Study on Hydroforming Process of a Copper Tube Using Finite Element Method

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Abstract

In recent years, a lot of investigations have been performed in order to analyze the tube hydroforming process. Uniformity of thickness and low cost are the most significant advantages of this process widely used in automotive industries because of the weight reduction and high strength. In tube hydroforming process, a tube is inserted in between dies and the hydraulic pressure will be increased till tube and die have contact with each other. Since there are some significant parameters such as friction between the dies and tube, initial thickness and internal pressure which can affect the bulge height of hydro formed tube, the process is simulated by FEA packages ABAQUS. Then, stress and displacement of tube are calculated and their effects are discussed on bulge height of product. Also Von Mises stress on a critical path of tube in different internal pressures is investigated. The results can be used before any experimental test to achieve the desired product.

Keywords: Hydroforming, Tube, Finite Element

Introduction

Many investigations have been performed in order to study and analyze the tube hydroforming process [1-3]. The hydroforming of T-tubes was studied and derived the estimation formula of each process parameter [4]. The parameters of forming Y tubes were investigated using stainless steel tubes and a branch pipe developed [5].Tube hydroforming of T-branch components using finite element method was done and compared to the experiments [6].

Kim and others [7] have proposed front sub-frame process parameters design which include pressure and holder force. The use of a new kind of medium for hydroforming at elevated temperatures up to 600 °C was investigated [8]. It has proven that different parameters of tube such as bending angle and radius have significant effect on thinning and final product [9, 10].

Tube hydroforming is a process to produce different variety of tube shapes into a die using axial feeding and internal pressure. Weight reduction and uniformity of thickness are the most significant advantages of hydroforming widely used in automotive industries because of the low amount of material with high strength.

In tube hydroforming process, a tube is inserted in between dies whose shape would create the external shape of the produced part. Actually, during the process the hydraulic pressure will be increased to tube and die have contact with each other.

Since the performance of this process depends on various factors such as friction between the dies and tube and internal pressure, its behavior can be simulated by FEA packages such as ABAQUS before experimental tests. In this study, stress and displacement of tube were calculated and effects of various parameters such as initial thickness of tube and internal pressure and friction are discussed on bulge height of product. Also von mises stress on a critical path of tube in different internal pressures will be investigated.

Problem

Tube hydroforming process is simulated in FEA packages ABAQUS as will be described below. The model consists of three major parts including: 1- die, 2- rigid body and 3-tube which is the only flexible part. Copper is used as the material of tube whose dimensions are mentioned in Table 2. Since the thickness is far less than length, tube was designed by shell model and then the thickness was applied.

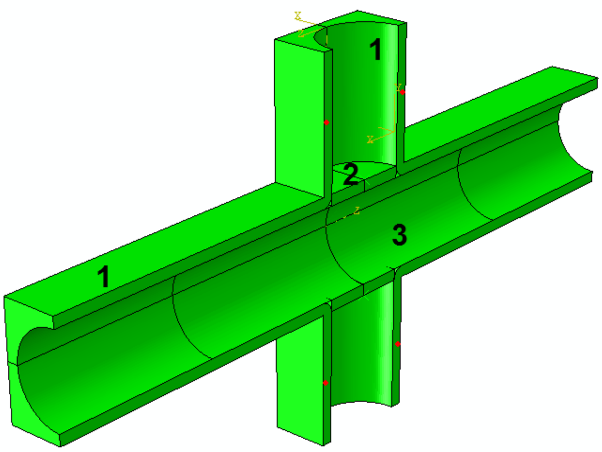

Fig. 1. Major parts of model: 1- die 2- rigid body 3-tube

Although the half of model is visible in Fig. 1, one-fourth of whole model was simulated in ABAQUS because of symmetric geometry and boundary conditions. In addition, dynamic explicit analysis is utilized to solve the problem.

Table 1. Mechanical properties of material used for tube (CU)

Density (x1000 kg/m3)	Elastic modulus GPa	Poisson's Ratio
8.9	124	0.3

Table 2. Dimensions of tube

Outer Diameter (mm)	Thickness (mm)	Length (mm)
12	1	107

A mesh convergence study using elements with dimensions of 2, 1 and 0.5 mm was performed. It was found the elements with the size of 1 mm would provide a converged Von Mises stress. Finally the model was meshed using 1080 linear quadrilateral elements.

Results

As can be seen in Fig. 2, Von Mises stress distributed symmetrically during. A noticeable reduction which is less than half of the maximum cab be observed in the amount of stress before the cross. The amount of stress in the rest of tube is about 240 MPa.

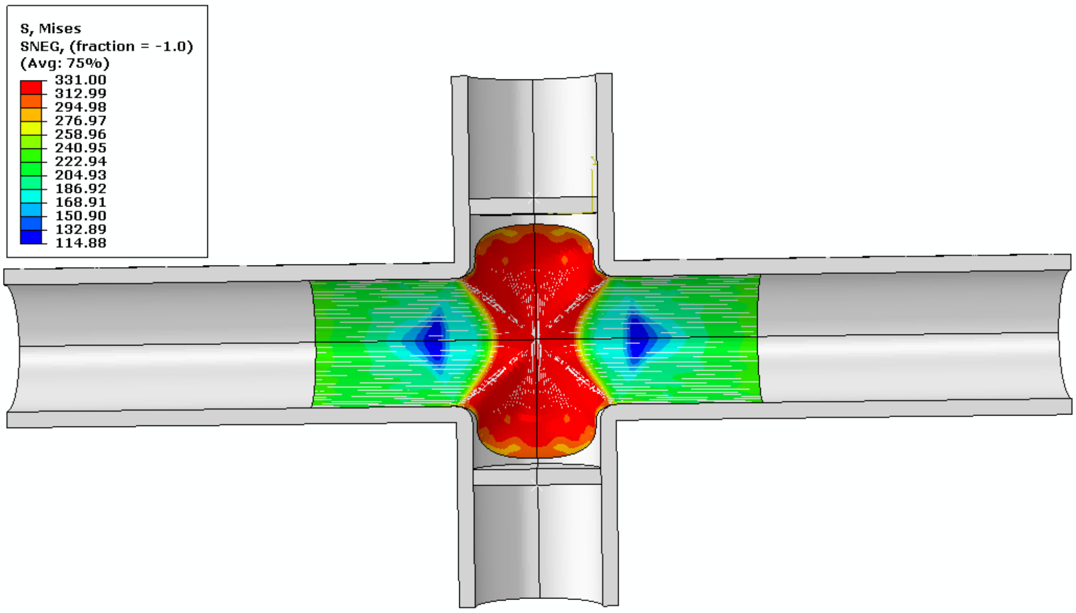

Fig. 2. Distribution of von mises stress in the tube caused by hydroforming process

Fig. 3. shows the bulge height of tube caused by different axial movements. Bulge height is raised while increasing the axial movement because more loads on the ends and more material will be available into the forming zone. The figure can be used to estimate axial movement as an input to produce needed bulge height.

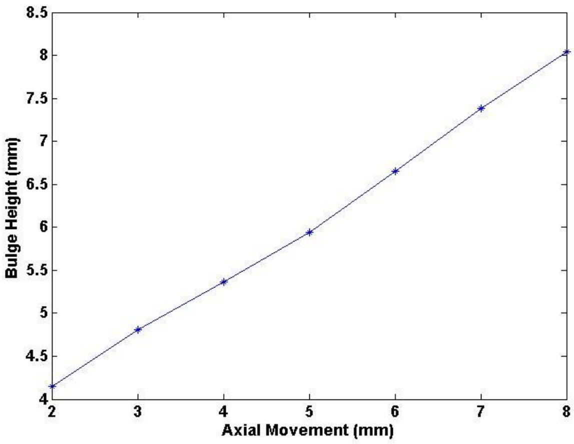

Fig. 3. Bulge height produced by different axial movements

Fig. 4. presents the bulge height of tube when friction between tube and die varies from 0.1 to 0.5. As can be seen, friction coefficient has a noticeable effect on the bulge height of tube which varies from 10 mm to a bit over 4 mm. The formula can be utilized to estimate bulge height in an available materials.

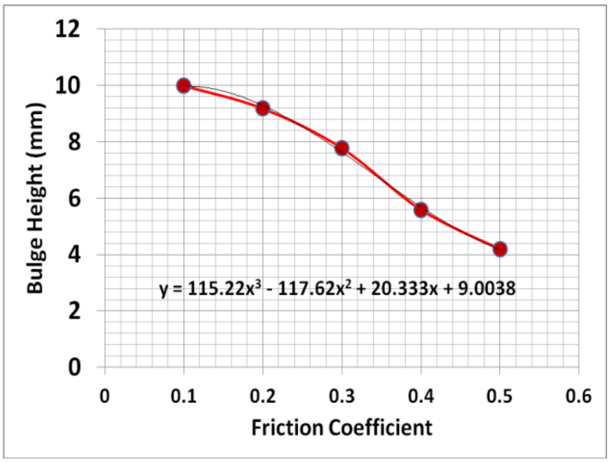

Fig. 4. Bulge height as a function of friction coefficient between tube and die

Fig. 5. depicts the bulge height of tube for similar tubes with different initial thickness which varies from 0.5 to 3.5 mm. It can be seen at the begging of the curve, bulge height remarkably decrease. Whereas the changes can be ignored for the rest of the curve.

