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Finite Element Method Analysis in Uniaxial Die Forming of Thick Walled Pipe with Back Pressure

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Abstract:-In the automotive industry, a fuel economy of vehicle according to emission regulation is an important issue. Development of weight saving technology is a way to achieve a low fuel consumption automobile. In particular, the hollow parts for transmission components such as a drive shaft has been attracting attention because of large effect on improvement of fuel efficiency. The required shapes of hollow shaft for stiffness are small diameter and thick wall at end, and large diameter and thin wall at midportion. Conventional manufacturing process has some problems such as many step process and highly cost. Thus, in this study, uniaxial die forming process of thick walled pipe by press forming was proposed. The purposes of this process are to form a thick walled pipe with reducing diameter and increasing wall thickness. Advantages of this process are the process that needs few manufacturing steps and satisfies a mass production. And the disadvantage is difficult to control the wall thickness. Also, a computer simulation of plastic forming for the purpose of cost reduction and speedy development has been expanding. In this study, finite element method analysis was operated to clarify the mechanism for the wall thickness increasing. The effect of back pressure on wall thickness increasing ratio in uniaxial die forming process was investigated by FEM analysis in this paper. Outer diameter, wall thickness and length of steel pipe were 39 mm, 7.6 mm and 160 mm, respectively. Taper angle of die and target diameter were 20 degree and 34.5 mm, respectively. Wall thickness increasing ratio with back pressure was 8.3 %. The ratio without back pressure was 4.7 %. It was possible to increase the pipe wall thickness by back pressure comparing to without back pressure. It was suggested that the wall thickness increasing was effected by the strain distribution and longitudinal direction stress.

Keywords:-Finite Element Method Analysis, Uniaxial Die Forming, Thick Walled Pipe, Back Pressure

I. INTRODUCTION

Recently, the global warming and other environmental problems has been an important international issue. In the automotive industry, the application of hollow parts for automobile has been expected to solve these problems because of weight saving technology of car.In particular, the hollow parts for transmission components such as a large length drive shaft has been attracting attention because of large effect on improvement of fuel efficiency. The required shapes of hollow shaft for stiffness are small diameter and thick wall at end, and large diameter and thin wall at midportion. Conventional manufacturing process for hollow drive shaft are such as friction welding, rotary swaging and etc.. These processes are multi step process and highly cost. Also the pipe reduction forming by planetary roller reducer was developed by Kiuchiet al. [1, 2]. And finite element analysis of planetary roller reducer for the purpose of pipe reduction and wall thickness increasing was operated by Kawabata et al. [3, 4]. However, the forming machine is complex and expensive comparing to conventional process. Thus, in this study, uniaxial die forming process of thick walled pipe by press forming was proposed. The purposes of this process are to form a thick walled pipe with reducing diameter and increasing wall thickness. Advantages of this process are the process that needs few manufacturing steps and satisfies a mass production. And the disadvantage is difficult to control the wall thickness. Also, a computer simulation of plastic forming for the purpose of cost reduction and speedy development has been expanding. In this study, finite element method analysis was operated to clarify the mechanism for the wall thickness increasing. The effect of back pressure on wall thickness increasing ratio in uniaxial die forming process was investigated by FEM analysis in this paper. Average axial load, average thickness increasing ratio, inner strain distribution and axial stress distribution were investigated.

II. FINITE ELEMENT METHOD ANALYSIS

A. Simulation Model

Fig. 1 shows the simulation model without back pressure. And Fig. 2 shows the simulation model with back pressure. Model size was 1/8 to reduce the computation time. Types of each objects are elasto-plastic body for material, rigid body for top die and elastic body for bottom die, respectively. Fig. 3 shows the overviews of each model. As shown in Fig. 2 and Fig. 3, back pressure pin was set at the position of taper exit. Applied back pressure during process was constant depending on each analytical conditions.

