Development of pantograph for the Series N700 Shinkansen

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Abstract

“The Series N700” Shinkansen train was developed under the concept “Latest, fastest and best rolling stock for direct operation on the Tokaido and Sanyo Shinkansen.” The Series N700 takes form to evolve the high-performance Series 700 and increased the maximum operating speed from 285 km/h to 300 km/h. [1]. In the case of high-speed railways, aerodynamic noise is dominant, since exterior noise level is increasing with proportional to the sixth power of speeds. Therefore, exterior noise is even more critical for the increase in speed.

The pantograph for the Series N700 Shinkansen trains is a single-arm type pantograph which was developed to focus on noise reduction and adjustment to adequate aerodynamic uplift force on contact wire. Current-collection system noise is known to account for a large part of exterior noise. The excessive aerodynamic uplift force causes damage to contact wire and the insufficient force also causes contact loss which decreases current-collection performance. Therefore, it is crucial to keep maintain adequate aerodynamic uplift force on contact wire.

To reduce exterior noise, the knuckle of pantograph frame, which was the noise emitting source on the conventional single-arm type pantograph for the Series 300 and 700, was covered by entire wind protection cover with a streamline shape. However, depending on running directions, fluctuation of aerodynamic uplift force swelled up because the shape of pantograph frame exposed to running wind changes from “<” for the Series 300 and 700 into “>” for the Series N700. To adjust aerodynamic uplift force, we changed the rising trajectory of panhead to convert the drag force of running wind into upward and downward lifting force. Consequently, noise reduction and adjustment to adequate aerodynamic uplift force was achieved simultaneously.

1. Introduction

The Series N700 debut and commenced commercial operation on July 2007. The Series N700 was developed under the concept “Latest, fastest and best rolling stock for direct operation on the Tokaido and Sanyo Shinkansen.” The Series N700 takes form to evolve the high-performance Series 700, and increased the maximum operating speed from 285 km/h to 300 km/h.

Current collection system noise is known to account for a large part of exterior noise, so that noise reduction of pantograph is an important issue. In the case of high-speed trains, especially, aerodynamic noise is dominant since aerodynamic noise level increases with proportional to the sixth power of speeds. On the other hand, pantograph requires adequate current-collection performance and aerodynamic uplift force on contact wire, and these parameters optimizations are not
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always compatible with noise reduction. The Series N700 pantograph as shown in Figure 1 achieved noise reduction, while keeping adequate current-collection and aerodynamic uplift force.

This paper introduces a method of noise reduction, adjustment aerodynamic uplift force with respect to pantograph of the Series N700.

Fig.1: Overview of the Series N700 pantograph

2. Preconditions and Targets of development

2.1 Preconditions of development

Preconditions of development are shown below.

- Maximum speed in the Sanyo section: 300km/h (Tokaido section: 270km/h)
- Height of roof: 3600mm (From rail level)
- Height of rolling stock gauge: 4500mm (From rail level)
- Height at "lower/upper operating position": 4800~5300mm (From rail level)
- Maximum collected current: 1000A
- Performance mentioned above is not depend on train running direction
- Adapted to body inclining system (air spring mechanism: 1° inclining) [2]

2.2 Targets of development

Targets of development are shown below.

- Aerodynamic noise level: 1.0dB lower than the Series 700 pantograph
- Current-collection performance: contact loss is adequate for standard of running test
- Aerodynamic uplift force: contact wire uplift and strain is adequate for standard of running test

2.3 Current collection performance of the Series 700 pantograph

Panhead is a very important part since it not only crucially affects current-collection performance but also directly contacts with contact wire. Thus, we adopted the same shape with the Series 700 panhead for the Series N700. Before the development of the Series N700 pantograph, we researched on the current-collection performance of the Series 700 panhead at a speed of 300km/h. On this examination, the Series 700 panhead resulted in an adequate current-collection performance. Therefore, we focused on pantograph frame and decided to use the panhead based on the
Series 700.

3. Method of Aerodynamic noise reduction
A View of wind tunnel test and noise source distributions (sound pressure level) of the Series 700 pantograph measured with the microphone array systemat wind tunnel test are shown in Figure 2 and Figure 3 respectively. Main noise sources were panhead, knuckle of pantograph frame and base frame, so that we made experimental pantograph called N700 prototype pantograph as seen in Figure 4.

![Figure 2 View of wind tunnel test (the Series 700 pantograph)](image1)

![Figure 3 Noise source distributions of the Series 700 pantograph (1000Hz, beam forming method)](image2)

(Red: high noise level, blue: low noise level)
3.1 Noise reduction of knuckle
In order to reduce the aerodynamic noise of knuckle, we shortened lower frame, moved knuckle position as low as possible and covered knuckle with wind protection cover.

3.2 Noise reduction of base frame and wind protection cover
To reduce the noise of base frame, noise sources of base frames such as installation part, pantograph frame storage part and air tubes were covered by wind protection cover with a streamline shape. To house pantograph frame, wind protection cover needs frame-moving-slit, and this slit also generates aerodynamic noise. So, wind protection cover has slit shutter. When frame moves upside, slit shutter covers frame-moving-slit, and when pantograph is housed slit shutter is housed in a wind protection cover. In addition, upper frame has wind protection plug to minimize the space between slit shutter and upper frame.

