

# Finite element analysis on process improvement of the multi-forming for the motor-case of an automobile

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## Abstract

Generally, an automobile has about 10 motors for actuators that are equipped with a cooling fan, air-conditioner, and door lock system. The shape of the motor-case is directly related to the noise and vibration of the components, so various forming processes such as deep-drawing, multi-step, and multi-forming, were developed to get higher accuracy and productivity. The multi-forming process is used in this study because it has the best productivity compared with the other forming methods.

The simulation technique of motor-case forming was developed to reduce the developing time and trial-error. The manufacturing processes of a motor-case consist of plate blanking, forming, and sizing. This study is focused on the core design of the multi-forming process. The blanked plate and forming dies are modeled to two- and three-dimension and analyzed by the finite element method using a commercial software DEFORM which is based on the elastic–plastic finite element theory.

Two kinds of core, a circle and an ellipse, have been designed. Because of the springback effect, the roundness of the elliptic core is better than that of the circular core. The same rule is applied to the diameter ranges (20–40 mm) and yield strength levels (175–240 MPa) of low carbon steel. © 2007 Published by Elsevier B.V.

**Keywords:** Motor-case; Core; Roundness; Multi-forming; Springback; FEM

## 1. Introduction

Recently, small motors are mostly used for the power parts of automobiles such as the cooling fan, the air-conditioner, and the door-lock system, in order to improve driver conveniences. When the form accuracy of the motor-case worsens, the motor rotates discontinuously due to a change in the magnetic force and vibration that occurs in the motor. Eventually, the motor's vibration will significantly influence the overall vibration and noise of the automobile. Thus, motor manufacturers strictly manage the form tolerance of motor-cases. The maximum tolerance in the diameter of a motor-case is 0.2 mm for a motor-case with an 80 mm diameter.

In the early stages, motor-cases were formed by a deep-drawing method using a press machine. Afterwards, the method developed into a multi-stage forming method. In the multi-forming of motor-cases, the power part driven by cams is arranged in the circumferential direction of a core, the steel plate is formed in the shape of a cylinder and both ends are fixed by

a puzzle lock method as shown in Fig. 1. In the multi-forming, the thickness of the motor-case is very small compared with the cylinder diameter, and therefore elastic deformation as well as plastic deformation takes place dominantly during forming, resulting in the occurrence of springback [1]. Accordingly, elastic deformation should also be taken into account in the forming analysis of the motor-case [2]. Research on the characteristics of springback have been conducted since the 1940s. However, the existing research [3–6] has been focused on the springback and residual stress of products in general plate forming processes, and no studies can be found on the springback characteristics of the multi-forming processes. Therefore, finite element analysis of the forming process of the motor-case has been performed to determine the optimal core shape which is suitable for obtaining the best roundness of the case.

## 2. 2D finite element analysis

### 2.1. Modeling and boundary condition

The properties of the materials used in the actual products are shown in Table 1. DEFORM 2D was used for the analysis.

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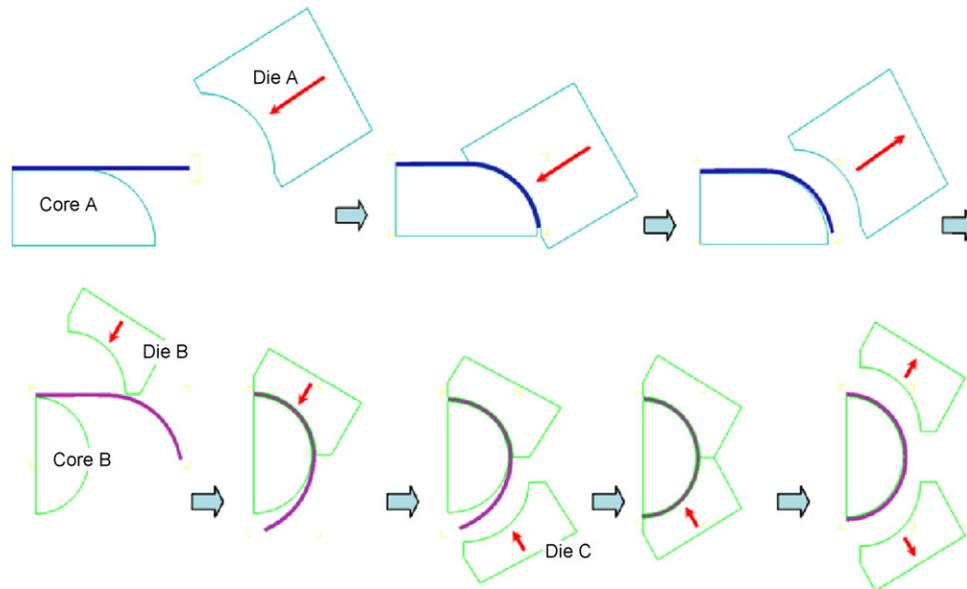


