# Interpretive article

# Research and Development toward Wear Reduction of Current Collecting System


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One of major R&D subjects regarding current collecting for EMUs and locomotives is extending the lifespan of both contact lines and pantographs by reducing wear. Here I will explain two approaches to these subjects for pantographs. The first is decreasing the rate of arcing by improving compliance characteristics through modification of pantograph heads and springs. The second is developing new materials for contact strips themselves to achieve both improvement of wear resistance and reduction of impacts on the contact wire by contact strips. Studies of those approaches for optimization are in progress, and have been showing success so far.


## 1 Introduction

The method by which current is collected from overhead contact lines over the tracks via pantographs is widely used to supply power to EMUs and electric locomotives.

Pantographs were first installed to trains in operation in Japan in 1914. Then, in 1922, the former Japanese National Railways completed the installation of pantographs to all electric locomotives and EMUs. Thus, pantographs have been playing the main role in current collection for rolling stock in Japan for nearly a century.

The most important function required of pantographs is to collect the required current efficiently to vehicles when needed. To do that, pantographs need to have conductivity and capacity appropriate to their usage. These functions also should be maintained even in high speed running.

Factors that determine the current collectivity of pantographs are largely classified into two factors: dynamic performance of the pantograph and wear resistance between the contact strip and the contact wire.

Pantographs absolutely must follow the vertical deviation of the contact wire even in high speed running without fail. Contact strips are installed to the top of a pantograph that contacts the contact wire, (Fig. 1). If a pantograph cannot follow the contact wire and contact strips lose contact to the wire while large current is flowing, arcs are generated or current collection worsens. Such a situation is called contact loss. Arcs caused by contact loss increase wear of contact strips and contact wire; and in worse case scenarios, they break both.

If contact wire or contact strips wear easily or cause wear on each other, that results in shorter lifespan and increase in maintenance expenses.

Based on these factors, the Technical Center is carrying out R&D projects with an aim of extending lifespan of both of contact wires and contact strips by decreasing wear of those. Here I will explain two of these projects from the perspective of rolling stock: developing a new pantograph and contact strips. One project is the development of a pantograph with high-compliance applying carbon fiber reinforced carbon composite (C/C composite) and the other is the development of contact strips of rice bran ceramic (RBC).

## 2 Development of High-Compliance Pantographs Applying C/C Composite

### 2.1 Overview

Fig. 1 shows an illustrative view of a single arm pantograph that is widely used for rolling stock for conventional lines.

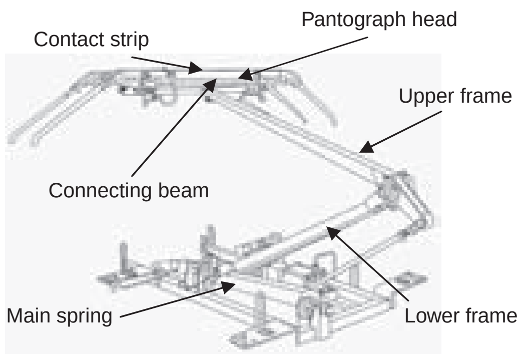



Fig. 1 Structure of Single Arm Pantograph

In order to improve the compliance of pantographs to contact wires to reduce arcing caused by contact loss, we studied design of a pantograph based on the single arm pantograph but that uses other types of heads and springs.

### 2.2 Examination for Improving Compliance of Pantographs

We worked to develop a pantograph with higher compliance characteristics by changing just the heads, connecting beams and supporting springs of PS33B pantographs that are used for E231 series trains, of which many run in the Tokyo area. For that purpose, we made a prototype pantograph for bench tests on which we could change parameters shown in Fig. 2, and we checked the optimal combination of those parameters. After choosing some combinations of parameters through simulations, we installed components and other devices that suited those combinations to the prototype and made measurements of compliance amplitude and contact loss rates[1] with that prototype. A parameter combination where quite high compliance to the contact wire in use could be expected was set through cutting the weight of pantograph heads and choosing lower spring constants of bellow springs and supporting springs; and we made a prototype pantograph which had that combination and could be installed to an actual train.

