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Development of single copper feeder messenger wire for overhead contact lines

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Abstract

Feeder messenger wire type overhead contact lines are drawing attention recently from the viewpoint of laborsaving for maintenance. Those that use two PH356mm^2 messenger wires are introduced in Tokyo, and those that use an SB-TACSR730mm^2 messenger wire are in the Kansai district. Regarding the number of messenger wires, the one-wire system is more advantageous, as it involves a smaller number of parts. As the material for the wire, copper is more advantageous 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 which has only one copper messenger wire.

1 Introduction

Feeder messenger wire type overhead contact lines have a structure to combine the function of feeder with the messenger wire. They are drawing attention recently in Japan from the viewpoint of laborsaving for maintenance. They use two hard-drawn copper stranded conductor PH356mm^2 messenger wires in Tokyo, and an aluminum cable steel reinforced SB-TACSR730mm^2 messenger wire in the Kansai

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district. Regarding the number of messenger wires, the one-wire system is more advantageous as it involves a smaller number of parts, and moreover, copper is more advantageous 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 which has only one copper messenger wire to realize the advantages of the two systems.

In order to determine which lines suit the new contact wire system, we chose a narrow-gauge line in Tokyo as a test site, studied whether electrical and mechanical characteristics of lines fulfill the target value and examined the current collecting characteristics by a simulation program about various types of lines. As a result, it is proved that the use of PH730mm^2 messenger wire is appropriate in the overcrowded sections in Tokyo.

Based on this result, we actually constructed a PH730mm^2 messenger wire and investigated the current collecting characteristics by using current collection testing equipment. Consequently, all of the current collecting characteristics satisfy the standard value at the speed of 160km/h. It is also proved that this wire system can be used for fair operation at the speed up to 160km/h.

2 Examination of the optimum lines

Table 1 lists the lines examined as a candidate of one-messenger wire. We examined the current capacity, voltage drop, tensile strength, minimum hanger length, and current collecting characteristics, to determine the applicability of the one-messenger wire system to these lines.

Table 1: Composition of lines

Line names	Types of lines	Total number of strand	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

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2.1 Current capacity

We examined whether the line temperature becomes below the allowable line temperature on the condition in Table 2. The allowable line temperature is 90 °C in hard drawn copper stranded conductor (PH) and 150°C in thermal-proof hard drawn copper stranded conductor (THDC). Figure 1 shows the line temperature rise when a current of 855A flows for 3600 seconds. The portion of slash marks represents surrounding temperature of 35 °C, and the black portion the temperature rise by the Joule heat. There are no lines of THDC or PH that show temperature rise over the allowable limit value under this condition.

Table 2: Condition 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	855A	Maximum current at A line in Tokyo for 3600 seconds

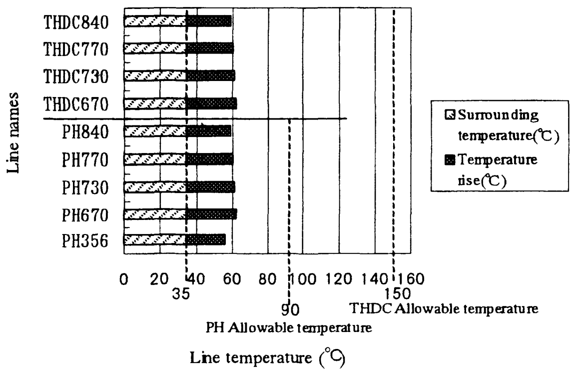

Figure 1: Line temperature rise (at a 855A current)

2.2 Line resistance after temperature rise

We evaluated the resistance of the lines from the viewpoint of whether the temperature rose when a current flows, is below the resistance of two PH356mm^2 messenger wires currently used on the narrow-gauge lines in Tokyo. In Figure 2, the slash in the bar graph shows the resistance after the temperature rise at a 855A current and black lines show the resistance of line temperature at 20 °C. When the resistance of two PH356mm^2 wires with that of test lines at 20°C(black), we

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understand that resistance of THDC670mm^2 and PH670mm^2 is larger than that of two PH356mm^2 wires. Moreover, in the case of the resistance after temperature rise (slash), only the resistance of THDC670mm^2 and PH670mm^2 is larger than that of two PH356mm^2 wires.

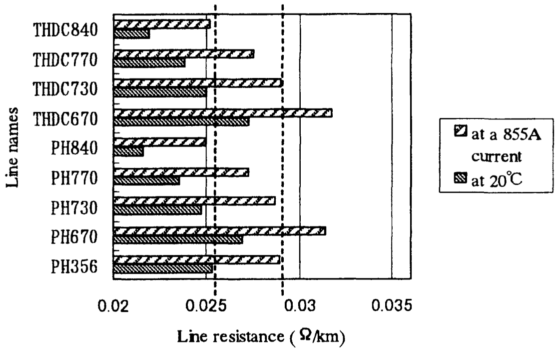

Figure 2: Line resistance (at a 855A current)

2.3 Tensile strength

Since it is assumed that this catenary system be constructed to a standard tension of 39.2kN, it is a condition that the maximum load is set at over 86.24kN, since the safety factor of copper is 2.2 in Japan. In this paper, all the maximum loads of the test lines are over 86.24kN.

2.4 Minimum hanger length

We calculated the minimum hanger length on the assumption that the messenger wire tension is 39.2kN; contact wire tension is 14.7kN, and span length is 50m. When we assume a standard system height equivalent to that of existing feeder messenger wire type overhead contact line in Tokyo, only the minimum hanger length of PH840mm^2 is less than 150mm. If the system height is assumed to be 960mm, the minimum hanger length of PH840mm^2 wire is larger than 150mm.

2.5 Current collecting characteristics

By a simulation program, we calculated the contact loss rate, contact wire uplift at support, and contact wire strain at support, when we apply each lines for test to the messenger wire, and compared the results with the standard values which can realize stable current collection. Simulation conditions are shown in Table 3 and standard values are shown in Table 4. The contact loss rate of the 2nd pantograph

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is shown in Figure 3. As a result of the simulation, contact loss rate of the 1st pantograph was set at 0% in all lines and contact loss rates of the 2nd and 3rd pantographs became several percent at the speed of higher than 180km/h. However, the contact loss rate up to the speed of 160km/h, the practical highest speed of a narrow-gauge line, is 0%. The contact wire uplift at support is shown in Figure 4, and contact wire strain at support is shown in Figure 5. In all lines, either is not over the standard value up to the speed of 200km/h.

Table 3: Conditions of simulation

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

Table 4: Standard value 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 70mm

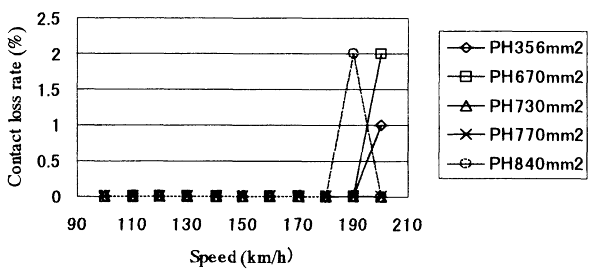

Figure 3: Simulation result (Contact loss rate)

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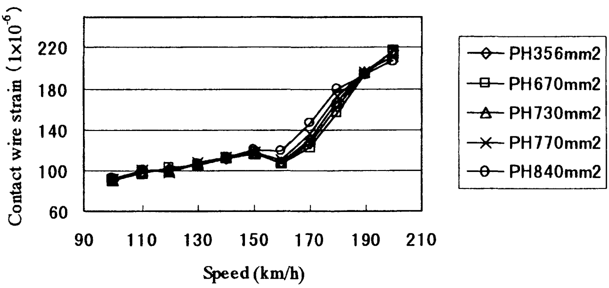

Figure 4: Simulation result (Contact wire strain at support)

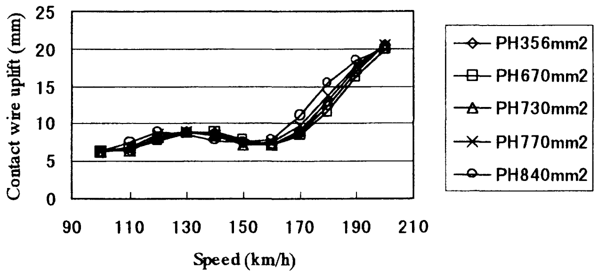

Figure 5: Simulation result (Contact wire strain at support)

2.6 Examination result

Since the tensile strength and current collecting characteristics fulfilled the standard value even if we use any line, we judged the appropriateness of the lines from the electrical properties. Electrical property judging criterion is shown in Table 5. When a current of 855A flows, we marked ○ if the current capacity and resistance fulfill this judgment standard, and × if not, when both conditions are satisfied we marked ○(netted). Consequently, we reached a conclusion that use of PH730mm^2 is appropriate with respected to the 855A current capacity.

Table 5: Electrical property judging criterion

	Judgment	Current capacity	Resistance
PH670mm^2	×	○	×
PH730mm^2	○	○	○
PH770mm^2	○	○	○
PH840mm^2	○	○	○
THDC670mm^2	×	○	×
THDC730mm^2	○	○	○
THDC770mm^2	○	○	○
THDC840mm^2	○	○	○

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3 Test by current collection testing equipment

Current collection testing equipment belonging to Railway Technical Research Institute used for this test has a full length of 500m and can carry out running tests up to the speed of 160km/h, by using a practical trolley wire and pantograph. We chose a PH730mm^2 wire among the lines which became appropriate in the test in Chapter 2, constructed as a messenger wire for the current collection testing equipment, and examined the current collecting characteristics. Test conditions are as follows.

