Design Optimization of the Forging Process for the Flare Nut using Computer Simulation

Kyu-Taek Han[1], Seok-Dae Kim[2]

[1] School of Mechanical Engineering, Pukyong National University, Busan, 608-739, Korea
[2] Graduate School of Mechanical Engineering, Pukyong National University, Busan, 608-739, Korea
e-mail: kthan@pknu.ac.kr

Abstract **— A flare nut is a small and important part used to joint a brake tube-end in automobiles. The purpose of this present paper is to investigate the optimal shape of the flare nut for automobiles using the DEFORM™-3D, finite element code. In this instance, we studied the optimal forging processes for the flare nut. 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. The shape of the flare nut is in agreement with the finite element simulation and the test results. Through this research, the optimal shape of the flare nut was achieved.**

1. INTRODUCTION

A flare nut is a small and important part used to joint a brake tube-end in which oil passes in automobiles. The flare nut has been made by machining during the past 20 years.

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 study, 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. In this present paper we researched the optimal shape of the flare nut for automobiles using the DEFORM™-3D, commercially available finite element code.

2. DESIGN OF FLARE NUT

2.1 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.1 shows the flow chart of the planning for flare nut forging process. Fig.2 shows the geometry of flare nut.

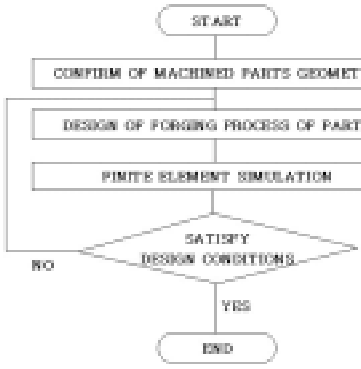

Fig.1 Flow chart of the process planning for flare nut

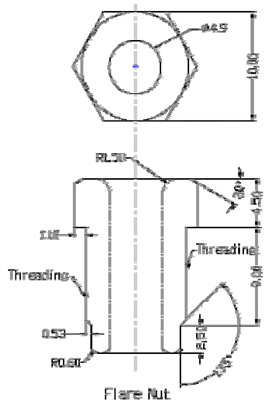

Fig.2 Geometry of flare nut

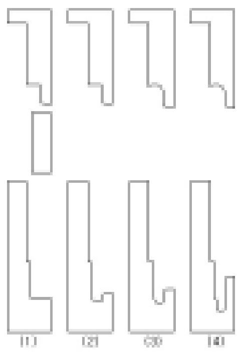

Fig.3 Forging processes for flare nut

Fig.3 shows the forging processes for flare nut and is expressed as a half section due to axisymmetric shape.

2.2 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 1.

Table 1 Material properties of SWCH 10A

Material properties		Diameter : 9mm
Mechnical 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 %

2.3 Finite Element Analysis

2.3.1 Analysis condition and preprocessing

In this study the flare nut is produced by the manufacturing process of cold forging which have an axisymmetric form. Generally the governing equations of axisymmetric problem can be expressed in terms of 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 expressed in the Fig.4 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 : $0 \le \varepsilon \le 1$
* Friction coefficient : $\mu = 0.08$
* Punch velocity : $\upsilon = 1.0$ mm/s
* Material dimension : $\phi 9.0 \times 14.0$ mm

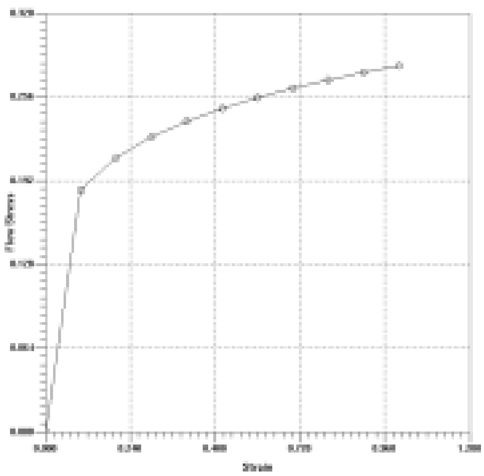

Fig. 4 Stress-strain curve of SWCH 10A

2.3.2 Forging process modeling

Fig.5 and Fig.6 show the modeling of each forging process using 3D CAD program.

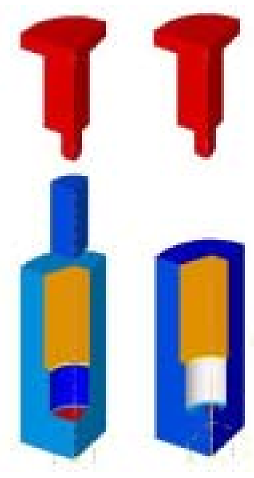

Fig. 5 Punch & die of 1 and 2 process

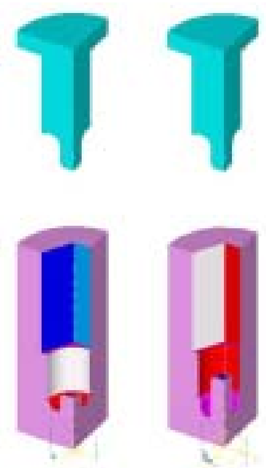

Fig. 6 Punch & die of 3 and 4 process

2.3.3 Results and discussions

Fig.7~Fig.9 are obtained by the simulation of the four stage forging process using DEFORM^{TM}-3D, commercially available finite element code. Fig.7 shows the mesh shape of each forging process. Fig.8 shows the effective stress distribution of each forging process. Stress value is expressed relatively larger at the part in which shape change occurs more and stress distribution became uniform according as each forging process progresses. Fig.9 shows the effective strain distribution of each forging process.

