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Fatigue analysis of reducer transmission parts

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Abstract: Each part of the reducer has a design life, if any of the parts fail to reach the design life, it will affect the normal operation of the entire equipment. The life of a part is affected by its own material, structure, load and environment, etc., and fatigue life analysis requires the S-N curve of the material. This paper mainly considers the influence of the material, structure and load of the part on the part, and analyzes the mechanical response of the transmission parts in the reducer under alternating load.

Keywords: Reducer; Fatigue; Alternating loads.

1. Fatigue life analysis method

In recent years, several life prediction methods have been formed for different fatigue failure modes of mechanical components, this paper mainly introduces the nominal stress method and local strain method, the nominal stress method is a method to calculate the fatigue life using nominal stress as a control parameter, and the fatigue life obtained by this method includes the overall life of crack initiation and propagation. The main design is based on the relationship curve between the applied stress level of the zero component and the fatigue life of the standard specimen, that is, the S-N curve through the test. The idea of using the nominal stress method to estimate the fatigue of zero components is shown in Figure 1.

Local stress-strain method, which is a method to estimate the fatigue crack formation life, based on the maximum local strain, combined with the cyclic stress-strain curve of the material, through finite element analysis or other approximate calculation methods to obtain the stress-strain spectrum of the dangerous part and estimate the life. However, the calculation results of this type of method only have the lifetime value, which roughly reflects the empirical mapping relationship of deformation-life, and pays less attention to the initiation and propagation mechanism of cracks, and the prediction accuracy depends significantly on engineering experience. The idea of using the local stress-strain method to estimate the fatigue of zero components is shown in Figure 2.

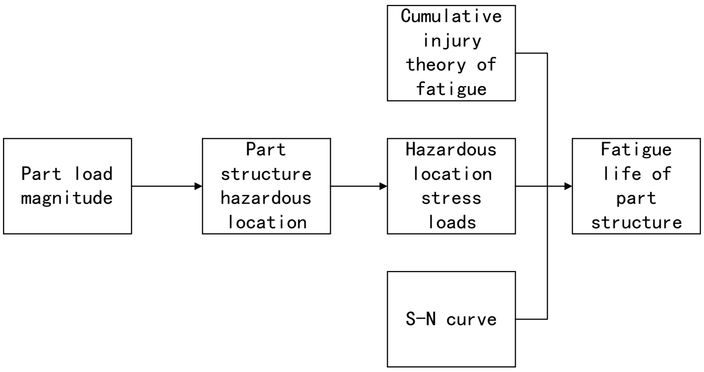

Figure 1. Nominal stress method estimation of fatigue processes

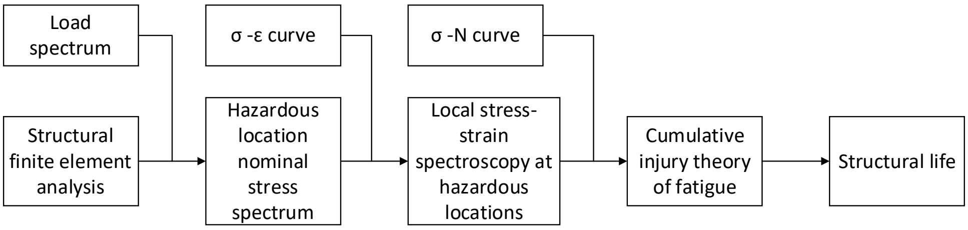

Figure 2. Estimation of fatigue life flow by local stress-strain method

When a metal is subjected to repetitive or fluctuating loads, the stress level of failure is lower than the stress level required to cause fracture under a single load. The nominal stress method was the first attempt to understand this failure process, and it is still widely used. The nominal stress method is most suitable for high cycle fatigue life checking, and the gear shaft in the barrier reducer is a key part for long-term use, and its fatigue failure form belongs to high cycle fatigue under the user's conventional use conditions, therefore, the nominal stress method is used to study the fatigue life of the reducer gear.

2. Fatigue S-N curve

Figure 3 is the S/N curve, SN curve is based on the alternating stress of the material standard specimen as the ordinate, the number of cycles as the abscissa, indicating the relationship between the alternating stress and the number of cycles of the standard specimen under a certain cycle characteristics, also known as the stress-life curve, with the material S-N curve of the part, the safety factor, damage rate and life of the part can be calculated according to the stress-cycle number curve and S-N curve of the part under the load spectrum conditions.

