THE EFFICIENCIES AND THE PROBLEMS OF DIAMOND CROSSING IN METROPOLITAN RAILWAYS, AND IMPROVEMENT OF THEM

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abstract: A turnout is a peculiar device of railroad and it is very important for track layout. But, a non-standard turnout was little used for its complicated structures, high outbreak rate of accidents, and so on. Here, we report our approaches to improve them.

1.INTRODUCTION

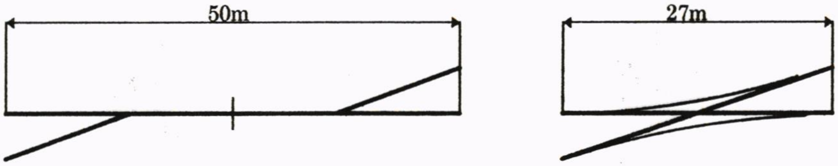
A basic form of railroad is a straight line. However, as network function of railroad progressed by advance of the city, track layout became complicated by intersection and divergence. The majority of them are located in station yards of metropolis, and we need various devices because they are weak points on route setting.

In particular, from the point of view of a turnout which is one of important devices for track, non-standard turnouts such as diamond crossing (DC), slip switches (SSS, DSS) are used because of limitations of track layout and track site in metropolitan railways. (fig.1)

(a) Diamond Crossing (b) Single Slip Switch (c) Double Slip Switch

(fig.1) Skeletons of non-standard turnouts

Although DSS has the same function with toe-to-toe layout of two standard turnouts, track length of the former is shorter than that of the latter. For example, the former is only 27m and the latter is 50m in case of NO.10 turnout.(fig.2)



(fig.2) Toe-to-toe layout of two standard turnouts and DSS (NO.10)

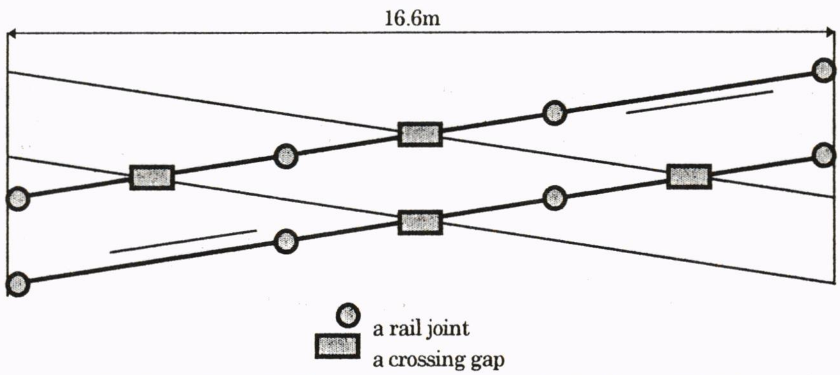
It is recognized that a non-standard turnout is one of very effective devices for track layout planning in metropolitan railways, but it has many problems because its structures are complicated. Here we introduce our countermeasures to solve them.

2.PROBLEMS OF NON-STANDARD TURNOUTS

2.1 A Limit Factor of The Passing Speed of Trains

In Japan, current passing speed of trains at the straight side of turnouts is unlimited virtually because they could be passed by 160km/h. But, it is limited to maximum 90km/h in the straight side of non-standard turnouts.

By the way, it is considered that the reason of speed limitation is 'the structure of them is complicated' or 'they are apt to occur a heavy impact load which let track deteriorate because they are composed of many rail joints and gaps in crossing'. For example, in the NO.6 DC, there are four rail joints and two crossing gaps in spite of only 16m in lengths.(fig.3) You can compare it with standard length rail whose length is 25m.

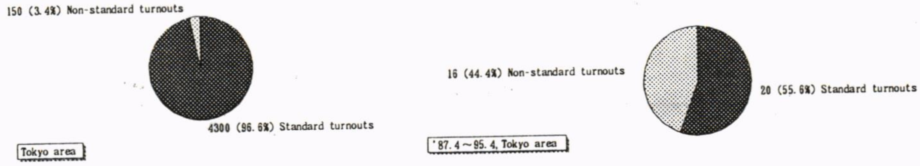


(fig.3) Locations of rail joints and crossing gaps in the rigid DC(NO.6)

Nevertheless, we don't have any data to let us know how fast trains can run in non-standard turnouts.

