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INCREASING PRECISION OF BATCH PIPE FORMING METHOD USING BURRING AND IRONING OF LARGE DIAMETER STEEL PIPE IN FEM ANALYSIS

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Abstract. This paper describes increasing precision of Batch Pipe Forming Method Using Burring and Ironing of Large Diameter Steel Pipe in FEM Analysis. Branch pipes are one of the components of the piping system in a factory that serves as a flow path for gases and fluids. The bifurcated tube is formed by burring as a typical molding technique. The burring process is to form a branch pipe by raising the peripheral portion of the prepared hole formed in the mother pipe. There is a problem that the cutting of the edge is required in the post process. Therefore, a branch pipe batch forming method has been developed in which burring processing that does not require a cutting step in the subsequent step is combined with ironing processing using FEM analysis. The purpose of this research is to improve the accuracy of FEM analysis in the branch pipe batch forming method using burring process and ironing process by cutting the material into a cylindrical shape and performing a compression test to obtain the deformation resistance of the actual material. The experimental results were compared with the analytical results and approximately good agreement was obtained.

1 INTRODUCTION

This paper reports on the increasing precision of batch pipe forming method using burring and ironing of large diameter steel pipe in FEM analysis. A branch pipe is one of the parts that make up the piping system in factory piping that serves as a flow path for gas and fluid. Figure 1 shows an overview of the branch pipe. SGP large diameter pipe is used as an example of a branch pipe. Burring is a typical forming technique for branch pipes, and a rigid body drawing method [1]-[5] has been developed. Burring is a process of forming a branch pipe with a circular end at the periphery of an elliptical pilot hole drilled in the mother pipe, and there is a problem that post process cutting takes time and cost. In addition, the pilot hole shape is often based on field experience and intuition, and it is difficult to say that it is the optimum shape. In the previous research, a branch pipe batch molding method that combines burring and ironing has been developed. By this branch pipe batch forming method, the end face of the branch part can be machined flat, and machining that does not require end face cutting in the subsequent process has become possible. Therefore, in this study, we cut out a test piece from an SGP large-diameter pipe, perform a compression test, and obtain the deformation resistance of the actual material, with the aim of further improving the accuracy of the branch pipe batch molding method in FEM analysis [6]-[7], and the analytical values were compared with the experimental values.

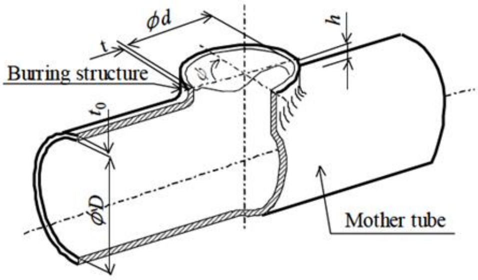


Figure 1: Overview of branch pipe [2]

2 EXPERIMENTAL CONDITION AND RESULT

A cylindrical specimen was cut out of an SGP large-diameter pipe and a compression test was conducted. Graphite-based lubricant was used as a lubricant. TENSILON (RTF-2430) was used for the experiments. The universal testing machine used in the experiments is shown in Figure 2. In the FEM analysis in the previous study, the deformation resistance was based on the AISI.cold data from FEM software DEFORM are shown in Table 1. AISI.cold is the flow stress curve of S10C and has a value of 4 points only. Therefore, it is thought that the use of the deformation resistance obtained by compression tests on actual materials can improve the accuracy of FEM analysis. The flow stress curve obtained from the compression test is shown in Figure 3.

Table 1: AISL cold

Strain [-]	Stress [MPa]
0	380
0.1	433.349
0.7	663.837
2	669

Figure 2: TENSILON(RTF-2430)

