Research on the Fretting Slip Characteristics of Interference Fit Surface of Train’s Wheelset Running in Heavy Loads

Jianfeng Song, Younian Song, Wenwu Wang and Yonggang Dong*
College of Mechanical Engineering, Yanshan University, Qinhuangdao 066004, China
Email: d_peter@163.com

Abstract. Running under the condition of heavy loads and accelerating status, the fretting damage of wheelset interference fit surface brings great hidden danger to the running safety of the train. Based on heavy loads train equipment parameters and running conditions by using the finite element software ABAQUS finite element model is established and simulated by different axle load and wheel inner hole under the conditions of different amount of interference with the axle wheel seat interference fitted surface fretting slip three-dimensional distribution, and the interference fit different axial location wheel revolving process of three feature points in axial and tangential fretting slip. The results show that the axial fretting slip of the edge of the interference fit surface is much larger than that of the middle, and the outer side is larger than the inner side, with a maximum value 22 μm; tangential fretting slip of interference fit surface reaches the maximum value 9.8μm, when the node rotates by about 270°. The influence of the value of shrink fit on fretting slip is more obvious than that of loads on the axle of the wheelset.

1. Introduction

In the actual operation of heavy haul train, the contact surface of wheelset is affected by alternating load, the contact surface of interference fit surface fretting slip happens, the process of the fretting slip due to different work environment, the performance of the material is different, different contact surface contact definition, as well as the medium, load, speed difference will produce certain effect. This paper mainly studies the causes of fretting slip, such as magnitude of interference, overloading, and so on, which cause the stress and strain in the contact surface, and then fretting slip occurs. The accumulation of damage caused by the interference surface to sprout cracks, and then lead to axle fracture and railway accidents, which we should try our best to avoid, which is the objective of the study. The research results of this paper can be used to provide valuable data reference on how to reduce the wear of train wheelsets in the future, and at the same time, it is also convenient for train maintenance and repair in actual operation.

Shi Xuefei[1] established the theoretical model of fatigue failure mechanism and analyzed the three parameters of contact load, contact stress and relative slip, and the results indicated that the coating can significantly increase the fretting fatigue life of the steel strands. Jouko Hintikka[2] is obtained through experiments, and the experimental evidence of the existence of unstable friction threshold is given in the form of friction data, slip data and fretting trace. Ahmad[3] according to the position of fretting slip obtained through experimental observation, in the case of friction, when the steel wire rope is subjected to axial and bending loads, that is, the crack starts at the contact point or the outer boundary of the contact point. Jing wei rui[4] used force analysis and finite element method to study the fretting and sliding problems between the inner hole of planetary gear and the outer ring of bearing. By dynamic simulation of fretting fatigue life under local sliding condition, Arnaud P.[5] proves that surface wear effect can be ignored under local sliding condition, but chip effect must be considered to...
predict fretting fatigue life under overall sliding condition. Xin Long [6] found that crack initiation and propagation was one of the failure modes of 690TT alloy when it was subjected to fretting wear under slant condition. R.A. Cardoso[7] conducted fretting fatigue tests on ti-6al-4v alloy under partial slip condition based on the evaluated data, and the accuracy of life estimation may be slightly improved by considering the impact of wear. L. Xin[8] studied the wear damage of alloy 690TT under local and total slip state at 320 °C by changing the fretting system obtained by the displacement amplitude control. By comparing the simulation results with the experimental results, Lang Zou[9] shows that the shape evolution of the fretting mark is mainly caused by fretting wear. Under different sliding conditions. Juoksukangas Janne[10] studied the fretting degradation and friction characteristics of large plate-plate fretting contact materials with medium nominal pressure. A new experiment was carried out under the condition of local slip. Almeida G.M.J [11]observed the influence of tangential load amplitude, average body stress and plate radius on crack direction. Chongfei Zhu[12] conducted a series of macroscopic and microscopic analytical stresses focused on grain boundaries and phase interfaces, and when it exceeded the material’s strength limit, microscopic cracks would initiate and propagate. Manoj Kumar [13] adopted an objective method that conforms to the artificial intelligence system and has certain classification standards to classify the abrasive particles, and obtained some impeccable abrasive particle analysis results.