2.2 High Outbreak Rate of Incomplete Closing of Switch Rail

The rate of the incomplete closing of switch rail in non-standard turnouts is 44%. On the other hand, the rate of number of non-standard turnouts is only 3% of all turnouts. So, the outbreak rate of the incomplete closing of switch rail in one non-standard turnout is about 25times than that in one standard turnout.(fig4)



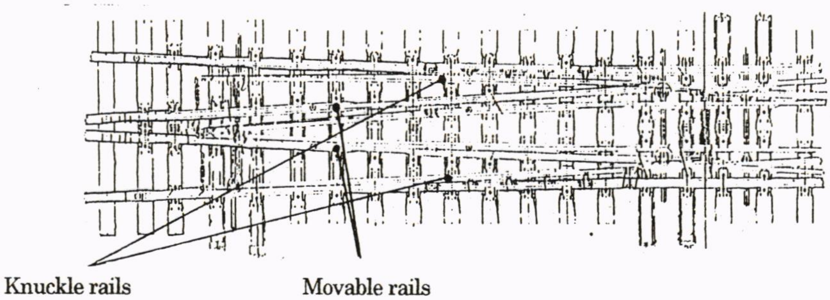
(a) The number of turnouts (b) The number of incomplete closing of switch rail
(fig.4) The number of turnouts and incomplete closing of switch rail

This high outbreak rate of accidents let user avoid to take non-standard turnouts in the point of view of track maintenance.

Here we show two reasons of incomplete closing of switch rail in non-standard turnouts.

(1)rail creeping

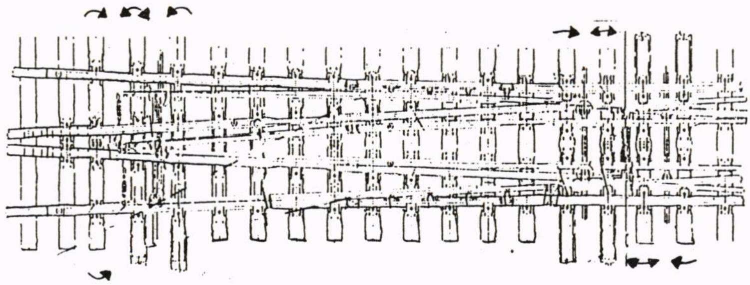
Rail creeping makes incomplete closing of switch rail occur because it take excessive force for throwing switch rails. In particular, a knuckle rail and a movable rail are apt to creep.(fig.5) These rails are fastened only 4 to 8 fastenings for one rail. So resistance to creeping of them are less than that of other rails.



(fig.5) knuckle rails and movable rails

(2)sleeper skewing

Some sleepers near the switch device are apt to skew, and after that ,they are in touch with switch rods. This phenomenon makes incomplete closing of switch rail occur.(fig.6) We think that sleeper skewing has occurred around the switch device, because it is relatively short of the amount of crushed stone of ballast by switch rods and longitudinal ballast resistance force is unbalanced at sleepers under the electric switch machine.



(fig.6) Sleeper skewing around the throwing devices

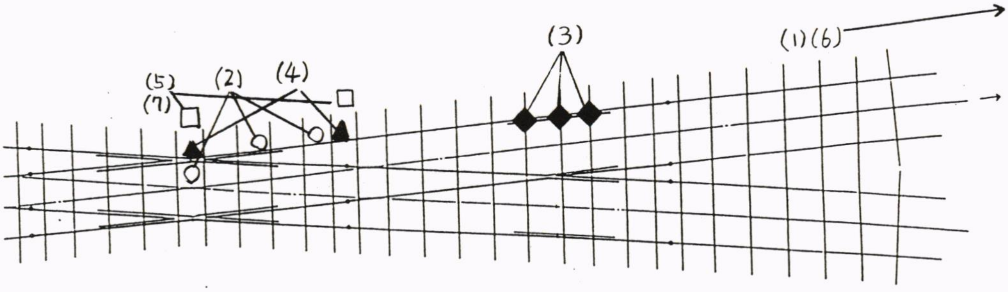
In any case, we think that incomplete closing of switch rail will happen when a turnout panel as a ladder is broken.