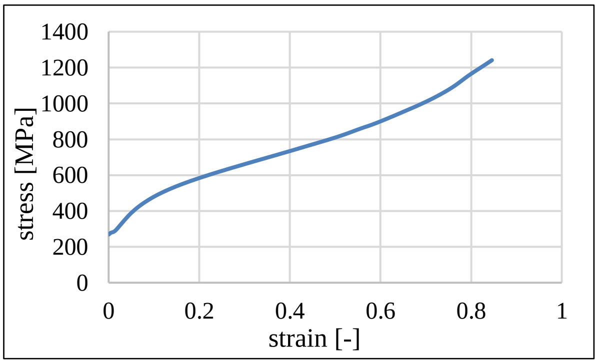


Figure 3: Deformation resistance obtained from

3 FEM ANALYSIS AND EXPERIMENTAL VALUE

FEM analysis was performed using the flow stress curve obtained from the experiments. In this study, a nominal diameter of 80A, a diameter of 89.1 mm, and a wall thickness of 4.2 mm for the SGP pipe and a nominal diameter of 50A, a diameter of 60.5 mm, and a wall thickness of 2.5 mm for the bifurcation pipe were selected. The height of the bifurcation is set at 10 mm. Figure 4 shows the target shape. A commercial FEM analysis software, DEFORM, was used for the analysis. Figure 5 shows the analytical model. The analytical model is a 1/4 model in consideration of symmetry. The analysis was performed with 50,000 tetrahedron elements. The analysis involves holding the SGP pipe in a die and pulling a spherical punch from inside the pipe in the direction of the arrow in Figure 5. The tapered portion at the bottom of the punch causes ironing at the same time as the burring process, and it is designed so that the edge face is flat when the material fills the space in the stepped portion of the die. A tapered portion is provided in the die so that the beveling can be machined at the same time as the branched portion is formed. The bending radius was set at 5 mm. Figures 6 and 7 show the die and punch drawings, respectively. The analysis was performed several times by changing the shape of the pipe preparation hole. After a good pipe bevel shape was obtained from the analysis, actual experiments were also conducted.

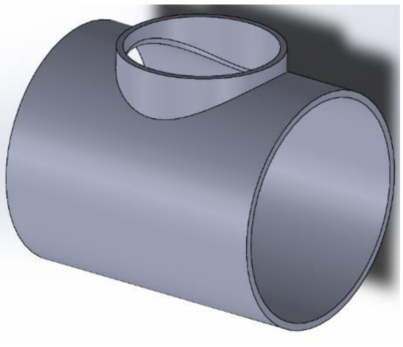


Figure 4: Target model

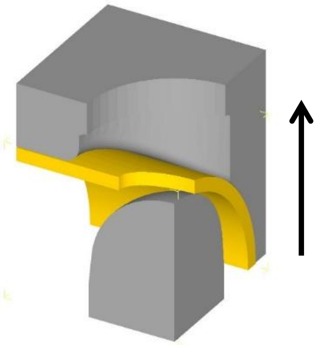
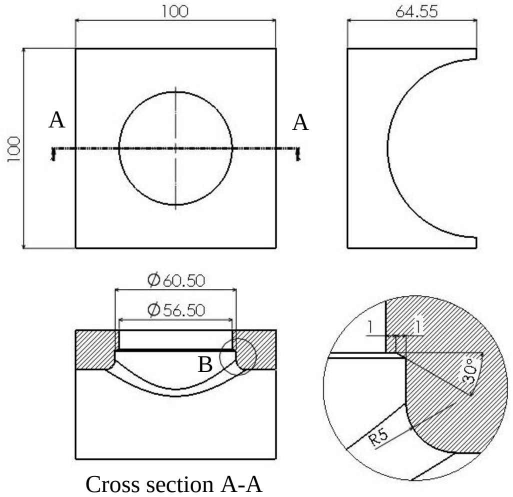