Fig. 1. Schematic diagram of motor-case multi-forming.

All stages of the process were analyzed in the same way as the actual processes are analyzed as shown in Fig. 1. Finite element analysis considering elastic recovery was performed with two kinds of core B (Fig. 1), the circular and the elliptic shaped core.

2.2. Analysis, results and discussion

When the core is a circle, the change in the radius of the motor-case increases due to the large springback, as shown in Fig. 2. The average radius of the final product was 39.246 mm. The maximum radius was 40.998 mm and the minimum radius was 36.972 mm, showing a roundness of 4.026 mm. It is necessary to modify the circular core considering the springback of each part.

In the early design stage of the elliptic core, the data of the circular core analysis was applied. As a result, the core size was decreased by 10.83% to 32.916 mm in the vertical direction and increased by 3.49% to 36.916 mm in the horizontal direction, when compared with the circular shape. Fig. 3 shows the final form following the completion of the fourth process with an elliptic core. As for dimensions, the radius in the vertical direction stood at 34.230 mm while the radius in the horizontal direction changed to 37.1177 mm. That is, 3.99% of elastic recovery took place in the vertical direction and 0.55% of elastic recovery occurred in the horizontal direction. This indicates that, when designing an elliptic core, the difference of length

Table 1  
Material property of SS330

Material	SS330 (SA293 GR. A)
Yield tensile strength (MPa)	175
Ultimate tensile strength (MPa)	399
Elastic modulus (GPa)	200
Stress strain relation (MPa)	$\bar{\sigma} = 503.35\epsilon^{-0.2128}$

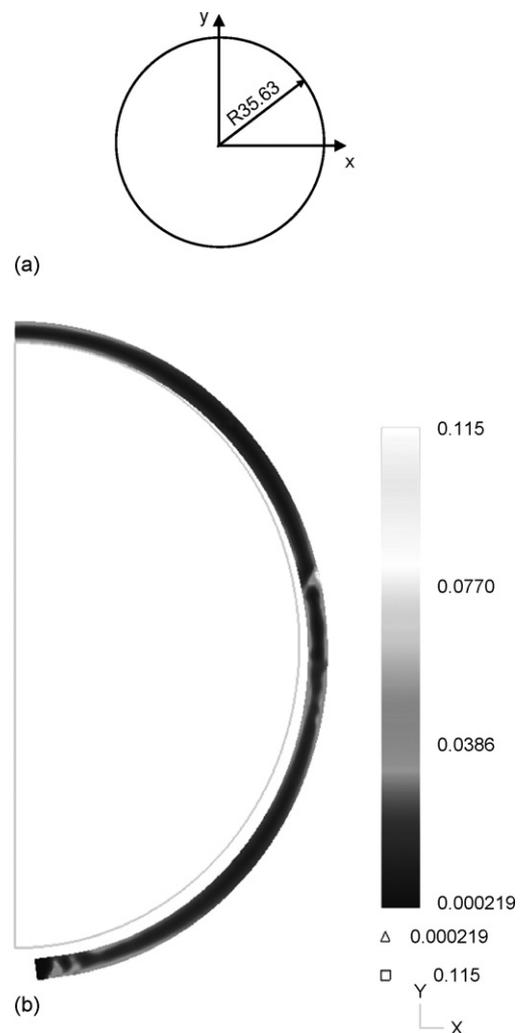


Fig. 2. Results of 2D analysis with circular core: (a) circular core and (b) analysis results.

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