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A Study on the Perforating Process of the Muffer Tube using FEM

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Abstract : Recently there has been a growing interest in the design and manufacturing of the muffler tube due to the strict environment regulations. A muffler is an important part used to reduce noise and to purify exhaust gas in cars and heavy equipment. The shape of the muffler tube and the number of the tube hole has been made variously according to the weight and function of the car. The perforating technique of the muffler tube has a great influence on the manufacturing cost. In this study, metal forming analysis has been carried out to investigate the perforating process for the muffler tube and predict an optimal forming conditions of the muffler tube. Also its simulation results by the finite element method were reflected to the die design and the manufacturing system for the muffler tube. The perforating process is performed in the longitudinal direction of the tube. According to the simulation results, when the shear angle of punch was similar to the tube curvature, the optimal shape was obtained. Also when the clearance of die was 0.2mm, the burr was minimized and optimal shear section was obtained.

Key words : Muffler tube, Perforating, Clearance, Finite element method

1. Introduction

Recently the performance of a muffler is rapidly developing for heavy equipment. Also there has been a growing interest in the design and manufacturing of the muffler tube due to the strict environment regulation.

The temperature of the exhaust gas passing through an exhaust valve is considerably high and the velocity of the gas almost reaches sound level. If the gas is released amongst the air, the gas is expanded rapidly which gives it a violent explosive sound.

The muffler is used to reduce this. A muffler is an important part used to reduce noise and to purify exhaust gas in cars and heavy equipment. A perforated tube has to be the structure to reduce sound pressure and wave. For the perforating pressure of multi-line, the precision die design is needed and also the die is requested to have durability

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according to the distance and number of the tube hole[1]-[4].

The perforating of the tube is easy to be damaged for the die and to be deformed for the product compared with the perforating of the plate[5]-[8].

In this study, we analyzed the burr and deformation of product as shear clearance, punch shape. The part of tube, punch, and die shape were modeled using the commercial S/W, I-DEAS. Also we studied the tube deformation, stress on punch using finite element code, DEFORM™ -3D, and analyzed the results through the experiments.

2. Perforating Process Analysis of Muffler Tube

2.1 Muffler tube

The specification and material property of the muffler tube are as follows:

Table 1 Specification of muffler tube

Diameter (mm)	Length (mm)	Thickness (mm)	Material	Perforate area (mm)	Hole Diameter (mm)
101.6	430	2.0t	SPCC	250	8

Table 2 Material property of the muffler tube

Tensile strength (N/mm^2)	Yield point (N/mm^2)	Elongation (%)	Hardness (HRc)
Min 300	Min 180	Min 25	60

The material of the muffler tube used is SPCC and it has thickness 2.0mm, diameter 101.6mm. An aluminum coating processing was done for the corrosion protection.

2.2 Perforating process design

In the perforating process, the die is inserted at the inside of the tube and the punch to be put to fixed arrangement operates to the vertical. Shearing process is processed in the part that the tube contacts with the punch. At this time we experimented by changing the punch shape and evaluating the relation between punch and clearance.

2.3 Theoretical background

2.3.1 Ductile fracture condition

The fracture of metal happens when maximum shear stress(τ_{max}) or maximum tension stress(σ_{max}) reached the critical slip shear stress(τ_{cr}). The conditional expression is as follows.

$$\tau_{max} = \tau_{cr} \quad \text{or} \quad \sigma_{max} = \sigma_{cr}$$

$$\text{where, } \tau_{max} = (\sigma_1 - \sigma_3) / 2 = H(\varepsilon)$$

$$\sigma_{max} = \sigma_1 = H\sigma(\varepsilon)$$

$$\tau_{cr} = a + b\sigma_H + c\varepsilon, \ \sigma_{cr} = a' + b'\sigma_H + c'\varepsilon$$

where, ε:effective strain, σ_H:hydrostatic stress

Also a, b, c, a′, b′, c′ is the function of temperature, deformation, and each velocity.

Ductile fracture condition is adopted to investigate the shear plane formation process of the piercing part using finite element method.