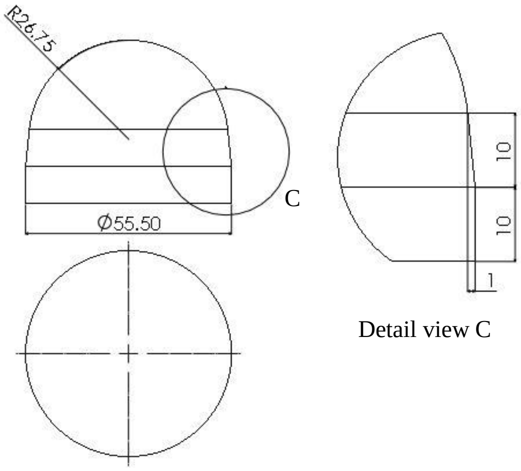
Figure 5: Analysis model



Cross section A-A

Detail view B

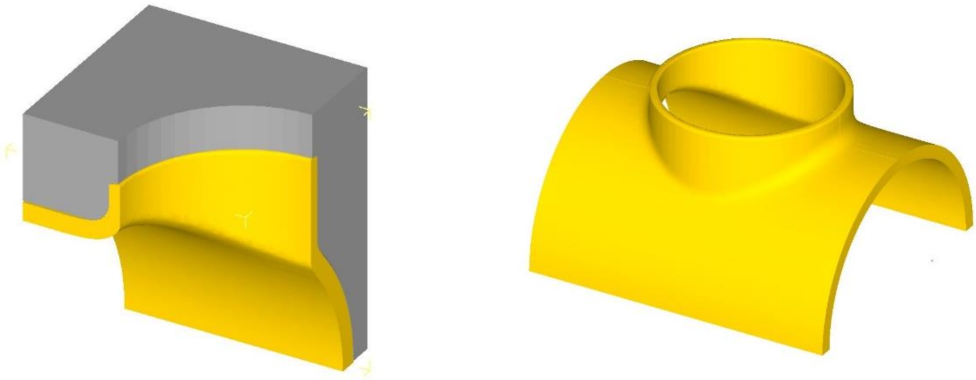
Figure 6: Drawing of die



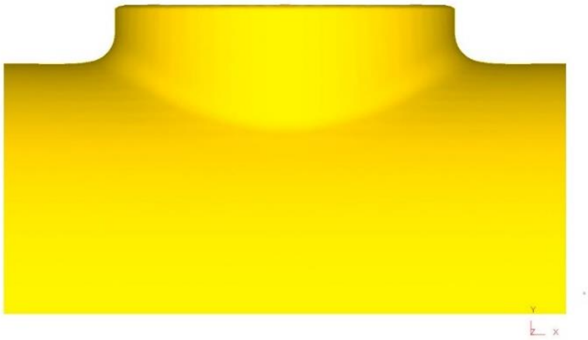
Detail view C

Figure 7: Drawing of punch

Figure 8 shows the results of the analysis. A flat bifurcation that does not require any subsequent processing was achieved. It is suggested that the beveling can be done simultaneously with the shaping of the bifurcation by this processing method. The experimental results are also shown in Figure 9.

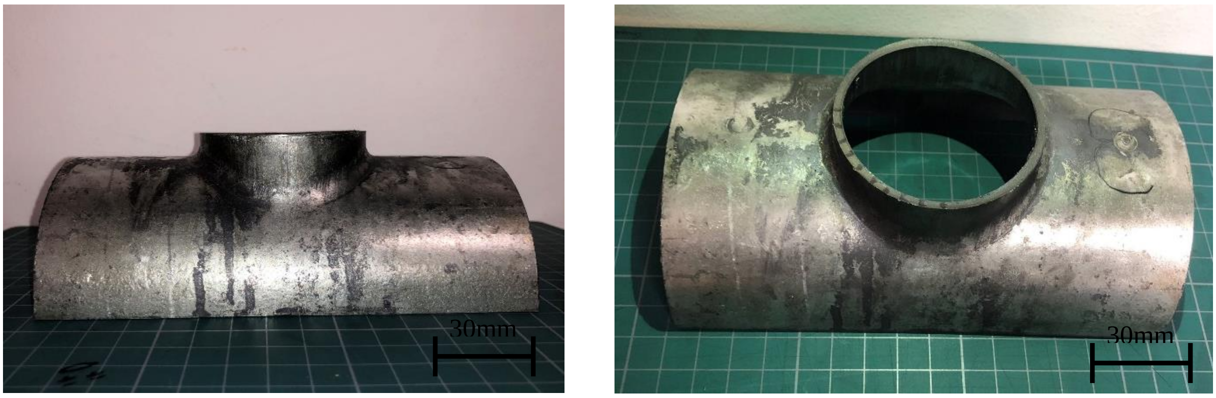


(a) 1/4 model (b) 1/4 model



(c) Side view

Figure 8: Analysis results



(a) Side view (b) Top view

Figure 9: Experimental results

Figures 10 and 11 shows a comparison between the analytical and experimental results for the wall thickness and burring height of the bifurcated pipe from 0° to 90°. The axial direction of the pipe is assumed to be 0°. The height of the burring was determined by measuring the distance from the cross section of the pipe to the end face of the branch pipe with a height gauge and subtracting the radius of the pipe from the value.

