1. Introduction

JR East has placed safety as the top-priority management issue since the company's establishment, and we have been making efforts to build a railway system that customers can use with peace of mind. We have been proceeding from fiscal 2009 with “2013 Safety Vision”, our fifth five-year safety plan. The challenge of achieving “no accidents involving injuries or fatalities of passenger and no accidents involving fatalities of employees” has been our constant target for the ultimate level of safety since the (second) Safety Basic Plan in 1994.

Collisions, derailments, overturns, door-related accidents and train fires are well known as incidents in the field of rolling stock that could result in serious accidents. Even after the formation of JR, a train collision occurred at Higashi-Nakano in December 1988, prompting us to found the Safety Research Laboratory in 1989. Since then, we have been taking actions for improvement of rolling stock safety, covering items from investigation of causes of accidents to proposal of countermeasures. Here I will introduce recent activities in research and development and issues to take on in the future.

2. Issues in Improving Rolling Stock Safety

Table 1 shows past serious accidents and major factors of those.

Factors marked with * are caused by human errors or work methods. We have thus equipped rolling stock with ATS and other backup systems and reviewed work methods that will not allow errors, such as double-checking. Factors marked with ◆ and ● are caused by device failure, and we have taken countermeasures for factors marked with ◆. Those countermeasures include introducing a fail-safe design concept, backing up by duplication and preventing expansion of damage in troubles by adding protectors of some sort.

Therefore, the remaining factors are the simplex system factors marked with ●. They are failure of bogies and wheelsets, flange climb derailment still under cause investigation and being caught in the door or dragged by the train that are involved with passenger’s behavior. We regard safety improvement in those as an immediate issue for rolling stock.

For external factors, improvement of rolling stock safety against crossing accidents, earthquakes and high wind is also an important issue on which we are proceeding with research and development.

3. Results and Progress of Research and Development

3.1 Investigating Causes of Flange Climb Derailment

The derailment accident in the yard of Nakameguro station on the Hibiya line of what is now the Tokyo Metro in March 2000 was a serious accident causing 68 casualties (five fatalities, 63 injuries). It occurred due to the last car of the train making flange climb derailment at the start point of a transition curve with a steep gradient and sharp curve when emerging from a tunnel to above ground, colliding with the side of the fifth and sixth cars of the oncoming train. It is known that flange climb derailment sometimes occurs near sharp curves and at turnouts with cars that had just experienced wheel turning, and that such derailment bears great risk of major secondary damage like in the Nakameguro accident.

Up to today, we have taken countermeasures for rolling stock to prevent flange climb derailment such as numerical control of balance of left and right wheel load, change of flange angle (60º raised to 65º) and flange lubrication after wheel turning. Countermeasures for tracks have also been taken such as control of combination of alignment and cross level and installation of derailment prevention guards. In February 2008, however, flange climb derailment occurred at the turnout in Oku station.

After the Oku incident, we made a reproduction investigation...
The derailment risk indicator (critical derailment coefficient \( \frac{Q}{P} \)) can be obtained by Nadal’s formula shown in Fig. 2 that represents the balance of forces. Up to now, we have calculated the rough safety target value on the assumption of the equivalent friction coefficient \( \mu_e = 0.3 \) (approximate friction coefficient of ordinary iron). However, under the above-mentioned conditions where flange climb derailment occurs, the friction coefficient is assumed to become larger than 0.3*. Thus, we might have to review the present uniform critical derailment coefficient to improve to an indicator appropriate to the conditions. Since obtaining the maximum friction coefficient value in the experiments will reveal the true limit value before derailment, we should clarify that as soon as possible. With those results, we will be able to make quantitative suggestions of the indicator and the control standard value to prevent flange climb derailment.

3.2 Introduction of the TC-Type Axle Box Temperature Detection Equipment System

Since abnormal heating of the axle box can lead to derailment and other serious accidents, maintenance of the bearings and prediction of abnormal heating are important issues. While Shinkansen cars that run at a high speed are equipped with sensors to detect heating of the axle, we check heating on cars for conventional lines using a thermo-label attached to locations such as the bearings. But we cannot check heating of cars while running with that method because we can check the label only when cars are in the depot. The Technical Center has thus developed a system to detect heating of the axle box bearings of running trains from the wayside. This is the TC-type axle box temperature detecting equipment system, and we will introduce that to line sections in the greater Tokyo area.

