Simulation of High-Speed Pantograph Dynamic Performance Based on Finite Element Model and Aerodynamic Pantograph Model

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Abstract. A coupled finite element model for the pantograph-catenary system and an aerodynamic pantograph model were built. Based on the models, the dynamic current collection and aerodynamic performances of the pantograph were studied using MSC-Marc and STAR-CD simulations of software. In the finite element model, the pantograph and catenary subsystems are integrated into a whole system through contact coupling between them to simulate the dynamic behavior of the pantograph-catenary system. Then, the aerodynamic performance of the high-speed pantograph was simulated on the three-Dimensional aerodynamic pantograph model. The simulation results show that the dynamic uplift and average contact force of simple suspension are smaller than those of stitched suspension.

Keywords: current collection; pantograph; finite element model; aerodynamic performance

1. Introduction
The current-receiving quality of the pantograph is the key to the safety of high-speed trains, such as the stability of high-speed bow-nets, high-speed aerodynamics, etc. Therefore, it is necessary to study the dynamic characteristics of high-speed current reception and reduce the range of such dynamic changes.

In the study of the theory of the flow-receiving of the pantograph system, the literature [1] proposed to improve the flow of the pantograph system by improving the uniform distribution of the contact network elasticity. The literature [2] studied the linear model of pantograph and the nonlinear model together, and discussed the process of linearization of the pantograph nonlinear models. The literature [3, 4] studied the theory of flow acceptance from the aspects of the dynamic characteristics of the pantograph system, the velocity of contact line fluctuations, and the off-line rate. The literature [5, 6] analyzed the development of the stable flow-receiving of high-speed electrified railway pantograph system, and studied the aerodynamics of high-speed trains. The literature [7] proposed some measures to improve the flow-receiving of the pantograph system by improving the uniform distribution of the contact network. The literature [8-11] studied the high speed. The suspension type and related parameters of the electrified railway catenary have theoretically explored and analyzed the characteristics of the dynamic flow-receiving characteristics. The literatures [12-14] gave the influence of the pre-sag of the catenary on the flow-receiving of the high-speed bow-net.
In this paper, the finite element method is used on the basis of the above research on the theory of flow-receiving. And numerical simulation of fluid mechanics to study the aerodynamic performance of pantograph receiving and pantograph at high speed, and extracted the pantograph and catenary from calculations. The main parameters and related mathematical models are given, and comparative analysis of the simulation results are discussed, respectively.

2. The proposed model for contact net pantograph system

The contact net is formed by bearing cables, contact wires, and suspension chains. The height, slackness, etc. need to be finely adjusted. The power receiving is composed of the upper frame, the lower frame, the bow head, the skateboard and other structures. The analysis for the contact net pantograph system is difficult to carry out, so a suitable model is desired. In the finite element numerical simulation calculations, the contact coupling is an interaction system.

In the numerical simulation, the Euler-Bernoulli beam is used in the finite element model of the catenary. The displacement of the clues under tension is simulated by the movement of the struts. The positioner on the strut causes the contact line to produce pull values within 1 span. The connection with the sliding board and the upper and lower frame is connected by a hinge and a non-linear spring. The hinge allows a relative rotation in the horizontal direction through the lifting bow spring. The lifting force is exerted on the boundary conditions, and friction exists between the pantographs. These are the main factors that cause the nonlinear interaction of the pantograph.

3. Pantograph Aerodynamic Model

High-speed trains operate in an air-medium space, and the research object is simplified to the problem of interaction between air fluids and rigid bodies. In the kinetics study, the molecular structure of the flow system is neglected and the fluid is considered as a continuous medium. There is no vacuum, no gaps between molecules and molecular transport. Because of the continuity of the fluid, the basic quantities (speed, pressure, etc.) of the kinematics of the fluid are regarded as certain physical quantities (time and space, the continuous function of the standard) solves the aerodynamic problem with a mathematical model of the continuous function. Fig. 1 shows the aerodynamic simulation model of the pantograph. The length of the field in the negative direction of the incoming flow is 5 times the height of the pantograph; in the positive direction of the incoming flow, i.e., the length of the wake, it is 6 times the height of the pantograph; The width of the plane in both directions is 5 times the height of the pantograph; the height is 5 times the height of the pantograph.

4. Results from Pantograph Dynamic Performance Simulation

Simulation and analysis of the interaction between different contact suspension modes and high-speed pantographs are demonstrated. The calculation condition is 250m/h, and pantograph calculation parameters are shown in Table 1 and 2, respectively.
Tab. 1 Parameters of catenary

| Suspension type          | Simple suspension | Elastic suspension |
|--------------------------|-------------------|-------------------|
| Span /m                  | 50                | 50                |
| Tension /kN              | 27+21             | 25+25             |
| Cross-sectional area /mm²| 120               | 120               |
| Hanging string material  | Cu                | Cu                |
| Cross-sectional area /mm²| 0                 | 0                 |

Tab. 2 Parameter of pantograph

| Pantograph components                              | Calculating condition |
|----------------------------------------------------|-----------------------|
| Skate density / g cm⁻²                             | 7.85                  |
| Upper frame member cross-section /mm²              | 7850                  |
| Material / g cm⁻³                                 | 1256                  |
| Down frame member cross-section /mm²              | 7850                  |
| Pusher cross-sectional area / mm²                 | 1256                  |
| Material / g cm⁻³                                 | 7.85                  |

4.1. Bownet dynamic simulation

In the bownet dynamic simulation, the MSC-Marc and STAR-CD software are used to simulate the pantograph system and elastic chain type. The calculation result of the dynamic lifting amount of the contact line of the suspension (the contact point of the positioning point and the contact line) are shown in Fig. 2.

(a) Dynamic uplift of elastic suspension        (b) Dynamic uplift of simple suspension

Fig. 2 Dynamic uplift of the contact wire with different suspension

From Fig. 2(a), it can be seen that: When the bow is not passing, due to the existence of clue gravity and sag, the static position in the cross is lower than the positioning point of 23mm; when the pantograph passes, the positioning point and cross. The dynamic lift at the midpoint is 65mm and 86mm, respectively. It can be seen from Fig. 2(b) that due to the absence of the pantograph, the sag and line are reserved. Cable gravity effect, the static position in the cross is lower than the positioning point of 27mm; when the pantograph passes, the dynamic lifting points of the positioning point and the midpoint are 30mm and 50mm, respectively. Through the simulation, it can be found that the simple chain suspension and the elastic chain type Hanging positioning points and mid-lift lift are small, but lifted Significant changes in volume, indicating that the simple chain suspension is more elastic than the elastic chain suspension.

The simulation results from the bownet contact pressure under the elastic suspension are shown in Fig. 3. It can be seen from Fig. 3 that the elasticity of the contact pressure of the chain suspension varies drastically with the span, the frequency is increasing, and the average contact pressure is large. With
obvious cycle variation in the span, the average contact pressure is small, there will be a phenomenon that the contact pressure is 0, if the contact pressure is reduced to 0, it will make as a result of off-line and spark. Therefore, the uniform pressure change of the bownet contact pressure is an important factor to ensure reliable flow performance.

![Elastic suspension](image)

**Fig. 3** Pantograph catenary contact pressure for elastic suspensions

5. Conclusion

The finite element model coupled with the pantograph and contact net established in this paper can correctly reflect the dynamic flow-receiving performance of the pantograph. Compared with the elastic chain suspension, the type of suspension reduces the amount of dynamic uplift, and the average bow contact pressure decreases, also the frequency of change is slower.

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