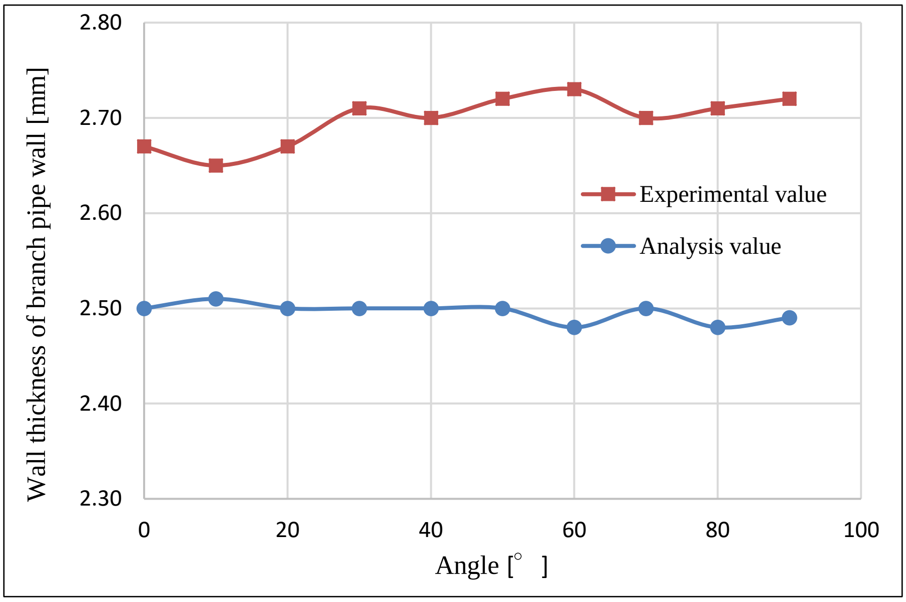


Figure 10: Relationship between wall thickness of branch pipe wall and angle

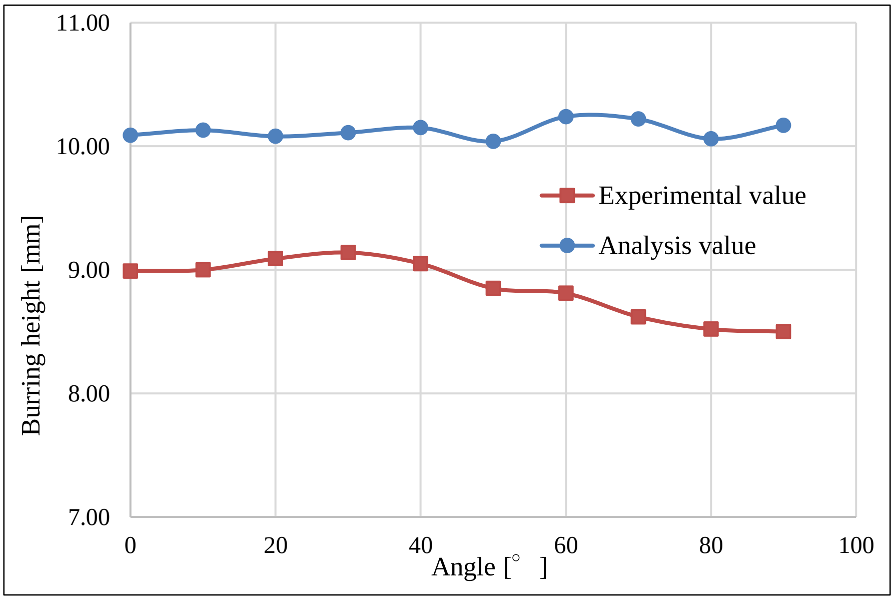


Figure11: Relationship between burring height and angle

Figure 9 shows that there were no cracks in the bifurcated pipe end of the experimental specimen. However, Figures 10 and 11 show that the wall thickness of the bifurcated pipe end was larger than that of the analysis, and the material did not fill the step of the mold, so the burring height was lower than that of the analysis, and the beveling process was not completed. This was due to the fact that the mold was treated as a rigid body in the FEM analysis and elastic deformation of the mold was not considered. In the experiment, the mold deformed elastically when a load was applied, and the steps of the mold gradually widened and failed to fill with material. In order to realize the beveling process in the experiment, it is necessary to use an elastic body instead of a rigid body in the FEM analysis, and to perform a more accurate analysis or to conduct several experiments while changing the shape of the lower hole to obtain an appropriate shape of the lower hole that does not produce burrs and allows the material to fill the mold step.