Cockroft proposed a growth model of pore and ductile fracture condition by the plastic deformation energy concept.

$$\int_0^{\bar{\varepsilon}_f} \sigma^* d\bar{\varepsilon} = C$$

where, ε_f is fracture strain, σ^* is maximum tension principal stress, ε is effective strain, and C is material constant.

The material constant to the above mentioned must be decided by experiment but it assumed that the fracture occurs if the value of C reached 3 in the simulation of this research.

2.3.2 Element removal technique and element net reconstruction

If an effective strain value of any specific element agrees to the fracture criteria, we kept progressing the fracture phenomenon of shearing process by removing this element.

After one step processing, an effective strain value is extracted in the database and we select the element to exceed that criteria. This element is considered as the fracture already has occurred. After removing the element, we redrew the geometry and remeshed element net again. Here the element net is reconstructed not to allow a negative Jacobian. We constructed the element net mainly at this region for observation.

2.4 Finite element analysis

2.4.1 Modelling

Solving the perforating process problem by three dimensional modeling instead of two dimensional analysis was used due to tube characteristics. In the analysis of three dimensional piercing process, the stress concentration occurred at edge level needing the mesh size to make smaller. Notably, it is modeled so that the observation of the part to be sheared is simple.

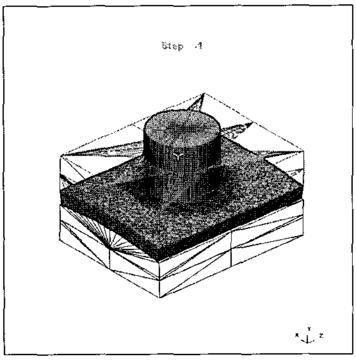


Fig. 1 Finite element model of muffler tube

We assumed the punch, stripper, and die to the rigid body as shown the Fig. 1. Also material is assumed rigid-plastic and the anisotropy of material according to the rolling direction is ignored.

One component of the piercing punch and die of fifteen column arrangement is modeled for the observation of the total behavior.

2.4.2 Process parameter

The physical properties perforating die, perforating part, and constant used analysis is shown Table 3.

Table 3 Simulation condition

Parameter	Unit	Value
Material	-	SPCC
Temperature	℃	20
Number of steps	-	100
Stroke per step	mm	0.03
Friction coefficient	-	0.08
No. of elements	EA	50,000
Clearance	mm	0.2
Shear angle	°	10

3. Experiment for Manufacturing the Muffler Tube

It is proposed the design dimension of

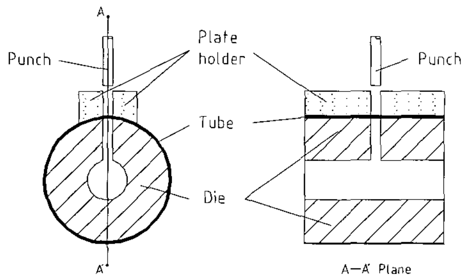


Fig. 2 Schematic diagram of shearing apparatus

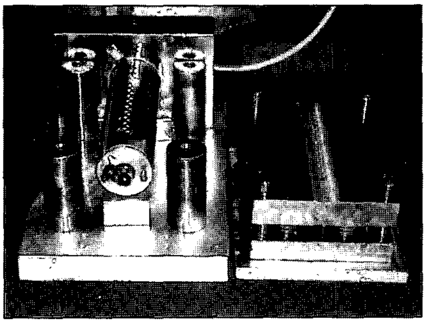
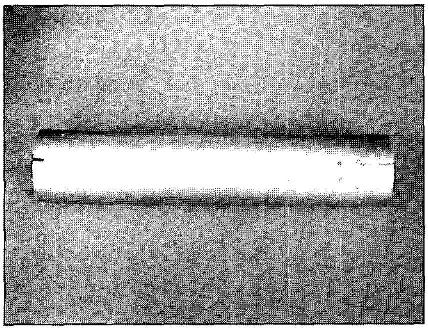
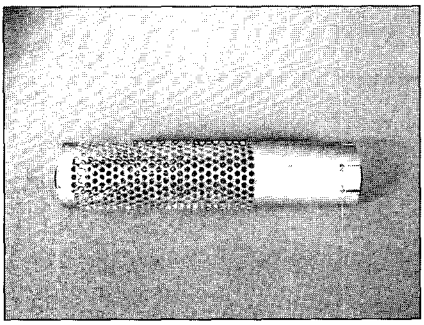


