Innovation of Turnout and Switch Machine System  
— Next Generation Turnout (NGT) —

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We at Research and Development Center of East Japan Railway Company are engaged in the development of a "Next Generation Turnout/Switch Machine" in order to prevent the occurrence of a turnout or switch machine failure and to minimize the maintenance burden. In this development project, the turnout as track equipment and the switch machine as signal equipment are considered as an integrated system. Based on the understanding of field maintenance problems and examining the turnouts and switch machines in overseas countries, we have succeeded in overall innovation of the structure. The final prototype has been built and has been placed in service on a commercial-service line (in Omiya station yard). This paper will introduce and discuss this system.

Keyword: Next generation turnout, grid type sleeper, fastening of stock rail from inside the gauge, next generation turnout, close contact type switch adjuster, status monitoring

1 Introduction

The turnout and switch machine are the sole movable components in the facilities around the rail, and are designed to have a complicated structure. They are not only characterized by difficulties in maintenance but also by their crucial importance in protecting stable traffic and transportation against a possible switch failure. Viewed in the worldwide context, there has been a remarkable development in the turnout and switch machine over the last ten and more years. Especially in European countries, development efforts are observed, for example, in designing a compact size switch machine, use of a long rail in the turnout, and fastening the rail in the turnout by spring. In Japan, by contrast, there has been no change in the basic structure since the 1970s.

To find a breakthrough, we have been developing a "Next Generation Turnout and Switch Machine" characterized by substantial innovation in structure, based on the concept of creating a failure-immune and maintenance-free system. This paper will introduce and discuss this system.

2 Turnout (point)

The part of the turnout that switches the track in the lateral direction is called "point." The machine that switches the point is called "switch machine." Normally, the point is placed under management as track equipment, while the switch machine is as signal equipment.

The facilities between the two are called "accessories of the switch machine." Here the equipment managed on the track side and that on the signal side are integrated, and this boundary area presents one of the biggest maintenance and management problems in the field. This chapter will discusses the point, with special reference to the point base plate, deformation of tracks in the point and current development of the switch machine accessories.

2.1 Point base plate

The following describes the current problems with the point base plate (Fig. 1):

(1) Fastening of the stock rail on one side

The stock rail is fastened only from outside the gauge, so the fastening force is smaller than that of the rail in the lateral direction.

(2) Fastening the stock rail by bolt

This requires management to prevent the bolt from getting loose. Further, loosening of the bolt will cause a rapid decrease in the
2.2 Track deformation of the point

If point track deformation has occurred, the switching function may deteriorate. This involves the following problems:

(1) Presence of the switch machine accessories between sleepers

Although a tip of the tongue rail is a very important, the amount of crushed stone is insufficient. This is the place where tamping work cannot be performed by a multiple-tie tamper (SMTT, a machine for tamping the track on the turnout) of the switch.

(2) Irregularity of alignment (Fig. 4)

Irregularity of alignment is caused by the repeated lateral force caused by trains running on the turnout side. Fig. 4 shows an example. This example can be observed in various places, and causes a contact failure, shortage of flange way width (space for ensuring safe passage of the wheel flange on the opening side of the tongue rail) and increase in switching force.

To solve these problems in the Next Generation Turnout, we have developed the following (Fig. 2):

(a) Fastening the stock rail from both sides by springs

We have developed a new S-rail of smaller height. The stock rail is fastened from both sides to ensure stable fastening force.

(b) High floor type base plate

Space is formed between the tongue rail bottom surface and stock rail by a newly developed S-rail to ensure that foreign substances do not enter.

(c) Ball bearing base plate

A ball bearing base plate has been adopted, because this structure does not allow entry of minute foreign substances, and eliminates the need for cleaning or lubricating the point.

(3) Contact of the tongue rail bottom surface with the stock rail

Switching failure is caused by the presence of iron chips and other foreign substances.

(4) Cleaning and lubrication of the point and protection of the point against snow

This work is one of the so-called “3D jobs” (dirty, dangerous, demanding). If timing of the work is incorrect, point trouble (switching failure) will occur.
(3) Irregularities on the height of the point base plate (sleeper)
Irregularities occur on the height of the point base plate (sleeper) due to repeated exposure to wheel loads. This may result in engagement failure, contact failure and an increase in switching force.

