A Study on the Manufacturing of Brake tube and Flare nut for Automobiles

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자동차용 브레이크 튜브 및 플레어 너트의 제조에 관한 연구

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Abstract

The purpose of the present paper is to investigate the optimal shape of the brake tube-end and flare nut for automobiles using the DEFORM^{TM}-3D, finite element code. A flare nut is a small and important part used to join a brake tube-end in automobiles. In this instance, we studied the optimal forging processes for the tube-end and flare nut. Finite element analysis has been carried out to predict an optimal shape of the tube-end and flare nut. Also the simulation results were reflected to the forging processes design for the tube-end and flare nut. The shape of the tube-end and flare nut is in agreement with the finite element simulation and the test results.

Key Words : Brake tube(브레이크 튜브), Flare nut(플레어 너트), Forging(단조), Rigid-plastic Finite Element Analysis(강소성 유한요소법)

I. Introduction

The brake tube is considered one of the most important parts in an automobile and it has a great influence on the function of the brake. The brake tube quality, such as the shape of the tube-end, needs to be guaranteed for the safety of the passenger. Therefore, we must make the brake tube-end through precision forming. Now, the brake tube-end is formed by a hydraulic press forming machine. In the forming of tube-ends, serious problems often occur because the tube is dented and pushed during the forming. That's why the life cycle of punch is short and the cost increases. The forming process of the tube-end is a kind kind of open-die forging and the forming process of the tube-end for automobiles using the open-die forging is considered a very appropriate

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process for the manufacturing of good products which satisfy the Korean Standard. Also a flare nut is a small and important part used to join a brake tube-end in which oil passes in automobiles. In recent years, there has been a growing interest in the forming by forging technology. Since mass production and standardization of quality due to frequent change in the machining condition are difficult, the production by machining has a disadvantage. According to the report, the quality of the flare nut produced by machining is not uniform and also the production cost is expensive. However, the production using forging processes could not be attempted due to the lack of technology. Recently, to produce the flare nut economically, the forging processes have been recommended. Also, according to the progress of computer simulation and the development of computer analysis technology, we can get the optimal results very quickly. In addition we can forecast the problem to be caused by using computer simulation. In this present paper, we simulated the forming parts of tube-ends using the DEFORM™-3D, commercially available finite element code. Based on the simulation results, we proposed the design condition of forming process for achieving the optimal shape of the tube-end. Also, finite element analysis has been carried out to predict an optimal shape of the flare nut and its simulation results were reflected to the forging processes design for the flare nut.

2. Brake tube for automobiles

2.1 Characteristics of brake-tube

In this study, the tube material used is SPCC and it is drawn to the shape dimension decided after roll forming and then forming to the structure of a double-wall. The mechanical properties and chemical compositions of the SPCC tube are as follows:

Table 1 Mechanical properties of the SPCC tube

Tensile Strength (MPa)	Yield Point (MPa)	Elongation (%)	Hardness (HRc)
Min 294	Min 177	Min 25(Gauge length :50mm)	60

Table 2 Chemical compositions

C	Si	Mn	P	S	Coating thickness	
					inside	outside
Max 0.12%	-	Max 0.50%	Max 0.04%	Max 0.045%	Cu: 3μm	Zn: 25μm

2.2 End-form of brake-tube

Fig. 1 shows the forming shape of brake tube and quality control parts. Fig. 2 shows the section picture of the brake tube before and after assembly. Part "A" and "C" take the role of the outflow suppression of the oil and the protection of the screw looseness at the same time. The purpose of this study is to find the condition under which the length of the part "A" and the angle of the part "C" become the optimal. To find the optimal condition we used the **I-DEAS** and the **DEFORM™-3D** (Oh et al., 1991), commercially available finite element code for analysis.

