Study on Damage Detecting System for Pantograph using Optical Fiber

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Abstract:
It is important to detect the damage of pantographs especially those installed with carbon sliders in service. A new detecting system using optical fibers has been studied. The method to detect the breakdown of plastic optical fibers provides a low cost system. Therefore, a detecting device and a new type insulator with optical fibers were manufactured and tested.
Optical fibers made of plastics, which have 250 degree Centigrade heat characteristics, go up from the detecting device in the car to the pantograph head, and comes down from the head to the detecting device. There are several joints of the optical fibers, which are easily fastened.
An insulator, in which optical fibers are molded, is installed on the roof of the car. It is on the optical fiber route and insulate the potential between the pantograph and the car roof.

The system has been tested in laboratories and on Shinkansen commercial lines using a test car. The results show that the system is convenient for practical use. It was confirmed from field tests that the heat characteristic of the optical fibers is sufficient for practical use.

Key words: Detecting system, pantograph, damage, optical fiber, insulator.

1. Introduction
It is important to detect the damage of pantographs especially those installed with carbon sliders in service. So there are several methods to detect the damage. A new detecting system using optical fibers has been studied. The method to detect the breakdown of the optical fibers made of plastics provides a low cost system. Therefore, a detecting device and a new type insulator with optical fibers were manufactured and tested.

2. Method to detect the damage of pantograph
There are several methods to detect the damage of pantograph. One is to use acceleration sensor on the pantograph head, but it needs a power source on the pantograph side. Another is to detect air pressure decreases, which is now used in Europe. This method is good in terms of electrical insulation, but it needs a specially designed pantograph.

Therefore we have developed a method to detect wear-down or breakdown of optical fiber. This method can be adopted for several pantographs of different designs, and features good electrical insulation and low installation costs.

3. Composition of the detecting system
3.1 System composition
The whole system is shown in Fig.1. An optical fiber, made of plastics, goes from the detecting device in the cabin to the pantograph head and returns to the device. If the fiber wears at the pantograph head, power of the receiving light will become lower.

The fiber has several joints consisting of easy-fastening connectors for the convenience of installation and maintenance of pantograph head. The fibers for connection are covered with tubes made of fluoro resin.
3.2 Optical fiber

The materials and characteristics of the optical fiber are shown in Table 1\(^6\). The fiber has high temperature heat-resistant characteristics. As the plastic fiber has a large core diameter, it can be jointed easily by using BNC type mechanical connectors. The minimum bent radius of the fiber is 10 mm.

The lengths of connecting fibers are shown in Table 2.

<table>
<thead>
<tr>
<th>Table 1. Characteristics of optical fiber(^6)</th>
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<tbody>
<tr>
<td><strong>Items</strong></td>
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<td>Materials &amp; sizes</td>
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<td></td>
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<tr>
<td>Transmission loss</td>
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<tr>
<td>Limiting hottest temperature</td>
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<tr>
<td>Long-time heat resistance</td>
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<tr>
<td>Maximum load</td>
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<td>Bending radius</td>
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<th>Table 2. Lengths of connecting fibers</th>
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<tr>
<td><strong>Connecting section</strong></td>
</tr>
<tr>
<td>Detector _ insulator</td>
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<tr>
<td>Insulator _ pantograph</td>
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</tbody>
</table>

3.3 Pantograph head

The optical fiber is installed on the pantograph head using holders made of resin. Its composition and cross section of the pantograph head are shown in Figs. 2 and 3.
3.4 Insulator with optical fibers
A low-cost polymer insulator in which optical fibers are installed has been developed. The shape and its cross section are shown in Fig. 4. It has been tested in a laboratory, and an exposure test has been performed successfully. The test results are shown in Table 3.

The polymer insulator with built-in optical fibers features a low cost and sufficient mechanical and electrical characteristics for use at 30 kV.

3.5 Detecting device
The detecting device has a LED to supply 670 nm light into the optical fiber\(^7\), a photo detector to receive the return light, and a alarm buzzer which works when the return light goes out.
<table>
<thead>
<tr>
<th>Items</th>
<th>Measured value</th>
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<tbody>
<tr>
<td>Power-frequency withstand voltage</td>
<td>&gt; 200 kV</td>
</tr>
<tr>
<td>Lightning impulse insulation level</td>
<td>&gt; 300 kV</td>
</tr>
<tr>
<td>Insulation resistance after 5-month exposure</td>
<td>200 M Ohm</td>
</tr>
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</table>

4. Laboratory tests

4.1 Power level of the light through the fiber

The power levels of the light at several points in the system were measured by using a power meter. The measured values are shown in Fig. 5. The power drop, which depends on the fiber length, occurs mainly in the connecting fibers. The power drops at joints are negligibly small.

The return light level is 8 nW, and the lowest level for detection is 1 nW. Therefore, when the total length of connecting fibers is less than 32 m, the system works well.

Fig. 5. Power level of the light at each point.

4.2 Wear tests

Wear tests for a pantograph head were carried out on the AC 400A current collecting condition. Because of the temperature rise of the slider, the power level of the light at the receiving point becomes slightly lower, but the drop level is not so large for practical use.

4.3 Insulator exposure test

An exposure test for the insulator with optical fibers was carried out for five months near the seaside. After exposure, the insulation level was measured and confirmed that the characteristics of insulation had not decreased as shown in Table 3.

5. Field tests

5.1 Test conditions

For the purpose of confirming the durability of the system, field tests were performed on Shinkansen lines. The system was installed on a test car for a current collection pantograph. It ran about 1900 km in the daytime while monitoring the receiving light level. Fig. 6 shows the composition of the field test.
Fig. 6. Set-up of the system for field test.

Fig. 7. Outlook of the test pantograph.

Fig. 8. Set-up of the insulator for field test.
5.2 Results of the field test

In the field test, the level of receiving light was about 22 nW, which did not change in tunnels or open areas. Fig. 7 shows the test pantograph, and Fig. 8 the insulator installed at the end of the car. After the test running, the system still worked well.

6. Conclusions

(1) A low cost pantograph damage detecting system can be constituted by using optical fibers made of plastics.
(2) An optical fiber which has 150 degree Centigrade long-time heat resistance characteristics is usable on the side of the pantograph head.
(3) A polymer insulator with built-in optical fibers features a low cost and has sufficient mechanical and electrical characteristics.

Acknowledgement

The field test was carried out on JR-East company Shinkansen lines. The authors thank the members of the company who cooperated to the test. The pantograph heads for the test were manufactured by Toyo Electric MFG. The authors also thank the design team in the company.

References

6) Hitachi Cable Co. : Technical report of optical fibers, TD23-1538, 1992
7) Omron Co.: Manual of Electric Switch E3S-X3CE4