Measurement Results for Power Facilities in FASTECH360 High-speed Running Tests

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The effect on wayside facilities of the increase in wind speed and vibration by passing trains needs to be evaluated in order to achieve an increase in Shinkansen commercial operation speeds. Wayside power facilities requiring evaluation include the overhead contact line system, lighting and power equipment including lamps and snow melting devices at turnouts and power transforming equipment. We thus evaluated the effect on those facilities in running tests using FASTECH360 high-speed test trains and confirmed that there are no problems in running at 360 km/h. This article will report the measurement and evaluation results for power equipment in the FASTECH360 high speed running tests.

●Keywords: Power, Overhead contact line, Lighting and power equipment, Power transforming equipment, Current collection

1 Introduction

Technical hurdles are high for maintaining current collection characteristics between overhead contact lines and pantographs when operating at the 360 km/h target of the Shinkansen speed increase project. We thus need to solve a variety of issues.

In the initial stage, we carried out high speed running tests in 2003 at 360 km/h using the same series E2 and E3 trains as for regular service. In those tests, we found improving the wave propagation velocity of contact wires and auxiliary messenger wires and controlling strain at supporting points to be issues[1]. We thus conducted technical development on an overhead contact line system for high-speed running and on light pull-off arms[2], and the results of the development were applied to construction on wayside facilities in the FASTECH high-speed running test section. Then, we measured current collection performance in running tests using type E954 and E955 high speed test trains between Sendai and Kitakami on the Tohoku Shinkansen from June 2005 at various overhead contact line system conditions and pantograph conditions. As a result, we confirmed that there would be no problems in current collection performance when running at up to 360 km/h provided that facilities required for such high-running speed were constructed.

We also measured performance with lighting and power equipment and substations, confirming that there were no problems.

Based on the test results, we made a comprehensive decision to increase commercial operation speed between Utsunomiya and Morioka on the Tohoku Shinkansen to 320 km/h.

2 Modification of Overhead Contact Line System to Handle High-speed Operation

Wave propagation velocity, i.e., the speed at which waves of the overhead contact line are propagated, needs to be increased to improve current collection performance at high-speed running. As expressed in formula 1 for wave propagation velocity, we need to decrease the weight of and increase the tension of the contact wire to increase that speed.

$$c = \sqrt{\frac{T}{\rho}} \quad \cdots\cdots (1)$$

c : Wave propagation velocity [m/s]
T : Tension of the contact wire [N]
ρ : Weight per unit length of the contact wire [kg/m]

From the perspective of facility maintenance, a larger cross sectional area of contact wire is more favorable to lengthen the replacement cycle of contact wires that become worn by contact pantographs. However, weight of a contact wire increases with a larger cross sectional area. We thus reviewed the balance between the cross sectional area and the tension of the contact wire for the heavy compound catenary system shown in Fig. 1, the standard overhead contact line system for the Tohoku and Joetsu Shinkansen, while keeping the total tension as it was. And we modified that heavy compound catenary system in the section between Sendai and Kitakami to the system shown in Table 1. The contact wire's weight was reduced and tension increased when modifying the existing system to the improved system (① and ③ respectively in Table 1). Changing the allocation of tension to each line of the system made it possible to modify without adjusting the length of the droppers between the messenger wire and the auxiliary messenger wire, contributing to a shorter work time[2].

We also developed a light pull-off arm to control excessive strain at high-speed running[1] and installed that to the improved overhead contact line system.

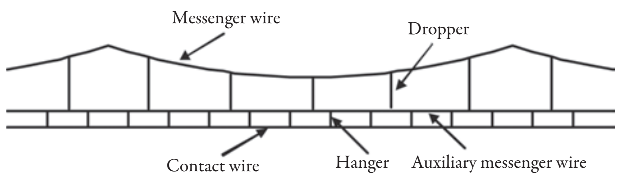

Fig. 1 Structure of Heavy Compound Catenary

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Table 1 Overhead Contact Line System According to Running Speed

	Contact wire	Auxiliary messenger wire	Messenger wire	Maximum speed handled [km/h]
Existing line system ①	Gt-Sn170mm^2	PH150mm^2	St180mm^2	275
	17.64kN	11.76kN	24.5kN	
Higher tension line system ②	Gt-Sn170mm^2	PH150mm^2	St180mm^2	320
	19.6kN	9.8kN	24.5kN	
Improved line system ③	PHC110mm^2	PH150mm^2	St180mm^2	360
	19.6kN	12.74kN	21.56kN	

Upper: Type of line Lower: Tension

3 Results of Overhead Contact Line System Measurements

In FASTECH360 running tests, we made a wide array of measurements on the overhead contact line system. Those were made because the running tests using two train sets of type E954 and E955 trains were conducted with more than one type of pantograph in different conditions such as with a single train set, trains passing each other and coupled operation. Here we will report the measurement results of running tests that were expected to have the largest impact on the overhead contact line system.

3.1 Background of Main Running Tests

① Type E954 and E955 trains passing each other

We made measurements because the wind speed around pantographs could increase and generate excessive uplift force when trains pass each other in a tunnel.

② Type E954 and E955 coupled operation

We made measurements because vibration of the pantograph to the front could increase uplifting of the pantograph behind it at passing when using two pantographs.

3.2 Major Evaluation Items of Overhead Contact Line System

For the overhead contact line system, we mainly evaluated performance for the following points.

① Contact wire uplift

Stoppers of pull-off arms activate when a contact wire has too much uplift, and impact of the contact wire with the pantographs could be excessive. The target value for uplift is 100 mm.

② Contact wire strain

Bending of the contact wire generates strain when a contact wire is lifted up, so the wire could break due to fatigue. Thus, ability to withstand 10^7 times repeated stress is specified as the fatigue limit. In high-speed running tests, we set the target value as 500μst for Gt-Sn170mm^2 and as 1,100μst for PHC110mm^2 and PHC130mm^2. 1μst means 1×10^{-6} m expansion and contraction per 1 m length.

3.3 Type E954 and E955 Trains Passing Test

Fig. 2 and Fig. 3 show the measurement results of type E954 and E955 trains passing each other in a tunnel. The results show that the maximum contact wire uplift was 80 mm and the maximum contact wire strain was 602μst, both less than the target values.

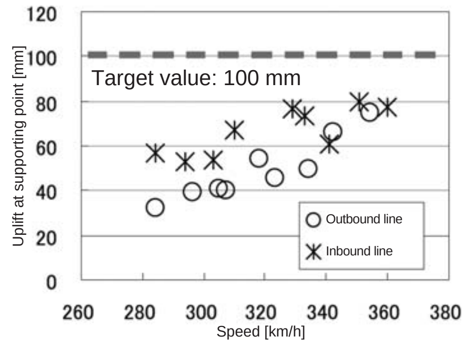


Fig. 2 Uplift of Contact Wire (in passing test, with improved line system ③)

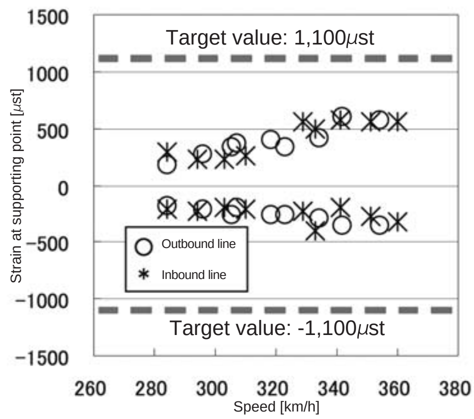


Fig. 3 Strain in Contact Wire (in passing test, with improved line system ③)

3.4 Type E954 and E955 Trains Coupled Operation Tests

As shown in Fig. 4, we measured the contact wire uplift and strain in coupled operation of type E954 and E955 trains.

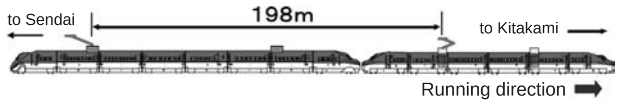


Fig. 4 Type E954 and E955 Train Sets for Coupled Operation Test

Fig. 5 and Fig. 6 show the measurement results for the higher tension line system ② in open sections. The results show that the maximum uplift was found to be 67.5 mm and the maximum strain 457μst, both less than the target values. In the speed range of 300 km/h or higher, however, we confirmed a high tendency for uplift and strain in relation to speed to be larger, while both were less than the target values.

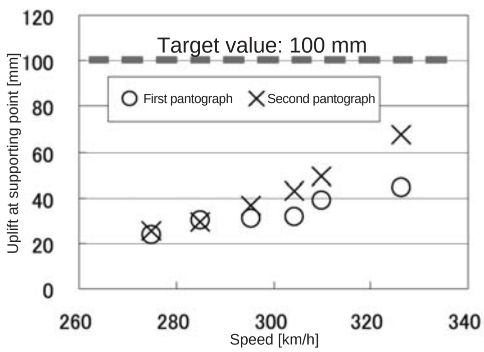


Fig. 5 Uplift of Contact Wire (in the coupled operation test, with higher tension line system ②)

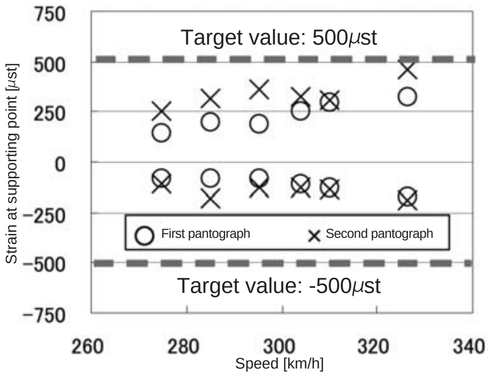


Fig. 6 Strain in Contact Wire (in coupled operation test, with higher tension line system ②)

Next, Fig. 7 and Fig. 8 show the measurement results of the improved line system ③ in a tunnel. The results show that the maximum uplift was found to be 89 mm and the maximum strain was 912µst, both less than the target values. In the speed range of 340 km/h or higher, however, we confirmed a high tendency for strain in relation to speed to be larger.

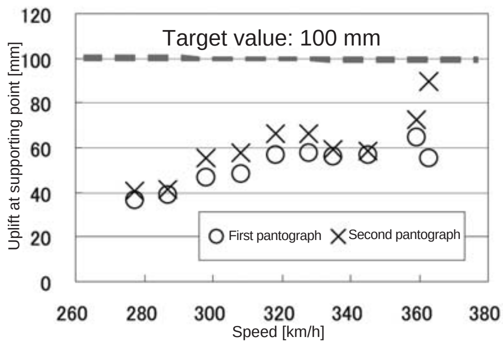


Fig. 7 Uplift of Contact Wire (in coupled operation test, with improved line system ③)

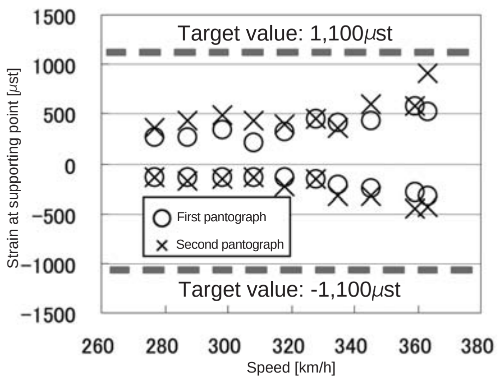


Fig. 8 Strain in Contact Wire (in coupled operation test, with improved line system ③)

