On Value of Connection Forces Acting upon Spring Rail Switches under Setting Movement in Presence of Geometric Irregularities

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Abstract: In this paper it is presented some aspects about the magnitudes of connection forces acting on the spring switch blades of a turnout to setting movement in the presence of geometric irregularities. The FEM computations show the action force limit can be exceeded by even more in the case of the existence of insignificant horizontal misalignments.

Key-Words: Railway turnouts, FEM modeling, Geometric irregularities of switch blade

1 Introduction
Spring switch blades are used for working out the set of switches. They are metallic marks, made of a rail length with a tongue rail profile and a rail length with a standard rail profile. The rail length with a tongue rail profile is made by means of a chip removing process at one end, both vertically and horizontally (for allowing the correct contact between switch blade and stock rail), and by means of drop forging at the other end. The end of the rail with a tongue rail profile made by drop forging is welded to the rail with a standard rail profile by electrically flash butt welding. The rail with a standard profile, from the structure of the spring switch blade, is usually weakened by the removal (cutting) of metal in the area of the rail foot on the side facing the heel of the switch.
The switch blade, from the toe to the active fastenings at the heel, rests freely on the slide plates. At the horizontal movement of the switch blade, some friction forces appear between the point foot and the slide plates.
For setting movement and locking the spring switch blades of the simple turnout S49-300-1:9 are used the double locking units (with two switch rods) or the simple locking unit (with one switch rod), which is going to be replaced. When setting movement the switch blades, the forces exerted upon them are transmitted through the clamp locks, which are connect to the blades by joints.
It should be emphasized that by connection forces one should understand the forces transmitted to a switch blade, by the clamp locks, which are necessary for the switch blade to be turned from the position “unlocked” to the position “locked”.

2 Value of connection forces acting upon the spring rail switch under setting movement
For some types of spring switch blades, used for the simple turnout S-49-300-1:9, the connection forces that act during setting movement upon the spring switch blade by the clamp locks have been calculated and compared.
The computations are based on some simplifying hypotheses, namely:
a) The spring switch blade is considered as being subjected only to bending. In fact, besides bending, it is also subjected to twist, as the friction forces, the reactions in the fixed link and the forces transmitted from the clamp locks are applied at different levels upon the switch blade;
b) The curved switch blade is considered straight.
Two possibilities of working out the flexible point have been considered, namely:
2. “switch blade with weakening”, i.e. with processing the rail foot with a standard rail profile, on the side facing the heel of the switch blade.

For both possibilities, the following situations have been considered:

A. Switch blade with friction between itself and the slide plates;
B. Switch blade without friction between itself and the slide plates.

For both possibilities, the following situations have also been considered:
I. Switch blade with two clamp locks;
II. Switch blade with only one clamp lock.

Spring switch blade is modeled in computations as being a fixed beam at one end and a free one at the other.

The total length of the spring switch blade, which it taken into consideration in the following calculations, is of 1275 cm. It is considered that the switch blade is fixed at 196.8 cm from its heel. On these 196.8 cm, the fastenings are in use. The rest of switch blade (1078.2 cm) has been discretized.

The discretization of the switch blade (fig. 1), in twenty-five beam elements, has been made in order to using for computations a structure analysis program with finite elements. The discretization has been made taking into account the physical and geometrical characteristics of rail.

The coefficient of elasticity for the steel of rail has been considered \( E=2.1 \times 10^6 \) daN/cm\(^2\). The initial data, for the tongue rail profile type 49, the standard profile type 49 and the standard rail profile type 49 weakened at the foot are introduced in table 1.

