BISTABLE MECHANISM IMPROVES SETTING OF SWITCH RAILS

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ABSTRACT
Railway switches with a single point machine often face the problem that the back of an open switch rail is struck by wheel flanges of passing trains. The potential safety risk related to flange back contact is that wear and tear and possibly also fatigue, affects the point machine parts. Ultimately this can lead to a split switch. In Hilversum (NL) this phenomenon has caused a derailment in 2014. Problems with narrow flange clearance mainly occur in turnouts with relatively long switch rails. Especially when resting on rollers in open position, the switch rail can easily bounce back and be hit repeatedly by subsequent wheels.

To overcome the above problem, a bistable mechanism has been developed that helps tumbling the switch rail. A tiltable block midway between the point machine and the heel, helps the switch rail tip over.

This mechanism lifts the switch rail up to 6 mm above the sliding chairs, generating enough potential energy to bring the rail into a stable end position, both when opening and closing the switch rail. Because the rail is lifted, friction between sliding chairs and the switch rail disappears and makes lubrication superfluous. This simple solution has been tested and proven to be effective to prevent flange back contact.

1. INTRODUCTION

Switches and crossings are an indispensable part of the railway track. The principle of horizontally moving switch blades to change the direction of a train is as old as the railways themselves. Its functioning must be safe and reliable. This paper covers issues of switch panels in the Netherlands and presents a proven solution to reduce friction of switch rails and prevent flange back contact of train wheels.

1.1 Risk of flange back contact

If the rod mechanism of the point machine suffers from fatigue and loses connection, it may cause a split switch, resulting in train derailment. Reconstruction of a derailment in Hilversum in the Netherlands has learned that a fatigue crack in the point machine had been caused by flange back contact between wheel flanges and the switch rail. An animation on YouTube [1] shows how this accident could happen. It also states that insufficient lessons were learned from previous train accidents caused by flange back contact, like the Grayrigg (UK) train derailment in 2007 [2].

The Dutch Safety Board (IL&T) concluded that flange back contact represents a safety risk that needs to be managed. As the problem occurs with a significant portion of all 7000 points in the Netherlands, recommendations have been made for the infrastructure manager ProRail to tighten the rules for the maintenance of switches in such a way that flange back contacts are effectively prevented.

Specifically switches with a single point machine and relative long switch rails, like 1:9, 1:12 and 1:15 turnouts, which constitute the vast majority of all points (fig. 1), are sensitive to the problem.

1.2 Friction of the switch rail

For several decades, lubrication of sliding chairs has been replaced by roller systems that (partially) lift the switch rail when it is moved to the open position. Each switch rail has got two or three of these rollers. Proper functioning of a switch rail, requires adequate adjustment and a good bearing condition of the rollers, which is not always the case. For the derailment in Hilversum, failure of the roller system was one of the causes of the accident.

Disruption of the track is often caused by switches and crossings. Figure 1 shows an overview of malfunctioning of switches in the Netherlands in 2014. Most frequent failure is: ‘No detection’ (56,5%) which in many cases means that the end position of the switch rail is not reached. Smooth movement of the switch blades by reducing friction can help solve the problem.

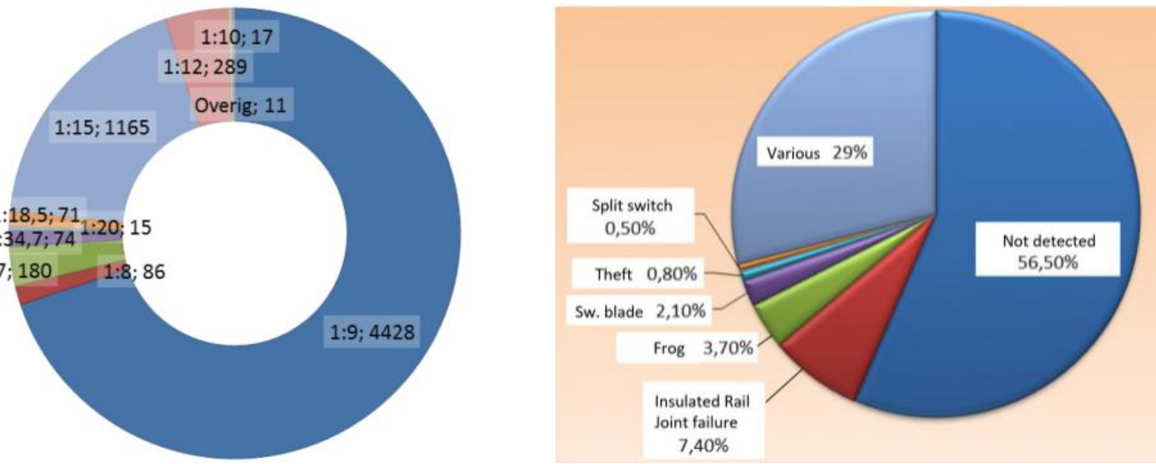

Figure 1 Overview of the number of points in the Netherlands per type. The figure on the right shows disruption causes in 2014.

2. Bistable mechanism

In order to find an effective solution to improve the flange way clearance in a switch panel, Movares, engineering consultants, together with Kampa BV and VoestAlpine TTNL have developed a device to overcome this problem. This solution reduces friction and promotes the tumbling of a switch rail. Its functioning and the tests that have been performed, will be explained hereafter.

2.1 Working principle of the bistable mechanism

The bistable mechanism named *DeltaSwitch*, uses a polyamide block that is able to rotate on a horizontal axis to carry the moving switch rail (figure 2). The shape of the block is such that it provides two stable positions to the switch blade witch are 70 mm apart. In longitudinal direction, the device is situated at the most suitable position between two bearers. This is – depending on the switch type – about halfway between the toe and the heel of the switch rail.

The top of the block has two planes with a radius between them. This shape causes the switch rail to be lifted when it is moved horizontally (figure 3). The potential energy of the lifted switch rail forces it to complete its stroke. Because the block lifts the switch rail more than 6 mm, only one device per switch rail is sufficient.

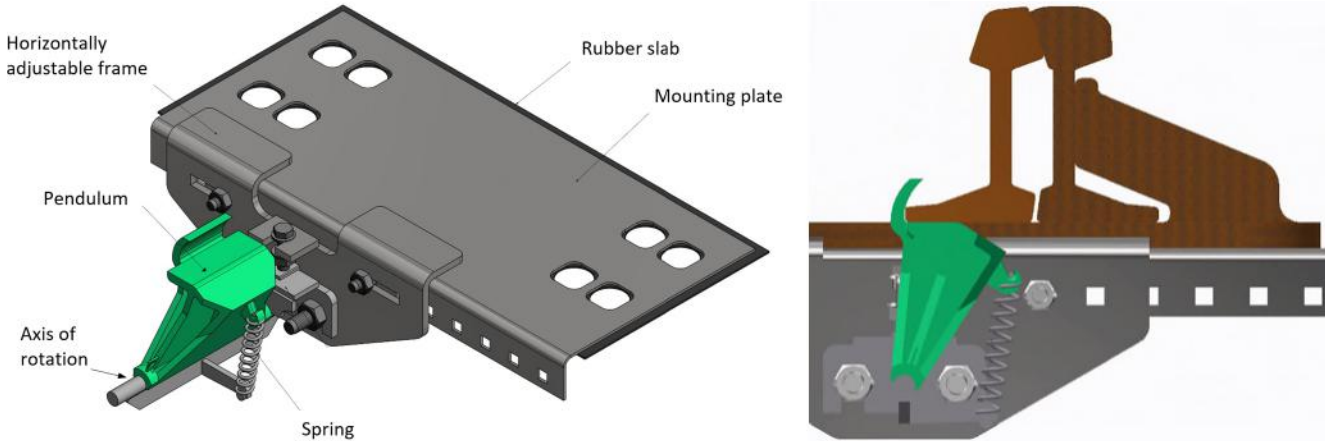

Figure 2 Bistable device. Cross section with switch rail in closed position (right picture).

A large active radius (125 mm) of the block and the use of polyamide on a steel bearing axis, ensures the friction of the switch rail being almost zero. The protruding lip at one side of the bistable block and the spring mounted on the other side, ensure the block to follow the horizontal movement of the switch rail (even if – for whatever reason – contact is lost between the switch rail and the supporting block).

The frame of the device is mounted below the sliding chairs and adjusted in the closed position of the switch rail (figure 2). The height of the axis is adjusted such that the block just touches the bottom of the switch rail. This avoids it being loaded by wheels running over the closed switch rail.