As shown in Fig. 3, this system makes accurate noncontact measurement of the temperature of the axle box using an infrared heat radiation sensor. If abnormal heating is detected, the system gives an alarm to the dispatcher’s office and the depot. In order to avoid shielding by devices such as the tachometer generator that is installed to the axle box, the system makes pinpoint measurement obliquely from below.

*1 While we discovered an increase of the friction coefficient in past tests using a model train, we have not yet verified it using an actual train
3.3 Introduction of Platform Detectors

When part of a train stops away from the platform, or the crew opens the door on the side opposite from the platform, passengers might fall off onto the track. In order to prevent such incidents, we have developed a platform detector and started installation in 2006 to cars used in the greater Tokyo area.

As shown in Fig. 4, the principle of the platform detector is that it determines the train being at the platform and allows the crew to open the doors when both of the ultrasonic platform detection sensors at the ends (front and rear) of the train detect the platform. Such sensors are installed on the left and right sides of the cars at the ends of the train. When part of the train is away from the platform, or the platform is on the side opposite of the doors to be opened, the sensors do not detect the platform. In that case, the system shuts off the circuit which outputs the door open command, even if the crew makes operations to open the doors.

Since the detection scope of the ultrasonic platform sensor is limited, there are some issues including adapting it to low platforms of local lines, such as using more sensors. We are thus developing a new detection system using laser sensors and RF-IDs.

3.4 Development of Detector of Objects Caught in the Doors with Improved Dragging Prevention Function

In May 2007, a train departed Kanda Station on the Yamanote line with a stroller caught in the doors. The boy in the stroller, his mother and another passenger who tried to help were injured in the incident. In light of that accident, we hardened part of the door stop rubber at the edge of the car door to enable detection of objects as thin as 2 or 3 mm width caught in the doors. We then put into effect plans for also introducing platform doors. Those will be installed at stations on the Yamanote line from fiscal 2010 (at two stations first, then to all stations within roughly 10 years based on the technical verification results for the first two stations).

Deployment of platform doors will take a long time, however. And there have been incidents reported with other railways where strollers were trapped and dragged by the train and reports of trains departing with backpacks, clothing or canes caught in the door. Preventing dragging due to being trapped in doors is thus an important issue.

Table 2 shows a comparison of the trapping and dragging detection functions of the system of current cars and the system under development (detector of objects caught in the doors with improved dragging prevention function). We aim to improve the trapping detection function and put the dragging detection function into practical use with the new system to prevent the above-mentioned dragging incidents.

Table 2 shows a comparison of the trapping and dragging detection functions of the system of current cars and the system under development (detector of objects caught in the doors with improved dragging prevention function). We aim to improve the trapping detection function and put the dragging detection function into practical use with the new system to prevent the above-mentioned dragging incidents.

Table 2 Comparison of the Trapping and Dragging Detection Functions

<table>
<thead>
<tr>
<th>Detection Type</th>
<th>Current System</th>
<th>System under development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detection of trapping</td>
<td>Detectable to as small as 20 mm²</td>
<td>Detectable to as small as 3 mm²</td>
</tr>
<tr>
<td>Detection of dragging</td>
<td>Not detectable</td>
<td>Detectable</td>
</tr>
</tbody>
</table>

Table 2 shows a comparison of the trapping and dragging detection functions of the system of current cars and the system under development (detector of objects caught in the doors with improved dragging prevention function). We aim to improve the trapping detection function and put the dragging detection function into practical use with the new system to prevent the above-mentioned dragging incidents.

With the new system, an air tube is embedded in the door stop rubber as shown in Fig. 5. A foreign object between the doors deforms the rubber and compresses the air tube. The system detects the presence of an object from the change of pressure in that tube. This system requires an intricate door stop rubber structure and a device to transform faint pressure changes into electric signals and transmit those. We are thus carrying out durability and reliability check of those items.

*2 When trapping a board of 100 mm width at 120 cm above the floor of the car
Many issues still remain in the improvement of rolling stock safety other than issues mentioned in the previous section. Those include improvement of resistance to natural disasters and alleviation of injury of passengers and crew in incidents such as crashes (secondary damage).

For example, we are proceeding with research and development on subjects such as the following.

- Study of prevention of large deviation from the track by derailed trains and buckling of cars in an earthquake
- Study of car body shape that ensures more stable running in high cross winds
- Proposal of car body structure that secures as large a survival space in the cabin and driver’s cab as possible and cabin fixtures that reduce injury of passengers and crew in case of a crash or turnover
- Evaluation of cabin materials with good fire resistance

For research and development on flange climb derailment and crashworthiness of vehicles, we think we will need to conduct verification using actual cars on a dedicated test line as necessary.