Research Article

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FEM Analysis for Burring Process of Large Diameter SUS304 Tube

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ABSTRACT

This paper describes a finite element method (FEM) analysis for cold burring process of large diameter SUS304 pipe. The large diameter pipes such as ϕ216.3 mm are used for a plant as a flow channel of gas and liquid. A burring process of pipe is generally for forming the branch. Burring molding is one of the typical molding techniques for branch pipes. The burring process is achieved by drawing of die from prepared hole. And the branch pipes are generally joined by welding. But this process has some problem. First, burring processing has a forming limit. Second, wall thickness and strain are uneven at the branch part of burring forming. Also, the hole important for burring processing is different from the optimum shape. In this study, we proposed calculation of suitable mother pipe holes. The target branch pipe in this study is a branch pipe with a uniform height of nominal diameter 100 A, diameter 114.3 mm, wall thickness 3.0 mm, burring height 10 mm. In this study, we aim to construct a burring analysis model and to calculate an appropriate hole shape which enables welding without requiring end face cutting when joining branch pipes. In the burring process, the initial shape is very important. In the process of this paper, we first construct a burring analysis model and decide the initial shape of the hole. Next, we analyze the initial shape and find problems. This problem depends on the hole shape. Therefore, we found that this hole shape improvement is necessary. In this paper, the results of the optimal hole shape improved and the analysis result are shown, decided from analysis. In this paper, the forming limit of the SUS 304 pipe of the mother pipe 200A and the branch pipe 100A was investigated. By this analysis, it was possible to reproduce the branch pipe with almost uniform height of the branch end part on the FEM analysis.

Keywords

Burring process, SUS304 pipe, Finite Element Method, Forming limit.

Introduction

The large diameter SUS304 pipes are used at plant. The gas or liquid flow into the pipes. The diameter of these pipes are over 100mm and the length are several meters. The demand of SUS304 pipe instead of conventional SUS304 pipe for plant pipe is increasing for food plant because the SUS304 pipe is without surface treatment such as zinc plating. A branch pipe is one of the components constituting a piping system in factory piping which is a flow path of gas and fluid. Figure 1 shows the outline of a pipe branch pipe. Example of pipe branch pipe, SUS 304 large diameter pipe is used. The SUS 304 pipe in this paper has a nominal diameter of 200 A, a diameter of 216.30 mm, and a wall thickness of 4.00 mm. There is burring molding in this branching pipe molding technology, and drawing method has been developed. Burring molding is to form a branch part with a circular end part by raising the peripheral part of the elliptical pilot hole drilled in the mother pipe. Because the portion to be processed changes three-dimensionally, the circumferential strain and wall thickness of the branch portion became uneven, and the formability and the forming limit were the subjects.

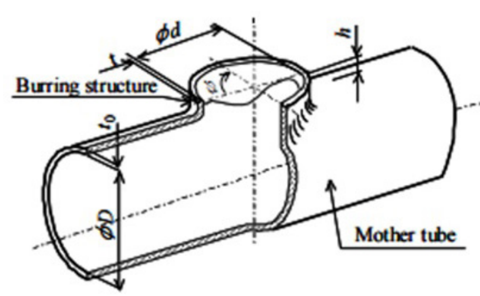


Figure 1: Outline of branched tube.

In this study, we proposed calculation of pilot hole shape of appropriate mother pipe in drawing method. The target branching part in this study is a branch part with uniform nominal diameter of 100 A, diameter 114.30 mm, wall thickness 3.00 mm, burring height 10 mm. However, calculation of pilot hole shape is not in previous studies, and calculation of pilot hole shape in experiment is difficult. In this study, we aim to calculate a suitable pilot hole shape that can be welded only by drawing process with burring analysis model and only withdrawing process without cutting end face of branch portion.

Experimental and Finite Element Method Analysis Conditions

Figure 2 shows the FEM analysis model. The analysis model was a 1/4 three-dimensional model. Finite element method software DEFORM was used. The material was rigid plastic. The true strain strain diagram used the data of SUS 304. cold by Yamanaka Gohkin.

