The Optimization of Engine Mounting Parts Using Hot-Cold Forging Technology

D. H. Park, Y. H. Tak, H. H. Kwon, G. J. Kwon, H. G. Kim

Abstract**—**The purpose of this study is to develop a forging process of automotive parts that satisfies the deformation characteristics. The analyses of temperature variation and deformation behavior of the material are important to obtain the optimal forging products. The hot compression test was carried out to know formability at high temperature. In order to define the optimum forging conditions including material temperature, strain and forging load, the commercial finite element analysis code was used to simulate the forging procedure of engine mounting parts. Experimental results were compared with the simulation results by finite element analysis. Test results were in good agreement with the simulations.

Keywords**—**Cold forging, hot forging, engine mounting, automotive parts, optimization.

I. INTRODUCTION

FOR modern automobiles, ride comfort and safety during driving and braking are posing as important factors as concept of comfortable and convenient living space becomes stronger more than transportation means. Engine mounting parts for the automobiles are being developed as hydro-mounting and active mounting etc. These mounting parts, while supporting power train which is composed of engine and transmission, reduce vibration and noise, thus enable those parts to contribute in improving ride comfort of a passenger [1]. Also, if rigidity of engine mounting is inferior, it is not beneficial for controlling engine behavior, and creep and durability could be deteriorated [2].

Hot-cold forging technology is a complex process that makes parts by implementing cold forging technology after hot forging by supplementing weakness such as oxidation and decarbonization occurred during hot forging process and crack at the flange which is generated when parts are manufactured by cold forging process. Hot-cold forging is applied in the forming parts wherein hot forging is executed if forming is difficult only with a cold forging method and shape of the parts are complicated. First, a hot forging process is executed, and then a cold process is executed for forming the parts. That means, when hot forging is adopted, surface precision issue arises. On the other hand, a mold breakage occurs during cold forging. Therefore, hot-cold forging method is implemented to resolve these issues.

Forging process is being developed because it can save materials by reducing chips, which otherwise produced in a large quantity during conventional cutting process, and to produce net shape parts which are the closest to the products [3]. With hot-cold forging technology, it is possible to prevent crack at the flange occurred during cold forging and to supplement weakness due to oxidation and decarbonization occurred during hot forging [4]–[9].

Existing engine mounting parts are produced by applying a cold forging with a total of nine processes, namely materials cutting and forward extrusion, upsetting, forging, sizing, annealing in each process, shot blast, and lubrication. In the sizing process, poor elongation of the parts and punch damage of mold are frequently occurred, causing production cost increased. For the automobile engine mounting parts, hot forging is applied to resolve mold breakage during cold forging, and then it is processed with cold forging to resolve surface accuracy issue occurred after hot forging.

This study was performed to evaluate physical properties of the engine mounting parts and forging simulation analysis, and to reduce a process of engine mounting parts, and to improve dimension accuracy and mold life by applying hot-cold forging complex technology between hot forging and cold forging.

II. MOLD DESIGN AND COMPRESSION TEST

A. Mold Design

Process was designed as hot forging, trimming, and cold sizing to prepare automobile engine mounting parts. A preformed material for hot forging was made to cut a round bar having diameter 28 mm and height 57.7 mm, and to heat it until temperature at 1,100 °C ~1,200 °C inside heating the furnace. Trimming process was designed to remove flash which is generated after hot forging. While, sizing process was designed to improve dimension accuracy. Table I shows process sequence design for the engine mounting parts. Process sequence design was to be carried out in the order of the first hot forging, the second trimming, and the third cold sizing forging. Fig. 1 (a) shows the hot forging mold of the engine mounting parts. While, Fig. 1 (b) shows trimming mold. Fig. 1 (c) shows the cold sizing forging mold. Hot forging was designed as an open mold with the outer diameter of top portion at 53 mm, the outer diameter of bottom portion at 18 mm, and the width of bottom portion at 16 mm. Cold sizing forging process was designed as a closed mold with the outer diameter of top portion at 53.3 mm, the outer diameter of bottom portion at 18 mm, and the width of bottom portion at 16 mm. The outer diameter of top portion and bottom portion was formed with the