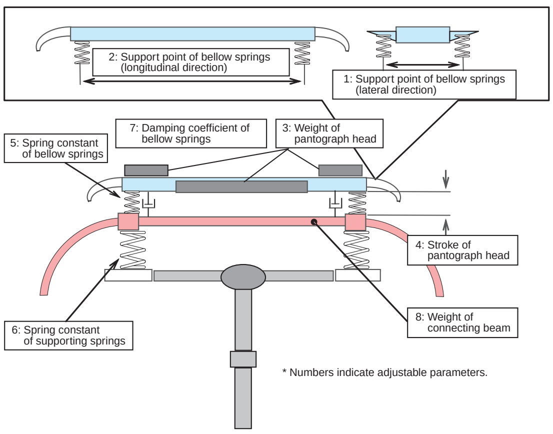



Fig. 2 Overview of the Bench Test Prototype Pantograph

### 2.3 Test Using an Actual Train

Here we call the second prototype as a "modified PS33B". We installed a modified PS33B and a present PS33B to a train set of 115 series cars and measured contact loss rate and contact force of those in test runs between Koganei station and Ueno station on the Tohoku line (Fig. 3).

The test results proved that the contact loss rate of the modified version was much improved compared to the present version and that the fluctuation range of the contact force of the modified was decreased while the average contact force was maintained. That means significant improvement of the compliance characteristics of the modified PS33B (Fig. 4, Fig. 5).

Fig. 3 Installed Pantograph and Measuring Device

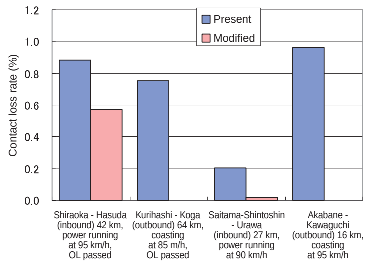



Fig. 4 Results of Optical Measurement of Contact Loss Rate (10-span length, approx. 500 m)

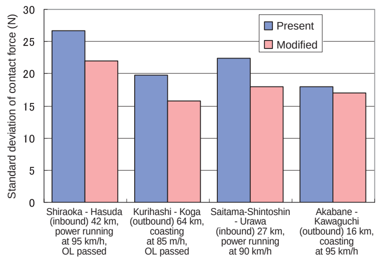



Fig. 5 Calculated Standard Deviation of Contact Force (10-span length, approx. 500 m)

### 2.4 Use of C/C Composite

The results of the tests using an actual train confirmed that a pantograph of higher compliance characteristics could be achieved by simply improving the PS33B's pantograph heads, connecting beam and the springs related to those. But, in this test, we used extremely thin contact strips to meet the weight parameters of the pantograph head. However, no matter how high the achieved compliance characteristics were, those would greatly shorten the replacement period of contact strips compared to the present and result in a large increase of maintenance work. Consequently, we cannot expect full-scale introduction of that modified version until the appropriate contact strips are developed.

Meanwhile, we acquired information about contact strips of C/C composite. C/C composite contact strips, mainly of carbon fiber, once had a weakness of low wear resistance, but recent information says that has been improved. C/C composite contact strips are light and can be directly screwed to the pantograph head without sheathing that is a fastening method used for present carbon contact strips (Fig. 6, Fig. 7). So, with an aim of using C/C composite contact strips for high compliance pantographs, we installed C/C composite contact strips to two train sets of 209-500 series cars operated on the Keihin-Tohoku line to compare the wear resistance with that of present PC78 contact strips.

As shown in Table 1, the test results confirmed that the wearing depth of the test contact strips was less than that of the present ones, in contrast to the expected increase in wear. The condition of the sliding surface of the test samples was also better as shown in Fig. 8.

1) The rate of the total contact loss time to the measurement time

Since we confirmed that the current C/C composite contact strips have higher wear resistance than present contact strips, we are planning to proceed with the development of high-compliance pantographs by utilizing the excellent characteristics of the C/C composite contact strips for practical use.