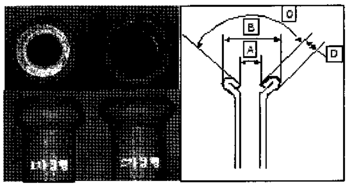

Fig. 1 Photo of end-form brake tube

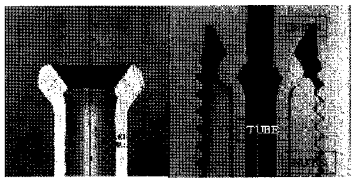

Fig. 2 Photo of tube section before and after assembly

3. Forming experiment of brake tube-end

The die which is used in this study is designed as the Fig. 3 and it is composed of first punch(top-die), second punch and chuck(bottom-die). We adhered a contact sensor at the front part of the die to accurately control the length which the tube is projected to the outside of die. Fig. 4 shows a photograph which the die is adhered at the hydraulic press forming machine to be used in the experiment. The die material used is SKD11 which is usually used as a cold forging material due to it's strength and rigidity(Keum et al., 2002).

We machined the groove of radius 2.35mm at the chuck to assemble the tube that diameter is 4.76mm accurately and assembled the guide pin at the central part of the tube. Also we made the 0.05mm projection at the middle of the groove to prevent the tube from being pushed. We experimented with a 0.1mm interval in each process until the distance between the punch and the chuck approaches to 0.5～3mm.

4. Finite element analysis

4.1 Modelling

Fig. 5 shows the finite element model of top die, bottom die and billet. To describe these we used the I-DEAS, commercially available CAD S/W. We assumed that the top and bottom die were rigid and the material was rigid-plastic, and the anisotropy according to the rolling direction of the material was not considered(Altan et al., 1983).

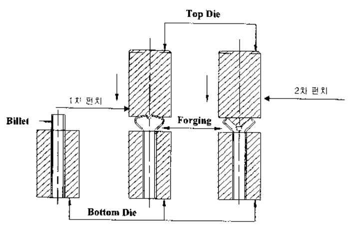

Fig. 3 Open-die forging process for tube

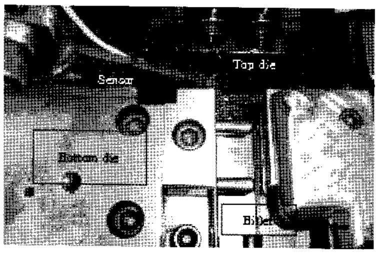

Fig. 4 Photo of experimental system

4.2 Process parameter

Table 3 expressed data to be used for the analysis. For the process analysis, we selected a total stroke to the 6mm. In the first stroke we applied from the 2mm to the 4mm with a 0.5mm interval and in the second stroke we applied from the 4mm to the 6mm with a 0.5mm interval.

4.3 Results and discussions

Fig. 6 and Fig. 7 show the change of the stress and shape of material according to the first and second punch respectively.

Fig. 8 shows the change of the stress and shape at the stroke of the first punch is 2.5mm. Fig. 8 shows thestress of the material becomes bigger as the stroke of the punch increases. In Fig. 9 we can know that the non-uniform stresses occur at the outside of forming part. Fig. 10 shows the change of the stress and shape at the stroke of the first punch is 3mm and we can know that the stress does not occur greatly. Fig. 11 shows the shape when the stroke of the second punch is 5mm and the shape is similar to the shape of a real brake tube-end to be desired.

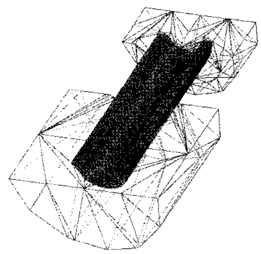

Fig. 5 Finite element model of the tube

Table 3 Data for simulation

Parameter	Unit	Value
Workpiece	-	SPCC
Temperature	℃	20
Step No.	-	100
Stroke per Step	mm	0.04
Friction coefficient	-	μ= 0.08

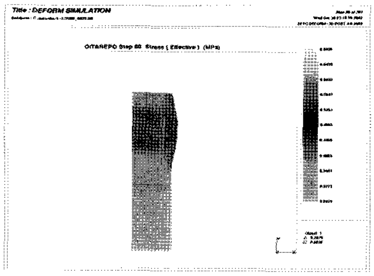

Fig. 6 Stress distribution after the first punch forming (stroke is 2mm)

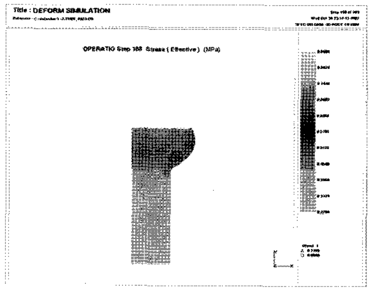

Fig. 7 Stress distribution after the second punch forming (stroke is 4mm)

