Development of a Sophisticated Double Layer Insulated Electric Wire for Railway Rolling Stocks

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ABSTRACT We have developed a sophisticated double layer insulated electric wire for railway rolling stocks, which has a thin wall and a high mechanical strength. For an electric wire used in railway rolling stocks, thinning of the insulation thickness is required to make the diameter of the electric wire smaller. Even though polyolefin is commonly used as the insulation material of the general-purpose electric wire which is used for domestic railway rolling stocks, if the insulation is simply made thinner, the values of its mechanical strength such as its abrasion resistance and its cut-through property becomes weak, therefore various manipulations are given on the materials. The authors have considered for ensuring the reliability not only of the materials but also of the structures and have developed the sophisticated double layer insulated electric wire which is using a high-strength polyamide for the outer layer. This electric wire has more or equivalent mechanical strength with its half of the insulation thickness when compared to a general-purpose electric wire, and a successfully improved safety. Here, we describe the characteristics of this electric wire.

1. INTRODUCTION

In recent years, many electronic devices, such as air-conditioners, seat heaters and interior monitors, are used in railway rolling stocks; therefore the wiring for connecting to those devices is increasing. However, the wiring spaces in the rolling stocks are restricted and the thinning of the electric wire is required. As an electric wire with smaller diameter, there is a lightweight electric wire which has a thinner wall. Even though the lightweight electric wire is superior because it has half of the wall thickness and also has an improved abrasion resistance compared to a general-purpose electric wire, however, further improvement for its reliability is desired.

This time, we have developed a sophisticated double layer insulated electric wire (double layer insulated electric wire, hereinafter) which has an equivalent wall thickness to the lightweight electric wire domestically used at the moment and also which has more or equivalent mechanical strength to those of the conventional general-purpose electric wire. We introduced the characteristics of this double layer insulated electric wire which has a higher mechanical strength and an improved safety.

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2. DEVELOPMENT CONCEPT

We have adopted the structure of a double layer insulation for a new type of a lightweight electric wire which has a thin wall and a high reliability.

The insulations of the general-purpose electric wires and the lightweight electric wires are only made of polyolefin, however the double layer insulated electric wire has the construction of an insulation using polyamide for the outer layer and polyolefin for the inner layer as shown in Figure 1. By using the high strength of polyamide tape as the outer layer, the mechanical strength of the electric wire is dramatically improved. It uses polyolefin which is superior in an electric property as the inner layer, therefore, even if a notch occurs on the outer layer; its structure can maintain an electric function without a propagation of the notch and also has a high reliability.

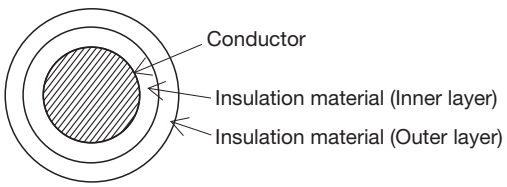

Figure 1 Cross section of the sophisticated double layer insulated electric wire for railway rolling stocks.

Additionally, the material which includes halogen generates toxic flammable gas in a fire and it has the risk of preventing an escape of passengers from railway rolling stocks. Therefore, the present developed wire uses non-halogen material for both its outer and its inner layers.

3. CONSTRUCTION OF THE DOUBLE LAYER INSULATED ELECTRIC WIRE

The materials and the thickness of the insulation of the double layer insulated electric wire are shown in Table 1. Those of a general-purpose electric wire and of a lightweight electric wire are also shown in Table 1 for comparison purposes.

Table 1 Materials and thickness of railway rolling stock cables.

Type	Designation	Insulation material	Insulation thickness
Double layer insulated electric wire	WJF1	Inner layer : Non-halogen flame resistance polyolefin Outer layer : Polyamide	0.4 mm
General-purpose electric wire (for comparison)	L-WL1	Flame resistance cross-linked polyolefin (halogen series)	0.8 mm
Lightweight electric wire (for comparison)	WXPL1	Flame resistance cross-linked polyolefin (halogen series)	0.4 mm

The constructions of the double layer insulated electric wire which has conductor size of 1.25 – 3.5 mm^2 are shown in Table 2.

Table 2 Constructions of the double layer insulated electric wire. (Standard specification)

Conductor			Coating thickness (insulation thickness)	Overall diameter
Nominal cross-section area	Configuration strand number / strand diameter	Outer diameter (reference)		
mm^2	pcs/mm	mm	mm	mm
1.25	50/0.18	1.4	0.4	2.2
2	37/0.26	1.7	0.4	2.5
3.5	45/0.32	2.3	0.4	3.1

4. CHARACTERISTICS OF THE DOUBLE LAYER INSULATED ELECTRIC WIRE

As characteristics of the double layer insulated electric wire, mechanical strength property, thermal property, electric property and combustion property are described in the followings.

The evaluation tests for the state of electric wire have been conducted on the samples of which conductor sizes are all 1.25 mm^2.

4.1 Mechanical Strength Property

4.1.1 Abrasion resistance test

[Test method]

To evaluate the mechanical strength to withstand the friction experienced during the electric wire installation or due to vibration during railway operation, the abrasion resistance test was conducted.