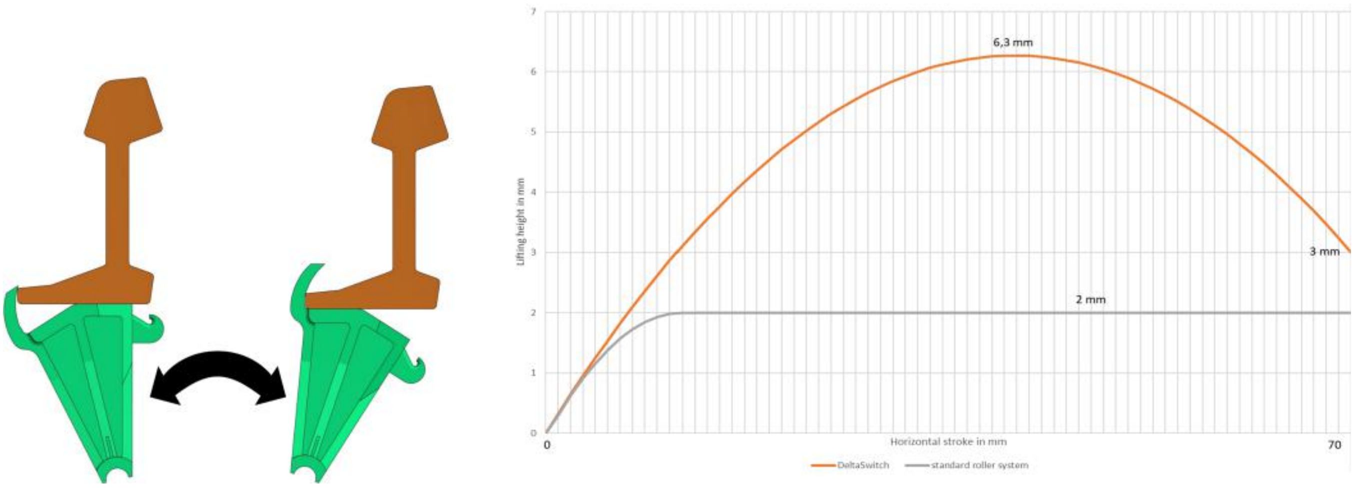

Figure 3 Position of the bistable block in open (L) and closed (R) position.
The orange line in the graph represents the movement of the switch rail.

The left picture of figure 3 shows both stable positions of the switch rail. The graph shows the vertical lift of the switch rail as a function of the horizontal displacement (orange line). The gray line shows the curve of the switch rail for conventional roller systems. It clearly indicates how much more the switch rail is lifted compared to conventional roller systems. This ensures that the switch rail is raised above the sliding chairs over greater length and friction is reduced to a minimum.

2.2 Testing the effectiveness of the device

Because of the characteristics of the bistable mechanism and the expected reduction of flange back contact it would contribute to, ProRail has requested tests to demonstrate the effectiveness in switch panels with angle 1:15 and 1:9. These tests have been executed at Railcenter – a test and education facility of ProRail – and at the production location for switches of VoestAlpine WBN near Hilversum.

These tests have been monitored using video cameras and motion recognition software that uses markers at different positions of the switch rail (figure 4). This enables accurate measurement of the horizontal and vertical movement of the switch rail, not only at the location where flange way clearance is critical, but also at locations closer to the heel and closer to the point machine. The results of a test with and without *DeltaSwitch* bistable mechanism are presented graphically in figure 5.

Figure 4 Testing a 1:15 switch panel at Railcenter, Amersfoort. The location 1 – 5 correspond to markers positioned along the switch rail.

