A NUMERICAL STUDY ON THE EFFECT OF VARYING THE PUNCHING LENGTH ON A BRANCH PIPE

Wonyoung Jeon and Youngjin Seo
Department of Mechanical Engineering, Kumoh National Institute of Technology, 61 Daehakro, Gumi, South Korea
E-Mail: yjseo@kumoh.ac.kr

ABSTRACT

In most industries, apipe is an essential mechanical component to transport fluids. In order to control the fluid flow, a branched pipe is necessary. The following pipe branching methods are typically used: a method using a specially designed pin, butt-welding after cutting a U-shape, and Tee branching. In this paper, we studied effects of the drilling length on the branch pipes, with a drawing method using a conical jig that complements the conventional Tee branching. We used two standard forming jigs (65A and 80A). Pipe forming simulation was conducted in each of the five different drilling lengths. We found that longer punching lengths decrease the load on the forming jig. A reduction in the residual stress distribution was also observed in the branch section at a height of 1.5 mm. However, the height of the branch section was reduced while reducing the drawing material. Therefore, in the selection of the processing parameters, we simultaneously considered the height of the branch section and the residual stress.

Keyword: branch pipe, punching, stress, load.

INTRODUCTION

A pipe is an indispensable component in industries because of its essential role in transporting fluids. A branch pipe is needed in accordance with the intended purpose. The conventional branch method involves butt welding two pipes, after cutting them in a U shape. A disadvantage of this method is that it requires a lot of expertise and long machining time. One of the most commonly used forming technologies is the rotary drawing method using a specially designed pin. However, this forming method is problematic because of the long working time, expensive cost of the pin, and short life cycle of the pin.

The following studies were conducted on branching of a pipe. Hwang *et al.* (2011) investigated hydro forming of a T-tube according to the shape of the die using the finite element method. Nam *et al.* (2007) predicted the height of the branched portion through a forming analysis of the branch pipes. They also conducted a strength analysis to predict the safety of the branch pipe. Sung-Ho Lee et al. (2008) studied safety of the 150A branch pipes through forming simulations and strength experiments.

The forming technique used in this paper is a method of forming by drawing a conical jig. This method has a short forming time of less than5 s and involves easy production of the forming jig. In this study, we conducted forming simulations to verify the effect of varying the punching length in a branch pipe.

BRANCH PIPE

Branch pipe forming processes

The branch pipe forming process has five steps. This process is shown in Figure-1.

First, keep a material on a die. If aseam exists, place it face down on the seam. Second, drill the material, according to the size of the branch desired, at the working location. Third, insert the jig into the pipe. Fourth, form the branch part by drawing a jig. Finally, face the branch part to flatten it.

Properties

The material used in this study is AISI 304 stainless steel. Properties of the material were used as internal values of DEFORM (DEFORM version 11.0, Scientific Forming Technologies Corporation, Columbus, Ohio, USA). The corresponding properties are listed in Table-1.

FORMING ANALYSIS

Theoretical background

We used the von Mises yield criterion. The yield criterion is expressed as follows:

$$(\sigma_{xx} - \sigma_{yy})^2 + (\sigma_{yy} - \sigma_{zz})^2 + (\sigma_{zz} - \sigma_{xx})^2 + 6(\tau_{xy}{}^2 + \tau_{yz}{}^2 + \tau_{zx}{}^2) = 2\sigma_Y{}^2 = 6\tau_Y{}^2 \qquad (1)$$

where σ is the normal stress in the respective coordinate direction and τ is the shear stress in each direction. σ_Y and τ_Y are the tensile and shear yield stresses, respectively.

Since processing is carried out at room temperature, the effects of temperature and humidity can be neglected. Thus, the governing equations can be represented as follows.

$$[K^{ep}]\{\Delta U\} = \{\Delta F\} \qquad (2)$$

where K^{ep} is the elasto plastic stiffness matrix of the entire structure, ΔU is the vector that defines the changing displacement, and ΔF is the variation force vector of the node.