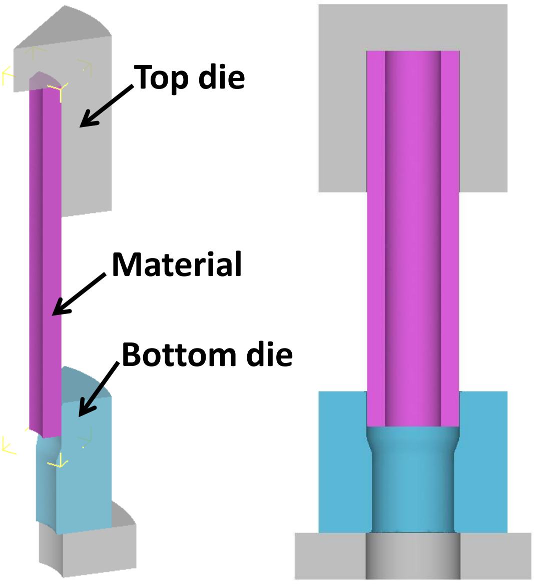


Fig.1 Simulation model without back pressure

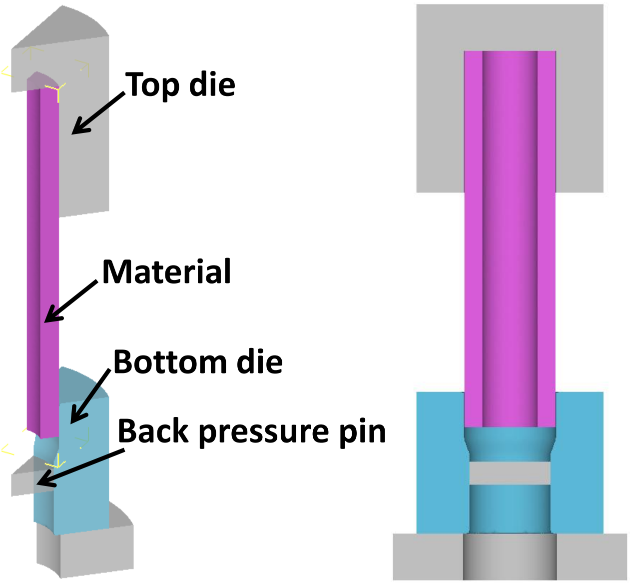
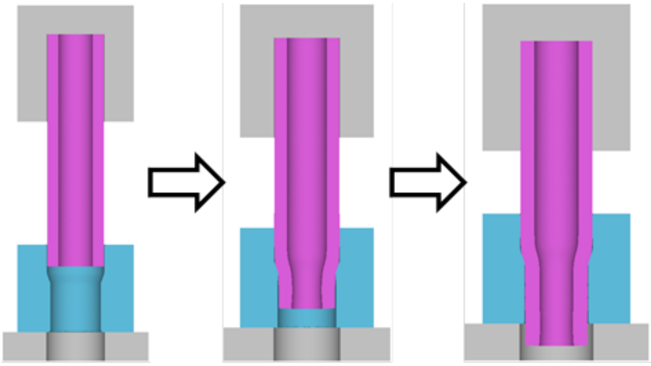
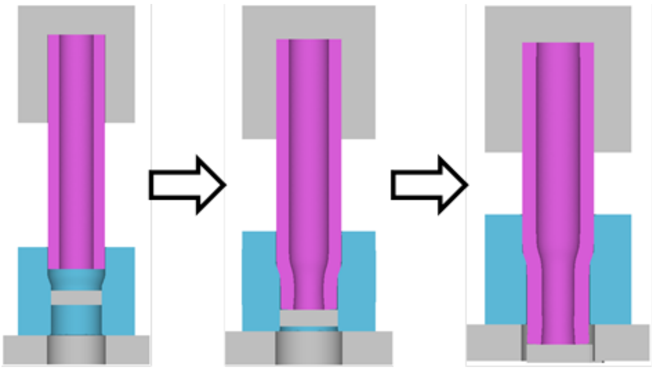


Fig.2 Simulation model with back pressure



(b) Uniaxial die forming without back pressure



(a) Uniaxial die forming with back pressure

Fig. 3Uniaxial die forming process of thick walled pipe

B. Analytical Conditions

Analytical conditions are shown in Table 1. Effect of back pressure on wall thickness increasing was investigated. Back pressure F were 0, 18, 31 and 49 kN, respectively. Die taper angle α, pipe reduction diameter D and feeding speed v were 20°, 34.5 mm, 100 mm/sec, respectively.

Table 1 Analytical condition

Pipe diameter d	**[mm]**	**39.0**
Pipe thickness t	**[mm]**	**7.6**
Pipe length L	**[mm]**	**160.0**
Taper angle α	**[degree]**	**20**
Feeding speed v	**[mm/sec]**	**100**
Back pressure F	**[kN]**	**0, 18, 31, 49**
Pipe reduction diameter D	**[mm]**	**34.5**

III. RESULTS AND DISCUSSION

Fig. 4 shows the relationship betweenback pressure and axial force. Axial force was increased with increasing of back pressure. Increasing amount of axial force was not equal to back pressure. It was suggested that the increasing axial force was effected by back pressure and friction. Fig. 5 shows the relationship between back pressure and wall thickness increasing ratio. Thickness increasing ratio was increased with increasing of back pressure. It was suggested that the axial elongation of pipe was inhibited by back pressure. Axial force and wall thickness increasing were linearly increasing with increasing of back pressure.It was possible to increase the pipe wall thickness by back pressure comparing to without back pressure.