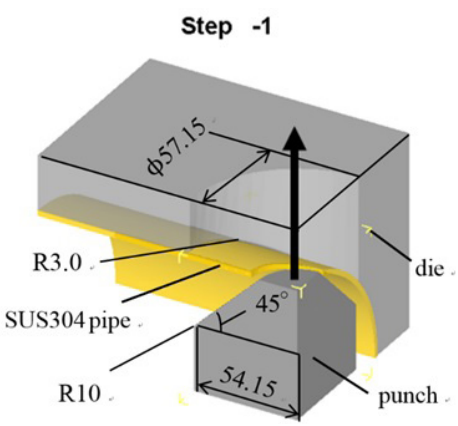


Figure 2: FEM model of cold burring process (1/4 analysis model).

This analysis was aimed at grasping the processing load and the vertical load in the burring processing of the SUS 304 pipe and estimating the shape of the prepared hole of the branch pipe suitable for this processing method. In this analysis, the SUS 304 pipe is held down with a mold, and a punch with a taper angle of 45 degrees is pulled out from the inside of the pipe in the direction of the arrow in Figure 2.

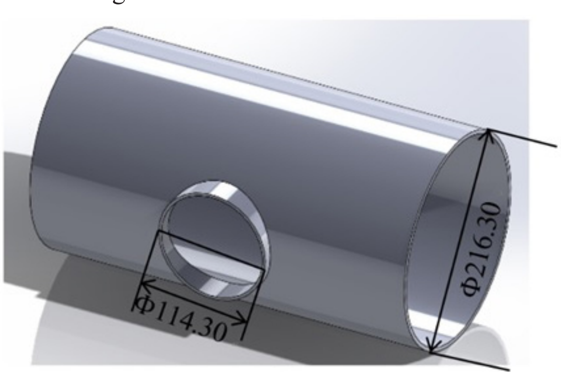


Figure 3: Target model.

The outer shape of the punch was the same as the SUS 304 pipe 100 A with an inner diameter of 108.3 mm. The bending radius was 3.00 mm. Because the target burring height is 10 mm, it must be set to R 10 or less. The fillet of R 3.0 was attached to the part of the tool which touched the material and where the bending occurred. In contact with the material of the punch, fillet of R10 was attached to the part where bending occurred.

Table 1 shows the dimensions of the SUS 304 pipe used in this study.

Nominal diameter [mm]	Outer diameter [mm]	Inner diameter [mm]	Wall thickness [mm]
200A	216.30	208.30	4.00

Table1: SUS304 pipe.

Table 2 shows the analysis conditions.

Analysis model	3 dimension
Material model	Rigid-plastic body
Element count	29496
Punch speed mm/sec	1
Step increment sec/step	0.1
Shear coefficient of friction of the punch and material	0.12

Table 2: FEM analysis conditions.

For the initial value of pilot hole shape, a target shape was constructed with 3DCAD software solidworks. Based on the dimensions of the target value, the pilot hole shape based on the four points in the state before processing was taken as the initial value. Figure 4 shows the pilot hole shape with the initial value. The number of elements was 50000. The analysis time was about 1 hour 50 minutes. The burring height was measured from the analysis result. For the measurement of burring height, calculation was made from the ratio of the dimensions of the image and the die, and the actual dimensions were calculated. Improvement of pilot hole shape was made from the measurement result and analysis was carried out.

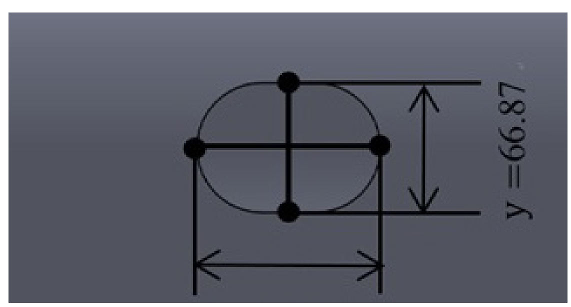


Figure 4: Pilot hole shape initial value.

Results and Discussions

Figure 5 shows the cross-sectional shape of the branch parts in the analysis result with initial values. From the analysis results, the burring height was uneven. When welding the branch part, end face cutting is required. Therefore, it is desirable that the burring height is uniform. From this result, it was suggested that improvement of the shape of the prepared hole which makes the burring height uniform becomes necessary.