Notably, it can be seen that the strain expressed increased value at the part in which large deformation occurs.

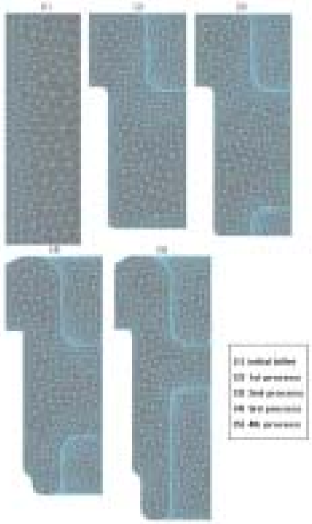

Fig. 7 Mesh shape of forging process

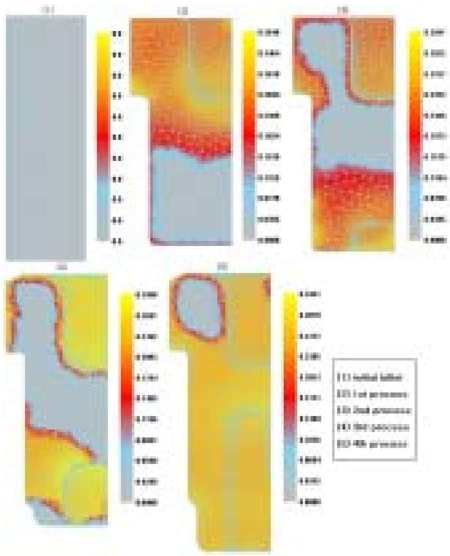

Fig. 8 Effective stress of forging process

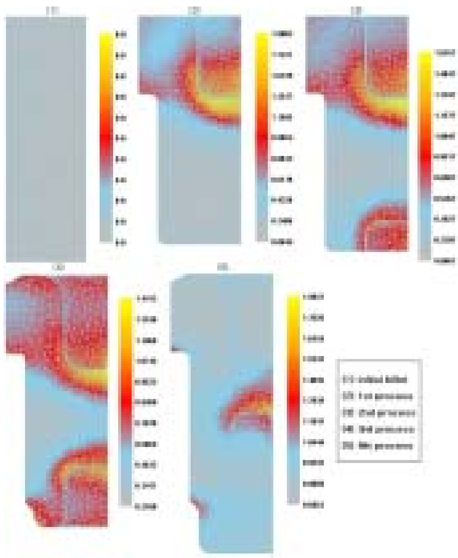

Fig. 9 Effective strain of forging process

Fig.10 shows effective stress-time curve. It illustrates that the maximum value of stress tends to increase in the beginning compared with later. Also it can be seen from Fig.10 that the interval where stress increases suddenly exists.

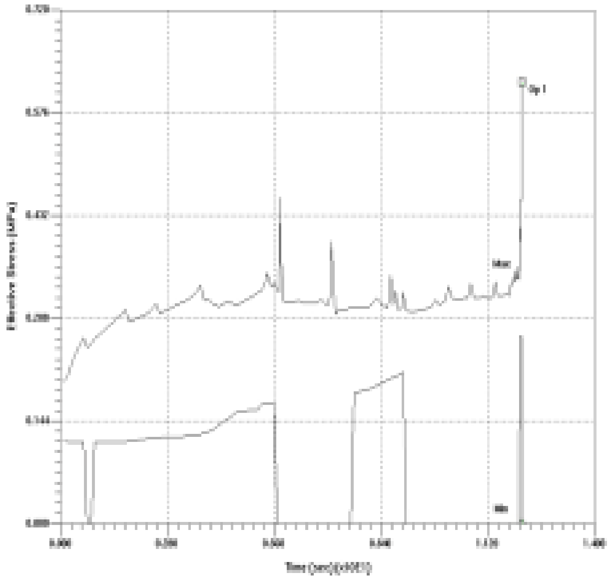

Fig. 10 Effective stress-time curve

The effective strain-time curve is shown in Fig.11. The strain increases to relatively small amounts and the strain value became the maximum in the first stage.

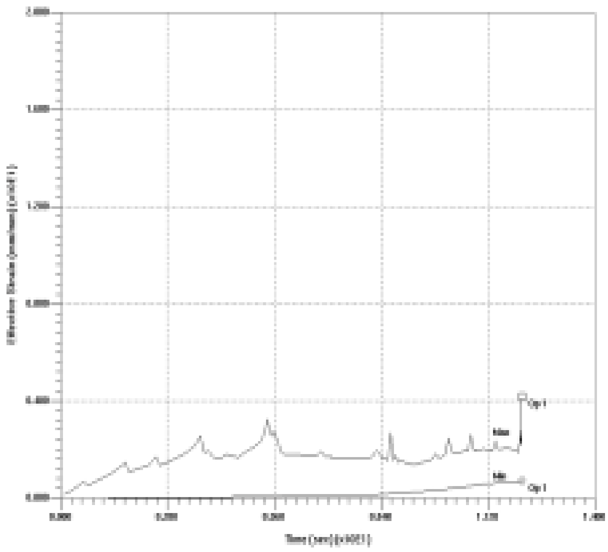

Fig. 11 Effective strain-time curve

Fig.12 shows load-time curve. The large load is evident in the last part of each process. Fig.13 shows nodal velocity-time curve. It can be seen that nodal velocity is very fast in the final part of the second stage and also the velocity of the final part of each process becomes faster compared to the other parts.

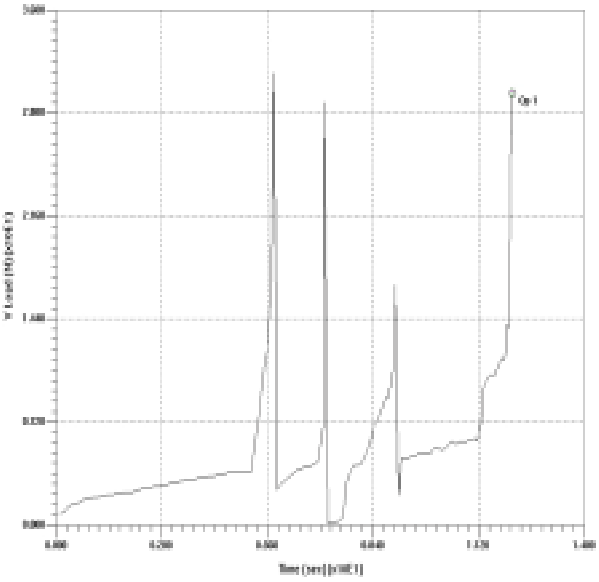

Fig. 12 Load-time curve

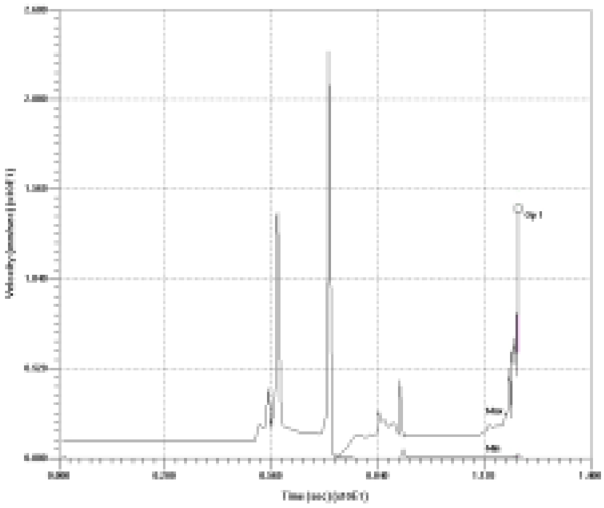

Fig. 13 Nodal velocity-time curve

2.3.4 Estimation of sample product

The analysis results obtained by using finite element analysis were good and as you can see from Fig.14, the shape of product obtained by experiment is very similar to the shape of simulation by FEM. From the result presented by Table 2, it can be seen that the precision forging for the inner diameter which tube is inserted can make the desirable product shape.

Also the mechanical and physical property of the product are turned out with added efficiency, respectively. Table 3 shows the effect of the forging process based on optimal design. It can be shown that the production by the forging process using plastic deformation is much better than that by machining at an economical viewpoint.

Fig. 14 Photo of flare nut

Table 2 Test of prototype

Content / Test item	Specification	Measured value	Judgment
Appearance	Scar	Undetected	OK
Material	SWCH 10A	Tried & True	OK
Coating thickness	MFZNT2-C (over 8μ)	Tried & True	OK
Corrosion resistance	Rust	Undetected	OK

Table 3 Process design effect of flare nut

Content / Development	Average manufacturing cost(won)	Average demand (ea/year)	Manufac-turing capability (day)	Appli-cation (item)
Before (import)	30 ~100	25,000,000	60	20
After (domestic)	25	1,200,000	30	1

3. CONCLUSIONS

In this study, the conditions to decide the optimal shape of the flare nut for automobiles are studied using finite element analysis and experiment. The conclusions obtained are as follows:

1. FEM simulation results have shown that the distribution of the stress and strain is uniform.
2. The optimal process design for the flare nut is induced by FEM simulation instead of machining.
3. 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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