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Figure-1. Forming process of branch pipe.

Table-1. Properties of stainless steel 304.

Tensile Strength, Ultimate	505 MPa
Tensile Strength, Yield	215 MPa
Elongation at Break	70 %
Modulus of Elasticity	200 GPa
Poisson's Ratio	0.29
Shear Modulus	86 GPa

Analysis method

The analysis consists of two cases corresponding to the size of the forming jig (65A, 80A). Figure-2 displays the schematic diagram of the drill hole, where L is the length of the drill hole and Φ is the hole diameter. The drilling length L was varied. Drilling was performed in each of the five cases.
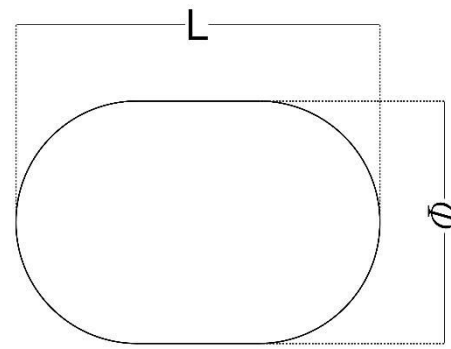

Figure-2. Schematic diagram of the drill hole.

Table-2. Analysis case.

Size	Φ (mm)	L (mm)
65A	35	55, 58, 60, 62, 65
80A	50	65, 68, 70, 72, 75

Design of the branch pipe

The three-dimensional (3D) computer-aided design (CAD) file to be used for the analysis was created using CATIA V5(Dassault SystèmesCedex – France).It was then converted to stereo lithography (STL) format and using the commercial finite element program the DEFROMmesh was created. The number of elements is about 430,000. The material was applied to AISI stainless steel 304. Employment of the elasto plastic assumption takes into account the spring back effect. The forming jig, upper, and side dies are considered to be rigid.

As shown in Figure-3, we used a quarter model. Before starting the study, we simulated two models (quarter and whole shapes) in order to determine whether the representation by using the quarter model was the same as that with the whole shape model. Comparison of the stress distribution justified application of $1/4^{th}$ shape of the assumptions.
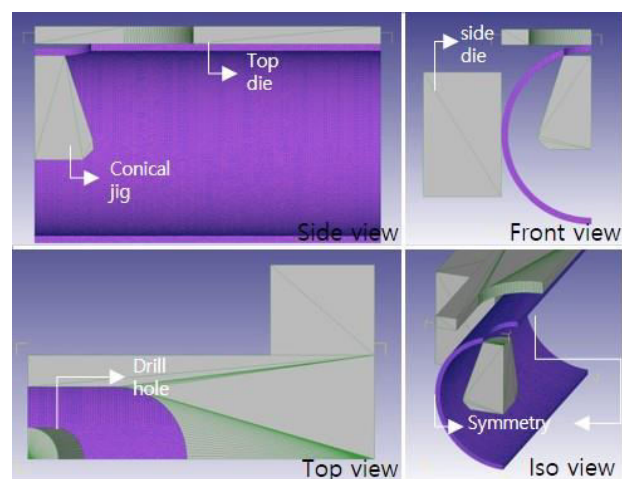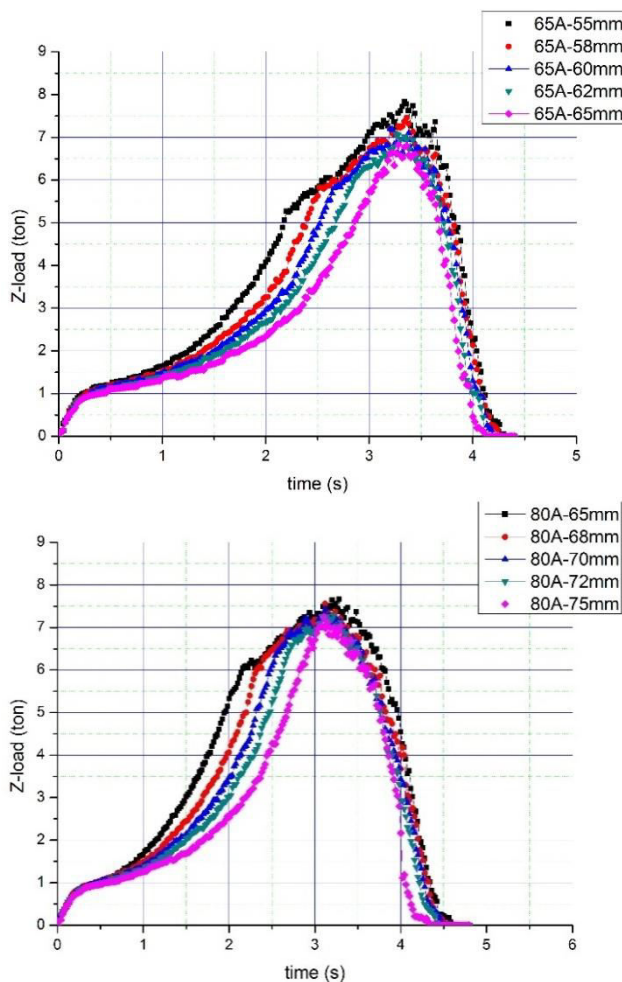

