MATLAB Simulation of Current-Carrying Friction between Catenary and Bow Net Of High-Speed Train under Fluctuating Load

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Abstract. The current carrying capacity of pantograph-catenary will also change dynamically with the continuous change of train speed. The influence of internal and external parameters such as running speed, current, pressure and vibration must be fully considered. Based on this, this paper first analyses the action relationship between CRH pantograph-catenary under fluctuating load, then studies the measurement of current carrying friction between CRH pantograph-catenary under fluctuating load, and finally gives the MATLAB simulation of current carrying friction between pantograph-catenary under fluctuating load.

Keywords: Pantograph, Catenary, CRH, Fluctuating Load, MATLAB

1. Introduction
With the iterative growth of social economy, the demand for transportation from all walks of life is becoming stronger and stronger. In this context, convenient and efficient transportation mode has become the focus of attention and research. As a transportation mode integrating economy and efficiency, high-speed railway has achieved rapid development in recent years, especially the development of high-speed railway makes more and more people choose train as a mode of travel and transportation [1]. On the other hand, with the continuous amelioration of people's concept of environmental protection, the traditional fuel powered locomotive has gradually withdrawn from operation, and the electrified railway has gradually become the dominant. The typical characteristics and key components of electrified railway locomotive include pantograph-catenary. These two components make the locomotive obtain power through mutual contact, so as to pull the locomotive forward. Therefore, they are very important key components in electrified railway system.

Pantograph-catenary components of electric locomotive involve friction and electrical contact. Their operation process is relatively complex, and will have a significant impact on the smooth operation of the train. The contact between them is directly related to the power of the locomotive. As the contact between pantograph-catenary conductor will cause wear, and with the continuous amelioration of train speed, the dynamic wear between pantograph-catenary will further aggravate, and its operating conditions will become worse and worse [2]. The current carrying capacity of pantograph-catenary will also change dynamically with the continuous change of train speed. The
influence of internal and external parameters such as running speed, current, pressure and vibration must be fully considered.

In addition, under the action of current carrying friction between pantograph-catenary of CRH under fluctuating load, the life of pantograph catenary sliding plate and catenary conductor needs to be effectively simulated with the help of computer simulation software, so as to ameliorate the simulation results according to the actual operation. Because of the inevitable vibration of the train during operation, the contact pressure load is also in a dynamic change process. The fluctuation of catenary current has certain regularity [3]. Only by fully exploring its regularity can we effectively maintain the good contact conductivity between pantograph-catenary and effectively reduce the conductor friction loss.

In short, with the rapid development of China's high-speed electrified railway, as an important part of electric traction power supply system and electric locomotive, it is very necessary to deeply simulate and study the friction and wear mechanism between pantograph-catenary conductor. The sliding contact current collection between pantograph-catenary conductor is the power source of electric CRH operation, which will have an important impact on the safe and stable operation of CRH. The parameters affecting the current carrying friction of catenary are multi-source. Therefore, the contact friction model is established with the help of computer MATLAB software, which establishes an effective premise for the prediction of pantograph catenary friction and the analysis of friction and wears performance [4]. Therefore, it is of great practical value to study the current carrying friction between pantograph and contact network of CRH under fluctuating load based on computer Matlab simulation.

2. Action relationship between pantograph-catenary under fluctuating load

2.1. Influencing parameters of pantograph-catenary of CRH under fluctuating load

During the operation of electric train, the air flow will affect the dynamic air force of pantograph. The value and variation law of hard point impact and contact line height difference are basically consistent with that of open line section. Secondly, the numerical distribution of pantograph catenary contact force will decrease with the increase of contact line height, resulting in the influence of pantograph by air dynamic force in operation. In terms of the relationship between the current collection performance of the pantograph and the running direction of the pantograph, the influence of aerodynamic force on the pantograph will lead to a direct relationship between the pantograph catenary contact force and the running direction of the pantograph [5]. The pantograph catenary contact pressure increases obviously with the increase of test speed, which shows that with the increase of electrical CRH speed, the influence of pantograph by air dynamic force also increases.

In addition, with the increase of train speed, the test values of hard points and impact acceleration are also gradually increasing, but the growth rate shows a slow trend. The material of contact wire will also affect the waveform and magnitude of hard point and impact acceleration, and the maximum amplitude in one span of contact wire decreases with the increase of speed.

