Development of Feeder Messenger Wire Type Overhead Contact Line with One Copper Messenger Wire

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Feeder messenger wire type overhead contact lines have drawn attention recently from the viewpoint of labor-saving for maintenance. A type that uses two PH356mm² messenger wires was introduced into the Tokyo district, while another that uses an SB-TACSR730mm² messenger wire into the Kansai district. In terms of the number of messenger wires, the one-wire type is more useful, as it involves a smaller number of parts. As the material for the wire, copper is better than aluminum, since it does not require connection with different metals. To realize the advantages of the two systems, therefore, we developed a feeder messenger wire type overhead contact line that has only one copper messenger wire.

Keywords : feeder messenger wire type overhead contact line, PH730mm² messenger wire, current collecting characteristics

1. Introduction

Feeder messenger wire type overhead contact lines have a structure to combine the function of feeder with the messenger wire. They have drawn attention recently in Japan from the viewpoint of labor-saving for maintenance. They use two hard-drawn copper stranded conductor PH356mm² messenger wires in the Tokyo district, and an aluminum conductor steel-reinforced SB-TACSR730mm² messenger wire in the Kansai district. In terms of the number of messenger wires, the one-wire type is more useful as it involves a smaller number of parts, and copper is better as the material for the wire than aluminum since it does not require connection with different metals. Therefore, we promoted this research for the purpose of developing a feeder messenger wire type overhead contact line that has only one copper messenger wire to realize the advantages of the two systems.

In order to determine what wires suit the new overhead contact line, we chose a narrow-gauge line in Tokyo as a test site, studied whether electrical and mechanical characteristics of wires satisfy the standard values, and examined the current collecting characteristics of various types of wires through simulation. As a result, it was proved that the PH730mm² messenger wire was the most appropriate in the overcrowded railway sections in Tokyo.

Based on this result, we actually constructed a PH730mm² messenger wire and investigated its current collecting characteristics by using current collection testing equipment to find that standard values were all satisfied at the speed of 160 km/h. It was also proved that this wire type could be used for operation at speeds up to 160 km/h.

2. Examination of the optimum wires

Table 1 lists the wires examined as candidates of one-

Table 1 Dimensions of wire

Wire name	Types of wire	Total number of strands	Diameter of strand [mm]
Hard-drawn copper stranded conductor	PH670mm ²	127	2.6
	PH730mm ²	91	3.2
	PH770mm ²	61	4.0
	PH840mm ²	127	2.9
Thermal-proof hard-drawn copper stranded conductor	THDC670mm ²	127	2.6
	THDC730mm ²	91	3.2
	THDC770mm ²	61	4.0
	THDC840mm ²	127	2.9

messenger wire. We examined the current capacity, wire resistance, tensile strength, minimum hanger length and current collecting characteristics, to determine the applicability of these wires to the one-messenger wire system.

2.1 Current capacity

We examined whether the wire temperature is below the allowable limit at the conditions in Table 2. The allowable temperature is 90 °C for the hard drawn copper stranded conductor (PH) and 150 °C for the thermal-proof hard drawn copper stranded conductor (THDC). Figure 1 shows the wire temperature rises when a current of 855 A, which is the maximum value for wires used in Tokyo, flows for 3,600 seconds. The shaded portion represents the surrounding temperature of 35 °C,

Table 2 Conditions of temperature calculation

Surrounding temperature	35 °C (rush hours in the morning)
Insolation	0.1 W/cm ²
Emissivity	0.9
Wind velocity	0.5 m/s
Load current	855 A (Maximum current at a line in Tokyo) for 3,600 seconds

Fig. 1 Wire temperature rises

and the portion of slash mark the temperature rises by the Joule heat. There are no wires of THDC or PH that show a temperature rise over the allowable limit under this condition.

2.2 Wire resistance

To evaluate the wire resistance, we compared several kinds of messengers with two PH356mm² messenger wires currently used on the narrow-gauge lines in Tokyo. In Fig. 2, the slash lined bars show the resistance after the temperature rise at an 855 A current flow and the shaded bars show the wire resistance at 20 °C. A comparison of the resistance of two PH356mm² wires with that of test wires at 20 °C (shaded bar), proves that the resistance of THDC670mm² wire and PH670mm² wire is higher than that of two PH356mm² wires. Moreover, in the case of the resistance after temperature rise (slash), only the resistance of THDC670mm² wire and PH670mm² wire is higher than that of two PH356mm² wires.

Fig. 2 Wire resistance

2.3 Tensile strength

Since it is assumed that this catenary system is constructed to a standard tension of 39.2 kN, it is a condition that the tensile strength is set at over 86.24 kN, as the safety factor of copper is 2.2 in Japan. All the tensile strengths for the test wires referred to in this paper are over 86.24 kN.

2.4 Minimum hanger length

We calculated the minimum hanger length on the assumption that the messenger wire tension is 39.2 kN; contact wire tension is 14.7 kN; and span length is 50 m. When we assume a standard system height (850 mm) equivalent to that of existing feeder messenger wire type overhead contact line in Tokyo, only the minimum hanger length of PH840mm² wire is less than 150 mm. If the system height is assumed to be 960 mm, the minimum hanger length of PH840mm² wire is larger than 150 mm.

