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Fatigue Life Analysis of Walking Wheel of Shearer Based on FE-SAFE

Shangxin Yu[1, a], Dejian Ma[1, b] and Wenbo Xu[1, c]

[1]Collage of Mechanical and Electronic Engineering, Shandong University of Science and Technology, Qingdao 266590, China.

[a]2174554255@qq.com, [b]1749269682@qq.com, [c]563288802@qq.com

Abstract

Taking the walking wheel of the traction part as the research object, based on the cumulative fatigue damage theory, the rain damage counting method was used to analyze the fatigue damage. Through fatigue analysis, the effects of different load sizes and different surface roughness on the fatigue life of walking wheels are analyzed, and the causes of fatigue damage are analyzed, which provides a theoretical reference for the further design and optimization of walking wheels).

Keywords

Walking wheel; fatigue analysis; cumulative fatigue damage theory.

1. Introduction

The walking wheel is the most important component of the entire traction mechanism, and it is responsible for the forward power of the shearer as a whole. Once the damage occurs, it will directly cause the shearer to stop [1]. The walking wheel has the characteristics of long continuous working time, low speed and heavy load, large impact load between the walking wheel and the pin row in actual work, so it often causes problems such as fatigue fracture of the gear, deformation of the gear, and cracks. Considering that the fatigue test in the field working state consumes more resources, requires a lot of material resources and manpower, and the fatigue test cycle of the gear teeth is too long, the entire test is difficult to achieve, so the simulation software is used to fatigue the working wheel. The life is studied, and the coal mine unit can refer to the fatigue life to replace and recycle the product. Therefore, the fatigue life analysis of the walking wheel is of great significance to improve the dynamic transmission performance of the walking part of the shearer and improve the coal mine production efficiency [2, 3].

2. Theoretical Basis

Usually when we use the S-N curve to directly predict the fatigue life of members subjected to alternating loads, the results often deviate from the actual results. At this time, it is necessary to use the cumulative fatigue damage theory to estimate the fatigue life of the construction. When the load on the component is greater than the fatigue limit stress of the material, damage accumulation will occur every time the load is applied to the component. When the damage accumulation on the component reaches a certain value, fatigue cracks will occur. As the cracks propagate, the components will have fatigue damage where the cracks occur, which is the theory of cumulative fatigue damage [4].

Miner theory is the most commonly used linear damage accumulation theory. In this theory, the sum of each damage of a component is the total damage suffered, and the single fatigue loss is independent of each other when the sum of all damages D_s to 1. , The energy obtained by the component reaches the peak, fatigue damage occurs, and the linear cumulative formula of total damage is:

$$D_s = \sum_{i=1}^{m} \frac{n_i}{N_i} \tag{1}$$

Formula: m is the number of stresses in the load on the component; n_i is the number of cycles of a single stress; N_i is the fatigue life.

3. Literature References Simulation analysis

3.1. Section Headings

For simpler single load history, the software multiplies the stress tensor per unit load and the time history of the load during calculation.
Get the elastic stress of the node:

$$S_K = S_{FE}\left(\frac{P_K}{P_{FE}}\right) \tag{2}$$

Node elastic strain time history:

$$S(t) = S_{FE}\left(\frac{P(t)}{P_{FE}}\right) \tag{3}$$

Formula: P_{FE} is the load condition data set; S_{FE} is the corresponding elastic stress; $P(t)$ is the time history of the load.

FE-SAFE can analyze the fatigue under multi-directional load. As shown in Figure 1, the finite element analysis result file contains the results of the elastic analysis in all loading directions. Corresponding to a unit load, FE-SAFE can give six stress tensors, time history and these six tensors. Multiply it to get the time history of the stress tensor accordingly, and then add it to the time of the first load. Do the same for other loads to get the time history of the combined stress tensor of the multi-directional load. When the load is applied, the direction of the principal stress of each node is constantly changing. Therefore, the critical plane is subjected to fatigue analysis, the fatigue damage is obtained by the rain flow counting method, and the fatigue life at the nodes is calculated based on the Miner criterion [5-7].

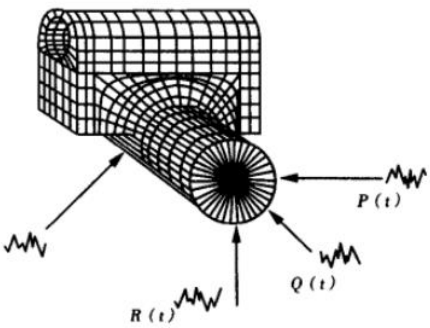

Fig 1. Schematic diagram of multi load history

For a stress data set, the elastic stress value at a node can be calculated by the following formula:

$$S = (S_{FE})_P \left(\frac{P}{P_{FE}}\right) + (S_{FE})_Q \left(\frac{Q}{Q_{FE}}\right) \tag{4}$$

Formula: S is the instantaneous value of one of the six stress tensors; $(S_{FE})_P$ is the finite element analysis P_{FE} load Elastic force at the node; P is the instantaneous value of the load time history; P_{FE} is the load of the first data set; $(S_{FE})_Q$ is the finite element analysis Q_{FE} load Elastic force at the node; Q is the instantaneous value of the load time history; Q_{FE} is the load of the second data set.