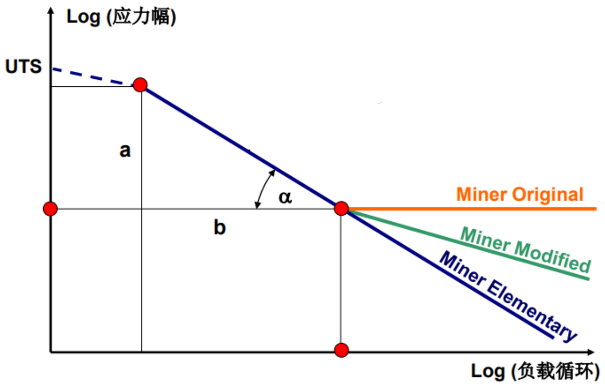

Figure 3. Fatigue analysis flowchart

As can be seen from Figure 3, the S-N curve consists of three segments, the first segment indicates that the part will quickly fatigue failure when the material is subjected to a certain stress and reaches a σ; The second paragraph indicates a specific σ corresponding to a specific fatigue life; The third paragraph indicates that when the stress is below σm, the part is subjected to several cycles without fatigue failure.

The S-N curve of the material is obtained by the test, but there are differences in the shape, size, processing, etc. of the standard specimen and the part, resulting in the S-N curve of the actual part and the S-N curve of the material, and the S-N curve is used as the basis for estimating the fatigue life of the part by the nominal stress method, and the more accurate the curve, the closer the fatigue life is to the true value. Due to the limitations of experimental conditions, the S-N curve (oblique part) of the material is modified to consider many factors that affect the S-N curve. In addition, the survival rate P of the conventional S-N curve is 50%, in order to improve the reliability design of the gear, the material S-N curve with a survival rate of 99.99% is used in this paper, and the 40Cr S-N curve is shown in Figure 4.

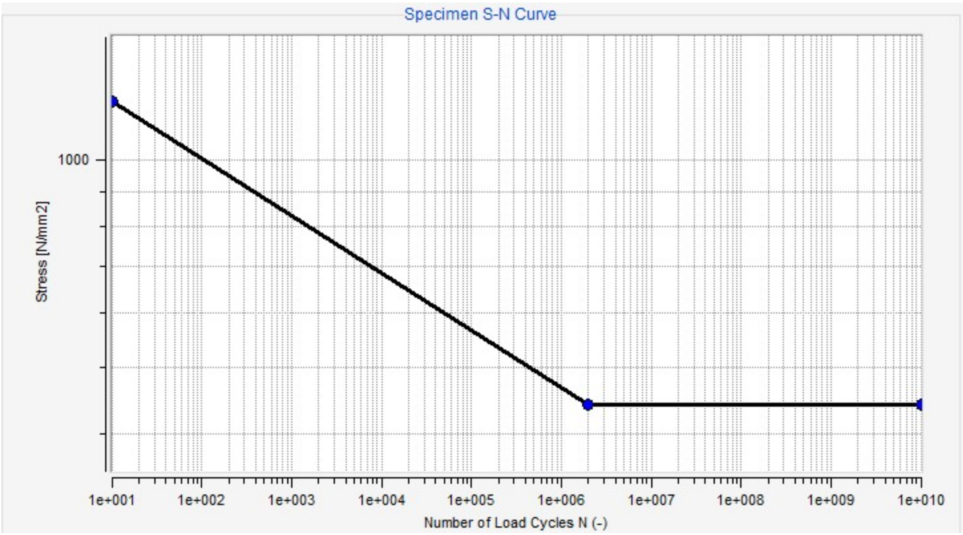

Figure 4. Curve of 40CrS-N

3. Introduction to FEMFAT software

FEMFAT (Finite Element Method Fatigue) is the world's leading software for finite element-based fatigue life prediction. It improves the reliability and durability of components in the automotive industry as well as in machinery and plant construction. FEMFAT can quickly identify critical points of fatigue and help optimize the process at a very early stage of development, outperforming time- and cost-intensive testing, thereby reducing development cycles and expensive hardware testing. FEMFAT software, which has been developed over the past 25 years, has gained wide trust outside the automotive industry and is considered the tool of choice for numerical fatigue analysis. FEMFAT engineering software is used for:

1) Reliable and effective finite element result evaluation general finite element software interface for newspapers and periodicals;

2) Fatigue analysis of single amplitude, average and normal stress;

3) Fatigue damage analysis can be performed using the load spectrum created by the ladder, rainflow matrix and synthesis method;

4) Safety factor analysis of fatigue limit; Safety factor analysis of fatigue limits;

5) Database of more than 350 different materials (steel, cast iron, aluminum alloy and magnesium alloy);

6) Many factors affecting fatigue strength are considered.