To solve these problems in the Next Generation Turnout, we have developed the following:

(a) Integration of the electric switch machine with the sleeper (Fig. 5)
Integration of the electric switch machine with the sleeper has been accomplished by the compact and lightweight configuration of the electric switch machine to be discussed later. The switch machine accessories are installed immediately above the sleeper. This arrangement ensures a sufficient amount of crushed stone and solves the problem with the position where tamping cannot be done by the SMTT. Further, this arrangement also ensures the space between the stock rail and electric switch machine, thereby eliminating the possibility of relative deformation.

(b) Development of a grid type sleeper (Fig. 6)
We have developed a grid type sleeper where the lateral sleeper is connected in the longitudinal direction of the rail. According to the experiment and analysis, we assume that lateral stiffness is about seven times that of the conventional structure and the stiffness in the vertical direction is two or three times that of the conventional structure. Further, this arrangement also eliminates any twist that may be caused by the relative deformation of the right and left rails. This sleeper allows the existing SMTT to perform the tamping operation.

2.3 Switch machine accessories
The following describes the current problems with switch machine accessories:

(1) Tie bar and front rod adjusting mechanism (Fig. 7)
The tie bar and front rod has turnbuckles for adjusting the space between right and left tongue rails. In the field, it is often observed that the turnbuckles are tightened excessively in order to force a close contact and adhesion, without the irregularity of alignment being corrected. This leads to an increase in switching force.

(2) Bent angle at the center of the tie bar and gauge insulation
Different materials are used at the center of the tie bar, which may therefore be bent in a dogleg form. Further, single gauge insulation is used.

(3) Switching load applied to the tie bar bolt
During the switching operation or when excessive tension is applied to the tie bar, loads are applied the tie bar bolt and collar, which are worn as a result. To prevent this, it is necessary to disassemble and examine it closely.

(4) Tie bar bolt tightening standard (Fig. 8)
The tie bar bolt tightening standard requires that the bolt should be tightened to the extent that it can be tightened by hand. This requires the worker to have a certain level of skill and experience.
At the same time, the level of finish differs according to each worker. This bolt is tightened or loosened from below, and this position undermines workability.

To solve these problems in the Next Generation Turnout, we developed the following (Fig. 9):

(a) Abolition of the use of rod and front rod adjusting mechanism
In addition to controlling the irregularity of alignment by the above-mentioned grid type sleeper, the tongue rail switching stroke has been increased about 10 mm. This arrangement absorbs the impact of manufacturing tolerance, and has made it possible to eliminate the use of the lateral tongue rail space adjusting mechanism (turnbuckles) of the front rod and tie bar.

(b) Double gauge insulation for tie bar and front rod
Insulation is positioned between the connecting plate and tongue rail to make the tie bar and front rod into one integrated structure, thereby removing the problem of bent angle. At the same time, the gauge insulation has been designed in a double structure.

(c) Abolition of the use of tie bar bolt (structured pin) (Fig. 10)
The connection plate and tie bar are designed in an integrated structure (pin structure) and the tie bar bolt has gone out of service. The pin hole of the tie bar is formed into a slot so that switching force is not applied to this pin.

3 Electric switch machine

The NS type electric switch machine chiefly used on the main lines at present is as heavy as 380 kg, and installation work requires much time and labor. Further, it has many problems such as occurrence of switching failure. Despite these disadvantages, no radical improvements have been made so far. The Next Generation Switch Machine has been developed with the object of achieving a compact size, a relay-free and maintenance-free structure.