Fig. 3 Perforating die and punch for muffler tube



(a) Muffler tube before perforating



(b) Muffler tube after perforating

Fig. 4 Muffler tube for heavy equipment

final die for the design optimization using analysis results like that stress-strain distribution and material deformation by the shearing force of punch and die. Fig. 2 shows the schematic diagram of shearing apparatus. Fig. 3 shows the experimental apparatus and Fig. 4 (a) shows tube before perforating and (b) shows the product with good shape and section after perforating.

4. Results and Discussions

The perforating process is simulated using finite element code, DEFORM^{TM} -3D. Fig. 5 shows the relation of load-stroke according to the punching. As we can see from Fig. 5, at the Case1 punch shape load was lower compared to the other Case and shear happened quickly. The forming result of the product was satisfactory the drawing dimension and the distribution of strain was uniform.

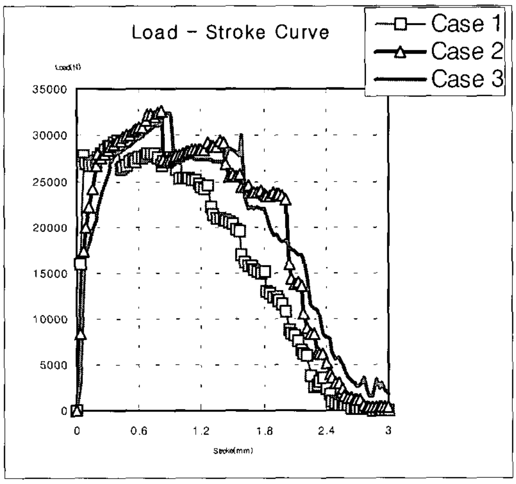
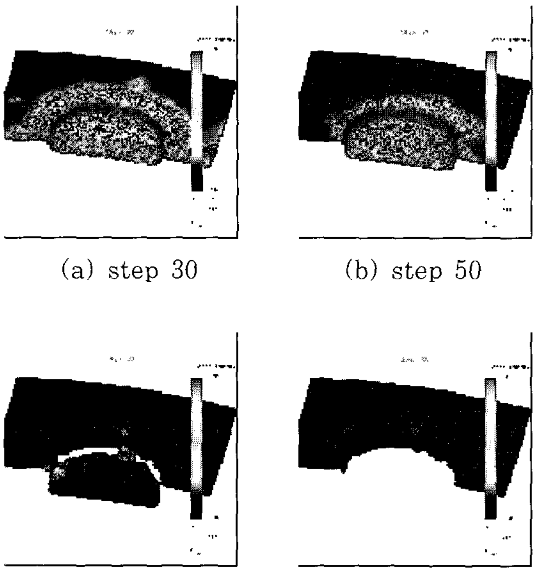


Fig. 5 Relation of load-stroke according to the punching



(a) step 30 (b) step 50

(c) step 80 (d) step 100

Fig. 6 Distribution of stress

Fig. 6 shows the stress distribution according to step. The maximum stress of the piercing process is occurred at the edge of muffler tube to be pierced but the area to receive the stress was not extensive.

As you can see from Fig. 6 internal stress is relaxed slowly as perforating process is performed.

5. Conclusions

In this study, the conditions to decide the perforating process of the muffler tube for automobiles are studied using finite element analysis and the experimental tests.

The material of the muffler tube used is coated SPCC. Forming analysis and performed experiment has changed the clearance and punch shape.

The conclusions of this study obtained can be summarized as follows:

1. When the shear angle of punch was similar to the tube curvature, the optimal shape was obtained.
2. When the clearance of die was 0.2mm, the burr was minimized and optimal shear section was obtained.
3. The analysis results by FEM simulation were reflected in the perforating process design for the muffler tube and better products in dimension and quality were obtained.

Acknowledgements

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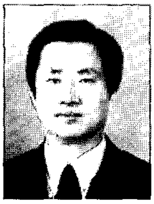
Author Profile



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