2.2. Fluctuating load of pantograph-catenary of CRH

The fluctuating load between pantograph-catenary of CRH is caused by the interaction of elasticity and inertia. The vibration of pantograph catenary system is random vibration, which is usually studied by mathematical statistics. The catenary of CRH includes contact wire, catenary, suspender, locator and other parts [6]. It has both uniform mass and concentrated mass. It is a very complex vibration system. The mid span elasticity of OCS is directly proportional to the span and inversely proportional to the sum of the tension of OCS and messenger cables. The consistency of elasticity along the span is expressed by the elastic non-uniformity coefficient of catenary. The elasticity and elastic non-uniformity coefficient are related to the contact line section, clue tension, catenary span, structural height, pre sag and the presence or absence of elastic slings, and are related to the construction accuracy of catenary.
2.3. Dynamic characteristics of pantograph-catenary of CRH
Each point on the catenary vibrates near the equilibrium position, and the vibration propagates along the catenary, as shown in equation 1-2 below. Where Cp is the speed of vibration propagation along the OCS anchor section, at a certain point, a force is applied to the contact line to eliminate the force, and the contact line vibration at this point is transmitted to L after S seconds. tj is the tension of train contact wire and mj is the mass constant of contact wire. Coefficient reflecting the increase or decrease of vibration wave amplitude of catenary.

\[
C_p = 3.6 \times \sqrt{\frac{T_j}{m_j}} \text{ (km / h)}
\] (1)

\[
\nu_{\text{max}} \leq 0.7 C_p
\] (2)

In addition, the vibration wave of OCS is reflected at heterogeneous points such as suspenders and clamps, which is the quality characteristic of OCS, as shown in formula3-4 below. Where mc and Te are the linear density and tension of the messenger wire, and mj and tj are the linear density and tension of the contact wire. The relationship between pantograph running speed and fluctuation propagation speed is shown in equation 3 below, where Cp is fluctuation propagation speed and v is pantograph running speed.

\[
r = \sqrt{m_c \cdot T_e} / (\sqrt{m_c \cdot T_e} + \sqrt{m_j \cdot T_j})
\] (3)

\[
\alpha = (C_p - v) / (C_p + v)
\] (4)

3. Measurement of current carrying friction between pantograph and contact network of CRH under fluctuating load

3.1. Measurement principle of interaction between pantograph-catenary
On the premise of ensuring the good dynamic interaction between pantograph-catenary, it is impossible to measure the contact force between pantograph-catenary directly. When the sliding plate is in contact with the contact line, it is also affected by the contact force, such as friction, aerodynamic force, inertial force, pantograph lifting force, etc [7]. Therefore, in the process of measuring the interaction between pantograph-catenary, the required contact force is calculated through experience and mathematical model. In this process, the interference of forces in other directions must be eliminated. Secondly, when selecting the rotation measurement sensor, it is necessary to comprehensively consider the effects of parameters and parameters such as environment and sensitivity, and measure the parameters of pantograph catenary dynamic interaction, such as displacement and arc.

3.2. Method of current carrying friction between pantograph and contact network of CRH
Firstly, in the selection of experimental equipment, the pin disc sliding electric contact friction and wear tester is used to dynamically simulate and measure the friction, coefficient, current, voltage and other data in the experimental process [8]. Secondly, the experimental conditions of different operation parameters are established with the help of fluctuating load experimental machine, so as to simulate the pantograph catenary contact state of CRH under different working conditions. In addition, in the selection of experimental materials, the metal impregnated carbon pin pattern processed by lathe and the copper plate made of red copper were selected. In the selection of experimental scheme, the key parameters of pantograph catenary sliding electrical contact current carrying characteristics and friction under fluctuating load are comprehensively considered, so as to find the variation law of current carrying characteristics and friction.
4. Matlab simulation of current carrying friction between pantograph and contact network under fluctuating load

4.1. Current carrying friction characteristics between pantograph and contact network under fluctuating load

The dynamic characteristics of sliding electrical contact current are simulated by pin disc tester. Firstly, on the influence of velocity and contact pressure fluctuation frequency on current carrying characteristics, there are significant differences in current carrying stability parameters at different speeds with contact pressure fluctuation frequency and current carrying stability. Secondly, on the influence of current and contact pressure fluctuation amplitude on current carrying characteristics, current carrying stability parameters are positively correlated with fluctuation amplitude and current intensity [9,10]. In addition, in the aspect of pantograph catenary sliding electrical contact friction characteristics under pressure load, the friction is positively correlated with the running speed and pressure of the train. The sliding electric contact friction between pantograph-catenary under fluctuating pressure load will be affected by many parameters, such as pressure load, speed, current, contact force, pressure frequency and amplitude.

