Snow that accumulates on side and end covers of bogies can damage wayside signal equipment and train cars as it falls from Shinkansen trains running at high speed. Therefore, a thermal heater system for bogie end covers was developed to prevent snow accumulation. These newly developed heater systems are currently being used on series E6 trains running at the maximum commercial speed of 320 km/h. However, the heater system cannot completely prevent snow accumulation on bogie end covers. Therefore, we redesigned the cover.

Keywords: Shinkansen rolling stock, Accumulated snow, Heater system, Bogie end cover

1 Introduction

In winter, there incidents occur where blocks of snow built up on bogie end or side covers of Shinkansen cars fall off from trains running at high speed and damage wayside signal equipment and the car body. In order to prevent those incidents, JR East manually knocks off the snow from rolling stock; however, this may cause operation delays and large costs.

With an aim of preventing damage from snow blocks falling from trains and operation delays, we have carried out research and development and verification using test trains and trains in commercial operation. As a result, we have been able to develop a heater system that can be attached to bogie end covers, the location where snow builds up the most. It was confirmed that the heater system was superior to other systems in terms of snow melting performance, cost, durability, and the like. The heater system is currently installed on the bogie end covers of all of series E6 mass-production trainsets, which run at 320 km/h.

However, in heavy snowfall, snow still accumulates on bogie end covers and around bogies, so the manual work of knocking off snow is still needed.

In light of that, we conceived in this development work the composition of a new bogie end cover using the heater system for series E6 mass-production trains in order to achieve higher snow melting performance.

2 Development of a New Bogie End Cover

2.1 Snow Accumulation on Series E6 Bogie End Covers

Due to the structure of the bogie end cover (hereinafter, the “end cover”) attached to series E6 mass-production cars, snow is easily melted at the center of the end cover where the heater is located by raising temperature. However, the heater cannot be attached on the cover periphery where there are bolt holes and the like, and thus temperature cannot rise high enough. Accumulation of snow therefore exceeds the snow melting performance of the heater system in heavy snowfall. Snow is assumed to build up from the periphery where the temperature does not rise sufficiently and eventually cover the whole surface of the end cover. Fig. 1 shows the position of the end cover in the bogie, Fig. 2 shows the composition of the end cover for series E6 cars, and Fig. 3 shows actual snow accumulation on the end cover.

2.2 Issue with Bogie End Cover for Series E6 Cars

As the heater melts only the center part of the snow accumulated over the entire end cover, a gap is generated between the end cover and the snow. We call this a snow mold. Since the appearance of the snow mold is almost the same as that of the
2.4.2 Bogie End Cover with Improved Heat Conduction
Using the end cover for series E6 cars as done with Type A, heat-conductive grease was applied to part of the heater to more effectively convey the heat to the surface of the end cover (hereinafter “Type B”). Fig. 7 shows the part to which grease was applied.

2.4.3 Integrated Aluminum Alloy Bogie End Cover
The surface plate of the end cover for series E6 cars (SUS304) and the casing (foam + FRP) were changed to an integrated component of aluminum alloy to enable the temperature of the whole end cover (hereinafter “Type C”) to rise easily. In order to achieve this structure, we made fins oriented from the top surface plate of the end cover to the rear surface, including the peripheral area, and attached heaters between those fins. Furthermore, the surface plate of Type C was made flat to more efficiently raise temperature (by reducing its surface area), while the surface plate of the end cover for series E6 cars was corrugated to ensure strength against impact from flying objects. Fig. 8 shows the internal structure and appearance of Type C.
2.5 Results of Stationary Performance Tests

Using the aforementioned three types of prototype end covers and an end cover for series E6 cars, we measured and compared temperature change at the surface of those end covers in a low temperature laboratory. Table 1 shows the test conditions and items tested.

Table 1  Conditions and Items of Stationary Test

<table>
<thead>
<tr>
<th>Condition</th>
<th>Low temperature laboratory: -20 ºC</th>
</tr>
</thead>
</table>
| Method           | - Heater turned on after end cover surface temperature lowered to around -20 ºC  
|                  | - Test duration: Approx. one hour after heater turned on  
| Tested Items     | Record change in end cover surface temperature for one hour from heater being turned on |

Temperature was measured at the periphery where temperature could not rise high enough and at the center where temperature became the highest with the current end cover for series E6 cars. To do that, we attached thermocouples to each end cover. Fig. 9 shows the positions of the thermocouples.

Fig. 9 Positions for Measurement of End Cover Surface Temperature

Fig. 10 to 13 show the results of temperature measurement with prototype end covers, and Table 2 lists the results. The measurements confirmed that the Type C end cover could better raise temperature at its periphery than the current and other prototype end covers.

Table 2  Summary of Measurement Results of End Cover Surface Temperature

<table>
<thead>
<tr>
<th></th>
<th>Maximum temperature [ ºC ]</th>
<th>Peripheral temperature [ ºC ]</th>
<th>Average temperature [ ºC ]</th>
</tr>
</thead>
<tbody>
<tr>
<td>End cover for series E6 cars</td>
<td>11.3</td>
<td>-12 – 1</td>
<td>2.9</td>
</tr>
<tr>
<td>Type A</td>
<td>17.2</td>
<td>-1 – 12</td>
<td>9.8</td>
</tr>
<tr>
<td>Type B</td>
<td>13.0</td>
<td>-12 – 4</td>
<td>4.6</td>
</tr>
<tr>
<td>Type C</td>
<td>28.5</td>
<td>13 – 28</td>
<td>22.2</td>
</tr>
</tbody>
</table>

Fig. 10 Measurement Results for Current End Cover for Series E6 Cars

Fig. 11 Measurement Results for Type A (heaters added)

Fig. 12 Measurement Results for Type B (grease applied)

Fig. 13 Measurement Results for Type C (integrated, of aluminum alloy)
2.6 Results of Running Tests Using Active Duty Cars

Based on the stationary test results, we made four sets of the Type C end covers, which showed better performance, and carried out performance evaluation in actual operation conditions. The Type C end covers were installed at the front of the first axle of car No. 17 and at the rear of the fourth axle of car No. 16, both cars near the front of the train where a relatively large amount of snow accumulates. Two sets each were attached on both sides of two of three end covers in each location (the remaining end covers were equipped with the original type used for series E6 cars). Fig. 14 shows the locations where bogies covers are installed and Table 3 outlines the running test.

At Shizukuishi Station, the turnaround point in the running tests, and at Akita Rolling Stock Center after the test, we visually checked snow accumulation on the end covers. Little snow accumulation was found on the Type C end covers, including at the periphery, while snow was built up over the entire surface end covers for series E6 cars. Thus, we could conclude that performance was improved over that of the end cover for series E6 cars. Fig. 15 shows snow accumulation observed at Shizukuishi Station.

Table 3 Overview of Running Tests

<table>
<thead>
<tr>
<th>Date</th>
<th>Nighttime of February 8 - 10, 2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section</td>
<td>Between Akita and Shizukuishi (one round trip, max. speed of 130 km/h)</td>
</tr>
<tr>
<td>Train used</td>
<td>Series E6 train (5M2T)</td>
</tr>
<tr>
<td>Items tested</td>
<td>Snow melting performance of end covers (snow accumulation visually checked at Shizukuishi Station and Akita Rolling Stock Center)</td>
</tr>
</tbody>
</table>

Based on the stationary tests and running tests using active duty cars, we were able to develop an end cover that can better raise temperature at its periphery than the current end cover for series E6 cars. However, the running tests were carried out this time only in a conventional line section, so the maximum train speed in the tests was 130 km/h. In high-speed operation at 300 km/h or more, wind from the train running might rob more heat from the surface of the end covers. In order to put the developed end cover into use on trains in commercial operation, we need to overcome the issue of keeping the surface of the end cover warm.

3 Conclusion

We conceived a composition for a new current bogie end cover utilizing the heater system for series E6 mass-production Shinkansen cars and produced prototypes of and evaluated a new end cover with the aim of improving snow melting performance. As a result of stationary tests of three prototype end covers, we confirmed that an aluminum alloy bogie end cover that integrates surface plate and casing had an advantage over the other types. We thus evaluated performance of that integrated aluminum alloy bogie end cover installed to an active duty car and evaluated performance in the actual operation environment. The running test results proved that temperature could be raised sufficiently at the periphery of the prototype end cover tested, improving the snow melting performance over that of the current end cover for series E6 cars.

Reference: