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A PRECISION COLD FORGING OF DIFFERENTIAL SIDE GEAR FOR AUTOMOBILE

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ABSTRACT

Forged gears have the obvious advantages with the greater utilisation of raw material and high productivity over the machined gears. The forged bevel gear has been used in differential gear for automotive with a high reliance. On the other hand, the studies have been continued to improve the accuracy and expand the applying areas.

In this paper, a whole manufacturing process for forged gear from die design and cold forging to heat-treatment was introduced. The stress and elastic deformation for forging die have been analysed by the 3D-FEM-package. The real elastic deformation of die was measured by the strain-gages. The elastic deformation of die was reached to 1mm, in terms of the present study. The analysed quantitative dimension of die was taken into consideration into the CAD/CAM data for forging die.

KEYWORDS: bevel gear, CAD/CAM, 3D-FEM, cold forging, die

1. INTRODUCTION

Forged gears have the obvious advantages with the greater utilization of raw material and high productivity, over the machined gears. The forged gears have been used the components for electronic products, such as driving shaft with outer spur gear. Also, forged gears have been widely used for the differential side gear and pinion in automotive. Specially, the straight bevel gear for differential units has been known as one of the most successful application with high reliability. Since there are more rooms for the increase of gear-accuracy, however, the studies for improving the accuracy have drawn a lot of attentions until now. The processes for forged bevel gear were begun by part-draw alteration from the machined part into the forged part, as shown in Fig.1. There are also six-factor after the forged part design. Among these factors, the die design is the most important factor. Especially the tooth profile should be designed with the consideration of the followings the machining tolerance of die, the elastic characteristics of die and workpiece, and the dimensional changes by the heat-treatment.

2. Manufacturing processes of die and forged part

The processes for die making were shown in Fig.2(a). The structure and dimension for forging die was designed by 3D-CAD system. The CAM(Computer-Aided-Manufacturing) data were generated and then transferred into MCT(Machine Center) to die machining. The die, machined by the MCT, was heat-treated to get the desirable strength and toughness. Heat-treated die were manufactured finally by the polishing. Die machining by the MCT has an advantage for eliminating the EDM-gap and changing the gear-profile.