3. IMPROVEMENT OF NON-STANDARD TURNOUTS

3.1 High Speed Test Runs at Non-standard Turnouts

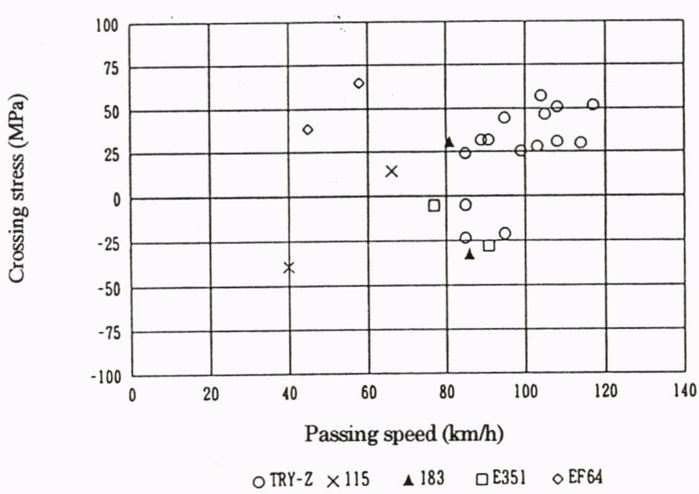
We tested high passing speed of trains at non-standard turnouts(a rigid DC at this time as a first step). We used 'TRY-Z' which was our high speed test train for existing line. We measured as below;(fig.7)

(1)wheel load, lateral force, and derailment coefficient (vehicle-borne measurement)
(2)stress of rigid K crossing(high manganese steel)
(3)back lateral force of guard rail(bolt stress)
(4)vibration acceleration of crossing
(5)vibration acceleration of ballast
(6)axle box acceleration (vehicle-borne measurement)
(7)rail pressure



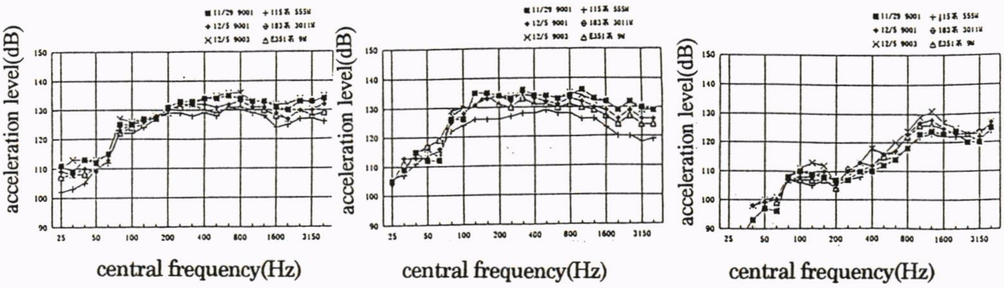
(fig.7) Measurement points of rigid DC

We knew that trains could run about 120km/h at a rigid DC from points of view of running stability and fatigue strength of members. For instance, we show the relation between stress of rigid K crossing and passing speed.(fig.8) Actual stress of crossing are quite less than 147MPa which is fatigue strength of it.



(fig.8) Relation between crossing stress and passing speed

We could know little difference of vibration modes between rail joints and crossing gaps. We show consequences of frequency analysis of one-third octave band of crossing vibration acceleration.(fig.9) (a) is a consequence of a crossing gap, (b) is that of a rail joint, and (c) is that of standard rail. (a) is similar to (b) from points of view of a total value and each value at any bands, while (c) is quite less than (a) and (b).



(a) a crossing gap (b) a rail joint (c) a standard rail

(fig.9) One-third octave band analysis of crossing

In consequence, the impact load of rail joints is the same with that of crossing gaps.

We compared consequences of rail pressures in order to analyze an influence for track deterioration. See the (table.1). A rail pressure at the crossing gap is less than that of the rail joint about 30%.We consider that the reason of them is a difference of a moment of inertia. Former is about 10 times larger than latter.