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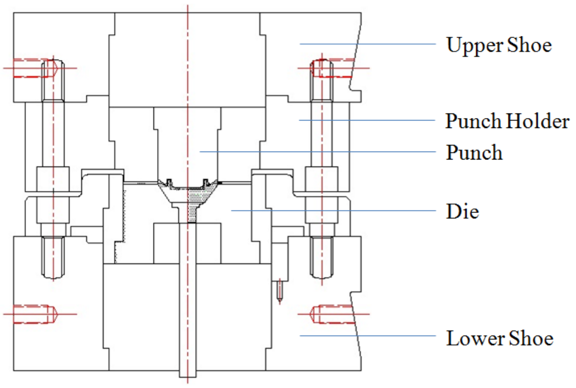
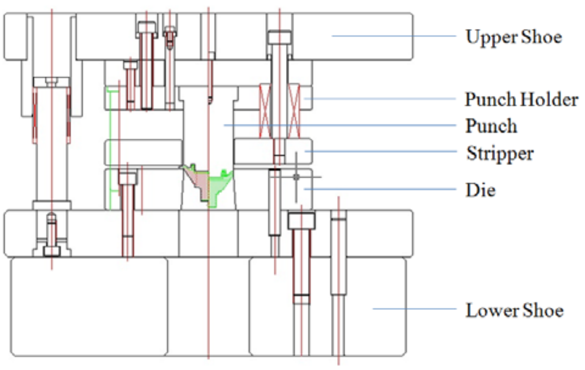
hot forging process to prevent mold breakage which may occur during cold sizing process.

TABLE I
PROCESS SEQUENCE DESIGN OF ENGINE MOUNTING PARTS

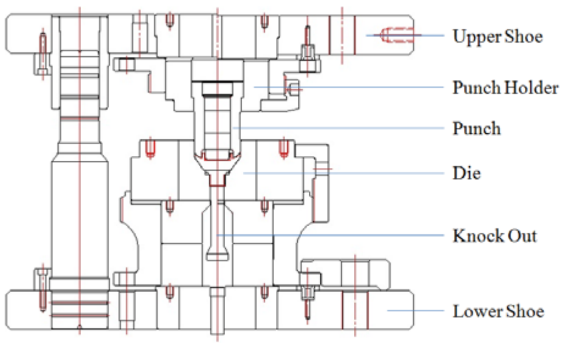
Stage 1	Hot forging
Stage 2	Trimming
Stage 3	Cold sizing forging



(a) Hot forging mold



(b) Trimming mold



(c) Cold sizing forging mold

Fig. 1 Process sequence mold for engine mounting parts

B. Compression Test

Mechanical properties of the workpiece SM45C [Korean Standards] for engine mounting parts were checked. Compression test yields as flow stress for large deformation. Compression specimen was made as a circular cylinder having diameter at 8 mm and height at 12 mm by using a wire cutting machine. Test temperature was set at 1,100 °C and 1,200 °C for test, and specimens were heated using an indirect heating method at 5 °C/sec. When specimens reached to the target temperature, a break for five minutes was given, and then compression test was performed with speed at 0.1 mm/sec. Asbestos was applied both upper and lower portion of the specimens to prevent heat loss from the specimens. Compression test was performed till reduction ratio of compression specimens reached to 60% (7.2 mm) under the deformation speed at 0.1/sec. Fig. 2 (a) shows the hot compression specimens at 1,100 °C, while Fig. 2 (b) shows hot compression specimens at 1,200 °C.

Fig. 3 shows the compression load according to compression height. Compression load was confirmed as 6.2 2kN under the reduction ratio of compression specimens at 60% under the temperature at 1,100 °C. Meanwhile, the compression load was 3.61 kN under the reduction ratio of compression specimens at 60% under the temperature at 1,200 °C. High temperature compression test data were used as mechanical properties for hot forging simulation analysis of the engine mounting parts.