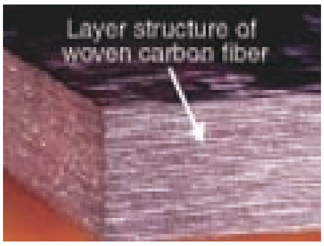



Fig. 6 Structure of C/C composite

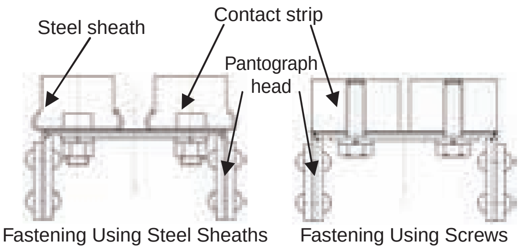



Fig. 7 Cross-Sectional View of Contact Strip

Table 1 Average Wearing Depth per 10,000 km of Operation

| | No. 81 train set | No. 84 train set |
|---|---|---|
| Present contact strip (PC78) | 0.93 mm | 1.17 mm |
| Test sample (C/C composite) | 0.86 mm | 0.97 mm |
| Wear rate of test sample compared to the present strip | 92.5% | 82.9% |
| Test running distance | 65,380 km | 57,390 km |

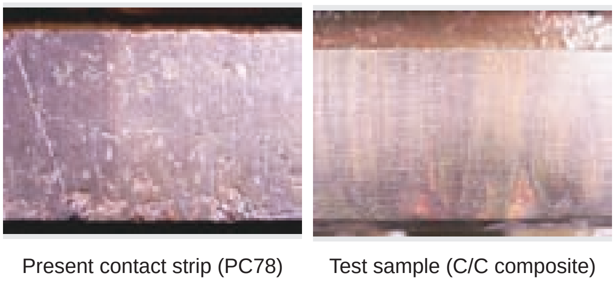



Fig. 8 Surface Condition of Contact Strips

## 3 Development of RBC Contact Strips

### 3.1 Overview

Rice Bran Ceramics, or RBC, is a new hard cellular carbon material that has recently been made from oil-pressed rice bran. It is widely used as new material with favorable characteristics such as low density, high hardness, low friction and high wear resistance. It also shows promise in that it does not create major damage to the environment from its production through use and disposal.

Furthermore, RBC powder (Fig. 9) can be compounded with other materials to develop new materials. RBC composites with resin or other ceramics have already been employed for various industrial products.

These characteristics of RBC can also be effective as the material of pantograph contact strips that require high wear resistance and low impact with the contact wire. So, we are carrying out a study to develop the ideal contact strip by mixing RBC powder to the material of carbon contact strips widely used on conventional lines as the base material. As the basic research, we have made some material samples for contact strips and conducted performance evaluation of those as the current collecting material. An overview will be given below.

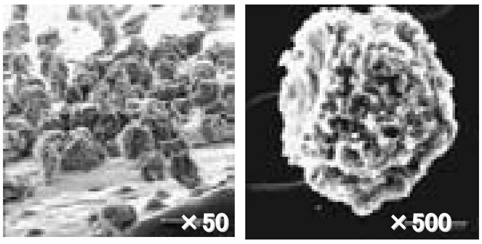



Fig. 9. RBC Powder

### 3.2 Testing and Results

There are mainly two methods of production of carbon contact strips; metal impregnation and mixed sintering. This time we selected mixed sintering to blend RBC powder, as that method allows more even blending.

We made as the base material mix-sintered carbon material of PC58 contact strips that are presently used, and we blended each material under conditions where the weight fraction of each material is Cu 60% + Carbon 40 to 0% + RBC 0 to 40% to produce test samples. In those tests, we used four types of RBC powder with average particle diameters of 150μm, 83μm, 30μm and 5μm to compare the characteristics by particle diameter differences. The following paragraphs will explain the test methods and results.

(1) Material Characteristics Test

We carried out measurement of bending strength and electric resistance of each test sample produced. Fig. 10 and 11 indicate the results. The more RBC was blended, the more bending strength tended to decrease and electric resistance tended to increase. And the smaller the particle diameter of RBC was, the more bending strength tended to increase and electric resistance tended to decrease. As a result, we found that the development targets of 100 MPa or higher bending strength and 3 mΩ • m or lower electric resistance could be achieved by blending RBC of 5 – 30μm particle diameter at approx. 5%.