3.1 Electric switch machine

(1) Compact size and light weight
The NS type electric switch is as heavy as 380 kg, and has required much labor. In this development project, we have reviewed and reexamined the switching mechanism and material, and have succeeded in achieving a substantial reduction in weight, with the result that the weight is reduced to 96 kg.
The following describes major improvements in material and the like:
(a) To protect the electronic equipment against temperature rise in the switch machine caused by the transformer and noise caused by the magnetic field, a step-up transformer is installed externally.
(b) A wedge clamping method has been adopted instead of the conventional method of connecting the outer frame of the main body and composite sleeper.
(c) The material for the lock rod protection cover has been changed from sheet metal to a plastic material.
(d) A servo motor has been adopted.
(e) A ball screw has been adopted in the switching mechanism.
(f) The material for the outer frame other than that of the electric
switch machine has been changed from cast iron to an aluminum alloy. To illustrate the consequence of the above-mentioned review, Table 1 shows the comparison between the Next Generation Switch Machine in use at Omiya station and the overseas switch machine.

(2) Relay-free switch machine

The NS type electric switch machine has a built-in relay (Fig. 11). After termination of switching under control conditions from the interlocking device, display is passed over to the interlocking device through the internal circuit controller. However, since it is installed in a switch machine characterized by strong vibration, switching failure may be caused by relay troubles.

In the Next Generation Switch Machine, an electronic circuit is built in the electric switch machine, and exchange of information including switching instruction is carried out through the optical fiber cable. Accordingly, the electric switch machine has no built-in relay, thereby eliminating the possibility of switching failure caused by a faulty relay.

(3) Maintenance-free arrangement

(a) Status monitor

For the existing electric switch machines, “lock position failure detectors” are installed on the main lines and others. Data on power voltage and switching force is not placed under proper management, and measurement is made during the night at the time of periodic inspection. Switching monitors are installed in some places, but this requires that a box other than the switch machine be installed in the switch machine and a separate cable be provided, with the result that the cost increases.

In addition to the exchange of data with the interlocking device, the controller of the Next Generation Switch Machine sends to an interface device installed in the machine room the voltage and torque data supplied from the servo amp. This arrangement allows the status to be monitored without installing another monitor. Further, this arrangement allows the status information to be sent using the optical fiber cable used to control the electric switch machine. This eliminates the need of installing a separate cable.

(b) Lock adjustment

To adjust the lock position at present, the lock piece position is adjusted by visual observation looking into the lock check window. This arrangement makes it difficult to perform adjustment at night. Further, since there is no gauge, adjustment must depend on human visual observation, with the result that differences occur according to the skill or experience of each worker.

In the present development project, the lock position is indicated on the cover of the electric switch machine by LED (Fig. 12). This makes it easier to observe even at night. The deviation of the lock pieces can be identified according to the number displayed on the LEDs.

![Fig. 11: Switch machine type NS](image1)

![Fig. 12: Lock display](image2)

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Table 1 Comparison of electric switch machines

<table>
<thead>
<tr>
<th>Item</th>
<th>Conventional type</th>
<th>Next generation type</th>
<th>Overseas switch machine (Chiba)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turnout</td>
<td>Flexible structure</td>
<td>Hard structure</td>
<td>Hard structure (without bearing plate)</td>
</tr>
<tr>
<td>switch machine</td>
<td>Not compatible</td>
<td>Not compatible</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>Approx. 380 kg</td>
<td>Approx. 96 kg</td>
<td>130 kg</td>
</tr>
<tr>
<td>Shape (volume)</td>
<td>1</td>
<td>1/3</td>
<td>1/3</td>
</tr>
<tr>
<td>Switching time</td>
<td>5 to 6 sec.</td>
<td>3 to 4 sec.</td>
<td>5 to 6 sec.</td>
</tr>
<tr>
<td>Operation rod drive</td>
<td>By cam</td>
<td>By ball screw</td>
<td>By ball screw</td>
</tr>
<tr>
<td>method</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>Built-in type</td>
<td>Electronic equipment</td>
<td>External portion</td>
</tr>
<tr>
<td>XCR</td>
<td>Built-in type</td>
<td>Microswitch</td>
<td>Microswitch</td>
</tr>
<tr>
<td>Transmission</td>
<td>Conditional</td>
<td>Optical transmission</td>
<td>Conditional transmission</td>
</tr>
<tr>
<td>Power supply</td>
<td>AC 110V</td>
<td>AC 200V</td>
<td>AC 100V</td>
</tr>
<tr>
<td>Lock method</td>
<td>Indirect locking (escape lock)</td>
<td>Indirect lock, Guide and herringbone track lock</td>
<td>Direct lock fishtail lock</td>
</tr>
<tr>
<td>Monitor function</td>
<td>External installation</td>
<td>Built-in</td>
<td>None</td>
</tr>
</tbody>
</table>

* Tentatively installed in the Higashichiba station yard in February 1999
There is no difference in adjustment according to each worker.