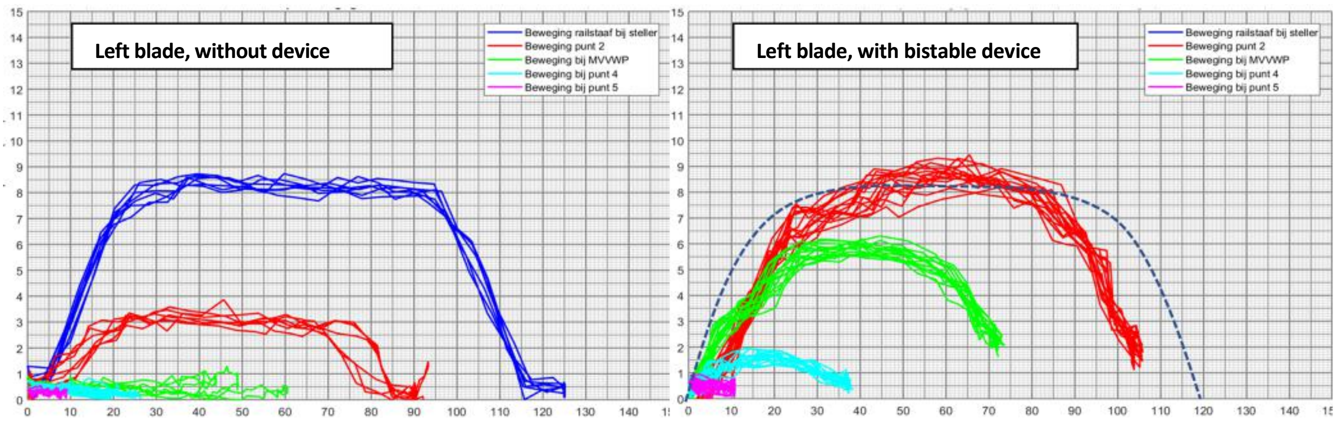

Figure 5 Graphical representation of the movement of the switch rail. Left picture shows a situation without mechanism. Right picture: with bistable mechanism.

The graphs of figure 5 show the horizontal and vertical movement of the switch rail while setting the switch. The graphs in the left figure show what happens without bistable mechanism. Greater part of the switch rail moves only horizontally. Merely the front part of the switch rail is lifted, because of a roller mechanism that is mounted at the toe. This roller lifts the toe of the switch rail when the point machine moves it from engaged to disengaged and vice versa.

As it becomes clear from the graph, this roller mechanism lifts the switch rail merely at the position of the first and second marker. Closer to the heel of the switch rail where flange way clearance becomes critical (at the position of the green line indicated with 'MVVWP'), the roller at the toe has no effect anymore.

The graphs in the right picture of fig. 5 show what happens when a bistable mechanism is mounted. From these figures it becomes clear that the mechanism has its effect. The horizontal stroke of the switch rail increases significantly, but at least as interesting is that the mechanism lifts almost the full length. This largely reduces the friction.

Mounted with the bistable mechanism, the switch rail is lifted 6 mm at the position of the third marker where the device is located. At this position, where the flange way clearance is critical, the horizontal stroke of the switch rail is extended to 70 mm (green line).

(Note that this green line in figure 5 – right graph, very well fits to the orange line of fig. 3.)

<u>2.3 Durability testing</u>

Because of the positive results, the Dutch railway manager ProRail has asked for an extended durability test in a 1:9 switch panel at Railcenter, Amersfoort in order to simulate the long time behavior of the bistable mechanism. Like all tests, this one has been executed with polyamide blocks produced by 3D SLS printing. Over 30,000 point settings have been performed with simultaneous video monitoring.

The test showed constant behavior and after the test no wear could be measured. This means that even the 3D printed blocks meet the material quality required. It can be expected that the final production technique of injection molding will at least yield the same quality.

Figure 6 Disassembled blocks during inspection and measuring

2.4 Hazard identification

To ensure that the bistable mechanism does not entail unforeseen risks, a 'Hazard Identification' has been organized with experts from ProRail, engineering consultants and Dutch manufactures of S&C.

In this session all aspects related to availability and safety of the track have been considered. No safety hazards could be identified. It is expected that the influence on the availability of the track will be positive. These conclusions are important for applying *DeltaSwitch* on a larger scale.

Figure 6 Close-ups of the bistable mechanism supporting the switch rail

3. CONCLUSIONS AND OUTLOOK

Railway switches with a single point machine have relative long switch rails entailing the problem that the horizontal stroke is reduced by friction. Most critical is the stroke half way between the toe and the heel of the switch rail. In the Netherlands about half of the switch panels suffer from flange back contact of passing train wheels.

The *DeltaSwitch* bistable mechanism comprises a tiltable block midway between the point machine and the heel that helps the switch rail tip over. Tests in different switch panels have proven this to be an effective means to reduce the friction between sliding chairs and the switch rail. Different from known roller systems, this bistable mechanism lifts the switch rail higher above the sliding chairs, generating enough potential energy to bring the rail into a stable end position.

This solution has been tested and proven to be effective. Not only does it prevent flange back contact, it also provides an almost friction free movement of switch rails that makes lubrication superfluous. Test have shown that this solution is easy to implement and does not suffer from wear.

Cost calculations have shown that *DeltaSwitch* pays for itself within two years. The solution will be wider tested in practice. It is expected that this solution will be released by ProRail soon.

References:

1 Animation Train derailment Hilversum: https://www.youtube.com/watch?v=p0CUEEDCJ_s
2 Train Derailment and Crash, Grayrigg Cumbria:
3 Animation of mounting DeltaSwitch in a point: https://www.youtube.com/watch?v=Yeb4RgWfS4w
4 voestalpine Turnout Technology Netherlands B.V.
5 Kampa BV (kampa-international.nl)
6 Ingenieursbureau Movares - adviseurs en ingenieurs