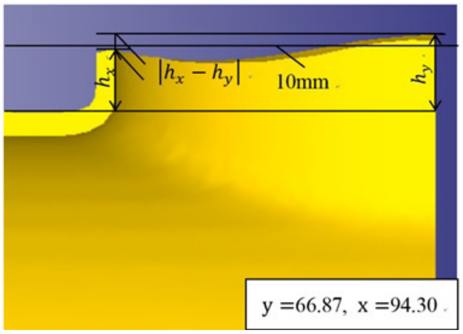


Figure 5: Cross-sectional shape at initial (1/4 model).

In this analysis, the vertical direction of the prepared hole shape is set to y = 66.87 mm and the side direction to x = 94.30 mm. The burring height in the x direction is hx. The burring height in the y direction is hy. The difference between hx and the target burring height of 10 mm was defined as Δhx. hy and the target burring height 10 mm is defined as Δhy. The difference between the burring height in the x direction and the burring height in the y direction is | hx - hy |. From Figure 5, Δhx = -0.02 mm with the initial value of the prepared hole shape. For welding with a difference of ± 1.00 mm, since it was judged that it is within the allowable range at the site, x was fixed value. Δhy = + 2.92 mm. From this result, it was judged that it is possible to make the burring height uniform by changing the value of y. hx, hy affect each other. This is due to a decrease in wall thickness in the direction of each other.

Improvement of pilot hole shape was made from the result of Δhy. We increased the value of y by 2, 4, 6 mm and analyzed. Figure 6 shows the relationship between Δhy and pilot hole shape y when it is increased by 2, 4, 6 mm. Analysis was also simulated y = 71 mm and y = 72 mm where Δh is around 0 mm. From the trend in Figure 6, the y value at which Δhy becomes 0 mm was 71.74 mm. From this result, we analyzed the value of y at 71.74 mm. Figure 7 shows the analysis result of y = 71.74 mm. At this time, Δhx, Δhy, | hx-hy | were 0.20 mm, 0.14 mm, and 0.06 mm, respectively. All of these values are within the acceptable range. Four values of x = 94.30 mm and y = 71.74 mm were fixed values.

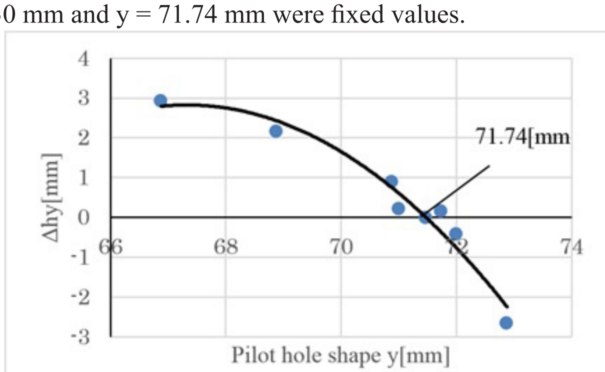
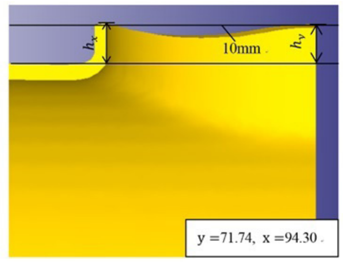


Figure 6: Relationship between pilot hole shape y and Δh_y.

From the results in Figure 7, the burring height in the x direction and the burring height in the y direction were almost uniform. However, it is heterogeneous in different directions other than x and y. Analysis was performed in the shape of a prepared hole formed by connecting the fixed 4 points with a spline curve. Figure 8 shows the results of this analysis. In this analysis, Δhx and Δhy were -0.48 mm and +0.03 mm, respectively. Assuming that the maximum burring height in Figure 8 is hmax and the difference between the target burring height 10 mm and hmax is Δhmax, Δhmax = + 1.29 mm. From this result, the coordinate of the pilot hole shape is increased by Δhmax from the coordinate before deformation so that Δhmax after deformation approaches 0 mm. Next, 8 points were specified and analyzed.



