When a train stops at an insulated overlap of a feeding section in a DC electric railway system, heat due to arcing (electric spark) or due to too large a current flowing between the feeding sections sometimes melts and severs the contact wire that supplies electric power to pantographs. We thus developed TC type insulated overlaps to prevent that. TC type insulated overlaps have a large surface area that brings about high heat radiation and a function of relieving the tension of the contact wire when heat softens and deteriorates the mechanical strength of the contact wire. In tests of the developed TC type insulated overlaps, we confirmed characteristics of high resistance to arcing and sufficient ability to function as components of the overhead contact line system. This article will introduce the developed insulated overlaps and give an overview of the tests.
We therefore conducted development to meet the following conditions, based on use of an aluminum case.

- Application to existing insulated overlaps
- Arc resistance in case a train stops at an insulated overlap
- Satisfaction of wind pressure characteristics, current collection characteristics and other mechanical characteristics as a component of the contact line system

2.2 Basic Study
The size of the aluminum case, an important element of this development, has to meet the following contradicting characteristics.
1) Items where a large size is desirable
   → Arc resistance, tensile strength and other mechanical characteristics
2) Items where a small size is desirable
   → Wind pressure characteristics, current collection characteristics

So, we examined and set targets for cross-sectional shape, cross-sectional height and unit weight of the aluminum sheath in theory. Then, based on the simulation results of the conditions that satisfy the above-mentioned characteristics, we made some prototypes. Finally, we carried out arcing tests in the laboratory, employing a prototype of a structure that is as light as possible while satisfying the required arc resistance.

2.3 Developed Insulated Overlaps
The developed insulated overlaps have a structure where the fixture shown in Fig. 3 can be installed on the cross section of the insulated overlap shown in Fig. 2, and they consist mainly of the following four parts.

(1) Aluminum case
The aluminum case is the most important component in this development. It has a large surface area, and the part that is connected to the contact wire is thick. This allows it to radiate the heat applied to the contact wire due to arcing and relieve the tension of the contact wire when the contact wire becomes soft. Based on examination of the shape of the aluminum case for the following conditions, we adopted the shape shown in Fig. 4.
   1) Shape that has the largest possible surface area and volume to enhance heat radiation in case of arcing
   2) Structure that has the strength to take over the tension of the contact wire in case it softens and durability as an overhead contact line
   3) Structure that is as light as possible to enhance the current collection of the pantograph when passing
   4) Structure that has the smallest possible height and width to enhance the wind pressure characteristic against strong wind
3 Wind Pressure Characteristics

For installation of the aluminum case, the following two points in wind gusts had to be checked.

1. Drag per unit length of the aluminum case to identify the lateral displacement to prevent dewirement of pantographs

We measured in a wind tunnel the wind pressure characteristic of the sample prototype shown in Fig. 9. The measurement conditions are as follows. FD is the drag (horizontal force), and FL is the lift (vertical force).

- Wind speed: 20 m/s, 30 m/s (the same as the train running speed)
- Wind direction: 0°, ±8°, ±16°, ±30°, ±45°

We measured in a wind tunnel the wind pressure characteristic of the sample prototype shown in Fig. 9. The measurement conditions are as follows. FD is the drag (horizontal force), and FL is the lift (vertical force).

\[ F_D = \frac{dF_L}{d\theta} < 0 \quad \text{...(1)} \]

Applying the results of Fig. 10 and Fig. 11 to formula (1), there is no chance of galloping occurring at 20 m/s and 30 m/s wind speed. So, we can say that no unusual vibration of the contact lines occurs at the wind speed of a running train.

When installing the aluminum case, however, the wind pressure load will become larger than with the existing overhead contact line. So, we have to examine in the time of design whether to increase the supports based on the conditions such as measurement result shown in Fig. 10 and the tension of the overhead contact line, type and support intervals of the overhead contact line.

4 Mechanical Characteristics

We carried out mechanical characteristic tests on the developed insulated overlaps to confirm mechanical strength. Table 1 shows the test results, each of which met the specified value. We also tested by severing the contact wire if the tension of the contact wire is transferred to the aluminum case when the contact wire softened as shown in Fig. 7. The transfer of tension of the contact wire is one of the important functions of the developed insulated overlaps. The tension was transferred to the aluminum case as expected, and we discovered no problems with the tensile strength of the aluminum case. We therefore confirmed that the mechanical strength of the developed insulated overlaps met the target.

5 Current Collection Characteristics

Usually, current collection characteristics of the overhead contact line are poor, the lower the total tensile of that contact line is and the heavier it is. Since the developed insulated overlaps need to have an aluminum case and other fixtures installed, the mass of the overlap of the feeding sections is larger. Thus, the current collection characteristics of the pantograph when passing may become poor.

So, we checked the current collection characteristics of simple catenary equipment using the current collection equipment of the Railway Technical Research Institute (RTRI). The equipment was chosen because the simple catenary equipment has the smallest total tension of the overhead contact line and the effect of installing...
the developed insulated overlaps is expected to be large. Fig. 12 illustrates the measured overhead contact line and Fig. 13 shows the test.

In the current collection characteristics test, we had to evaluate the following items.

1) Contact wire uplift at supports
   Checked the possibility of overlifting that damages the overhead contact line

2) Strain of the contact wire and the aluminum case
   Checked possibility of overstress of the contact wire and the aluminum case that leads to fatigue breakdown from vibration by passing pantographs.

3) Maximum contact loss time
   Checked possibility of overly long contact loss that causes power failure in the train.

Fig. 14 shows the measurement results of contact wire uplift at the supports. The results show that the maximum lift up was 48 mm, much lower than the allowable value of 70 mm.

Fig. 15 shows the measurement results of strain of the contact wire at the support points. The result shows that the maximum strain was 339 X 10^-6, much lower than the allowable value of 500 X 10^-6.

Fig. 16 shows the measurement results of contact wire uplift at supports. The results show that the maximum uplift was 48 mm, much lower than the allowable value of 70 mm.

Fig. 17 shows the measurement results of strain of the contact wire at the support points. The result shows that the maximum strain was 339 X 10^-6, much lower than the allowable value of 500 X 10^-6.

There was concern that overly large strain would occur at the ends of the TC type insulated overlaps where the linear density radically changed. However, the results showed that the maximum value was lower than 200 X 10^-6. This could be because the stress relaxation fitting limited such large stress.

The maximum actual strain of the aluminum case measured was -117 X 10^-6, which was much lower than the allowable value of 1,817 X 10^-6 that we calculated from the 129 N/mm² fatigue strength of the aluminum alloy.

We further measured the maximum contact loss time. If installation of the developed insulated overlaps causes overly long contact loss, that might lead to power failure in the train at the usual running speed. The test results show that the longest contact loss at 120 km/h or less—actual running speed with the simple catenary equipment—was 15 ms. That is lower than the allowable time of 20 ms with SIV (Static Inverter) auxiliary machine. At 150 km/h or less, the maximum contact loss time was 44 ms, which is lower than the allowable time of 200 ms when the auxiliary machine is a motor generator. Hence, we can say that the developed insulated overlaps have no problem in terms of maximum contact loss time.

We carried out arc tests of the developed insulated overlaps, in the same conditions of trains being stopped and running under power at insulated overlaps of feeding sections. In the test, no severing of the contact wire from melting occurred, confirming high arc resistance characteristics.

Then, we installed the developed insulated overlaps to the insulated overlap locations of feeding sections and carried out arc tests using an actual vehicle. In the tests, we simulated as follows a train stopping and then running at the insulated overlaps.

1) Setting of potential difference at the insulated overlap locations
   We set the potential difference between different power supplies at 150V, which is around the maximum potential difference actually measured at insulated overlaps

2) Train stopped at the insulated overlap
   We stopped a vehicle at the insulated overlap to cause insufficient contact between the contact wire of the side with higher potential and the contact strip, making continuous arcing occur. Then we applied for five minutes 100A current equivalent to the auxiliary machine.
3) Running under power from the insulated overlap

After stopping for five minutes, we started the vehicle at the insulated overlap and applied when starting approx. 300A arc current equivalent to that at powered running.

Fig. 16 shows arcing in the test and the Fig. 17 shows the measurement results of the temperature increase at the contact wire and the aluminum case. The highest temperature at the contact wire in this test was 273°C and that of the aluminum case, 257°C, much lower than the 500°C at which the contact wire melts and is severed. And we found no affects such as softening of the contact wire from arcing, even after running. Thus, we could confirm that the developed insulated overlaps have high arc resistance.

As we confirmed that the developed insulated overlaps have good arc resistance characteristics and function as a components of the overhead contact line, we installed the developed insulated overlaps to the insulated overlap locations between Tachikawa and Nishi-Tachikawa on the Ome line and between Saitama-Shintoshin and Omiya on the Tohoku main line to carry out field tests.

We have observed good results so far. Fig. 18 shows the installed insulated overlaps between Tachikawa and Nishi-Tachikawa on the Ome line.

As explained, we developed TC type insulated overlaps that have high arc resistance characteristics for insulated overlaps. The insulated overlap functions and the findings in the tests are as follows.

1) The aluminum case, a major component, can radiate the heat from arcing and take over the tension of the contact wire if the contact wire softens.

2) There is no possibility of galloping and other unusual vibration at the wind speed of 30 m/s or less when a train is running.

3) The mechanical strength test results show that the developed insulated overlaps have sufficient mechanical strength as components of the overhead contact line.

4) The measurement results of uplift and strain of the contact wire, deformation of the aluminum sheath and maximum contact loss time showed that the developed insulated overlaps have no problems in terms of current collection performance in simple catenary equipment.

5) The arc tests using an actual vehicle proved high arc resistance characteristics of the developed insulated overlaps. These results proved that the developed insulated overlaps have no problems in actual use for the overhead contact line. We are therefore carrying out field tests on the Ome and Tohoku main lines for further checks.

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