Simulation Analysis of Cam Wear in Shedding Mechanism of Loom

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Abstract. Aiming at the serious wear of the cam surface in the shedding mechanism of the loom weaving, which is likely to cause uneven movement of the heald frame, this paper proposes to add a layer of copper-plated carbon fiber composite material to the cam surface to improve the cam wear during the operation of the shedding mechanism. In finite element ABAQUS®, the cam is modeled, material properties and boundary loads are set, and ALE adaptive mesh technology and Umeshmotion subroutine are also used for wear analysis. The simulation results show that under the same conditions, the wear between the cam and the roller with a copper-plated carbon fiber layer is much smaller than the wear between the pure metal cam and the roller.

1. Introduction

During the carbon fiber shedding weaving process, the cam and the roller of the shedding mechanism will produce greater abrasion. There is little research on the wear of the shedding mechanism of looms at home and abroad. For example, Yang Jie of Tianjin University of Technology and others conducted experimental studies on the friction and wear between carbon fiber tows and the friction and wear between carbon fiber tows and reeds during weaving. The results show that the wear between the carbon fiber tow and the dent and the wear between the carbon fiber tow increase with the increase of the load[1]. Scholars from Hangzhou Dianzi University conducted a research on the wear of the cam mechanism. First, the Achard model was used to simulate the wear of the cam, and then the fatigue life of the cam was studied using the Miner fatigue damage theory. The wear is the most serious near the midpoint[2]. Scholar Xu Zhonglan optimized and improved the mathematical model of cam wear calculation, analyzed the influencing factors of cam wear, introduced several major types of wear, and applied the Achard wear model to the wear of the cam mechanism. It was concluded that the wear of the cam increased with the speed. The increase of the wear can be reduced by reasonable control of the cam speed[3]. At present, lubricating oil is used to reduce the wear of the cam of the split mechanism, but the lubricating oil cannot quickly dissipate the heat of the cam when the cam is running at a high speed, and adding lubricating oil will generate grease on the surface of the cam and cause environmental pollution. Therefore, in order to improve the serious wear of the open cam during operation, this topic proposes to add a copper-plated carbon fiber layer on the cam surface to improve the wear resistance of the cam. The wear volume cloud diagram is obtained through the finite element wear simulation analysis. The result of this research can be the open The research field of mechanism wear provides theoretical reference.
2. Choice of Wear Theory Model

There are many kinds of theoretical calculation models for mechanical wear. This topic mainly focuses on the simulation analysis of the adhesion and wear mechanism between the cam and the roller. Since the roller and the cam in the open mechanism are mainly rolling and the sliding motion is supplemented, Archard wear is selected. The calculation model is used to study the wear resistance of the cam in the shedding mechanism of the loom.

The formula of Archard model[4] is:

\[ q = \frac{k}{H} PA \hat{\gamma} \]  

(1)

In formula 1: \( q \) is the volume loss rate of the material (m³/s); \( k \) is the dimensionless friction coefficient; \( H \) is material hardness (N/mm²); \( P \) is the normal pressure at the interface (MPa); \( A \) is the contact area (m²); \( \hat{\gamma} \) is the interfacial slip rate.

This wear simulation analysis is based on the above-mentioned Achard wear calculation formula in the finite element software ABAQUS®/Standard static analysis module using the ALE mesh adaptive technology and the secondary development of the Umeshmotion subroutine to realize the simulation simulation of the wear process. It can be divided into the following several steps:

1. After importing the cam wear model of the shedding mechanism into ABAQUS®, define the area where the ALE adaptive grid is located and the control node of the Umeshmotion subroutine in the finite element pre-processing.
2. In ABAQUS®/Standard, the quasi-static contact problem of the cam and roller contact in the cam wear model of the open mechanism is solved.
3. Constantly update the grid frequency according to the set ALE. When the number of times of convergence of the incremental step of the frequency is reached, the grid subroutine Umeshmotion is called and the ALE adaptive grid algorithm is activated.
4. Obtain the sliding distance and contact pressure of the node under the current incremental step through the called subroutine Umeshmotion, and calculate the wear amount of each node under the incremental step according to formula 1.
5. Determine the wear direction of the node first, then adjust the node contacting the surface according to the calculated amount of node wear, and perform mesh re-sweep and node variable mapping for the remaining nodes.
6. Determine whether the current load step i has reached the load step m set by the ALE adaptive grid, if it has reached the load step m, end the analysis, if not reached, repeat the above steps until the conditions are met[4].

The above-mentioned ALE grid adaptive technology is a displacement analysis method that combines Euler's method and Lagrangian method. When performing wear simulation or large deformation, this method can make the grid move independently and prevent the grid from moving. Excessive distortion has occurred. The subroutine Umeshmotion is called by the grid update frequency set by ALE after each incremental step, which is mainly used to control the nodes of the adaptive grid area. The offset generated by each incremental step can be expressed as:

\[ \Delta X = P \cdot K \cdot D \]  

(2)

In formula 2: \( P \) is the normal contact stress (N) of contact surface nodes; \( K \) is wear coefficient; \( D \) is the wear distance (m); \( \Delta X \) is the offset produced by each incremental step.

3. Finite Element Pretreatment of Cam Wear

This topic divides the problem of wear between the cam and the roller during the working process of the opening mechanism into two aspects for research: ①The simulation analysis of the wear between the metal cam and the metal roller; ②The cam and the metal roller coated with a layer of copper-plated carbon fiber between wear simulation analysis. The material parameters of the metal cam, roller, T300-3k carbon fiber and copper plating layer are shown in table 1. The copper-plated
carbon fiber on the cam surface is shown in figure 1. It consists of T300-3k carbon fiber monofilament and copper plating layer composition.

**Table 1.** Cam wear material parameters of shedding mechanism

| Category     | Metal cam, roller | Fiber          | Metal coating |
|--------------|-------------------|----------------|---------------|
| Material     | 45 steel          | T300-3k carbon fiber | Copper        |
| Mass density(kg/m³) | 7890             | 1800           | 8900          |
| Elastic Modulus(Gpa) | 210              | 230            | 110           |
| Poisson's ratio | 0.269            | 0.3            | 0.34          |

**Figure 1.** Copper-plated carbon fiber on the cam surface

The surface of the cam has a large number of carbon fiber monofilaments in the copper-plated carbon fiber tow. Figure 1 only shows the internal structure of the tow. Each carbon fiber monofilament is plated with a copper layer of 1 micron, while the carbon fiber monofilament and when the surrounding copper plating layer is 1 micron, the wear resistance is better, so the 1 micron copper plating layer is selected for analysis. The simulation can be automatically generated by the carbon fiber script subroutine in the finite element software ABAQUS® and the tow model has passed tensile test and simulation verify its feasibility. The overall thickness of the copper-plated carbon fiber tow on the cam surface is set to 1mm. If the thickness of the copper-plated carbon fiber tow on the cam surface is set too small and the size of the cam itself is large, the wear calculation time is too long and too complicated. In the finite element software ABAQUS®, the three-dimensional model of the cam roller of the split mechanism used for wear analysis is assembled and each material is given its own elastic modulus, Poisson's ratio and mass density, etc. And the model of the cam roller assembly for wear analysis is shown in figure 2. Since the copper-plated carbon fiber layer is in full contact with the metal cam surface, the two use binding contact settings to ensure that the copper-plated carbon fiber layer and the cam surface will not slip relative to each other during the simulation. The carbon fiber layer angle on the cam surface is 0°.