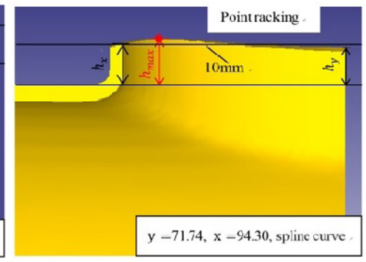


Figure 7: Cross-sectional shape at y=71.74 (1/4 model).

Figure 8: Cross-sectional shape at spline curve of 4 point.

In Figure 9, this 8 point (black spot) is specified, and the shape of the prepared hole tied with a spline curve is shown. Figure 10 shows the analysis results. From the analysis results, Δhx, Δhy, Δh, Δhmax were +0.09 mm, -0.32 mm, +0.41 mm, and +0.46 mm, respectively. This value is ± 0.50 mm from the target height of all 8 points. From this, all eight points are within the acceptable range. From this the optimum shape value of 8 points was calculated. Discuss the damage value. Damage values in this analysis were all 1 or less. Therefore, when the damage is 1 or less, it is understood that the SUS 304 pipe does not crack and can be processed. The maximum processing load at the optimum shape value of 8 points in this analysis was 9.98 tons. From the results in Figure 10, the burring height became uniform as compared with the initial sectional shape. From this analysis, it was calculated the optimum preliminary hole shape based on the drawing method of 8 points.

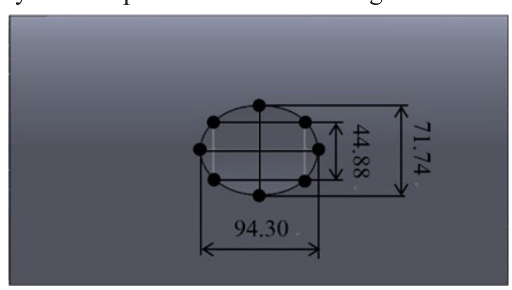


Figure 9: Pilot hole shape of spline curve at 8 point.

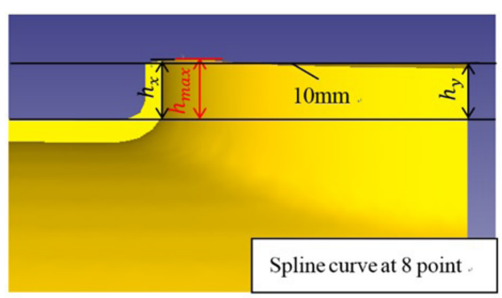


Figure 10: Cross-sectional shape at spline curve of 8 point.

Summary

In this study, the forming limit of the SUS 304 pipe of the mother pipe 200A branch pipe 100A was investigated by FEM analysis of the burring processing in the rigid body drawing method. Summary is below.

By this analysis, it was possible to reproduce the branch pipe with almost uniform height of the branch end part on the FEM analysis. The heights h_x and h_y of the branch parts are affected by each other. This tends to affect mutual wall thickness reduction in the x and y directions.

Based on the analysis results, the damage value was 1 or less in all pilot holes. When the damage value is 1 or less, it was possible to form the branch pipe of the mother pipe 200A branch pipe 100A. The maximum machining load in the shape of the prepared hole with reference to 8 points was 9.98 tons.

In this analysis method, it is possible to reproduce the uniformization of the height of the branch portion. As a result, the forming limit can be improved.

Acknowledgment

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References

1. Lu Y. Finite Elements in Analysis and Design. 2004; 40: 305-318.
2. Yeh F. Journal of Strain Analysis for Engineering Design. 2007 42: 315-324.
3. Sun ZC, Yang H. Free deformation mechanism and change of forming mode in tube inversion under conical die. Journal of Materials Processing Technology. 2006; 177: 171-174.
4. Kwan CT. Key Engineering Materials. 2008; 364-366, 949-954.
5. Tan CJ, Chong WT, Hassan MA. End formation of a round tube into a square section having small corner radii Journal of Materials Processing Technology. 2013; 213: 1465-1474.
6. Yuung-ming HUANG. Transactions of Nonferrous Metals Society of China. 2011; 21: 371–377.
7. Ajay Kumar Choubey. Materials Today: Proceedings 4. 2017; 2511-2515.
8. An YG. Journal of Materials Processing Technology. 2004; 155-156, 1616–1622.