4 RELATIONSHIP BETWEEN DAMAGE VALUE AND CRACKING

Figure 12 shows the distribution of the damage values obtained by the analysis.

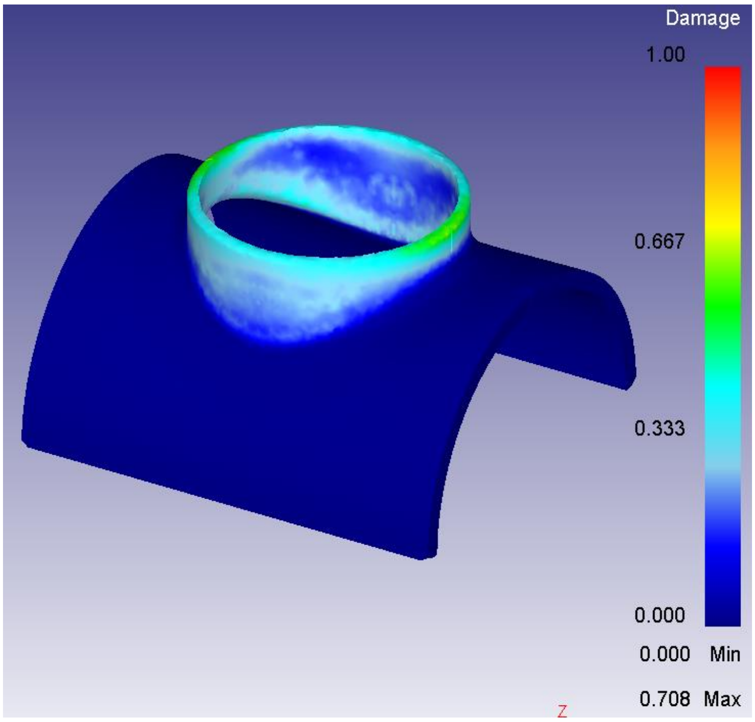


Figure 12: Distribution of the damage values

From Fig. 12, it can be confirmed that the highest damage value is less than 1, which means that no cracking will occur.

5 CONCLUSION

This paper reported on the improvement of the accuracy in FEM analysis of a batch pipe forming method using burring and ironing of large diameter steel pipes and the comparison between experimental and analytical values from actual experiments.

In order to obtain the deformation resistance, which is considered to improve the accuracy of FEM analysis, compression tests using actual materials were conducted. The beveling process was obtained without the need for subsequent machining, but no bifurcation was obtained in the actual experiment due to elastic deformation of the mold. Therefore, in order to reproduce the beveling process experimentally, it is necessary to change the mold material to a more rigid material or to conduct several experiments while changing the shape of the lower hole to obtain an appropriate shape of the lower hole that does not produce burrs and allows the material to fill the mold step. It was predicted that the proposed processing method would not cause any cracking.

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REFERENCES

[1] Okada, K., et al. Analysis of deformation behaviour in burring of tube using temperature gradient. *Journal of the Japan Society for Technology of Plasticity*. (1991) **32** (364): 583-588.

[2] Teramae, T., et al. Optimum Forming Conditions for Incremental Tube Burring with a Bar Tool Using FE Simulation. *Journal of the Japan Society for Technology of Plasticity.* (2009) 50 (581): 560-564.

[3] Teramae, T., et al. Effect of material properties on deformation behavior in incremental tube-burring process using a bar tool. *Journal of Material Processing Technology.* (2007) 191 (1-3): 24-29.

[4] Yang, C., et al. Dieless incremental hole-flanging of thin-walled tube for producing branched tubing. *Journal of Materials Processing Technology.* (2014) 214 (11): 2461-2467.

[5] Alves, L.M., et al. Tube branching by asymmetric compression beading. *Journal of Materials Processing Technology.* (2012) 212 (5): 1200-1208.

[6] Ishikawa T. Current status and trends of numerical simulation of metal forming. *Journal of Japan Institute of Lite Metals*. (2009) **59** (7): 365-370.

[7] Ishikawa T. Prediction of Ductile Fracture in Cold Forging. *Journal of Japan Society for Technology of Plasticity*. (2012) **53** (620): 790-794.