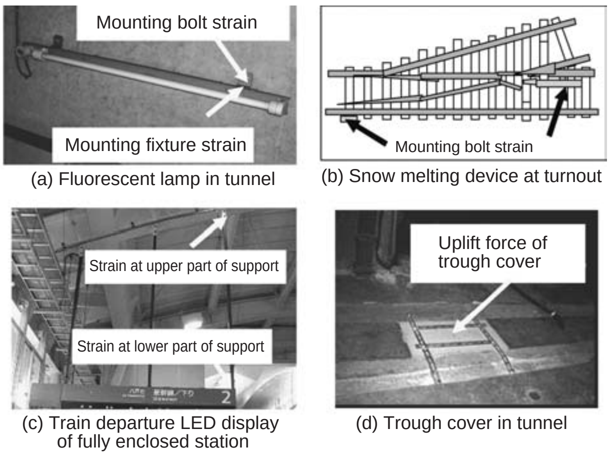
In the same way, we measured contact wire uplift and strain at a ordinary overhead crossing and found that there was no risk of dewirement and that target values were met.

According to the results shown in Fig. 5 and Fig. 6, the higher tension line system ② of the overhead contact line system thus met current collection performance requirements at 320 km/h.

From the results shown in Fig. 7 and Fig. 8, we confirmed that the improved line system ③ also meets target current collection performance requirements at 360 km/h.

4 Results of Lighting and Power Equipment Measurement

Lighting and power equipment including lamps and snow melting devices at turnouts is installed in various places, so it is necessary to evaluate the effect wind speed and vibration in high-speed running has on it. We measured in high-speed running the evaluation items shown in Table 2 for the equipment shown in Fig. 9.



(a) Fluorescent lamp in tunnel (b) Snow melting device at turnout (c) Train departure LED display of fully enclosed station (d) Trough cover in tunnel

Fig. 9 Measured Lighting and Power Equipment

Table 2 Evaluation Items for Lighting and Power Equipment

Equipment	Component	Measurement item	Running test
Fluorescent lamp in tunnel	Mounting bolt	Strain	E954 and E955 passing each other
	Mounting fixture	Strain	
Snow melting device of turnout	Mounting bolt	Strain	E954 (single train set) E955 (single train set)
Train departure LED display of fully enclosed station	Support	Strain	E954 (single train set)
Trough cover in tunnel	Trough cover body	Uplift force	E954 and E955 passing each other

Fig. 10 shows the measurement results for fluorescent lamps in a tunnel. The results for specific components are as follows.

- Mounting bolt: The maximum value measured was 243µst, much less than the target value of 1,800µst.
- Mounting fixture: The maximum value measured was 531µst, much less than the target value of 2,200µst.

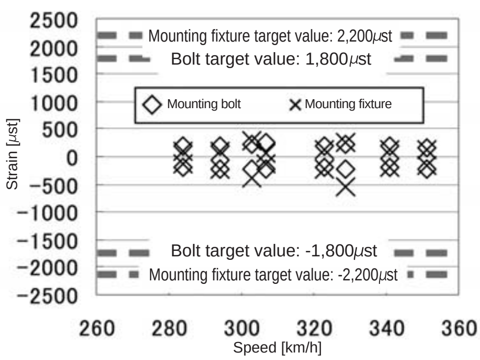


Fig. 10 Measurement Results of Fluorescent Lamp in Tunnel

Fig. 11 shows the measurement results for a mounting bolt of a snow melting device at a turnout. The results show that the maximum strain was 423μst, less than the target value 750μst. We also confirmed that the strain at the passing of the high-speed test train was equivalent to that at the passing of current trains in service.

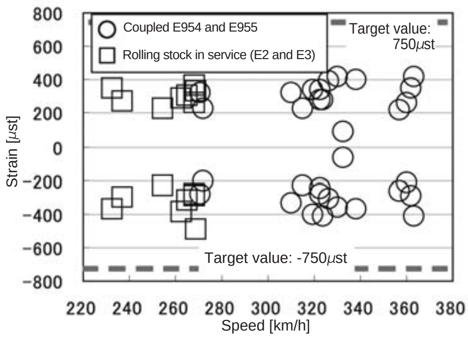


Fig. 11 Measurement Results of Snow Melting Device at Turnout

We also confirmed that there were no problems with other lighting and power equipment at 360 km/h or slower. Based on those results, we concluded that no problems would occur with existing lighting and power equipment at the target of 360 km/h.

5 Results of Power Transforming Equipment Measurements

We need to evaluate the effects of increases in load current with high-speed running and the effects of new rolling stock on the power supplied to substations. Thus, we measured the items shown in Table 3 in high-speed running tests.

Table 3 Evaluation Items of Substation

Item	Description
Feeding voltage	Maximum value, minimum value, fluctuation
Feeding current	Maximum value, minimum value, fluctuation
Active power	Maximum value, minimum value, fluctuation
Reactive power	Maximum value, minimum value, fluctuation
Feeding voltage harmonics	Content

Fig. 12 and Fig. 13 show the relative harmonic content for which we had the most concern about effect among the items in Table 3. The measurement results shown are instantaneous values. For reference, average target values of harmonic control in 30 minutes are shown in Fig. 12 and Fig. 13[3]. As shown by those results, no values higher than the target were measured.

There were no problems with other measured items either. Accordingly, we have concluded that it would not be a problem to use existing substations at the 360 km/h target.

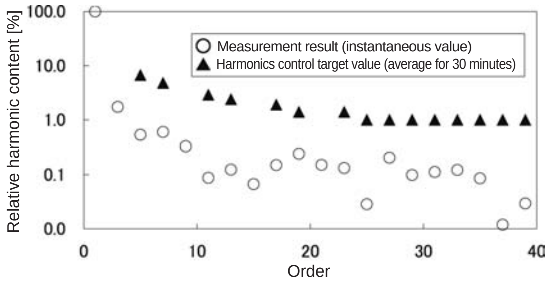


Fig. 12 Measurement Results for Relative Harmonic Content (Type E954, powered running current: 486A)

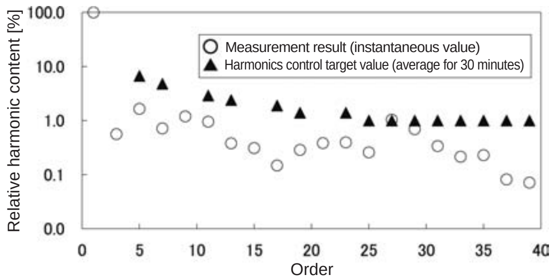


Fig. 13 Measurement Results for Relative Harmonic Content (Type E954, regenerative current: 486A)

6 Facility Improvement for High-speed Commercial Operation

Since the commercial operation speed increase to 320 km/h was decided on for the section between Utsunomiya and Morioka of Tohoku Shinkansen, we replaced the existing overhead contact lines ① with those of higher tension ② as shown in Table 1.

7 Conclusion

In order to handle test runs at 360 km/h, we have developed a new overhead contact line system and confirmed that it has stable current collection performance in running tests at up to 360 km/h. We also confirmed that lighting and power equipment and substations also had no problems. The measurement results introduced in this article will be valuable data for further Shinkansen speed increases and of help in facility maintenance.

Reference:

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2) Kunio Ikeda, Atsushi Iwainaka, Masayuki Takahashi, Katsuo Kawashima; "Techniques for improvement of catenaries to serve 360 km/h run in commercial line", 2005 Annual Conference of Institute of Electrical Engineers of Japan, Industry Applications Society, 3-80, pp. III-337 - 338, 2005
3) Nuclear and Industrial Safety Agency; "Guidelines for Harmonics Control for Users Receiving Electricity at High Voltage or Special High Voltage", 2004