3.2 Switch machine accessories
Use of a measuring instrument makes it difficult to adjust the conventional switch machine accessories, so this adjustment must depend on manual work, which requires skill and experience on the part of the worker. Thus there are variations among individual workers. Further, switching failure occurs due to excessive tension and breakage of the front rod elbow metal (Fig. 13). In this development project, in order to reduce the number of adjustment positions and to ensure adjustment that does not depend on experience of individual workers, we have developed accessories.

(1) Next generation switch adjuster
In the development project, we have adopted a close contact type switch adjuster. A spring has been utilized to keep the degree of contact constant. For adjustment, a mark is placed on the switch adjuster (Fig. 14), and the nut is adjusted within the marked area, thereby eliminating the need for checking the degree of close contact with a large-sized wrench. The jaw pin at the connection of the operation rod is placed on the upper portion so that the split pin can be easily split.

(2) Next-generation front rod
The next-generation front rod has no tension adjuster at the top end. (This also applies to the tie bar). Further, the weaker portion as found in the conventional elbow metal has been eliminated by connection with the tongue rail in a straight line.
For both the front rod and switch adjuster, the number of gauge insulations has been increased to two. This has reduced the possibility of gauge short circuiting, and a double insulation configuration has been adopted (Fig. 15).

4 Other adopted technologies
The next-generation turnout and switch machine has been developed with major emphasis placed on the point and switch machine. For other portions, the achievements of recent studies have been adopted wherever possible. This will be described briefly in this chapter.

4.1 Tongue rail tip
The tongue rail tip is designed in a slender form and is subjected to rapid wear and damage since it is constantly exposed to considerable lateral force on the turnout side by the steep curve. In some extreme cases, it must be replaced as often as four times a year. A serious problem is found in the horizontal fissure that occurs to the tongue rail used JIS 60kg rail. It may lead to a climbing derailment accident if it advances rapidly.
To solve this problem, the next-generation turnout has adopted the cross section where horizontal fissures hardly ever occur. This had been studied since the time of the former Japanese National Railways. This has been adopted in the present project.
4.2 Crossing

To achieve the target of a maintenance-free system as one of the goals of the next-generation turnout, it is necessary to use welding for all rail joints, and to apply to the requirements of a long rail. For this purpose, a rail-made crossing has been manufactured. This was manufactured by processing a rail. However, this crossing had a problem in that a damage called crushing was caused by the impact of a passing train.

To solve this problem, we have adopted “two-stage sloped crossing” that was developed in recent years with consideration given to conformance with the wheel tread profile.

4.3 Guard

The main line rail (called main rail) of the guard has been fastened only from outside the gauge, similarly to the case of the point section. The high base plate developed for the point in the project has been adopted for the guard (Fig. 16). The main rail is fastened from inside the gauge, according to this new structure.

4.4 Applying to the long rail requirements

As it has been referred to in the discussion of crossings, the subsequent turnout is required to be designed in order to apply to the long rail requirements. So a strong “glued insulated joint” has been adopted for the rail insulation that makes it difficult to apply to the long rail requirements. Further, the “movement preventive metal” for transmitting long rail axial force in the turnout has been provided as a standard item.

5 Conclusion

The final prototype of the next-generation turnout/switch machine introduced above was installed at turnout 80A (32,000,000 annual tonnage 16 switching operations per day) located in the yard of Omiya Station on the night of February 10, 2002. On the night of installation, a highway rail crane was used for replacement, with the electric switch machine mounted on the turnout (Fig. 17).

Since that time, this system has been working satisfactorily without any particular trouble. A further follow-up survey will be continued to verify the effect of this system and to improve it.

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