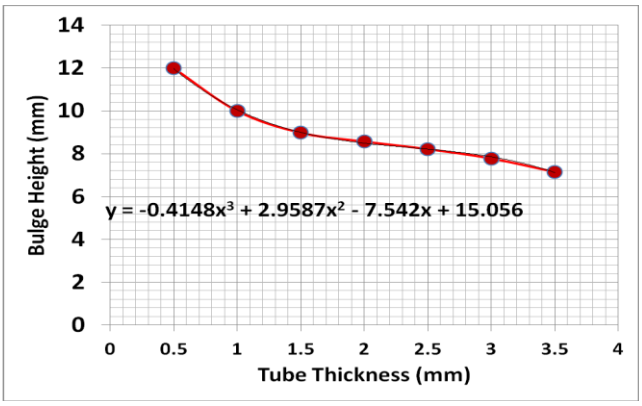

Fig. 5. Bulge height as a function of initial thickness of tube

Fig. 6. presents the bulge height of tube for different internal pressures. It can be observed that bulge height is almost the same when internal pressure varies from 5 to 15 MPa. Then the curve increases noticeably to less than 12 mm. Since the displacement of rigid body is 12 mm, bulge height can not be more than it.

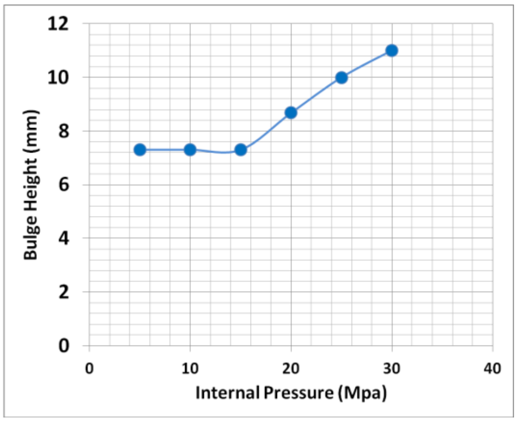

Fig. 6. Bulge height as a function of internal pressure

Fig. 7. depicts von mises stress on a critical path of tube from the beginning to the middle of tube in different internal pressures. The maximum stress occurs in the middle of tube which is in touch with the rigid body and it is almost the same for all internal pressures because of the displacement of rigid body. There is a significant reduction in the amount of stress in the tube before the cross.

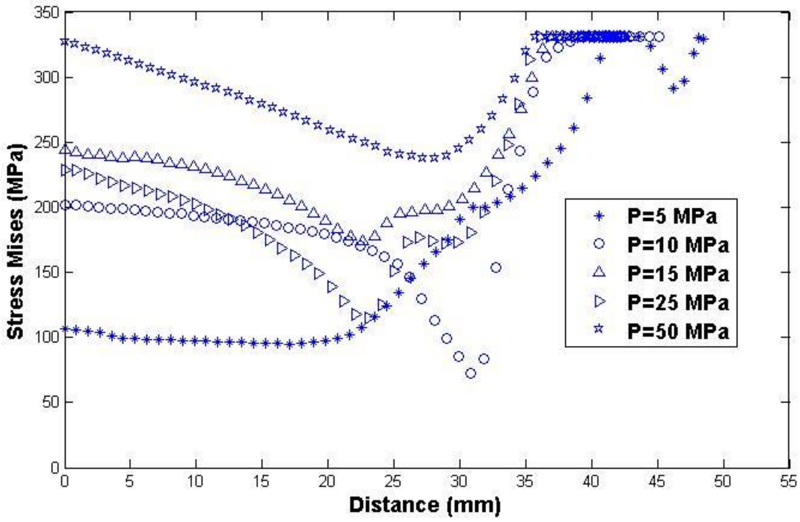

Fig. 7. Von mises stress on a critical path of tube with different internal pressure

In conclusion, there are some significant parameters which affect the bulge height of tube produced by hydroforming process. Some of them such as initial thickness of tube, internal pressure caused by liquid in the tube and friction coefficient between tube and die or rigid body were investigated in this study and their results can be used before any experimental test to assure the desired achievement.

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