3.1 Test condition

3.1.1 The basic composition of catenary and used pantograph

The catenary composition of the testing equipment was made to the specification shown in Table 6, which is used for narrow-gauge lines in Tokyo. This system has two PH356mm^2 messenger wires and contact wire of GTM-SN170mm^2.

Table 6: Conditions of simulation

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

The composition figure and the measuring point of equipment is shown in Figure 6.

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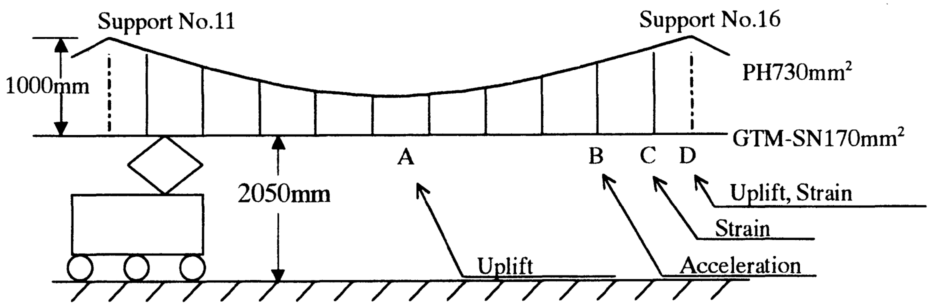

Figure 6: Catenary composition and measuring point of Current collection testing equipment

3.2 Test results

The test results are shown in Figure 7 - Figure 9 when messenger tension is set at the standard value (39.2kN). In addition, ● and ■ marks show the case where there is a pantograph damper and the case where there are no dampers, respectively.

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 (● mark), it is 0.26% at the speed of about 156km. However, it is substantially less than the standard value of 5%. In the case where there are no dampers (■ mark), the contact loss is not generated up to about 150km/h.

3.2.2 Contact wire strain

Figure 8 shows the contact wire strain at support. The allowable stress for oscillating fatigue of copper contact wire is set at 60MPa by the 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 150km/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 10.8mm at about 120km/h, it is considerably less than the standard value of contact wire uplift at support.

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From Figure 7 - Figure 9 that show the difference in the characteristics by the existence of a pantograph damper, we understand that the contact wire strain in the case where no dampers are used is a little small. Regarding other items, the current collecting characteristics are virtually not different irrespective of whether a damper is used.

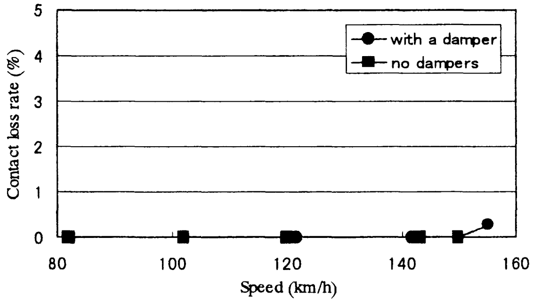

Figure 7: Test result (Contact loss rate)

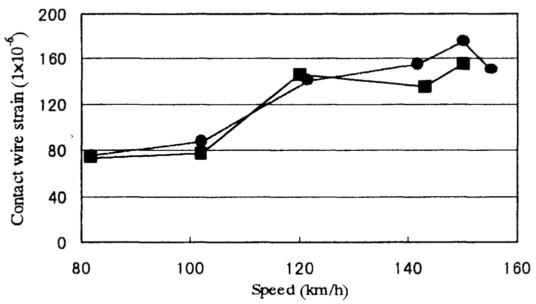

Figure 8: Test result (Contact wire strain at support)

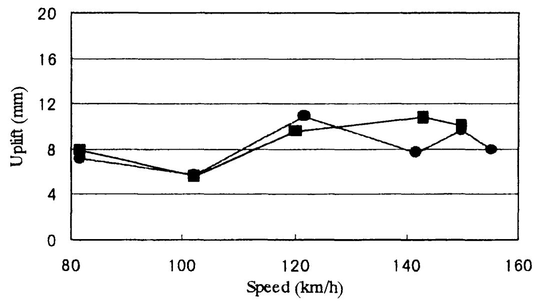

Figure 9: Test result (Contact wire uplift at support)

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3.3 Conclusion of the test

When a PH730mm^2 wire is selected and constructed to the standard tension of 39.2kN as a messenger wire, the contact loss rate, contact wire strain, and contact wire uplift at support satisfy the target value. We understood that this wire system can be used up to 160km/h. Moreover, when the pantograph damper was 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 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 line of copper system. We selected a PH730mm^2 wire used it for a messenger wire, and examined the current collecting characteristics at the speed up to 160km/h by using current collection testing equipment. Although this wire system has a heavy large-diameter line, and may require difficult construction work, no important problems are 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 transportation service.

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