### Table 1 Initial data

<table>
<thead>
<tr>
<th></th>
<th>Rail with the tongue rail profile type 49</th>
<th>Rail with standard rail profile type 49</th>
<th>Rail with standard profile type 49 weakened at the foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cross-section area ([\text{cm}^2])</td>
<td>79.2</td>
<td>62.5</td>
<td>55.4</td>
</tr>
<tr>
<td>Weight ([\text{daN/cm}])</td>
<td>62.2 \times 10^{-2}</td>
<td>49.0 \times 10^{-2}</td>
<td>43.4 \times 10^{-2}</td>
</tr>
<tr>
<td>Moment of inertia to the vertical axis ([\text{cm}^4])</td>
<td>653.0</td>
<td>320.0</td>
<td>157.0</td>
</tr>
<tr>
<td>Coefficient of resistance to the vertical axis (W_z) ([\text{cm}^3])</td>
<td>81.4</td>
<td>51.2</td>
<td>44.8</td>
</tr>
</tbody>
</table>
The initial data, similar to those from table 1, have been also established for the toe of the switch blade, designed to make the correct contact between switch blade and stock rail.

For the situation in which there is friction between the switch blade and the slide plates, it has been considered that the maximum value of the coefficient of friction is \( f = 0.25 \).

For every node of the discrete model (fig. 1), has been established a friction force proportional to the weight proper for every node of the structure. The switch blade, when it is distanced from the stock rail, should not be hit against the wheel flange.

When the setting movement of the switch blade is provided with two switch rods, its travel must be of 16 cm next to the toe clamp lock and of 9 cm next to the intermediate clamp lock. When the setting movement of the switch blade is provided with only one switch rod, its travel should be of 16 cm next to the toe clamp lock.

In the model (fig. 1), the toe clamp lock is next to node 2, whereas the intermediate clamp lock is next to node 9.

### Table 2 – Spring switch blade type 49 with only one clamp lock. Shifts and forces

<table>
<thead>
<tr>
<th>Friction coefficient</th>
<th>Imposed shift ( \Delta_2 )</th>
<th>RESULTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \Delta_9 )</td>
<td>( P_2 ) [daN]</td>
</tr>
<tr>
<td>Switch blade without weakening</td>
<td>( f = 0 )</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>( f = 0.25 )</td>
<td>16</td>
</tr>
<tr>
<td>Switch blade with weakening</td>
<td>( f = 0 )</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>( f = 0.25 )</td>
<td>16</td>
</tr>
</tbody>
</table>

For the spring switch blade with only one switch rod the shift \( \Delta_2 = 16 \) cm has been imposed. The results are centralized in table 2.

One could notice that the forces \( P_2 \), which are transmitted to the switch blade by means of the toe clamp lock, rise approximately three times at “switch blade without weakening” and approximately four times at “switch blade with weakening” when the coefficient of friction increase from the value \( f = 0 \) to the value \( f = 0.25 \). The forces \( P_2 \) are lower at “switch blades with weakening” compared with “switch blades without weakening”, no matter which the value of the coefficient of friction is. For the spring switch blade with two switch rods the shifts \( \Delta_2 = 16 \) cm and \( \Delta_9 = 9 \) cm have been imposed. The results that have been obtained are centralized in table 3.

One could notice that the forces \( P_2 \), which are transmitted to the switch blade by the toe clamp lock, are lower at “the switch blades without weakening” compared with “the switch blades with weakening”, no matter which the value of the coefficient of friction is. The forces \( P_2 \), which are transmitted to the switch blade by the intermediate clamp lock, are lower at “the switch blades without weakening” compared to “the switch blades with weakening”, when the coefficient of friction is \( f = 0 \) and the forces \( P_2 \) are higher at “the switch blades without weakening” compared to “the switch blades with weakening”, when the coefficient of friction is \( f = 0.25 \).