**Figure 2.** Cam roller assembly model coated with copper-plated carbon fiber

The cam speed of the cam wear simulation analysis is 120 r/min, and the total wear time is set to 1 s, which means that the pure metal cam roller wear and the cam roller wear with copper-plated carbon
fiber layer are analyzed under the same boundary conditions and the same load conditions within 1 s. The wear simulation has two analysis steps. The first analysis step is to load the cam roller wear model to ensure its stable operation before unloading, because the cam will produce elastic deformation after loading. If it is not unloaded, it will affect wear results; the second analysis step is used to calculate the wear of the cam roller model. The geometric nonlinearity must be set in the on state for both analysis steps, and the number of incremental steps must be set to be larger, so as to ensure a reasonable amount of wear calculation. The surface of the metal cam and the copper-plated carbon fiber tow adopt binding contact, and the surface-to-surface contact between the copper-plated carbon fiber layer and the roller adopts the finite slip formula, the main surface smoothness is set to 0.2, and the contact property is tangential. The behavior uses the penalty function friction formula, the friction coefficient is set to 0.25, and the normal contact stiffness is set to 100000. The camshaft and the swing arm shaft are fixed, and the contact between the roller shaft and the roller, between the swing arm shaft and the swing arm, and between the cam shaft and the cam are all in the way of coupling contact, and each of the three sets of cooperation all give torque, as shown in figure 3. In the ABAQUS®/Standard statics meshing module, the metal cam and roller meshing unit type uses C3D8R, which is an eight-node linear hexahedron, to reduce the integral. When seeding the cam edge, it does not need to be too dense, too dense will increase the calculation quantities and time, using hexahedral element shape and neutral axis algorithm for sweeping meshing. The copper-plated carbon fiber layer uses an ALE adaptive grid. The area in contact with the roller surface is the ALE adaptive grid area. The C3D8 grid unit is used. It should be noted that the reduced integral cannot be used here. Each incremental step must be refreshed, and the subroutine Umeshmotion is called to divide the structure grid. The flow chart of the cam wear simulation is shown in figure 4.

Figure 4. Cam wear flow chart

4. Analysis of Cam Wear Results of Shedding Mechanism
It can be seen intuitively from figure 5 and figure 6 that the maximum wear between the pure metal cam and the roller is 0.06938mm, while the cam and metal roller with a copper-plated carbon fiber layer under the same working conditions, the maximum amount of wear between them is 0.005302mm, which shows that the cam with a copper-plated carbon fiber layer has better wear resistance. When the shedding mechanism of the loom runs at high speed, the friction between the metal cam and the roller at high speed, the adhesion between the two is very serious, which makes the roller and the cam improperly cooperate, resulting in uneven movement of the heald frame, and the carbon fiber tow and
the friction in the heddle eyelet is severe, resulting in increasing fuzzing and thread breakage of the carbon fiber tow. Therefore, plating copper-plated carbon fiber with better wear resistance on the surface of the metal cam can better improve its wear resistance and service life, and improve the efficiency of carbon fiber weaving.

Figure 5. Wear of pure metal cam roller

Figure 6. Wear of cam rollers with copper-plated carbon fiber layer

5. Conclusion

This subject mainly studies the wear of cams and rollers in the shedding mechanism of looms. The wear simulation calculations of cams and rollers are carried out in the finite element software ABAQUS®. The Archard adhesive wear formula is used to calculate the wear of the cams. The ALE adaptive grid and Umeshmotion subroutine control the cam wear model. The wear between the pure metal cam and the roller is compared with the wear between the cam and the roller with a copper-plated carbon fiber layer on the surface, and the following conclusions are drawn:

(1) The amount of wear between the cam with a copper-plated carbon fiber layer and the metal roller during medium and high-speed operation is much less than the amount of wear between the pure metal cam and the roller during medium and high-speed operation, and the surface has a copper-plated carbon fiber layer. The cam has better wear resistance.

(2) The copper-plated carbon fiber is plated on the metal surface to improve the wear resistance of the metal.

References

[1] Yang jie. Study on the Friction and Wear Behavior of Carbon Fiber in Weaving [D]. Tianjin Polytechnic University, 2019.

[2] Yu Xukang. Research on cam wear of camshaft overhead valve train [D]. Hangzhou Dianzi University, 2015.

[3] Xu Zhonglan, Liang Shenglong. Research on mathematical modeling of cam mechanism wear calculation [J]. Silicon Valley, 2010(20): 54-55.

[4] Xu pu. Research on Performance Simulation of Automatic Tensioner in Engine Front Accessory Drive System [D]. South China University of Technology, 2018.

[5] Chen chen. Study on sewing technology of carbon fiber laminated cloth [D]. Xi’an Polytechnic University, 2019.