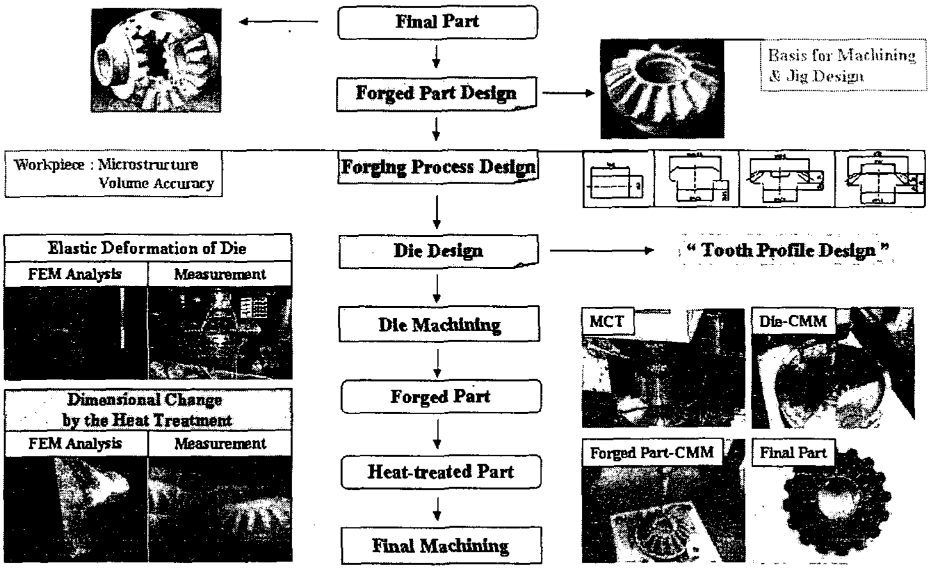

Fig. 1. Cold forging processes of differential side gear for automobile

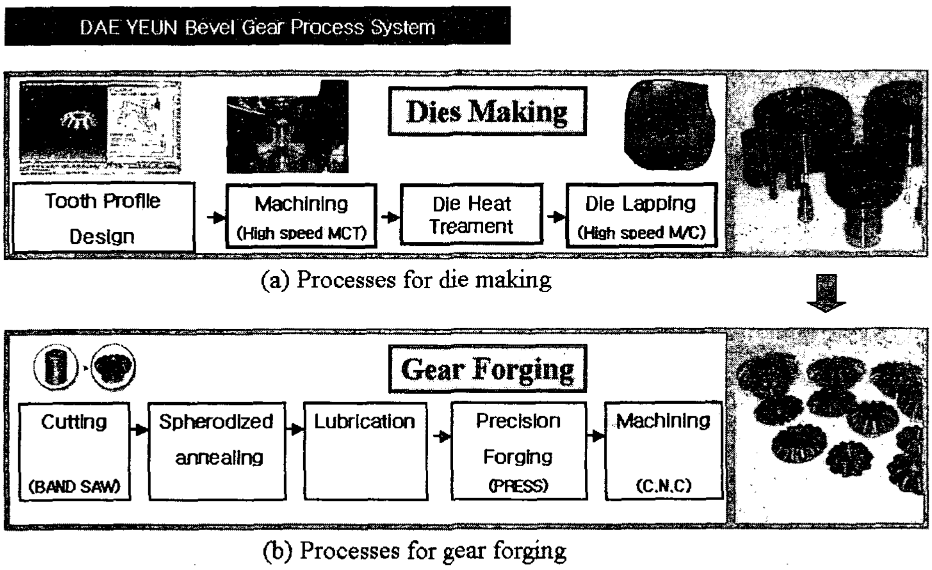

Fig. 2. Processes of die making and forging for side gear

Fig.2(b) represents the manufacturing processes of differential side gear. The set-up of origin for a machining is also very most important factor in a forged gear. The origin should be set-up from the die design to final machining of forged part. The dimensional changes of tooth profile at each stage were calculated based on this origin.

3. FEM analysis and experimental to investigate the changes of involute profile

The involute profile was changed from the CAM data to the profile after heat-treatment. In this study, the profile changes have been investigated to get the updated-CAM-data by the FEM and experimental, as shown in Fig.3.

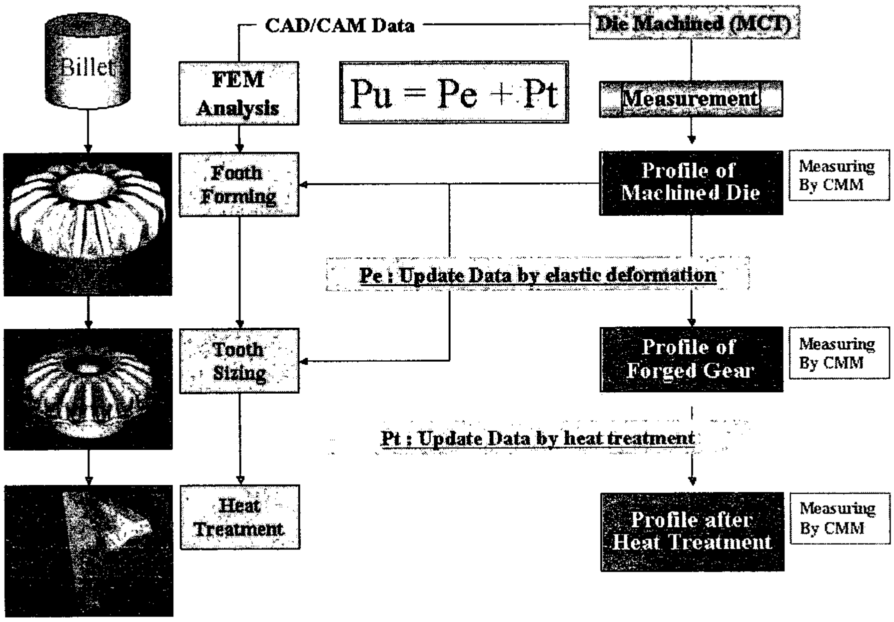

Fig. 3. Flow for investigating update data of tooth profile

The stress and elastic deformation for forging die have been analysed by the 3D-FEM-package, DEFORM-3D^{TM}. The calculated values were compared with experimental results that measured by the strain gages. Fig. 4 represents the elastic deformation of die on loading. The hoop strain measured in strain gage No.2 is 1.7 x 10^{-3}. The elastic deformation amount is about 0.8 mm, if the strain is converted to deformation amount.