In this paper, finite element software is used to simulate and matlab is used to analyze the fretting slip of the train under the condition of heavy loads.

2. Dimensions and Mechanical Properties of Wheelset
At present, the wheel tread shape is LMA type, the rim width is 135mm, the maximum abrasion diameter is 790mm, the rolling circle diameter is 860mm. Axle hollow diameter is 70mm; The axial distance of the contact surface of interference fit surface is 176mm and the radial diameter is 200mm. The outer diameter of the wheel is 860mm; The track is U75V heavy track. The basic properties of wheel and axle materials are shown in table 1.

| Category | Material | Mass density(kg/m³) | Modulus of elasticity (MPa) | Poisson's ratio | The yield strength (MPa) |
|----------|----------|---------------------|----------------------------|----------------|-----------------------|
| Wheel    | ER8 steel| 7850                | 206000                     | 0.3            | 540                   |
| Axle     | EA4T steel| 7850                | 212000                     | 0.28           | 830                   |

2.1. Build Model
As shown in figure 1, the wheels, axles and assembly models established by finite element software ABAQUS. The model of axle and wheel is modeled in ABAQUS with 3D deformable body, and the analytical rigid body of rail is used to reduce the computational burden. In the ABAQUS/CAE Mesh function module, the Mesh of interference fit surface area is refined, and the seed unit is 3mm. Hexahedral element, sweep grid and advanced algorithm are adopted on the contact surface. The element type is C3D8R, that is, eight-node linear hexahedral element and reduction integral (to avoid the non-convergence of calculation results caused by excessive deformation). The number of axle elements is 29,725, and the number of wheel elements is 11,700. During the division, the axle must be aligned with the grid on the wheel, which is the basis for the analysis and calculation of the fretting displacement and fretting slip speed on the contact surface.
ABAQUS and MATLAB were used to simulate the relative slip process and analyze the distribution of relative slip on the fit surface. As shown in figure 2 to the wheel to the mesh in the ABAQUS, axial end face and inner surface along the circumferential direction of the wheel is divided into 100, a total of 100 nodes, along the axis, it is divided into 17 parts and a total of 18 nodes, wheel hub inner surface and round appearance in the face of nodes should be collocated, take the interference at the bottom of the fitting surface flattening area in central radian is 0, the wheel hub inner surface and the shaft seat on the selection of the corresponding node (later crushed zone node set for short). In addition, in order to facilitate the research, we take the inner endpoint -- a, the middle endpoint -- b, and the lateral endpoint -- c, the inside of the endpoint.as shown in figure3.

2.2. Loads of Wheelset
The loads on the wheelset are shown in figure 4. The external forces mainly include the supporting force Q, load P exerted by the track. B is the distance from the load P to the symmetry plane at the center of the axle.

![Figure 3](image1.png)
*Figure 3. Corresponding node figure of Wheelset*

![Figure 4](image2.png)
*Figure 4. Force sketch of wheel set*

3. Fretting Slip Analysis
Post-processing module of ABAQUS is used to establish the column coordinate system, to extract the wheel hub and wheel corresponding node across surplus mating surfaces on the time variable axial, tangential displacement and axial displacement and poor, slip, converting time curve can get slip process along with the change of rotation angle, slip the positive and negative of the value represents the direction of the sliding, when the slip is as representative in absolute coordinates system, wheel hub nodes on the sliding distance is greater than the wheel seat sliding distance, on the contrary, when the slip is negative on behalf of the nodes in the system of absolute coordinates hub sliding distance is less than the wheel seat sliding distance. Finally, matlab is used to fit the obtained data, so as to estimate and predict the relationship between the slip and the important factors in the rotation process of the wheelset.