4.2. Simulation of current carrying friction between pantograph and contact network under fluctuating load

With the amelioration of operation speed, the dynamic interaction between pantograph-catenary becomes more and more important. Only considering all kinds of supporting system equipment including pantograph-catenary, can a practical and useful design scheme of pantograph-catenary system be obtained. Computer Matlab simulation is an effective choice to simulate the dynamic interaction of these components. The purpose of the dynamic interaction simulation of pantograph-catenary under fluctuating load is to determine the time-dependent characteristics of the moving contact friction acting on the contact line and the relationship with the lifting of the contact line. The measurement of pantograph catenary contact force and lifting of positioning point shall meet the specified requirements and can be confirmed accordingly. Only in this way can the measurement results of these parameters be scientific and objective. The relationship between current carrying friction and speed of pantograph and contact network under Matlab fluctuating load is shown in Figure 1 below.

![Dynamic contact force distribution of several pantograph catenary systems](image)

**Figure 1.** Dynamic contact force distribution of several pantograph catenary systems

5. Conclusion

In summary, the sliding contact current collection between pantograph-catenary conductor is the
power source of electric CRH operation, which will have an important impact on the safe and stable operation of CRH. In addition, the parameters affecting the current carrying friction of contact network are multi-source, so it is necessary to deeply study its contact friction model. Through the analysis of the action relationship between pantograph-catenary of CRH under fluctuating load, this paper studies the influencing parameters of pantograph-catenary of CRH under fluctuating load. Secondly, through the research on the measurement of current carrying friction between pantograph and contact network of CRH under fluctuating load, the measurement method of current carrying friction between pantograph and contact network of CRH is analyzed. Finally, the MATLAB simulation characteristic analysis of current carrying friction between pantograph and contact network under fluctuating load is given.

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References
[1] Chen Fu, Xiao Zhengming, Ying Lirong. Dynamic modeling and analysis of two-stage planetary gear transmission system with friction [J]. Mechanical design and research, 2017, 33 (1): 63-71.
[2] Chen Zhonghua, Tang Bo, time, Hui Lichuan, Guo Fengyi. Optimal pressure load under multi-objective sliding electrical contact between pantograph-catenary [J]. Journal of electrotechnics, 2015, 30 (17): 154-160.
[3] Guo Fengyi, Liu Shuai, Wang Zhiyong. Simulation study on transient temperature field of sliding electrical contact of pantograph catenary system [J]. New technology of electrical energy, 2017, 36 (3): 29-34.
[4] Li Kemin, Shang Guanbao, Du Sanming, Zhang Yongzhen. Effects of friction velocity and current density on current carrying friction and wear properties of copper matrix composites [J]. Mechanical engineering materials, 2015, 39 (3): 22-31.
[5] Li Tong, Li Jun. simulation and prediction of denitrification effect of sewage treatment plant based on BP neural network and Markov chain [J]. Journal of environmental science, 2016, 36 (2): 576-581.
[6] Liu Jie, Yang Peng, LV Wensheng, Liu agudamu. BP and RBF artificial neural network modeling and classification evaluation of urban air quality [J]. Safety and environmental engineering. 2014, 21 (6): 129-139.
[7] Ni Shasha, Chi Shichun. Inversion of permeability coefficient of high core rockfill dam based on particle swarm support vector machine [J]. Journal of geotechnical engineering, 2017, 39 (4): 727-734.
[8] Satoru Maegawa,FumihiroItogiwata,Takashi,Nakamura, Hiroshige Matsuoka, Shigehis. Fukui Effect of Tangential Loading History on Static Friction Force of Elastic Slider with Split Contact SurfaceTribology Letters, 2017, 65(2):1-9.
[9] Shi Liping, Tang Jiasheng, Wang Panpan, Han Li, Zhang Xiaolei. Stator fault diagnosis of induction motor using optimal wavelet tree and ameliorated BP neural network [J]. Journal of electrotechnics, 2015, 30 (24): 38-45.
[10] Wu Zhipan, Zhao Yuelong, Luo Zhongliang, Du Huaying. License plate number recognition technology based on PSO-BP neural network [J]. Journal of Sun Yat sen University (Natural Science Edition), 2017, 56 (1): 46-51.