(a) 1,100°C

(b) 1,200°C

Fig. 2 Specimens for hot compression test

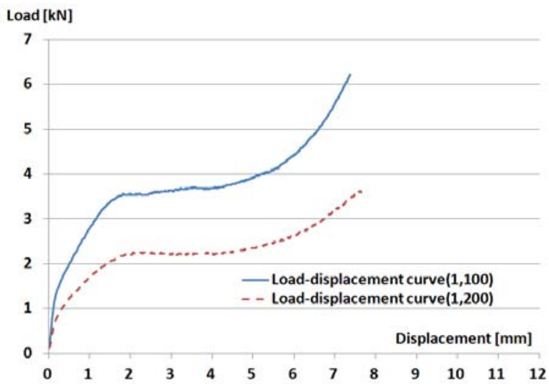


Fig. 3 Load-displacement curve of hot compression test for SM45C

III. MOLDING ANALYSIS

Engine mounting parts was designed trimming process, cold sizing forging after hot forging by cutting a round bar material of SM45C. The finite element model was made as shown in Fig. 4 for hot forging simulation. Table II shows the conditions for hot forging simulation. A cylindrical preformed shape with a diameter 28 mm, height 57.7 mm is modeled for forming analysis. Molding analysis was performed by using high temperature compression test data under the temperature at 1,100 °C and 1,200 °C, while setting strain speed at 0.1/sec same as high temperature compression test.

Fig. 5 shows the hot forging simulation results while heating the preformed material at 1,100 °C. Fig. 6 shows the hot forging simulation results while heating the preformed material at 1,200 °C. Fig. 7 presents maximum punch load of the engine mounting parts. In Fig. 7 (a), maximum punch load is 197 tons at 1,100 °C, while Fig. 7 (b) shows maximum punch load 145 tons at 1,200 °C. Hot forging simulation results for the engine mounting parts showed when effective plastic strain was compared. Hot forging formability was good with the lower stress and higher temperature distribution at 1,200 °C. Also, effective plastic strain was found to be high at the extruded bottom portion, which was expected that air was compressed at the lower die, causing a problem in the forming. Therefore, air holes were provided in the lower die during forging.

TABLE II
SIMULATION CONDITIONS OF HOT FORGING

Plastic material	SM45C
Initial material size	Ø28×57.7mm
Material temperature	1,100°C, 1,200°C
Die temperature	350°C
Friction coefficient	0.3
Velocity	100SPM

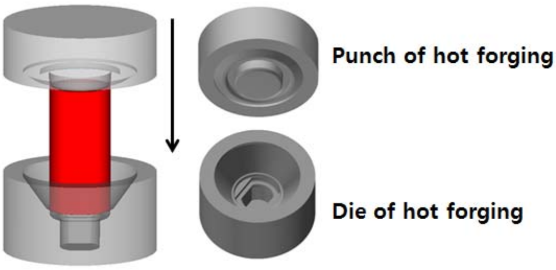


Fig. 4 The finite element model for hot forging simulation

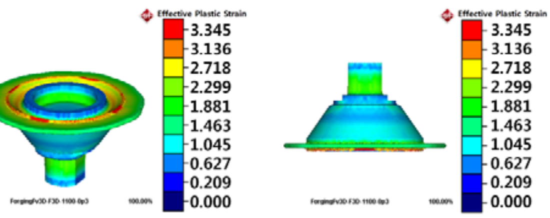


Fig. 5 Simulation results of effective plastic strain after hot forging at 1,100°C

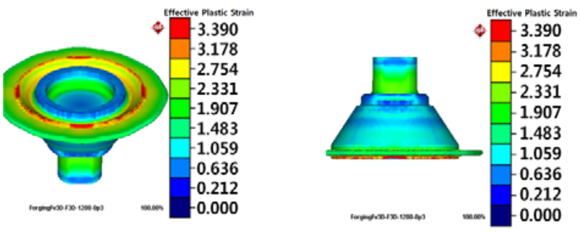
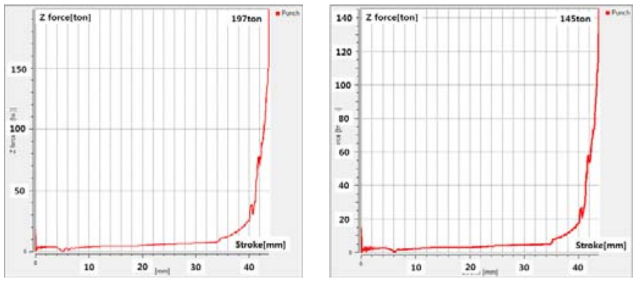


Fig. 6 Simulation results of effective plastic strain after hot forging at 1,200°C



(a) 1,100°C (b) 1,200°C

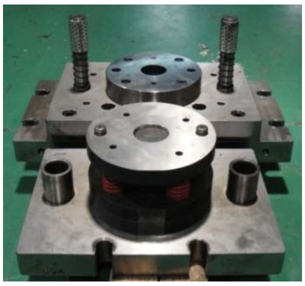
Fig. 7 Maximum load of punch

IV. Test Results and Discussion

In order to produce engine mounting parts, the preformed material of SM45C was made to cut a round bar having diameter 28 mm and height 57.7 mm, and it was heated by setting the heating furnace temperature at 1,200 °C. Mold temperature was maintained at higher than 350 °C, because temperature reduction was expected when material was transported to the press after heating. Also, pressing of material was prevented by spraying a release agent. A blowout grade was given to die to make ejection of the product easy since material is stuck at the extruded bottom portion during hot forging. Flashes which were generated after the hot forging process was removed by using a 110 ton press in the trimming process after the hot forging process. Final engine mounting parts could be completed in the cold sizing forging followed by the trimming process.

Fig. 8 (a) shows punch and die of the hot forging mold, while Fig. 8 (b) shows the trimming mold. Fig. 8 (c) shows punch and die of the cold sizing forging mold. With hot forging simulation results, it was judged that hot forging was possible under the temperature at 1,200 °C than under the temperature at 1,100 °C due to decrease of the maximum load and heat loss during moving. Engine mounting parts was possible at the actual forming experiments. A blowout grade was given to die to make ejection of the product easy since material is stuck at the extruded bottom portion during hot forging. Pressing of material was prevented by spraying a release agent. Lubrication effect was obtained by spraying the release agent during hot forging, thereby coefficient of friction was decreased, which could make better product than expected simulation results. With the trimming mold, the final product that satisfied the dimension accuracy of engine mounting parts could be obtained from the cold sizing forging mold.

(a) Hot forging process



(b) Trimming process

(c) Cold sizing forging process

Fig. 8 Punch and die of engine mounting

V. Conclusion

This study proposes a hot-cold complex forging process for the automobile engine mounting parts from existing cold forging process. Material properties evaluation, forming analysis, mold design and fabrication, and performance evaluation for a good product were performed in order to produce automobile engine mounting parts with a hot-cold forging technology. The results obtained through this study are summarized as follows.

(1) It was possible to save the cost by reducing number of processes comprising hot forging, trimming, and cold sizing forging of the engine mounting parts, which otherwise produced through a total of nine processes.
(2) Compression load of material SM45C according to the compression height was checked through high temperature compression tests at 1,100 °C and 1,200 °C.
(3) Strain, stress, and temperature distribution according to the heating temperature were checked by performing a hot forging simulation, and formability of engine mounting parts was checked at 1,100 °C as well as at 1,200 °C to get a good product.
(4) Breakage of the engine mounting mold which otherwise might occur in the conventional cold forging process could be reduced by implementing the hot-cold complex forging technology, so that mold life was improved at least more than five times.

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