### Table 3 - Spring switch blade type 49 with two clamp locks. Shifts and forces

<table>
<thead>
<tr>
<th>Friction coefficient</th>
<th>Imposed shift ( \Delta_2 )</th>
<th>RESULTS</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>( \Delta_9 )</td>
<td>( P_2 ) [daN]</td>
</tr>
<tr>
<td>Switch blade without weakening</td>
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<td>16</td>
</tr>
<tr>
<td></td>
<td>( f = 0.25 )</td>
<td>16</td>
</tr>
<tr>
<td>Switch blade with weakening</td>
<td>( f = 0 )</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>( f = 0.25 )</td>
<td>16</td>
</tr>
</tbody>
</table>

### 3 Value of connection forces acting upon spring rail switch under setting movement in presence of geometric irregularities

On a discrete model, similar to that in fig. 1, the situation in which the switch blade under setting movement gets into contact with the stock rail next to node 13, situated at the end of the processed area, has been analyzed. This is possible if the production technology there are no machine-tools of chip removing process in the coordinates.

Practically, for analysis it has been considered that on the processed side of the switch blade facing the stock rail, there is a geometrical irregularity with the maximum value \( \eta_{13} \) (by few millimeters) next to node 13 in the model. This irregularity may be the result of the processing of the switch blade according to a wrong direction. The setting movement forces that are necessary at the clamp
locks for the switch blade to be locked (fig. 2 to 9) have been established.

**Fig. 2** Chart \( P_2 - \eta_{13} \) for the spring switch blade type 49 with weakening, without friction and with only one clamp lock

**Fig. 5** Chart \( P_2 - \eta_{13} \) for the spring switch blade type 49 without weakening, with friction and with only one clamp lock

**Fig. 3** Chart \( P_2 - \eta_{13} \) for the spring switch blade type 49 with weakening, with friction and with only one clamp lock

**Fig. 6** Chart \( P_2 - \eta_{13} \) and \( P_9 - \eta_{13} \) for the spring switch blade type 49 with weakening, without friction and with two clamp locks

**Fig. 4** Chart \( P_2 - \eta_{13} \) for the spring switch blade type 49 without weakening, without friction and with only one clamp lock

**Fig. 7** Chart \( P_2 - \eta_{13} \) and \( P_9 - \eta_{13} \) for the spring switch blade type 49 with weakening, with friction and with two clamp locks
Similarly, but independently, the situation when in node 1 there is a maximum irregularity, \( \eta_1 \) has been analyzed. The results are the ones in table 4.

Analyzing the results that have been obtained, one can draw the conclusion that the design and the technology of execution of the switch points and stock rails are decisive for obtaining some low setting movement forces.

The geometrical irregularities in the area of the physical toe are extremely important; during the process of clinging the switch blade to the stock rail one shall avoid the contact between the physical toe of the blade and the stock rail.

4 Conclusions

The computations and analysis that have been carried out have led to the following:

<table>
<thead>
<tr>
<th>SPRING SWITCH BLADE TYPE 49</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>with only one clamp lock</strong></td>
</tr>
<tr>
<td>( P_2 ) [daN]</td>
</tr>
<tr>
<td>Switch blade with weakening, without friction</td>
</tr>
<tr>
<td>Switch blade without weakening, without friction</td>
</tr>
<tr>
<td>Switch blade with weakening, with friction</td>
</tr>
<tr>
<td>Switch blade without weakening, with friction</td>
</tr>
</tbody>
</table>

a) Both at the switch blades with only one switch rod and at those with two switch rods, the maximum connection forces, transmitted to the blades under setting movement by the clamp locks, do not lower considerably at “switch blades with weakening” as compared to “switch blades without weakening”. Moreover, these forces, when there are two switch rods, are, generally, higher at “switch blades with weakening” as compared to “switch blades without weakening”. For this reason, using of “switch blades with weakening” cannot be justified;

b) It is supposed that the frictions between the switch blades and the slide plates are lower than the ones considered throughout the analysis (by lubrication of the slide plates during the maintenance works and by producing of vibrations during the motion of vehicles);

c) Checking the geometry of the spring switch points after execution is extremely important. The possible geometrical irregularities in the area of the contact switch blade–stock rail can lead to an excessive increase of the setting movement forces. The calculations show that the limit motive power can be by far exceeded even in case of some very low misalignments.
References:

