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Numerical Simulation on Application of Airfoil Cross-Section Rod of Pantograph

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SUMMARY:
Pantograph is a kind of structure composed of multiple rod parts. Due to its complex structure, the drag of pantograph is relatively high in the drag of the whole high speed train. In order to reduce the aerodynamic drag, many scholars put forward methods such as adding a deflector and installing a baffle plate on the roof of the train, but these methods have little effect on improving the lift force of the pantograph. Regarding this situation, this paper applies airfoil section (naca0012) to the panhead section of the pantograph strips. Knuckle-downstream and knuckle-upstream operating conditions with three running speeds (300km/h, 350km/h and 400km/h) are considered. The drag and lift forces are compared with those of regular pantograph strip in order to confirm the improvement of aerodynamic performance. It indicated that the optimized panhead pantograph has a better performance in drag and lift forces under all the conditions except the lift force rises 14 percent at knuckle-upstream.

Keywords: pantograph,aerodynamic performance, high-speed train

1. GENERAL INSTRUCTIONS

As one of the main components of high-speed train, pantograph has important influence on train safety. With the continuous increase of train speed, the aerodynamic characteristics of pantograph become more and more complex, which requires a pantograph with better aerodynamic performance. When the train running speed is greater than 250 km/h, aerodynamic resistance accounts for 75-80 percent of the total resistance, while aerodynamic resistance of pantograph accounts for about 12 percent of the total resistance (Dai, Li, Zhou, et al., 2021) The aerodynamic characteristics of pantograph have been optimized by domestic and foreign scholars. (Xiao et al., 2020) studied the influence of pantograph platform sinking on pantograph aerodynamic characteristics. (Dai, Li, Deng, et al., 2021) studied the influence of the strips spacing on aerodynamic performance of pantograph with double strips. (Ikeda et al., 2008) made the bow head blow air to carry out active control of pantograph, and achieved certain results. The panhead in pantograph is mainly composed of carbon strips and horn. The general cross-section shape of carbon strip is a blunt body. Some scholars attempted to change the section shape of carbon strip of pantohead to obtain better aerodynamic performance. (Cao et al., 2018) changed the strip section into a bionic feather shape, which effectively suppressed vortex shedding, thus contributing to the optimization of aerodynamic noise of the pantograph. Through the above research can be found that changing the cross section shape of pantograph slide strip can largely affect the aerodynamic performance of a pantograph. We all know that the streamline shape has less drag and more lift, however, the design target of the pantograph is to make drag and lift both small. In this paper, we consider an optimized panhead with two airfoil section (naca0012) strips. The aerodynamic performance will be studied under several running speeds. Finally, the practicability of pantograph assembled with this airfoil section is discussed.

2. NUMERICAL METHOD

2.1. Pantograph Model

In this paper, a simplified pantograph model is adopted to investigated the aerodynamic performances. The simplified pantograph model and the composition parts of pantograph is showed in Fig. 1. The original and optimized panhead are shown in Fig. 2(a)(b). The sections of two strips of the panhead is reformed to an airfoil shape, naca 0012. However, the original panhead strips is rectangular sections.

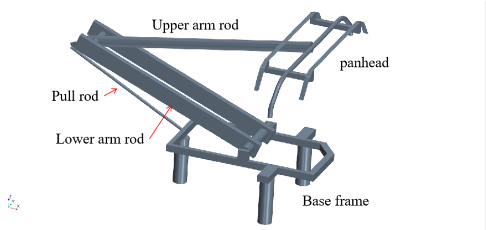

Figure 1. Simplified pantograph model.

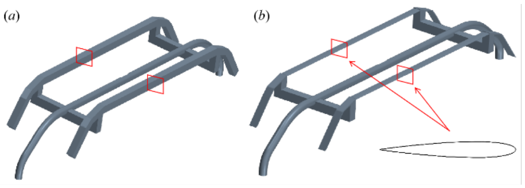

Figure 2. Comparison of the panheads: (a) original rectangular panhead (b) optimized airfoil panhead.

2.2. Equations

In this study, Reynolds-average Navier-Stokes (RANS) method is used in this paper to solve the CFD computation. The SST $k-\omega$ turbulent model is used, which combines the advantages of $k-\varepsilon$ model and the $k-\omega$ model, the equations are as follow:

$$\frac{D\rho k}{Dt}=\tau_{ij}-\beta^{*}\rho\omega k+\frac{\partial}{\partial x_j}\left[(\mu+\sigma_k\mu_t)\frac{\partial k}{\partial x_j}\right] \tag{1}$$

$$\frac{D\rho\omega}{Dt}=\frac{\tau}{\nu_t}\tau_{ij}\frac{\partial u_i}{\partial x_j}-\beta\rho\omega^2+\frac{\partial}{\partial x_j}\left[(\mu+\sigma_\omega\mu_t)\frac{\partial k}{\partial x_j}\right]+2(1-F_1)\rho\sigma_{\omega 2}\frac{1}{\omega}\frac{\partial k}{\partial x_j}\frac{\partial\omega}{\partial x_j} \tag{2}$$