Figure-3. Shape of branch pipe (quarter model).

Figure-4. Z- direction load applied to the forming jig.

Figure-5. Stress distribution at the branch position at 1.5 mm height.

Analysis condition

The upper die's role is to prevent emergence of any unnecessary portion during the forming process. The side die fixes the material. Therefore, the side die and material were under an inseparable conditon. Boundary of the material was used as a symmetry condition. We did not consider the influence of temperature because of cold forming. The friction coefficient between the forming jig and material was chosen as 0.12. This is a value typical for a steel die.

The forming jig was passed through the pipe within 4 to 5 s ata constant speed. Time step size was 0.02 s. The entire process involved 220 to 250 steps that were completed in 4.4 to 4.8 s. The operation was carried out using the Newton - Raphson algorithm. The maximum number of iterations was limited to 200 per step.

RESULTS AND DISCUSSIONS

Figure shows the load applied to the forming jig during the forming process. It can be seen from the Figure that nearly 8 tons of load is required during pipe forming. Figure 5displays the residual stress distribution in the branch section at 1.5 mm height. Residual stress causes deformation.
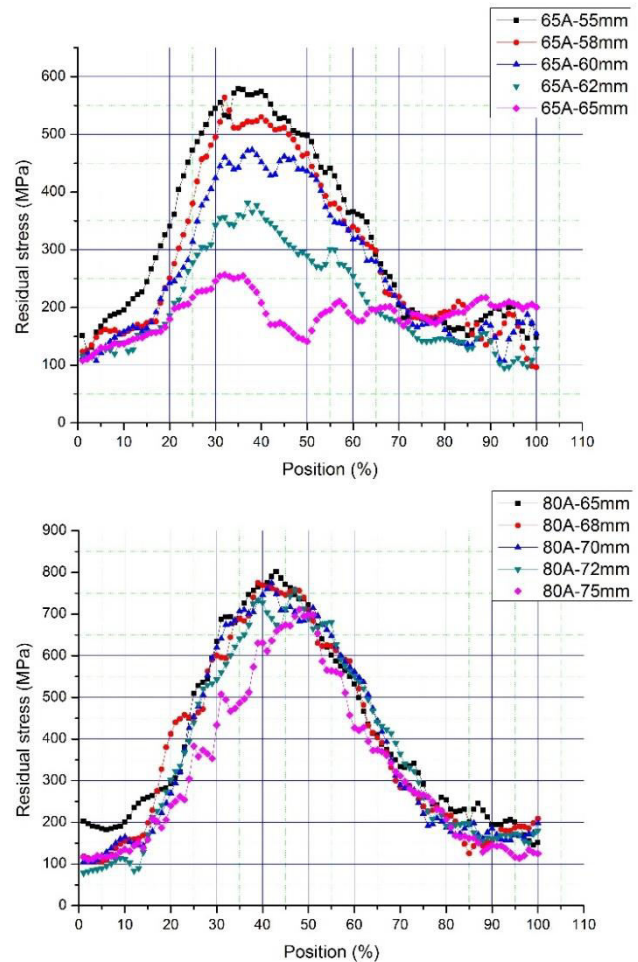
Therefore, it is an important factor for determining the quality of the products. It is noticeable from Figure-5 that at longer punching lengths the residual stress of the pipe decreases. Figure 6 shows the branch height as a function of the punching length. The longer length of drilling reduces the material. We can determine the decreasing height of the branch section. We also consider the height of branch section and the residual stress simultaneously.