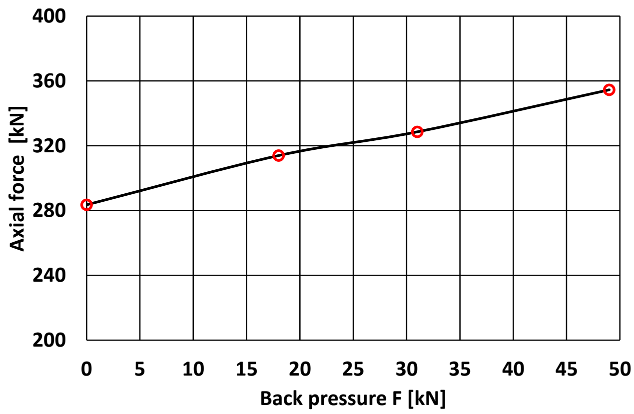


Fig. 4Relationship between back pressure and axial force

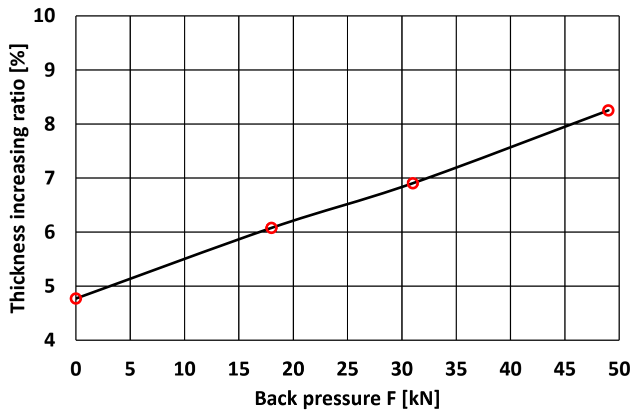
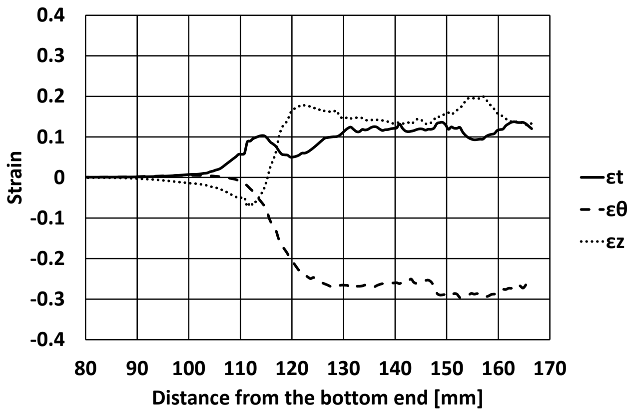
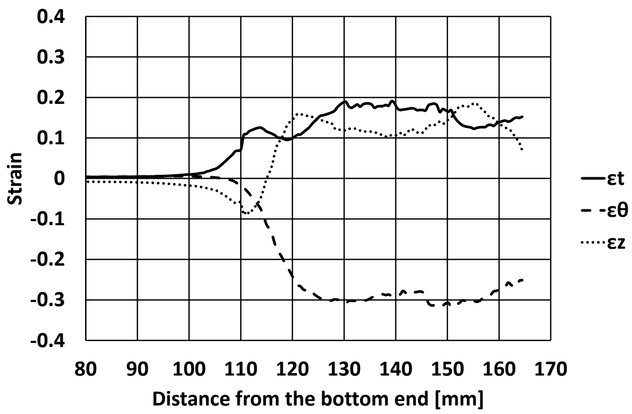


Fig. 5Relationship between back pressure and wall thickness increasing ratio

Fig. 6 shows the strain distributions of inner surface. Fig. 6 (a) shows the result of F = 0 kN. And Fig. 6 (b) shows the result of F = 49 kN. In this figure, εt, $\varepsilon\theta$ and εz are thickness direction strain, circumferential strain and axial strain, respectively. Average wall thickness increasing ratio was calculated by εt at formed part. Elongation of pipe, εz was inhibited a little by back pressure. Circumferential strain $\varepsilon\theta$ was not affected by back pressure because $\varepsilon\theta$ was affected by the diameter of die. Therefore, thickness direction strain εt was increased because of volume constant condition. It was suggested that the inhibition of εz with back pressure was effective to increase the wall thickness.



