Modeling and Finite Element Analysis of Timing Gear Cover for an Engine

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Abstract. With the increasing demand for high speed and light weight, the requirement of engine power, volume and weight is also improving. In this paper, a three dimensional modeling of an engine's timing gear cover is made by using Pro/E software, and then the finite element model is established by ANSYS software. Static analysis of the timing gear cover is carried out by using ANSYS. The maximum deformation and equivalent stress are gained. Modal analysis of the timing gear cover is simulated by finite element analysis and the natural frequency and mode vibration are obtained. Based on the analysis results, the feasibility and reliability of the structure are confirmed. The method proposed in the paper effectively shortens the design cycle and reduces the error of repeated test and experience judgment. It is of great significance to popularize the application of the finite element analysis in the enterprise and to the future product development.

1. Introduction

With the continuous growth of demand for light and high-speed vehicles, the power, size and weight requirements of the engine continue to improve. In the design and development of automotive engine timing gear cover, the finite element method is used to carry out the simulation. Structural strength and stiffness can be obtained by static analysis of the finite element analysis.

The three dimensional model of the timing gear cover of an engine is established by using Pro/E software, and then the finite element model is created by ANSYS software. Static analysis of the timing gear cover is carried out by using ANSYS and the maximum deformation and equivalent stress are gained. Modal analysis of the timing gear cover is simulated by finite element analysis and the natural frequency and mode vibration are obtained. This study effectively shortens the design cycle and reduces the trial error. It plays an important role in promoting the application of finite element method in the future development of the company and products.

2. Establishment Of 3d Model Of Engine Timing Gear Cover

Aluminum alloy die-casting timing gear cover of an engine is made by thin-walled and die-casting of aluminum alloy. The average wall thickness is 5mm, the minimum wall thickness is 4mm, and the overall shape size (length×width×height, the unit is mm) is 271mm×185mm×70mm. The physical picture of timing gear cover of the engine is shown in the Figure 1.

The three dimensional model of timing gear cover of the engine is established by using Pro/E software. The structure of timing gear cover of the engine is shown in Figure 2.

But the geometric model should be considered for proper simplification before importing into ANSYS. The method of simplified structure model is as following principles. Ignoring the casting fillet and chamfer on the timing gear of the engine, simplifying or ignoring the stiffeners and grooves on the timing gear of the engine, the simplified solid geometric model is obtained as shown in Figure 3.
3. Static And Modal Analysis Of The Timing Gear Cover Of The Engine

3.1 Mesh Division of the Timing Gear Cover of the Engine

The tetrahedron element is used for establishing finite element model of the timing gear of the engine. The advantage is that it can be quickly and automatically generated mesh. The number of grid nodes in this model is 50,960 and the number of grid elements is 27,546. The result of dividing the grid is shown in Figure 4.
3.2 Set Material Load and Constraint of Timing Gear Cover of the Engine

As the main key component of the engine, timing gear cap has complex structure and always bears variable load in work. The constraint condition is very complicated. At the same time, it bears high temperature. The structural strength of timing gear cap mainly depends on the fatigue characteristics and structural condition of the material. Because the engine achieves the purpose of heat dissipation, it used to be made of cast iron. With the development of material technology, casting aluminum alloy is generally used for the integral timing gear cover. As a new type of high specific strength material, casting aluminum alloy has attracted more and more attention of researchers and designers in mechanical manufacturing, especially in the engine industry has been widely used.

Static analysis of the timing gear cover of the engine is carried out by using the Static Structure module. The applied load is divided into two kinds. One is temperature load. According to the information provided by the manufacturer, the surface temperature of the contact area on the inner surface of the timing gear cover of engine bears 140°C, while the outer surface temperature of the timing gear cover of engine is 80°C. Therefore, the internal and external temperature of the timing gear cover is 140°C. The temperature difference is 60 degrees. The other kind of load is the pressure one. The normal pressure of the timing gear cover is about 0.8 MPa, which provided by the manufacturer. According to the temperature and pressure load, and some other constraints, the static analysis of the timing gear cover is carried out.

4. Results And Discussion

The finite element model is solved by ANSYS software and the deformation and equivalent stress under two kinds of load conditions are obtained. By summarizing and contrasting the analysis results under two kinds of load conditions, it can summarize the conclusions as following.

