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Development of the Sub Gear for the Scissors Gear System for Automobile Engines

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Abstract

P/M enables the economical production of components for many kinds of gears. Functionally, the sub gear requires high tooth accuracy and bending fatigue strength. The whole tooth profile was sized after sintering to satisfy the gear tooth accuracy specification. The part was redesigned to reduce machining requirements. The required bending fatigue strength was achieved through appropriate material choice and induction of compressive residual stress by shotpeening after carburizing. The P/M sub gear replaced a forged steel gear, satisfied performance requirements, expanded the use of P/M applications and provided over 30% cost reduction.

Keywords : gear tooth accuracy, sizing, bending fatigue strength, shotpeening

1. Introduction

A scissors gear system can make an engine quieter and more compact. A sub gear with a helical gear profile is used in that system.
Conventionally, the sub gear was manufactured by hobbing a forged steel gear, with the attendant high machining cost. Material, net shape and manufacturing process were selected to take full advantage of the P/M process. As a result, the gear cost was reduced drastically and the P/M sub gear replaced the forged steel sub gear.

Fig. 1. Photograph of the finished P/M sub gear.

2. Accuracy and Shape

To maintain low engine noise, the sub gear has very severe tooth accuracy requirements. Profile deviation must be less than 0.02mm, helix deviation less than 0.03mm and flatness of the face that contacts a mating part less than 0.095mm. Conventional sizing with a round die will not satisfy these requirements, as only the face of the part is sized. Therefore, the entire tooth profile was sized in the tools, and the accuracy requirements were met.
The sub gear has a large diameter and is relatively thin, and is sintered at high temperature. These factors cause the as-sintered part to have large distortion. In addition, the sub gear, as originally designed, had a large area over which the flatness specification applied. This would normally mandate a machining step in the process to ensure flatness. The shape of the part was redesigned to reduce the area of required flatness, and the machining step was avoided. (See Figure 2.)

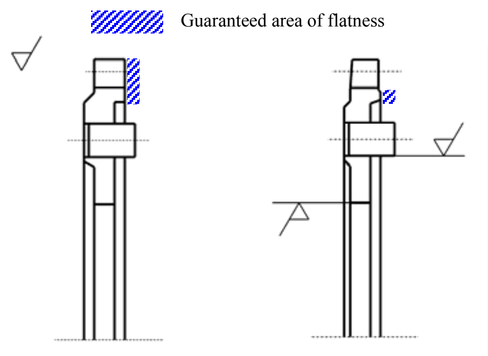

Fig. 2. Original and redesigned shape.

3. Material and Process

The sub gear requires bending fatigue strength of 400MPa because of the large load on the gear tooth. A Fe-Ni-Cu-Mo-C alloy system was originally considered, as it would meet this specification, but rejected due to high as-sintered hardness, which makes sizing difficult. A Fe-Mo-C system was selected, which has lower as-sintered hardness, but high fatigue strength and wear resistance after carburizing. Parts were compacted to 7.0-7.1g/cc, sintered at 1300℃, sized and carburized.

However, Fe-Mo-C did not meet the required bending fatigue strength. To enhance the bending fatigue strength, compressive residual stresses were induced after heat treatment by shotpeening.

Shot particles of three different diameters, 0.17, 0.30 and 0.60mm, were tested. Figure 3 shows that as the shot particle size decreases the affected depth decreases, and the depth of the peak residual stress moves toward the surface.

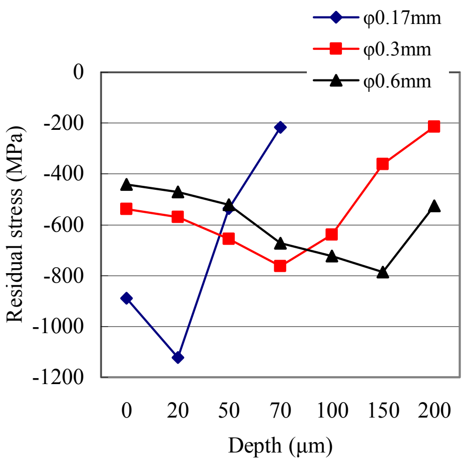

Fig. 3. Effect of depth and shot particle size on residual stress.

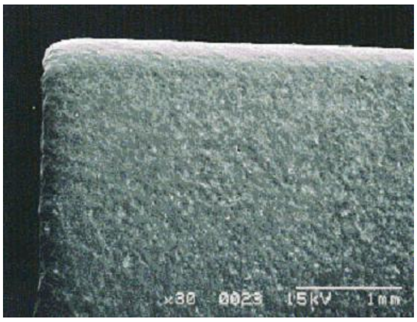

Fig. 4. SEM photogragh of the gear tooth surface after shotpeening.

Due to cost-effectiveness and functionality, 0.30mm diameter shot size was selected. Through the addition of the shotpeening operation, the bending fatigue strength was improved by 30% (Figure 5) and the sub gear requirement was met.

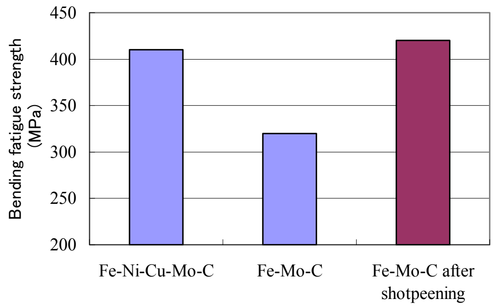

Fig. 5. Comparison of bending fatigue strength.

4. Evaluation

To confirm the bending fatigue strength, parts were tested using test rig and motored engine tests.

5. Summary

A forged sub gear was successfully replaced with P/M, giving a 30% cost reduction. Full-tooth sizing was done to meet gear accuracy requirements. Shotpeening after carburizing to induce residual stress gave sufficient bending fatigue strength to the Fe-Mo-C alloy system to meet part requirements. Application of P/M choice has been increased as a result.

6. References

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