3.2. Data Analysis

3.2.1 Effect of load size on fatigue

Affected by the harsh working environment of the underground, during the traveling process of the coal mining machine, the uneven force of the two walking wheels is common, that is, one walking wheel is biased, and the other is weak. It appears that a single traveling wheel bears all the torque and transmission force, and the other traveling wheel does not work. The situation of single-wheel traction is extremely dangerous. Therefore, the effect of the magnitude of the load on the fatigue life is studied, and the relationship between the load coefficient and the fatigue life is expressed in the form of a curve, as shown in FIG. 2. With the increase of the load factor, the fatigue life of the gear teeth decreases sharply. The service life when the load factor becomes 1.1 is only 44% when the factor is 1.0, and the service life when the factor is 0.9 increases by 2.6 times that when the factor is 1. 0.

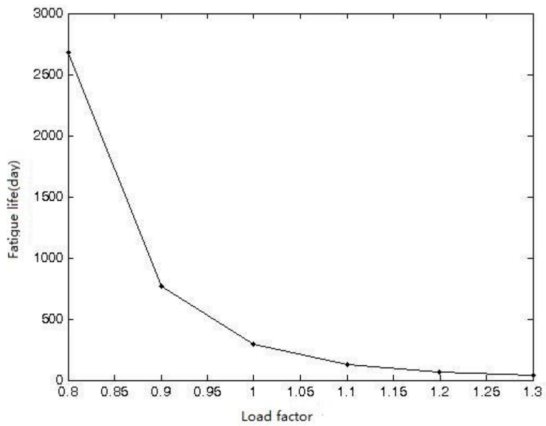

Fig 2. Influence of load factor on fatigue life curve

3.2.2 Effect of surface roughness on fatigue life

The walking wheel is a large-modulus gear, and most of them are manufactured by wire cutting. Among them, the surface roughness cannot be processed according to the general surface roughness method of the gear, so the quality of the tooth surface of the walking wheel is not high. . The lower roughness results in various defects on the tooth surface of the gear teeth, plus the effect of heavy load for a long time, it is easy to occur fatigue damage, so the impact of surface roughness on fatigue life is analyzed. The analysis result is shown in a curve as shown in FIG. 3, the higher the roughness, the lower the life. It can be seen from the figure that the roughness is about 6 times longer than 4 μm <Ra ≤ 16 μm and 16 μm<Ra ≤ 60 μm. The accuracy of the later higher grades is about 7.87 times, 18.51 times, 28.94 times, and 46.13 times higher than that of grade 5. In fact, the actual roughness of the tooth surface is closer to 4 μm <Ra≤16 μm, and the gear tooth processing life can be greatly improved by improving the gear processing technology, such as adding a finer milling machine.

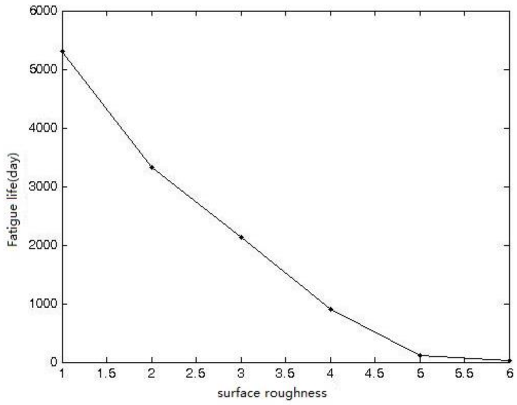

Fig 3. Influence of surface roughness on fatigue life curve

4. Conclusion

This article first describes the fatigue analysis method, and then uses professional fatigue life simulation software to analyze the fatigue life of the walking wheel, and obtains the effect of different load sizes and different surface roughness on the fatigue life:

By comparing the impact of the walking wheel on its fatigue life at different load multiples, the results show that the fatigue life of the walking wheel will decrease when the load of the walking wheel increases, and the load on the walking wheel will have a greater impact on its fatigue life. Therefore, in the working process of the coal mining machine, try to avoid the uneven load distribution of the front and rear walking wheels.

By comparing the influence of the roughness of walking gear teeth at different levels on their fatigue life, the results show that the higher the surface roughness of the walking gear teeth, the lower fatigue life. Therefore, increasing the surface roughness of the teeth of the walking wheel can effectively improve its fatigue life.

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