Referenced standard :

JASO D 611-94

12. Abrasion resistance test

(2) Blade running back and forth method

Test condition :

Blade shape : 0.25 mm diameter of spring steel needle

Blade back and forth speed : 60 cycles/min.

Blade load weight : 1500 g

Evaluation criterion : measuring the number of back and forth cycles when the blade and the conductor get into touch each other

[Test results]

The test results are shown in Figure 2.

Compared to a general-purpose electric wire and a lightweight electric wire, the double layer insulated electric wire has the value of one-digit higher or more and it can be confirmed that the resistance against the abrasion is substantially improved.

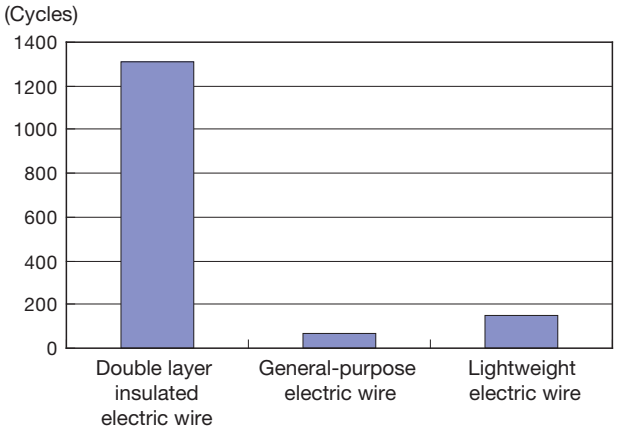

Figure 2 Results of the abrasion resistance tests for rolling stock cables.

4.1.2 Cut through test

[Test method]

To simulate a large load weight will be added locally on the electric wire in a situation such as the electric wire is imposed to an edge of some structures during the electric wire installation, the cut through test was conducted as an evaluation method against such situation.

Referenced standard:

CSA22.2 No. 0.3 4.14 Cutting complied

Test condition :

Blade : metallic 90°sharp edge

Blade falling speed : falling at the speed of 1 mm/min.

Evaluation criterion : measuring the force (kgf) when the blade and the conductor get into touch each other

[Test results]

The test results are shown in Figure 3.

Compared to a general-purpose electric wire and a lightweight electric wire, the double layer insulated electric wire has a higher value and it can be confirmed that it has a substantial resistance against the local load.

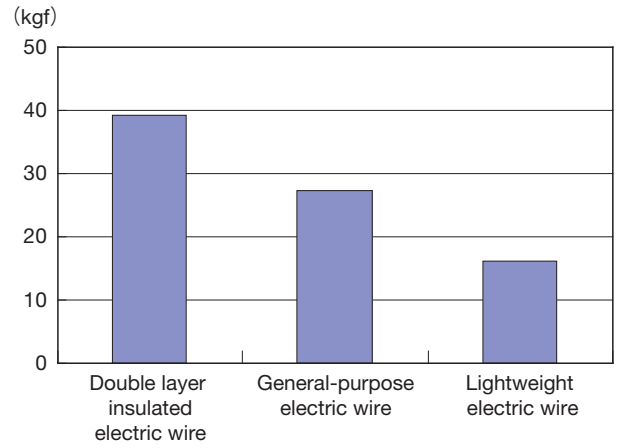

Figure 3 Result of the cutting through for rolling stock cables.

4.1.3 Impact test

[Test method]

To simulate that the electric wire will be received some impact by unexpected falling objects or flying incoming objects, the impact test was conducted. Assuming the temperature during its operation, the test was conducted under three conditions of -15℃, ordinary temperature (25℃) and 80℃. The schematic of the impact test is shown in Figure 4.

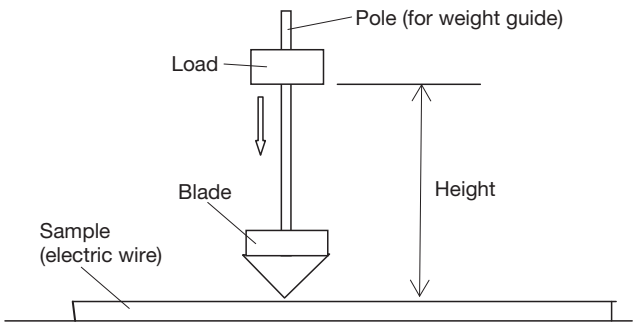

Figure 4 Schematic of the impact test.

Test procedure:

Place the metallic blade which has 90°sharp edge on the sample and drop the load from the specified height. And then, soak the notch part of the sample in water and conduct the withstand voltage test (at 2200 V for 1 minute).

The sample was left out at specified temperature for more than one hour before the test. And then it was taken out and the impact test was immediately conducted.

Test condition :

Temperature conditions : three conditions of -15℃, ordinary temperature (25℃) and 80℃

Blade weight : 85 g

Pole (for weight guide) weight : 150 g (235 g in total)

Load weight : 100- 400 g

Height of the falling load : 30 cm

Evaluation criterion : Soak the samples in water after the impact test and it should pass the withstand voltage test at 2200 V for 1 minute.

Number of the test : twice for each condition.

[Test results]

The test results are shown in Table 3.

It can be confirmed that the double layer insulated electric wire has a resistance higher than the one of the lightweight electric wire and equivalent level to the one of the general-purpose electric wire.

Table 3 Result of the impact test.

Temperature	Load W (g)	Result of the withstand voltage test (at 2200V for 1minuite) after impact tests		
		Double layer insulated electric wire	General-purpose electric wire	Lightweight electric wire
-15℃	100	All passed	All passed	All passed
	200	All passed	All passed	Failed
	400	Failed	Failed	Failed
Ordinary temperature (25℃)	100	All passed	All passed	All passed
	200	All passed	All passed	Failed
	400	Failed	Failed	Failed
80℃	100	All passed	All passed	All passed
	200	Half passed	Failed	Failed

4.2 Thermal Property

4.2.1 Heating deformation test

[Test method]

If load is added on the electric wire and the insulation deforms significantly at the high temperature, it electrical problems may occur. Therefore, the heating deformation test was conducted.

Referenced standard :

JIS C 3005 4.23 heating deformation

Test condition :

Heat the wire at the specified temperature for 30 minutes, and then apply the specified load and heat it for 30 more minutes. Measure the deformation rate of the insulation after heating.

Heating temperature : 120℃

Load weight : 10 N

[Test results]
The test results are shown in Table 4.

The smallest result with the double layer insulated electric wire can be obtained as the rate of the heat deformation at 120℃and it can be also confirmed that the double layer insulated electric wire has a substantial resistance at high temperature.

Table 4 Result of the heating deformation.

Sample	Rate of heat deformation (%)
Double layer insulated electric wire	1.5
General-purpose electric wire	9.0
Lightweight electric wire	9.7

4.2.2 Notch propagation test

[Test method]
If the electric wire gets a notch on its surface, there is the possibility of its notch propagation due to heat or chemicals. After cutting the electric wire, heat it or expose it to chemicals and investigate the presence of the notch propagation.

Test procedure :

After cutting the surface of the electric wire, wind it on a bar which has the specified diameter, (a) heat it or (b) expose it to chemicals and confirm the presence of notch propagation.

Test condition :

(a) Heat test

Winding diameter : equivalent to the electric wire diameter

Initial cut depth : 0.2 mm

Heating temperature : 120℃

Heating period : 1 day, 3 days, 7 days

Confirming for the notch propagation : visual check

(b) Chemical exposing test

Winding diameter : equivalent to twice of the electric wire diameter

Initial cut depth : 0.2 mm

Chemical type : Cable slider (liquid)

Exposing way : Soaking

Exposing temperature : 50℃

Exposing period : 1 day, 3 days, 7 days

Confirming the notch propagation : visual check

[Test results]
The test results are shown in Table 5.

No notch propagation exists at all test conditions and it can be confirmed that the double layer insulated electric wire has a substantial resistance for the notch propagation.

Table 5 Result of the notch propagation test.

	1 day later	3 days later	7 days later
(a) Heat test	No notch propagation	No notch propagation	No notch propagation
(b) Chemical exposing test	No notch propagation	No notch propagation	No notch propagation

4.3 Electric Property (Insulation Resistance)

[Test method]
To confirm the insulation property of the electric wire insulation, the measurement of the insulation resistance on the condition of the wire is conducted.

Referenced standard :

JIS C 3005 4.7 insulation resistance,

4.7.1 insulation resistance at normal temperature

Test condition :

Preparation : Soak in clear water for 1 hour, Temperature 20℃

Measurement voltage : more than or equal to 100 V, measurement equipment high insulation resistance tester

[Test results]
The test results :

2000 MΩ・km or more

The test sample has a sufficient resistance value in water at the insulation resistance measurement, and it can be confirmed that the double layer insulated electric wire has no problem for its use as an electric wire.

4.4 Combustion Property

[Test method]
As an evaluation method of the materials used for railway rolling stocks, there is a combustion test standard of materials for railway rolling stocks.

The test was conducted by this combustion test standard.

[Test results]
The test results are shown in Table 6.

There are no lingering flame and no dust remaining and smoke generated is low. Therefore, the classification becomes “ultrahigh flame resistance” and it can be confirmed that the material has a high safety.

Table 6 Result of the combustion test.

Structure	During alcohol combusting				After alcohol combusting			
	Ignition	Inflaming	Smoke	Intensiveness of fire	Lingering flame	Dust remaining	Charring	Deformation
Double layer insulated electric wire	Exist	Exist	Less	Weak	None	None	Not reach to the top	Deformation exists on the surface
Judgment	Ultrahigh flame resistance							

5. CONCLUSION

It is confirmed that the double layer insulated electric wire which we have developed this time, even though its insulation thickness is thin, retains its mechanical strength, has high resistances for thermal property and for electric property and also has a high safety in its combustion.

We regard that this electric wire can contribute not only to the reduction of the weight but also to improvement of reliability and safety for railway rolling stocks in the future.

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