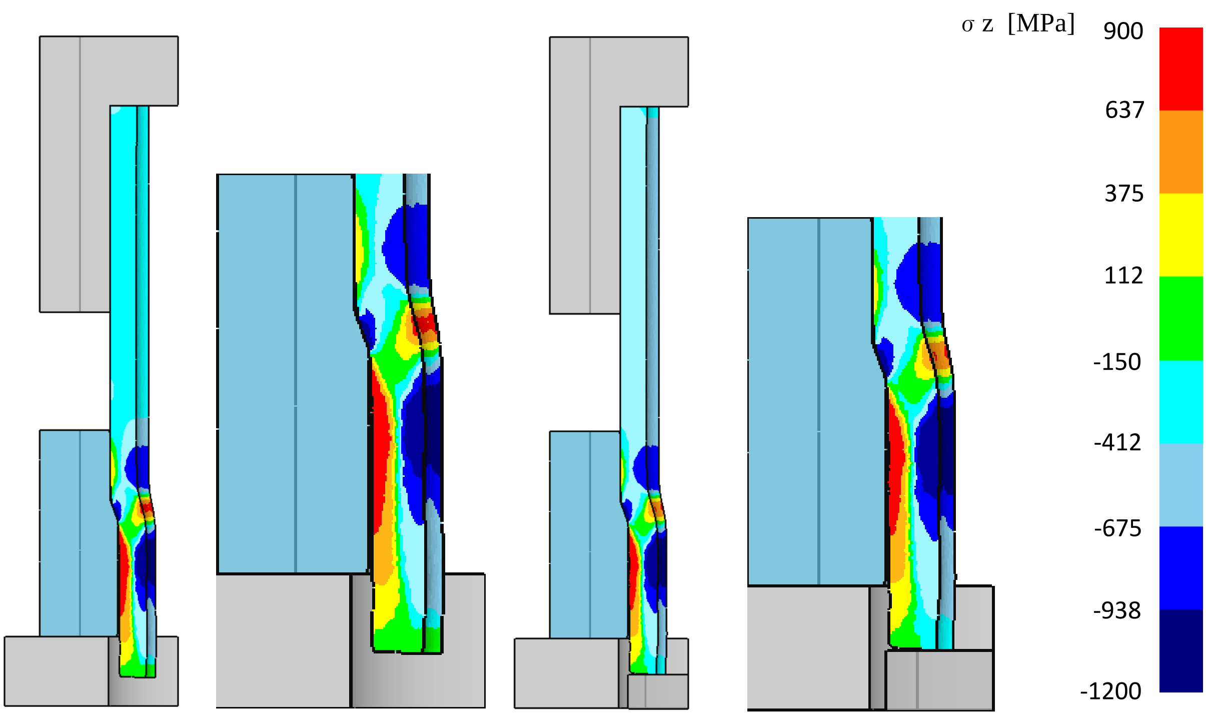
(a) F = 0 kN (without back pressure)



(b) F = 49 kN

Fig. 6Strain distributions of inner surface ((a) without back pressure, (b) F=49 kN)

Also, Fig. 7 shows the axial stress distributions with or without back pressure. It was noted that a clear different was observed at taper position of inner surface of pipe. Axial stress at taper position was tensile stress in both conditions, however the value with back pressure was smaller than that without backpressure. It was suggested that the axial tensile stress at taper position was able to be inhibited by back pressure. And it was suggested that inhibited axial tensile stress increased the wall thickness increasing ratio.



(b) Without back pressure, F = 0 kN **(a) With back pressure, F = 49kN**

Fig. 7Axial stress σ_z distributions

IV. CONCLUSIONS

Uniaxial die forming process with back pressure of thick walled steel pipe was proposed. And the effect of back pressure on wall thickness increasing in uniaxial die forming process was investigated by FEM analysis. Conclusions are below;

1. Pipe wall thickness increased with increasing back pressure.
2. Inhibition of axial strain εz with back pressure was effective to increase the wall thickness.
3. Inhibited axial tensile stress of inner surface at taper position was effective to increase the wall thickness increasing ratio.

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