4.1 Deformation analysis of the Timing Gear Cover of the Engine

The figure 5 and Figure 6 gives the overall deformation of the timing gear cover of engine under two kinds of load conditions. It can be seen that maximum deformation location of the timing gear cover of the engine occurs at the central of the model. Due to the urging force of the engine, the maximum deformation of the temperature load applied end reaches 0.18287 mm. While the timing gear cover of the engine under pressure load, the maximum deformation location of the timing gear cover of the
engine occurs at the central of the model. It is 2.0719 mm. As there are some constraints in support pin hole, it is relatively small deformation.

Based on the results of two kinds of finite element analysis, the deformation of pressure load on the timing gear cover of the engine is more serious than that of temperature load. So, a certain amount of deformation should be reserved in the structural optimization design stage of the timing gear cover of the engine to avoid the influence of local deformation on the working of engine.

Figure 5: Overall deformation of the timing gear cover of the engine under temperature load

Figure 6: Overall deformation of the timing gear cover of the engine under pressure load

4.2 Equivalent stress analysis of the Timing Gear Cover of the Engine

The figure 7 and Figure 8 gives the equivalent stress of the timing gear cover of engine under two kinds of load conditions. It can be seen that the equivalent stress location of the timing gear cover of the engine occurs at the left and right side of the model. Due to the urging force of the engine, the equivalent stress of the temperature load applied end reaches 239.73 MPa While the timing gear cover of the engine under pressure load, the equivalent stress location of the timing gear cover of the engine occurs at the lower side of the model. It is 513.41MPa.

Based on the results of two kinds of finite element analysis, the equivalent stress of pressure load on the timing gear cover of the engine is more serious than that of temperature load. So, a certain amount of deformation should be reserved in the structural optimization design stage of the timing gear cover of the engine to avoid the influence of local deformation on the working of engine.

Figure 7: Equivalent stress of the timing gear cover of the engine under temperature load

Figure 8: Equivalent stress of the timing gear cover of the engine under press load
From the results of deformation and equivalent stress analysis, we can conclude that the deformation and equivalent stress of the timing gear cover of engine is within the allowable range of the design.

4.3 Modal analysis of the Timing Gear Cover of the Engine

While implemented modal analysis of the timing gear cover of engine, any applied force load in the modal analysis need not be considered, just set the constraints. The condition of the modal analysis of the timing gear cover of engine is same as the static analysis. Since the external excitation frequency of the timing gear cover of engine is relatively low and the low order mode plays a decisive role in the modal analysis of the timing gear cover of engine, the first six orders natural frequencies and vibration mode of the timing gear cover of the engine are calculated by using the method of Block Lanczos. The first six orders natural frequencies and mode vibration descriptions of the timing gear cover of the engine are described in Table 1 as followings.

Table 1: First six orders natural frequency and mode vibration of the timing gear cover of the engine

| Order | Frequency /Hz | Mode Vibration descriptions |
|-------|---------------|-----------------------------|
| 1     | 1390.6        | Central of timing gear cover vibrates along Y axis |
| 2     | 1517.0        | Upper edge of timing gear cover swing along X axis |
| 3     | 2002.6        | Upper edge and central of timing gear cover twist along Y axis |
| 4     | 2240.0        | Lower edge and central of timing gear cover twists along Z axis |
| 5     | 2382.7        | Overall of timing gear cover swing along Z axis |
| 6     | 2831.1        | Lower edge of timing gear cover twist along Z axis |

The analysis shows that the natural frequency of the timing gear cover of engine mainly concentrates on 1000-3000Hz, and the maximum relative amplitude is relatively large and appears far away from the constraint. Therefore, the thickness and height of the timing gear cover of engine can be increased locally and the bending stiffness of the timing gear cover also can be improved. In summary, the main vibration mode of the high-order frequency section is the twist and swing of the timing gear cover of the engine.
5. Conclusions

In summary, static analysis and modal analysis of the timing gear cover of the engine are carried out by using the finite element analysis. Design efficiency is greatly improved and the development cycle is shortened. The main conclusions of this paper are as follows.

(1) Three dimensional solid modeling of engine timing gear cover is established by using Pro/E, and the model is simplified. The finite element model is meshed and the timing gear cover is divided into 27546 elements and 50960 nodes. The model can simulate the actual engine timing gear cover well.

(2) Static analysis of engine timing gear cover under temperature load and pressure load is carried out, and the maximum deformation and stress position are obtained.

(3) Modal analysis of the timing gear cover of the engine is carried out by using ANSYS. Its natural frequencies and mode vibration are obtained. The modal analysis can provide reference for the design of the timing gear cover of the engine and select of reasonable parameter, make the design of the structure of the timing gear cover of the engine more reasonable. It is significant to decrease the labor intensity, improve the work efficiency and shorten the design cycle.
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7. References
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