2.5 Current collecting characteristics

We calculated the contact loss rate and contact wire uplift and strain at support by simulation when we use each tested wire as a messenger, and compared the results with the standard values that can realize stable current collection. Tables 3 and 4 show simulation conditions and standard values, respectively. Figure 3 shows the contact loss rate of the 2nd pantograph. As a result of the simulation, the contact loss rate of the 1st pantograph was set at 0 % for all wires and contact loss rates of the 2nd and 3rd pantographs became several percent at speeds higher than 180 km/h. However, the contact loss rate up to 160 km/h, which is practically the highest speed on narrow-gauge lines, is 0 %. Figures 4 and 5 show the contact wire uplift and strain at support, re-

Table 3 Conditions of simulation

Composition of Catenary	Contact wire	GTM-SN170mm ²
	Messenger tension	39.2 kN
	Contact wire tension	14.7 kN
	Span length	50 m
	Distance between two hangers	5 m
Pantograph	System height	850 mm
	Type	PS26
	Number	3
	Distance	80 m, 60 m
Speed		100 ~ 200 km/h

Table 4 Standard values of current collecting characteristics

Contact loss rate	Less than 5 %
Contact wire strain at support	Less than 500×10^{-6}
Contact wire uplift at support	Less than 70 mm

Fig. 3 Simulation results (Contact loss rate)

Fig. 4 Simulation results (Contact wire strain at support)

Fig. 5 Simulation results (Contact wire uplift at support)

spectively. Either is not over the standard value up to the speed of 200 km/h with any wire.

2.6 Examination results

Since the current capacity, tensile strength and current collecting characteristics satisfied the standard values no matter which wire we use, we judged the appropriateness of the wires based on the wire resistance. Table 5 shows the judgment results. Under the condition of an 855 A current flow, we marked "O" if the wire resistance satisfies the judgment standard and "X" if not. Consequently, we reached a conclusion that use of PH730mm² wire is appropriate with respect to the 855 A current capacity.

Table 5 Judgment results

	Judgment
PH670mm ²	X
PH730mm ²	O
PH770mm ²	O
PH840mm ²	O
THDC670mm ²	X
THDC730mm ²	O
THDC770mm ²	O
THDC840mm ²	O

3. Test by current collection testing equipment

The current collection testing equipment of the Railway Technical Research Institute used for this test has a full length of 500 m and can carry out running tests up to the speed of 160 km/h, by using an actual contact wire and pantograph. We chose a PH730mm² wire among the wires which were appropriate for the test in Chapter 2, constructed it as a messenger for the testing equipment,

and examined its current collecting characteristics. Test conditions are as follows.

3.1 Test conditions

3.1.1 Basic composition of catenary and used pantograph

The catenary of the testing equipment was composed to the specification shown in Table 6, which is used for narrow-gauge lines in Tokyo. This system has two PH356mm² messenger wires and a GTM-SN170mm² contact wire.

Table 6 Test conditions

Composition of catenary	Messenger wire	PH730mm ²
	Contact wire	GTM-SN170mm ²
	Messenger wire tension	39.2 kN
	Contact wire tension	14.7 kN
	Span length	50 m
	Distance between two hangers	5 m
Pantograph	System height	1000 mm
	Type	PS26
	Static upward force	53.9 kN
Speed	80, 100, 120, 140, 150, 160 km/h	

3.1.2 Pantograph damper

We used a PS26 pantograph with a damper currently used for the limited express trains on narrow-gauge lines, and also examined the case where the damper is removed to assume common vehicles.

Figure 6 shows the catenary composition and the measuring points of testing equipment.

Fig. 6 Catenary composition and measuring points of current collection testing equipment

3.2 Test results

The test results are shown in Figs. 7 to 9 when messenger tension is set at the standard value (39.2 kN). In these Figures, the results in the cases with and without pantograph dampers are compared.

3.2.1 Contact loss rate

Figure 7 shows the relation between speed and contact loss rate. In the case where there is a pantograph damper, it is 0.26 % at the speed of about 156 km/h. However, it is substantially less than the standard value of 5 %. In the case where there are no dampers, the contact loss is not generated up to about 150 km/h.

3.2.2 Contact wire strain

Figure 8 shows the relation between speed and con-

Fig. 7 Test results (Contact loss rate)

Fig. 8 Test results (Contact wire strain at support)

Fig. 9 Test results (Contact wire uplift at support)

tact wire strain at support. The allowable stress for oscillating fatigue of copper contact wire is set at 60 MPa based on the results of an experiment, or 500×10^{-6} when converted into strain. Since the strain in this experiment is considered as the difference between the maximum and minimum values, the standard value of contact wire strain is set at 1000×10^{-6} at the full amplitude. As it takes a maximum value at about 150 km/h, the value is 175×10^{-6} at the maximum, which is considerably less than the standard value of contact wire strain.

3.2.3 Contact wire uplift

Figure 9 shows the relation between speed and contact wire uplift at support. As it takes a maximum value of 10.8 mm at about 120 km/h, it is considerably to be

less than the standard value of contact wire uplift at support.

Figures 7 to 9 show the difference in the characteristics when a pantograph damper is used or not, we understand that the contact wire strain in the case where no dampers are used is a little smaller. Regarding other items, the current collecting characteristics are virtually not different from each other irrespective of whether a damper is used or not.

3.3 Conclusion of the test

When a PH730mm² wire is selected and constructed to the standard tension of 39.2 kN as a messenger, the contact loss rate, contact wire strain and contact wire uplift at support satisfy the standard values. We understood that this system can be used up to 160 km/h. Moreover, when the pantograph damper is removed, it turns out that the current collecting characteristics do not change much or there are no problems in running. However, in the actual case where two or more pantographs are used, and the state of catenary is considered to be worse than on this testing equipment, the field running tests need to be performed for final judgment.

4. Conclusion

We performed this research to investigate high-quality feeder messenger wire type overhead contact lines and examined a wire of copper system. We selected a PH730mm² wire and used it as a messenger wire, and examined the current collecting characteristics at the speed up to 160 km/h by using current collection testing equipment. Although this system has a heavy large-diameter wire and may require difficult construction work, no important problems were experienced in the construction of the test equipment. It is required, however, to investigate the problems that will arise in the construction work on actual railway lines in service.

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