CONCLUSIONS

We conducted pipe(AISI stainless steel 304) forming analysis that is widely used in the industry. Two types of forming jigs were used for each of the five cases of length of the drill hole. Analysis results, as demonstrated in Figure 7 are similar to the actual shape. The load applied to the jig was approximately 7-8 tons. This suggests that we require a machine with load capacity greater than 8 tons for pipe forming. As the punching length increased, the residual stress distribution was found to decrease. The lower residual stress is determined to be good. But longer the drilling length, lower was the height of the branch pipe. Therefore, achieving a reasonable height of the branch pipe will require application of a

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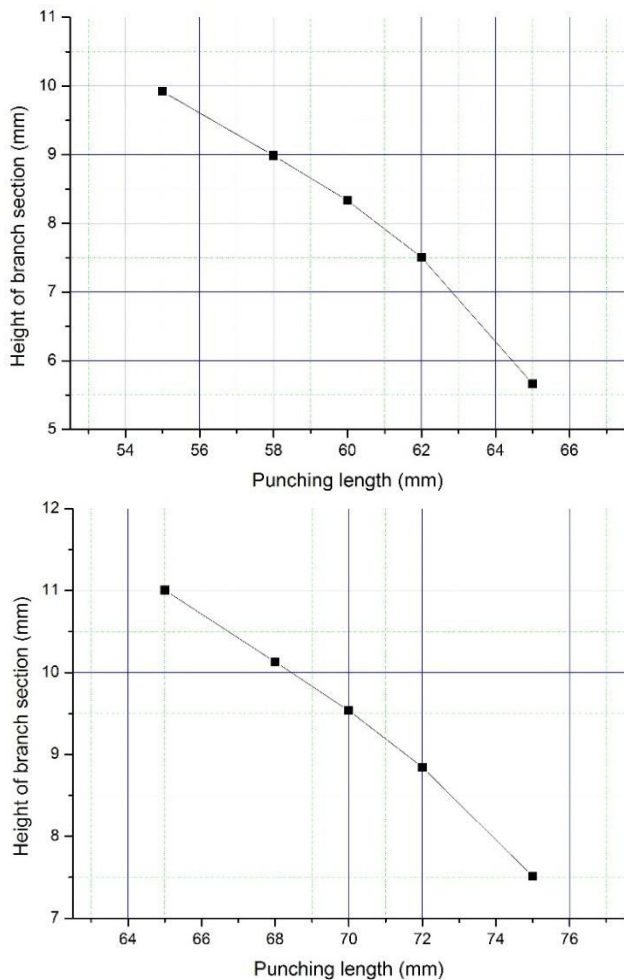suitable drilling length. Future experiments will verify the validity of the analysis.

Figure-6. Height of the branch section (65A, and 80A).

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Figure-7. Comparison of the actual shape with the analytical model.