The FEMFAT software performs fatigue calculations in combination with widely used finite element programs such as NASTRAN, ABAQUS, ANSYS, I-DEAS, Medina, PATRAN, PRO/MECHANICA. Provides complete and convenient integration with the user's CAE process. Early in the design process, FEMFAT provides engineers with reliable information about the fatigue life of the structure, reducing the mass dimensional characteristics of the model and its cost. The femfat calculation results can be displayed graphically using the FE post-processor or the VISUALIZER module.

4. Fatigue simulation analysis

Add torque to the worm gear and helical gear, rotate and release the worm gear and helical gear axis, close the other 5 degrees of freedom, the 6 degrees of freedom of the worm and gear shaft are closed, analyze fatigue according to the average output torque of the motor shaft torque 1.3N·m, the speed fluctuation of the motor shaft output torque is roughly 0-2 times the average output torque, the torque amplitude of the lifting rod and the falling rod condition is the same, so only one working condition is analyzed, so the amplitude change of 0-2 times the average torque is used to calculate the fatigue strength. The green surface is where the constraint is added, as shown in Figure 5, to analyze the fatigue life of the transmission part.

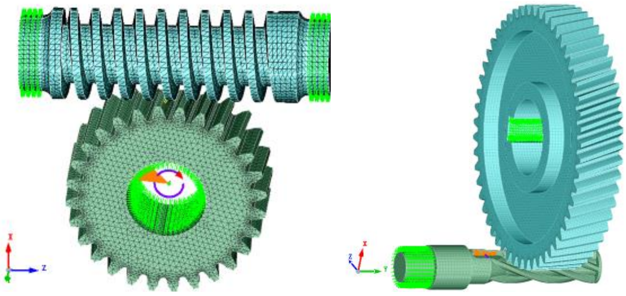

Figure 5. Loads and boundary conditions

Figure 6 is the fatigue analysis results of worm gear, and the fatigue safety factor of the worm gear meshing area is greater than 26. Far beyond the fatigue allowable safety factor of 1.1, from the worm fatigue life distribution chart can also be seen that there is no danger point on the worm, so the worm fatigue life to meet the design life of the barrier 100,000 times, as shown in Figure 7, the fatigue safety factor of helical gears are greater than 21.7, as shown in Figure 5-6, the fatigue safety factor of the red area at the gear shaft keyway is lower than 1, the minimum value is 0.12, and fatigue damage is easy to occur.

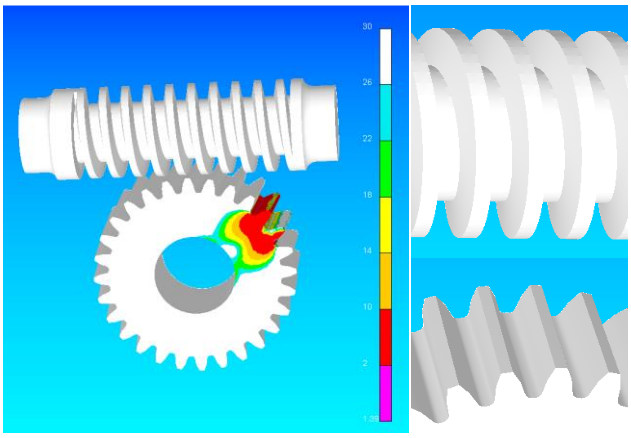

Figure 6. Worm gear and worm fatigue safety factor distribution cloud map

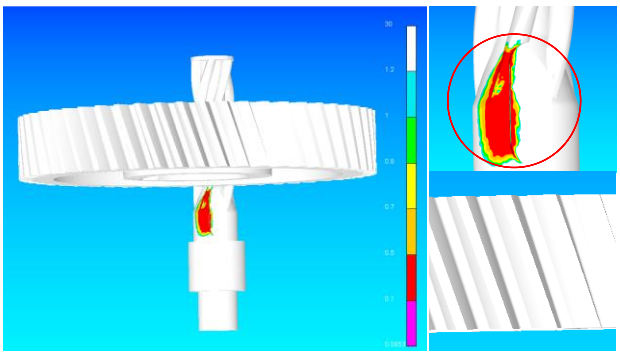

Figure 7. Fatigue safety factor distribution cloud of gear shaft and helical gear

5. Summary

By analyzing the reliability of each transmission part in the barrier reducer in the professional fatigue analysis platform FEMFAT. The results show that only the fatigue life of the gear shaft is lower than the design life, the fatigue safety factor at the keyway of the gear shaft is 0.12, which is less than the allowable fatigue safety factor of 1.1, and the gear shaft fracture is directly related to the keyway structure, which indicates that the gear shaft has not reached the design life of 100,000 times.

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