(2) Mechanical Wear Resistance Test

Using a pin-on-disc type sliding friction tester shown in Fig. 12, we measured the friction performance under dry conditions.

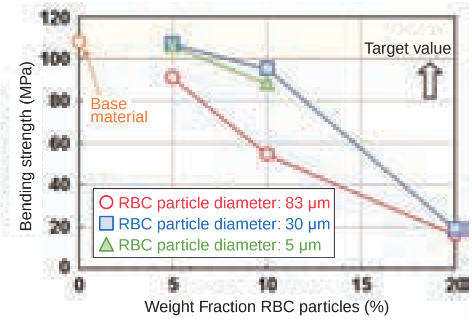



Fig. 10 Measurement Results of Bending Strength

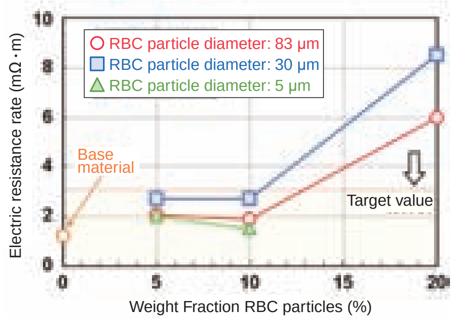



Fig. 11 Measurement Results of Electric Resistance

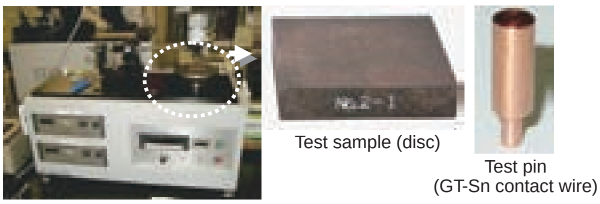



Fig. 12 Pin-on-Disc Type Sliding Friction Tester

Fig. 13 illustrates the relation between comparative wear[2)] of test samples and sliding speed in the test. As shown in this figure, appropriate blending of RBC of smaller particle diameter can significantly reduce the comparative wear of the test samples compared to that of the base material. Since this tester cannot operate fast, we set a high contact force to achieve wearing as close as possible to that of actual running.

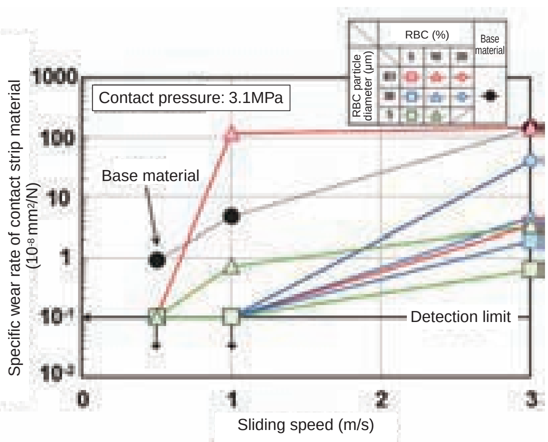
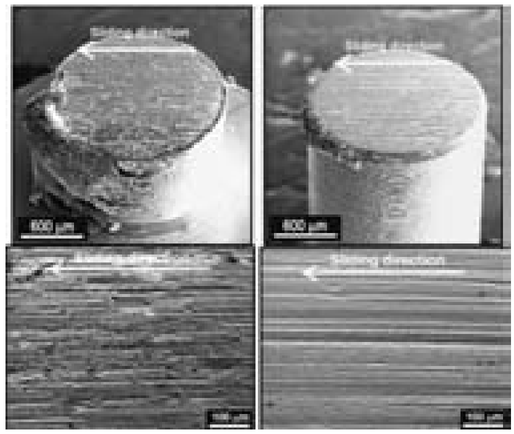



Fig. 13 Relation Between Sliding Speed and Comparative Wear

Fig. 14 shows the surfaces of the opposing material (contact wire material) that were observed with a scanning electron microscope after testing. The surface of the opposing material of the base material is rough with linear scarring by plastic flow of copper, while the surface of the opposing material of the RBC-blended material is smooth with little linear scar.