3.1. Fretting Slip Distribution on Assembly Surface
Select load of 75 KN, interference fit (δ) of 0.25 mm, the angular acceleration is 2.33 rad/s² simulation to get round to rotate a circle, with nodes on the surface of the circumferential and axial distribution of relative slip as shown in figure 5, the radian of the x coordinate is the location of nodes, y said node along the axial direction to the outside of the fitting surface, the distance z coordinate nodes relative slip.

![Figure 5 a](image3.png)
*Figure 5 a). Distribution of tangential fretting slip*

![Figure 5 b](image4.png)
*Figure 5 b). Distribution of axial fretting slip*
As shown in figure 5 that the circular slip crushed zone node set along the axial pouring outside of mating surface changed little in the end to end, the biggest slip in rotate 270° for about 15 microns, crushed zone node set axial slip when rotating at 180° to peak at about 20 microns, and in part on both ends of the wheel with the right company inside and outside, while the interference fit in the middle part of the axial symmetry slip is very small, change also has been relatively modest.

As can be seen from figure 6, crushed zone node set to choose three different position of the node of the axial and tangential slip value outside the interference fit surfaces in the end to side slip vice value distribution. When the node rotates about 270°, the tangential slip value reaches the maximum value. The distribution position of the node along the axial direction has a great influence on the tangential slip value, while the position near the inner side has a great influence on the tangential slip value. The axial slip begins to peak when the node rotates to 210°, that is, the symmetrical zone of the flattening zone.

![Figure 6. Slip at different positions](image)

### 3.2. Influence of Load on Fretting Slip

The following is the simulation of the influence of different loads on the fretting slip. With 100kN, 87.5kN and 75.0KN as different loads, the wheelset is rotated once under the condition that the interference fit is set to 0.25mm. As shown in figure 7, the slip of the nodes on the outer end of the interference fit surface of the wheelset under different load conditions is obtained. It can be seen from the figure that the slip is little affected by the load. The composite slip is the joint action of both axial and tangential slip. It can be seen from the figure that different loads have similar effects on the composite slip, and there is no difference due to different loads.

![Figure 7a. Effect of the value of loads on slip (δ=0.25mm)](image)

![Figure 7b. Effect of the value of loads on composite slip (δ=0.25mm)](image)
3.3. Effect of Interference Fit on Fretting Slip

As shown in figure 8a, compared the axial slip and tangential slip of the outer endpoints with the interference fit of 0.20mm, 0.25mm and 0.30mm, respectively. It can be seen that the size of the interference fit has a significant effect on both types of slip. The smaller the interference fit is, the larger the slip is, and the range of axial slip is smaller than that of tangential slip. As can be seen from figure 8b, two endpoints and midpoints with 0.25mm of interference fit are selected for observation. It can be seen that the size of the interference fit has a similar effect on the composite slip of the two endpoints.

![Figure 8 a). Effect of the value of interference fit on slip(P=75KN)](image)

![Figure 8 b). Effect of the value of interference fit on composite slip(P=75KN)](image)

4. Conclusion

(1) The tangential slip is the largest in the symmetrical area of the flattening zone, and the auxiliary value of tangential slip varies little from the outer end to the inner end of the fit surface along the axial direction; When the wheelset rotates 270°, the axial slip reaches the maximum value, and the auxiliary value of axial slip along the axis changes little.

(2) When the node rotates to about 270°, the tangential slip value reaches the maximum value, and the distribution position of the node along the axial direction has a great influence on the tangential slip amount. When the node rotates to about 200°, the axial slip reaches its peak. The maximum value of tangential slip is greater than the maximum value of axial slip.

(3) The influence of load on the slip is small, but the influence of load on the tangential slip is small but larger than that of axial slip. The interference has a great influence on the axial and tangential slip, especially when the interference fit exceeds 0.20 mm, and the axial slip is less than the tangential slip.

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6. References

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