension-percentage elongation for trial test of the material according to the standard SR EN 10002-1.

![Figure 1. The state of tension in the tube](image1)

![Figure 2. Curve of tension-percentage elongation for traction test](image2)

One important fact on production of the tubular parts, it is the change of wall thickness. Because of the deformation and the tension inside of the material of the tubes, the parameters are change. On different specimens of aluminium tubes was scanned with very precise machine. Figure 3 it is present the variation of the wall thickness of aluminium AL 99.5 which was tested in this paper. This was measurement on 3D scanner with optical devises. The measurements of the specimens were performed in the same way they are presented by other authors [8,9]. In this figure it can be observed that it is a big variation of the thickness, between 1.46 mm and 1.58 mm. The theoretical thickness must be 1.5 mm.
These specimens were cut on the water jet machine OMAX, to don’t be influenced by material parameters, because with this techniques the properties of mechanical parameter are not influenced [10-12].

The standard EN 10002-1: 1995 and EN 10002-2: 1995 show the shape and dimensions of the test specimens for uniaxial tensile strength.

After extracting these specimens, these were tested for uniaxial traction on machine Zwick - Roel Z150 which is in Technical University of Cluj-Napoca, as show in figure 4.

To determine the mechanical properties characteristics it is good to make uniaxial tensile strength testing. This test involves the application of a tensile force on a specimen until fracture.

Figure 5 presents the stress-strain curves in the case of Al 99.5 ENAW 1050 H0
4 The own achievement of hydroforming

In order to carry out the hydroforming process it was necessary to design and realize a deformation stand. This stand was made from: (1) - the hydroforming mould; (2) - hydraulic high pressure pump; (3) – Tinius - Olsen traction-compression test machine with rated force of 100 kN. In this stand it was necessary to control parameters of hydroforming.

In this stand it was necessary to control certain parameters. The most important parameters were the internal pressure of the liquid this was done by means of the pump (2 of figure 6). Another important parameter is the ram force; this can be controlled with the help Tinius - Olsen traction-compression test machine (3 of figure 6). The sealing force is given by the hydroforming mould (1 of figure 6).
The shape of the hydroforming mould is identical to the shape of the deformed tube. In figure 7 it is presented mould of hydroforming. This mould was made by CNC machine. [13-15]

Figure 8 shows the steps of the hydroforming process inside the mould. Hydraulic oil is used to deform the tubes. The specimen length was 220 mm. It can be seen that depending on the shape of the mould, you get the shape of the hydro former tube, a procedure very similar to vacuum casting [16-18]. Figure 9 shows the tubes made by hydroforming. It is possible to observe the inner and outer surface of the tubes [19-21]. Figure 9a shows the difference in roughness caused by the hydroforming process. For the deformation process, tubes manufactured by the drawing process are suitable [22,23]. In figure 9.b it can be seen that the surface of the tube in the deformed area is better, also having a better roughness.
5 Conclusions

This paper focused on the determination of the main factors influencing the hydroforming process of the tubular parts. The experiments in this paper focused on determining the main factors that influence the hydroforming process. Also took into account the quality of the tubular parts obtained.

As a result of the hydroforming process it can be observed that the obtained parts have much better strength and rigidity. Another effect of this process is to reduce the number of operations in order to obtain the finished piece, as well as to reduce its weight. Another important feature is the realization of complex shapes, and the optimal use of space. This process significantly reduces subsequent assembly operations. It is recommended to use hydraulic oil to reduce the friction forces between the piece and the die. After the laboratory tests, a theoretical model of calibration of the hydroforming process was made for different materials used. A great advantage of this simple device is that it is possible to install on universal cold pressing equipment.

This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation, CNCS/CCCDI–UEFISCDI, project number PN-III-P2-2.1-BG-2016-0216, within PNCDI III.

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