3. RESULTS AND ANALYSES

In order to analyze the aerodynamic forces distribution of pantograph system, the drag and lift force of each component of airfoil section pantograph and regular pantograph during knuckle-downstream and knuckle-upstream operation at 350km/h was obtained, as shown in Fig. 3 and 4, respectively. As can be seen from figure 6, the resistance of rectangular panhead accounted for 41.7% and 40.5% of the total resistance in both knuckle-downstream and knuckle-upstream operation, while the resistance of airfoil panhead accounted for 21.4% and 21.1% of the total resistance in knuckle-downstream and knuckle-upstream operation, which decreased by 20 percentage points compared with rectangular pantograph. It can be found that the change of the panhead strip section has little effect on the aerodynamic resistance of other pantograph components.

In Fig. 4, it is observed that the aerodynamic lift of rectangular panhead is negative in both knuckle-downstream and knuckle-upstream operation, while that of airfoil section panhead is positive. Aerodynamic lift of airfoil panhead in knuckle-upstream is smaller than that in knuckle-downstream operation because of different incident angles. These results confirm that the panhead is the main component that determines the aerodynamic performance of the pantograph system. Therefore, changing its shape can effectively optimize the aerodynamic performance of the pantograph.

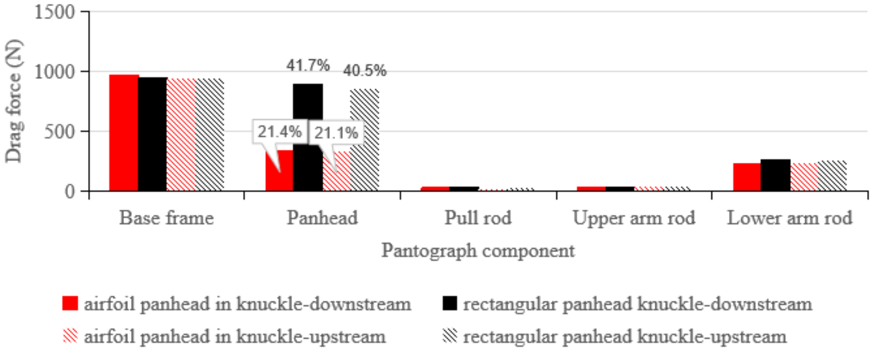

Figure 3. Distribution of drag force for different parts of pantograph.

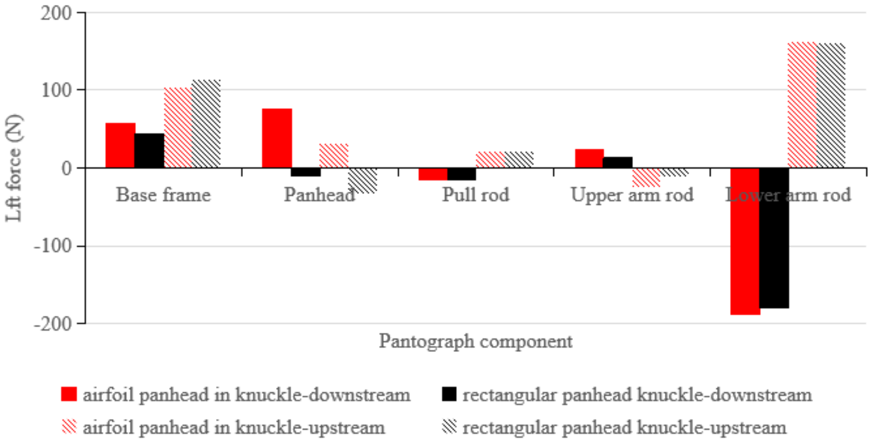

Figure 4. Distribution of lift force for different parts of pantograph.

4. CONCLUSIONS

In this paper, the section of pantograph panhead is replaced by the section of airfoil naca0012, which is compared with the regular panhead, and the conditions under different speeds of knuckle-downstream and knuckle-upstream operations are calculated. Through numerical simulations, it is found that: 1). The drag force of pantograph with airfoil section panhead decreases by 26% in knuckle-downstream operation and 15% in knuckle-upstream operation, and the absolute value of lift force decreases by 70% in knuckle-downstream operation and increases 14% in knuckle-downstream operation. 2). The upstream strip of the panhead has a uplift force, while the downstream strip has a downward lift. The drag forces of the both strips are nearly the same. 3). Airfoil section panhead has superior performance in the reduction of resistant and lift force under the knukle-downstream condition. The aerodynamic performance of airfoil is sensitive to the incident angle. Considering the various incident angles of the wind in the real situation, further studies on that need to be done to investigate the applicability of the airfoil section panhead pantograph.

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