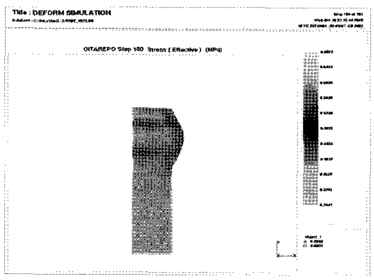

Fig. 8 Stress distribution after the first punch forming (stroke is 2.5mm)

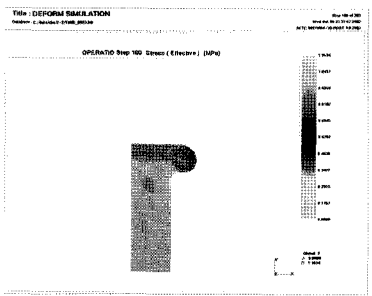

Fig. 9 Stress distribution after the second punch forming (stroke is 4.5mm)

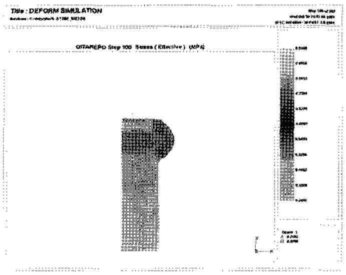

Fig. 10 Stress distribution after the first punch forming (stroke is 3mm)

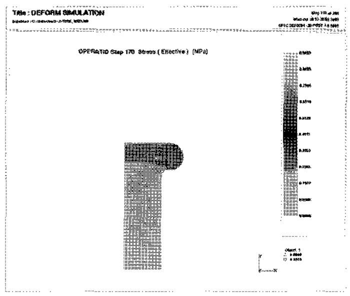

Fig. 11 Stress distribution after the second punch forming (stroke is 5mm)

5. Design of flare nut

5.1 Forging process design

In this study we designed a multi-stage forming process to promote the manufacturing process of the flare nut. After modeling the flare nut by the 3D CAD program, finite element analysis has been carried out using the commercial finite element code. Also we designed the forging die as a four stage process, and at the inner part which tube is inserted, precision forging was performed. Fig. 12 shows the flow chart of the planning for flare nut forging process. Fig. 13 shows the forging process.

5.2 The material characteristics of the flare nut

The SWCH 10A is used as the material of the flare nut and the material properties are presented in Table 4.

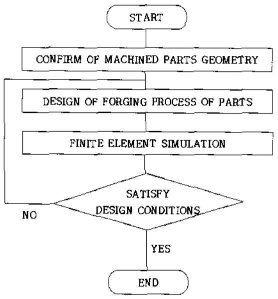

Fig. 12 Flow chart of the process planning for flare nut

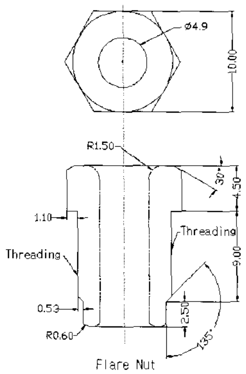

Fig. 13 Geometry of flare nut

Table 4 Material properties of SWCH 10A

Material properties		Diameter : 9mm
Mechanical properties	Tensile property	Over 340 N/mm^2
	Elongation	Over 11%
	Section contraction ratio	Over 45%
	Roughness	Below 85 HRB
Chemical compositions	C	0.08~0.13%
	Si	0.1%
	Mn	0.3~0.6%
	P	Below 0.03%
	S	Below 0.035%
	Al	Over 0.02%

5.3 Finite element analysis

5.3.1 Analysis condition and preprocessing

In this study the flare nut is produced by the manufacturing process of cold forging which has an axisymmetric form. Generally the governing equations of axisymmetric problem can be expressed in terms of cylindrical coordinates, the z-axis being the axis of symmetry. Due to the forging process of the flare nut being an axisymmeric problem, it is possible to solve the problem as one fourth of the full size. The flow stress-strain relation curve of the material SWCH 10A is depicted in Fig. 14 and process condition is assumed using the reference and experimental data as follow:

○ Plastic stress-strain relation : $\sigma = 0.28\varepsilon^{-0.28}$MPa
○ Effective strain : $0 \leq \varepsilon \leq 1$
○ Friction coefficient : $\mu = 0.08$
○ Punch velocity : $v = 1.0$ mm/s
○ Material dimension : $\phi 9.0 \times 14.0$ mm

5.3.2 Results and discussions

Fig. 15~Fig. 17 are obtained by the simulation of the four stage forging process using DEFORM™-3D, commercially available finite element code. Fig. 15 shows the mesh shape of each forging process. Fig. 16 shows the effective stress distribution of each forging process. Stress value is shown to be relatively larger at the part in which shape change occurs more and stress distribution becomes uniform as each forging process progresses. Fig. 17 shows the effective strain distribution of each forging process. Notably, it can be seen that the strain increases at the part in which large deformation occurs.

6. Conclusions

In this study, the conditions to decide the optimal shape of the brake tube-end and flare nut for automobiles are studied using finite element analysis and the experimental tests. In the experiment, a specially designed piece of equipment for open-die forging was used and the forming processes were performed with a hydraulic press forming machine. The result about each process which has been accomplished using finite element analysis expressed a similarity to the real shape.

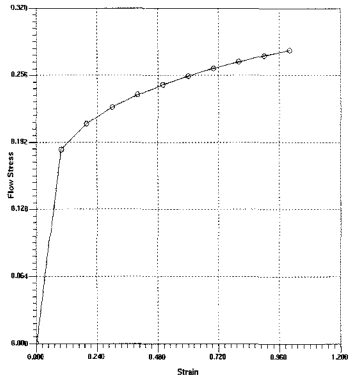

Fig. 14 Stress-strain curve of SWCH 10A

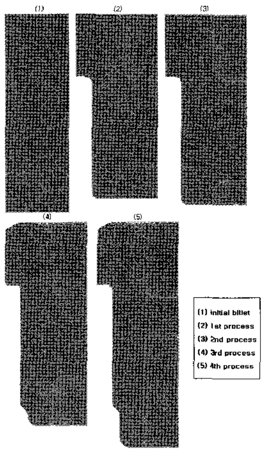

Fig. 15 Mesh shape of forging process

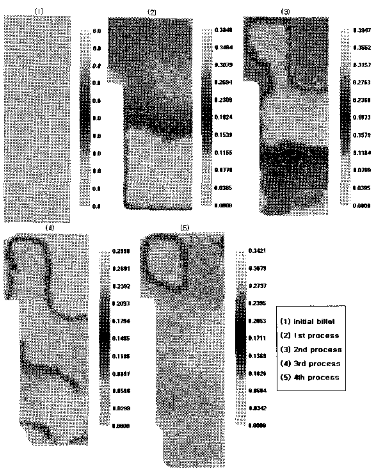

Fig. 16 Effective stress of forging process

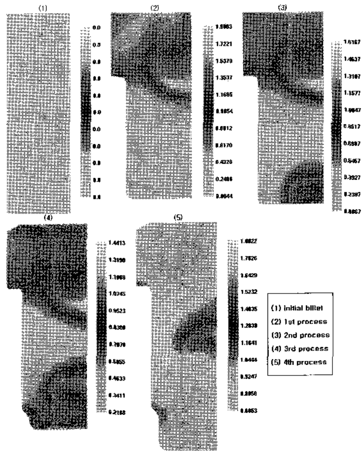

Fig. 17 Effective strain of forging process

The conclusions obtained are as follows:

1. The stress which the material receives is small when the stroke of the first punch is the 2mm.
2. The stress which the material receives becomes bigger when the stroke of the first punch is 2.5mm and the non-uniform stresses happened at the outside of forming part.
3. The distribution of the stress is uniform when the stroke of the first punch is 3mm. Also we could get similar shape most with the shape of the real brake tube-end.
4. After the simulation of the open-die forging process using the rigid-plastic FEM, it was possible to predict the weak part of the die and the material and its results were reflected in the die design, and finally a product of good quality can be obtained.
5. FEM simulation results have shown that the distribution of the stress and strain is uniform.
6. The analysis results by FEM simulation were reflected in the forging processes design for the flare nut and better products in dimension and quality were obtained.

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