(table.1) Moment of inertia and rail pressure in each part of rigid DC

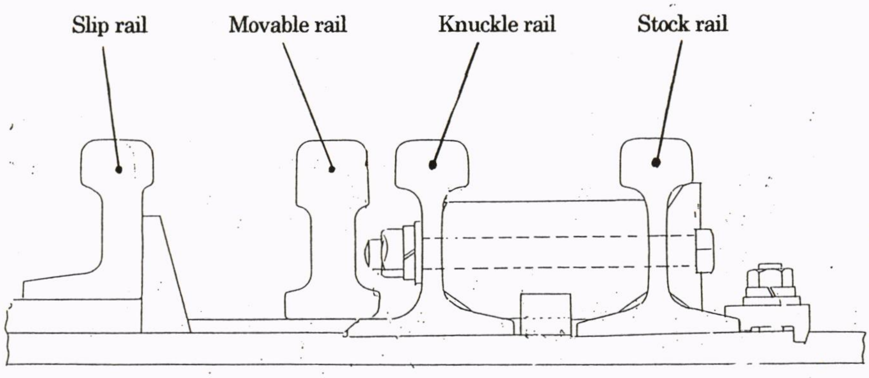
	$EI_x/10^9$	rail pressure (kN)
crossing gap	13.30	34.29
rail joint	1.26	47.44
standard rail	4.12	41.32

We can say that track deterioration of crossing gaps is less than that of rail joints about 30%.

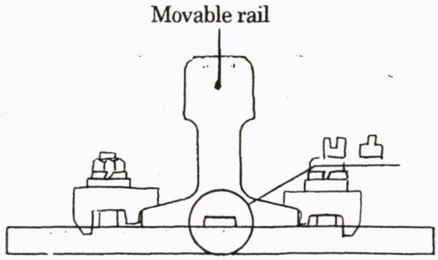
As a result, trains are able to run at the rigid DC about 120km/h. But we prefer to eliminate rail gaps in DC considering an influence to track deterioration. Now we are designing a new rigid DC for high passing speed of trains. And we will test it until 130km/h.

3.2 Analysis and Improvement of Some Factors of Incomplete Closing of Switch Rail

We said that breaking a ladder of turnout panel make incomplete closing of switch rail occur. Here, we take a knuckle rail and a movable rail which are apt to creep because of their few numbers of fastenings and we suggest some structures to avoid their creeping. (fig10.11)



(fig.10) An idea for a knuckle rail



(fig.11) An idea for a movable rail

We tested resistance to creeping in each structures as (fig.12) to confirm their effects. (Table.2) indicates that a knuckle rail resists about 4.5 times than now, and a movable rail does about 3.6 times.

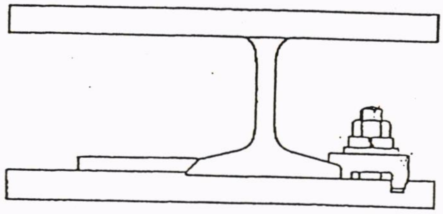
(Table.2) A result of resistance to creeping test(tf)

	(a)now in use	(b)trial product	(b)/(a)effect
Knuckle rail	2.270(T.P.1)	7.985(T.P.3)	3.52
		10.12(T.P.4)	4.46
Movable rail	3.175(T.P.2)	11.60(T.P.5)	3.65

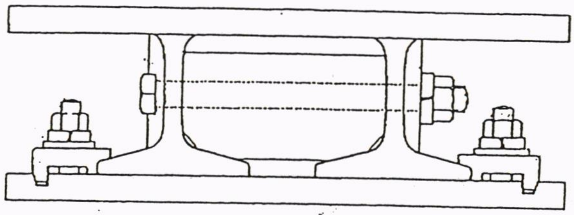
note: an average of 3 times tests

Besides, we are developing a new fastening system to keep a minimum rail clamping force to resist rail creeping of turnouts.