(a) Against base material (b) Against RBC contact strip material

Fig. 14 Wear of Opposing Material (Contact Wire Material)

(3) Current Wear Test

We carried out constant-speed wearing tests with 100A current on the test sample that showed good results in the mechanical wearing test, using the current collecting material wearing tester shown in Fig. 15. That test is to check the condition under stable current collection. We set 0.39 MPa as the contact pressure of the test sample, which is nearly equal to the standard static upward force of the pantograph against the contact wire.

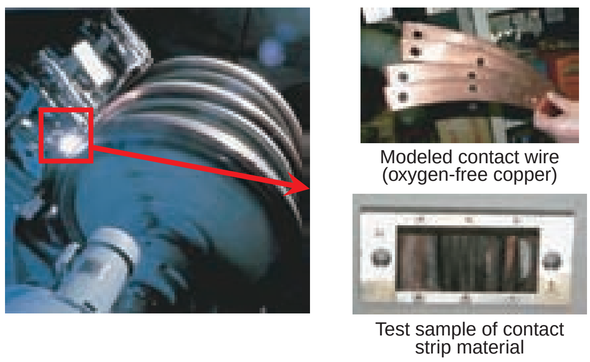



Fig. 15 Current Collecting Material Wear Tester

Fig. 16 and 17 indicate the results. At 27.8 m/s sliding speed (100 km/h), wear of the test sample blended with RBC was reduced by 98% compared to that of the base material. Wear of the opposing contact wire material also showed 23% reduction.

2) Worn volume per unit of weight and per unit of sliding distance

### 3.3 Current Approaches

As mentioned above, we were able to achieve good results in material-level basic tests. Now we are carrying out different bench tests by installing full-size prototype contact strips to pantographs.

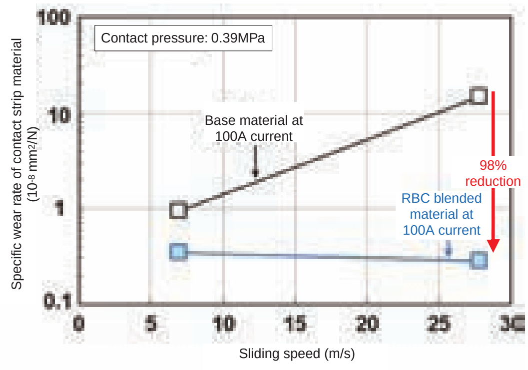



Fig. 16 Specific Wear Rate of Contact Strip Test Sample

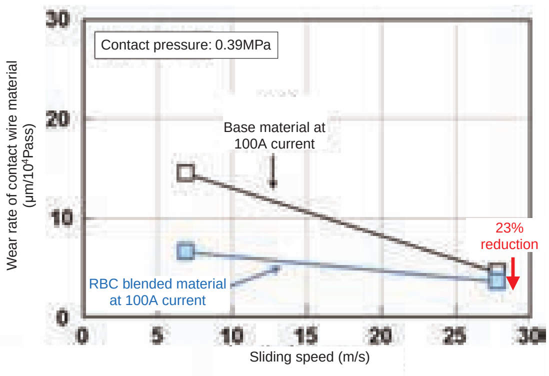



Fig. 17 Wear Rate of Opposing Contact Wire Material

## 4 Conclusion

Application of high-compliance pantographs and contact strips with high wear resistance and low impact against contact wires will be meaningful in reduction of environmental burden such as reduction of volume of materials used and energy in production, in addition to reducing railway business costs. Such technical development to achieve both cost reduction and reduction of environmental burden will no doubt increase in importance in all sectors of society in addition to current collection of electric railways.

At the Technical Center of JR-East, we will continue to always consider the technical contributions we can play, including for such issues, while proceeding with further research and development.

**Reference:**

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2) Hiroshi Tsuchiya (Railway Technical Research Institute): Wear Properties of C/C Composite Contact Strips, Solid Lubrication Symposium Lecture Drafts pp. 103 – 107, Solid Lubricants (The 2nd category), Japanese Society of Tribologists