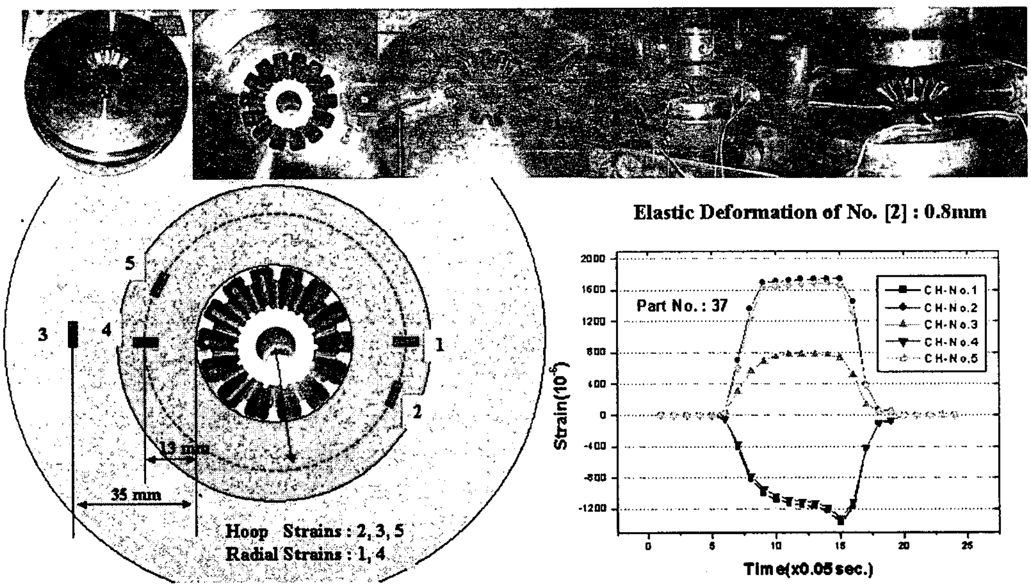

Fig. 4. Elastic strains of die measured by strain gages

Elastic deformation of forged part and die were also investigated by the FEM analysis, as shown in Fig.5. The data generation for changes of involute profile were summarized based on the origin, as mentioned before. The changes of involute profile by elastic deformation were taken into consideration, along with the effects by the heat-treatment. The update-data for involute profile could be summarized between 0.4 and 1.2% of standard profile at each section. The above update-data were different at each section because the involute profile of straight bevel gear is different.

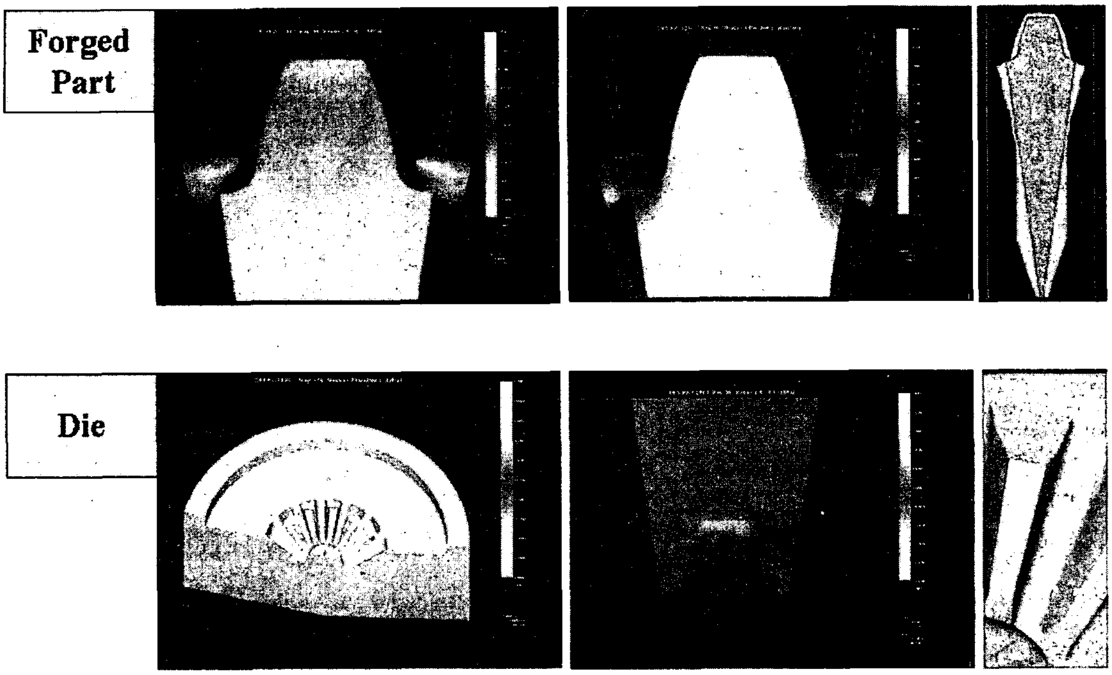

Fig. 5. FEM analysis to generate the changes of involute profile

5. Summary

Since forged gear has many advantages, many researches have been performed to enhance the dimensional accuracy and enlarge the application fields until now. This study introduces the research trends to investigate the dimensional changes from die and to final forged part, for example a differential side gear. A forged side gear has been used for automotive differential units from a long time ago, however there are some rooms for enhancement of the dimension accuracy. A FEM analysis would be useful to upgrade the accuracy of forged gear.

References

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