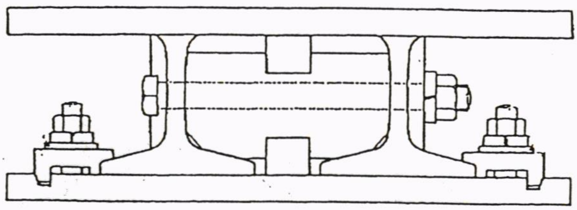
Test Piece 1 Now in use for knuckle rail



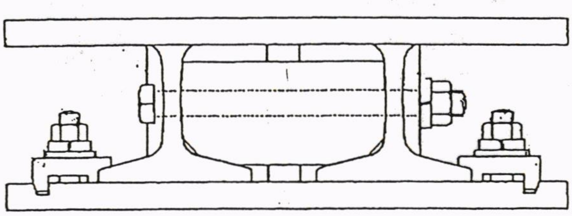
Test Piece 2 Now in use for movable rail



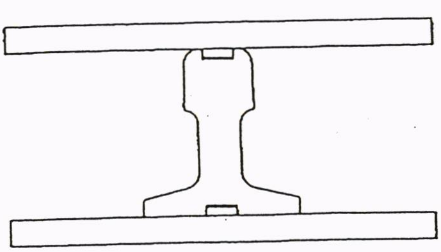
Test Piece 3 trial product for knuckle rail 1



Test Piece 4 trial product for knuckle rail 2

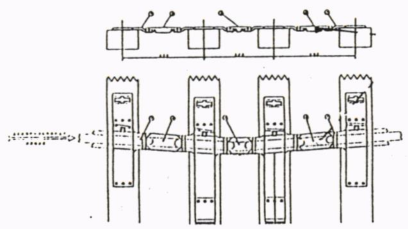


Test Piece 5 trial product for movable rail

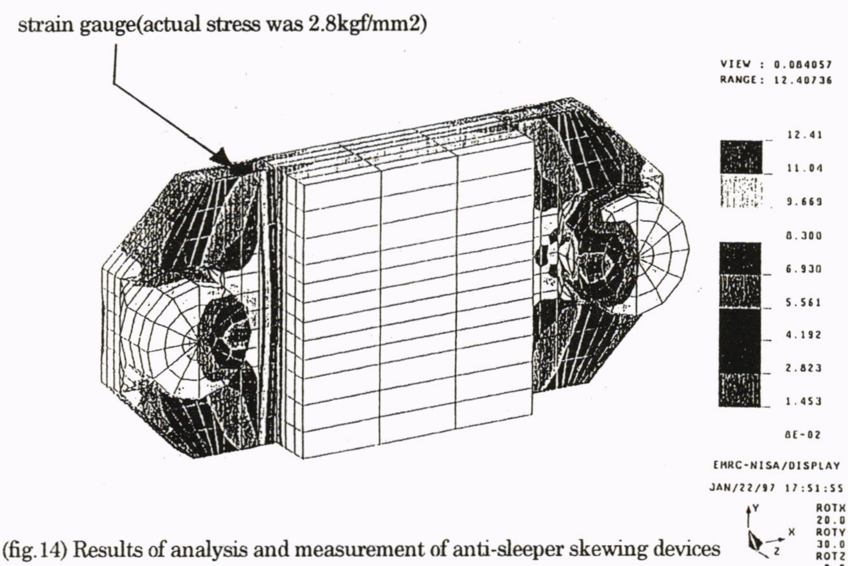


(fig.12) Test Pieces for resistance to creeping

On the other hand, we suggested anti-sleeper skewing devices and tested their effects.(fig.13) We show the test result which analyzed and measured stress condition.(fig.14). Analyzed stress is in accordance with actual one on the side face of link parts. A maximum stress is about 12 kgf/mm2 as a result of analysis. It is less than allowable stress of SS400 steel. This device is effective to resist sleeper skewing.



(fig.13) anti-sleeper skewing devices (link type)



(fig.14) Results of analysis and measurement of anti-sleeper skewing devices

4.CONCLUSION

Non-standard turnouts are very effective devices for track layout in the metropolitan railway system. But they have a lot of faults as stated above. Now we are improving their faults to realize a high quality metropolitan railway system.