3.3 Noise reduction result and aerodynamic uplift force of N700 prototype pantograph
N700 prototype pantograph achieved about 1.0 dB noise reduction compared with the Series 700 pantograph at a full-scale wind tunnel test, but aerodynamic uplift force of N700 prototype pantograph was considerably different from the Series 700 pantograph. In concrete terms, aerodynamic uplift force greatly fluctuated depending on running directions. The excessive aerodynamic uplift force causes damages or wears to contact wire and the insufficient force also causes contact loss which decreases current-collection performance. Taking those facts into consideration, we needed to adjust aerodynamic uplift force to the same level of the Series 700 pantograph.

4. Adjustment of aerodynamic uplift force
4.1 Aerodynamic character of N700 prototype pantograph
Generally, in the case of single-arm type pantograph, aerodynamic uplift force on contact wire is a total of aerodynamic lifting force by frames and panhead. In knuckle upstream direction, aerodynamic lifting force by upper frame is downward and lower frame is upward. In the case of the Series 700 pantograph, both of upper and lower frames are exposed to running wind and each aerodynamic lifting force generated by those frames is cancelled. Thus, aerodynamic uplift
force on contact wire has little difference between knuckle upstream direction and downstream direction as shown in Figure 6. On the other hand, in the case of N700 prototype pantograph, upper frame was only exposed to running wind. Thus, aerodynamic uplift force on contact wire had great difference, depending on directions as shown Figure 7. Figure 8 shows aerodynamic lifting force of N700 prototype and the Series 700 pantograph at full scale wind tunnel test.
4.2 Method of aerodynamic uplift force adjustment

Generally, the rising trajectory of panhead is almost vertical and straight, to minimize the influence of drag force on aerodynamic lifting force. Taken advantage of this point, we change its trajectory vertical to slightly oblique in order to convert the drag force into lifting force. In the knuckle upstream direction (lift of frame is only downward) dragging force of panhead is converted into upward force. In the knuckle downstream direction (lift of frame is only upward) dragging force of panhead is converted into downward force as seen in Figure 9.

This method can achieve adequate aerodynamic uplift force without changing the shape of pantograph. Another method, which attaches an airfoil on upper frame, to adjust aerodynamic uplift force has been already used in other high-speed railways but the airfoil increases aerodynamic noise. In our case, airfoil is not necessary since we already achieved aerodynamic noise reduction and adequate aerodynamic uplift force without the usage of airfoil.
5. Adaption of body inclining system

Contact strip of the Series 700 Pantograph is composed of principle strip; iron based sintered metal, and sub strip; aluminum alloy to reduce its weight. Principle strip is arranged in the center, sub strips arranged across the principle strip. Contact wire slides mainly on principle strip.

Series N700 pantograph changed the length of principle strip from 540mm to 600mm, because the Series N700 is equipped with body inclining system and the area the overhead wire slide become wider than that of the Series 700. To determine the dimensions of contact strip, we research frequency distribution of relative position of contact strip and contact wire using “Dr. Yellow”; the electric and track inspection car which is not equipped with body inclining. Based on the data from the research we estimate the relative position of contact strip and contact wire when a body inclining system is equipped. From this estimation we decided to expand the length of principle strip by 60mm, to keep the equal frequency that principle strip contacts overhead wire.

6. Noise reduction of insulator and insulator cover

Around pantograph, supporting insulator, cable head, emergency grand switch and high voltage cable are equipped. Insulator cover is mounted around pantograph as a windbreaker because all these equipments are also cause of aerodynamic noise [3].

The Series 700 pantograph is supported by four insulators, and one cable head is arranged on the side of the pantograph. In the case of the Series N700, pantograph is supported by two insulators and one cable head, and cavity length inside the insulator cover is shorter than that of the Series 700.

Reduction of the number of insulators and a small insulator cover contributes to weight reduction too.
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7. Composition of the Series N700 pantograph

Figure 11 shows the configuration of the Series N700 train set. Pantograph is mounted on car numbers 5 and 12 (the same car numbers as those in a Series 700 train set). The distance between two pantographs is 162m. This length is determined to avoid resonance caused by two pantographs and overlap of peak level of noise caused by pantograph and the leading car. It also considered the length of neutral section at car washing shops.

The mounted direction of pantograph is decided in consideration of current-collection performance and noise character. Lifting force of the rear pantograph is constantly higher than front pantograph, because rear pantograph is affected by contact wire fluctuation which is generated by front pantograph. When the train travelling westbound for Hakata, the pantograph on car number 5 is mounted as knuckle upstream direction, and the pantograph on car number 12 is mounted as knuckle downstream direction.

Table 1 shows main specifications of the Series N700 pantograph.

![Configuration diagram of the Series N700 train set](image)

**Fig.11 The configuration of the Series N700**

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<th>Tab.1 Main specification of the Series N700 pantograph</th>
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<tr>
<td><strong>Type of rolling stock</strong></td>
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<td><strong>Type of pantograph</strong></td>
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<td><strong>Frame type</strong></td>
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<td><strong>Height</strong></td>
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<td>Housed</td>
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<td>Minimum working</td>
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<td><strong>Operating system</strong></td>
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8. Conclusions
In running test on the Series N700 prototype train set, the Series N700 pantograph achieved more than 1.0dB noise reduction compared with the Series 700 pantograph. And adequate current-collection performance and aerodynamic uplift force were achieved, since adequate for standard of running test. Therefore, we decided adoption of the Series N700 pantograph.
Since the Series N700 was in service on commercial lines in July 2007, it has been providing a great deal of satisfaction to the customers and the Series N700 pantograph has no problem in general overhaul so far.
We are developing more technologies which will be able to apply to our high-speed railway systems without a break. A new pantograph will make it more silent and will achieve better current-collection performance.

9. Reference