Simulation analysis of gear contact stress in reduction gearbox

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Abstract: In this paper, the contact stress of reducer gears is simulated and analyzed, and the assembly error is considered. Application of three-dimensional modeling software SolidWorks helical gear model is set up, and carried out in accordance with the working condition of two kinds of error assembly, including the backlash error and axis parallelism error, and the finite element analysis software ANSYS, the contact surface and tooth root, the contact stress of the online statics and dynamics analysis, it is concluded that the stress under two kinds of error and change situation, the size of the summary analysis of the influence on gear transmission, in the future has reference and guiding significance to the actual production of gear assembly. Combining the powerful modeling function of CAD software with CAE, it embodies the integration of CAD and CAE technology.

1.Introduction
Reduction gearbox is a transmission device used for deceleration, used between the power machine and the working machine. The main function of it is to decelerate. The gear is a transmission part, a basic component in the mechanical structure, and a core component of many equipment. When the gear is working, it will receive a certain load. If there are some abnormal conditions, it will affect the normal force of the tooth flank and appear uneven load. If it happens often, the tooth flank will be damaged due to long-term use, influencing the working performance of the reduction gearbox. Most of the analysis of gear contact stress in recent years has been biased towards theoretical algorithm research, and seldom considers actual working condition. The theoretical analysis and research results have little guiding significance for gears in actual production. Therefore, this article focuses on analyzing the influence of assembly errors on the contact stress of meshing gears, and studying the effects on gears under two working conditions, which is conducive to the assembly and installation of gears in actual applications, so as to develop a higher performance and durability reduction gearbox.

2.Simulation Analysis of Gear Contact Stress
In this article, we generate gear model and assemble it according to two kinds of error conditions with toolbox which comes with the Solidworks software. Consider the situation when there are assembly errors, which are the error of the gear backlash and the parallelism of the shaft. The static simulation analysis of gear contact stress under two error conditions is carried out.
2.1 The static solution result under the error of the gear backlash

When the gear pair is working normally, the maximum stress usually occurs at the contact surface or the tooth root. Therefore, the stress analysis of the gear should focus on these two parts. The following figure shows the stress cloud diagram of the contact surface of the driving gear, driven gear and the gear root. Fig. 1 is the stress cloud diagram of the contact surface of the driving gear. Fig. 2 is the stress cloud diagram of the driven gear. Fig. 3 and Fig. 4 are respectively the analysis diagrams of the gear root stress of the driving gear and the driven gear.

In order to analyze the change trend of the stress along the face width on the contact line, the stress of the contact line of the driving gear and driven gear is analyzed and displayed, as shown in the following figure. Fig. 5 and Fig. 6 are respectively the contact line stress diagram of the driving gear and driven gear.

![Stress diagram of contact surface of driving gear](image1)

Fig. 1. stress diagram of contact surface of driving gear
(maximum value is 292.02Mpa)

![Stress diagram of contact surface of driven gear](image2)

Fig. 2. stress diagram of contact surface of driven gear
(maximum value is 272.55Mpa)

![Stress diagram of gear root of driving gear](image3)

Fig. 3. stress diagram of gear root of driving gear
(maximum value is 158.29Mpa)

![Stress diagram of gear root of driven gear](image4)

Fig. 4. stress diagram of gear root of driven gear
(maximum value is 99.737Mpa)
Fig. 5. stress diagram of contact line of driving gear
(maximum value is 255Mpa)

Fig. 6. stress diagram of contact line of driven gear
(maximum value is 233.08Mpa)

It can be seen from the figure that when there is a backlash error, the stress of the contact surface of the gear tooth is higher than the stress of gear root, and the maximum stress tends to be on the contact surface, the stress values on the contact surface of driving gear and gear root are greater than the stress values on the contact surface of driven gear and gear root. Take 24 pitch points along the face width on the contact surface of the gear tooth. Fig. 7 below clearly and intuitively reflects the law of stress changes on the contact line.

Fig. 7. pitch point distribution curve on contact line

The figure above is the law of the stress value on the contact line changing with the pitch point number, that is, the law of the stress on the contact line changing along the face width direction. It indicates that when there is backlash error, the stress distribution in the contact area of the gear tooth is uneven and irregular. The existence of the backlash error is easy to produce impact force, and thereby destroying the tooth flank, so in the assembly process of the gear, it’s necessary to strictly control the backlash error of the gear.

2.2 statics solution results when the axes are not parallel

The following is the static analysis stress diagram of the contact surface of the meshing gear tooth and the root, Fig. 8 and Fig. 9 are respectively the stress diagram on the contact surface of the driving gear and driven gear. Fig. 10 and Fig. 11 are respectively the root stress diagram of the driving gear and driven gear. In order to analyze the changing trend of the stress value along the face width direction on the contact line of gear tooth, the stress of the contact line of the driving gear and driven gear is analyzed, as shown in the following figure. Fig. 12 and Fig. 13 are respectively stress diagram of the contact line of the driving gear and driven gear.
Fig. 8. stress diagram of contact surface of driving gear (maximum value is 2943.7Mpa)

Fig. 9. stress diagram of contact surface of driven gear (maximum value is 1454.6Mpa)

Fig. 10. stress diagram of root of driving gear (maximum value is 259.89Mpa)

Fig. 11. stress diagram of root of driven gear (maximum value is 141.13Mpa)
Fig. 12. stress diagram of contact line of driving gear (maximum value is 2739.3Mpa)

Fig. 13. stress diagram of contact line of driven gear (maximum value is 1272.9Mpa)

It can be seen from the figure that when there is a shaft parallelism error, the stress of the contact surface of the gear tooth is higher than the stress value of the root, and the maximum stress value is biased towards the contact surface of the gear tooth. The maximum stress value on the contact surface of the driving gear is greater than the maximum stress value on the contact surface of the driven gear. And the maximum stress value on the root of the driving gear is also greater than the maximum stress value on the root of the driven gear.

Take 24 pitch points along the face width direction on the contact surface of gear tooth. In order to clearly and intuitively see the change law of the stress value of the 24 pitch points on the contact line of the driving gear and the driven gear, graphs are drawn respectively, as shown in Fig. 14 and Fig. 15 below.

Fig. 14. stress distribution curve of pitch point of driving gear
Fig. 15. Stress distribution curve of pitch point of driven gear

It can be seen from the stress change curve of the pitch point in the above figure that the stress change along the face width on the contact line of the driving gear and driven gear is very different. It indicates that stress concentration occurs when the axis parallelism error is 0.4 degrees. The appearance of stress concentration will cause the stress value of local point to be too high, easily exceed the yield limit of the material, reduce the bearing capacity of the component, and affect the working performance of the gear. Therefore, during the assembly process of the gear, the parallelism error of the shaft should be strictly controlled.

3. Conclusion

In this paper, a simulation analysis of the contact stress of the reduction gearbox is carried out. Considering the presence of assembly errors, the gear backlash is necessary, leaving a certain amount of backlash can make the gear run well and avoid gear jamming, but the larger error of the gear backlash will cause the gear to move discontinuously and unevenly, and the load distribution of gear contact area is uneven. And it is easy to have the impact force on the tooth flank, damage tooth flank and affect the working performance of the gear. Therefore, the gear backlash error should be controlled strictly when the gear is assembled. In the process of assembling the gear, if there is a large axis parallelism error, the load on the gear will be unevenly distributed along the face width direction, and the torque cannot be transmitted smoothly. There may be stress concentration, or even stress singularity, and tooth breakage happens. Therefore, the axis parallelism error of the gear should be controlled strictly when assembling the gear.

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