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Function and Safety of the Turnout Spring Setting Device in Finland

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Abstract

In the turnouts, the present-day point machines are very complex and also expensive technical solutions. Therefore, a need has arisen to look for more cost-effective solutions with which at least part of the point machines of a single switch could be replaced. In this article, one such solution which is discussed, is a fully mechanical spring-actuated setting device. These kinds of setting devices have been used in the Finnish rail network since 1991 and, nowadays, there are over 1500 devices on track. The device is simple and effective, yet, at the same time, it has been suspected to contain properties that increase vibration, which can result in the opening of switch blades and derailment. To investigate this issue, this article presents the basic operating principle of the spring setting device currently used in Finland, and the mathematical and experimental force curve generated by the device. In addition to the force curve, this article also presents the dynamic vibration properties of the device which, if correctly adjusted, do not add to the vibration elsewhere in the turnout structure, thus allowing the switch blades to be held securely in place. In the inspections of the devices, however, it has been noted that there are a lot of spring setting devices with misalignments in the Finnish rail network. This has a drastic impact on the forces holding the switch blades in place. This article also presents a spring setting device piloted in Finland which is more versatile, when it comes to its adjustment properties, than the device that is currently in use.

Keywords: turnout, point machine, spring setting device, security.

1 Introduction

Uninterrupted functioning of turnout structures is one of the most important factors for safety and railway traffic operation. Railway turnouts are the locations joining the tracks directly to the rolling stock from one track to another. The turnout area is equipped with much more complex technical solutions than a standard track section, where trouble-free operation of turnouts calls for great attention with regards to both their planning and maintenance.

One of the most significant technical solutions in the turnout is the point machine. The point machine is an integrated system which takes care of moving and locking the switch blades, monitoring their position and, of course, communicating with the interlocking system. These are, in practice, the most important tasks of the turnout structure, and, therefore, securing the functionality of the point machine is of utmost importance for uninterrupted traffic [1].

The functioning of this integrated system is even more important in long turnouts where several point machines are used to move the switch blades in a certain accurately defined order. In this situation, the functioning of a single point machine is not sufficient, rather, it comes down to controlling the whole turning system at once.

Naturally, using this kind of a turning system does not come without cost. To cut down the cost, when multiple turning points are used and controlled simultaneously, various hydraulic [2,3] and mechanical [4] transmission solutions have been developed in which the force located at the tip of the switch is transferred to other points of the switch blade. This is not, however, the prevalent method in all countries. In Finland and in India [5], for example, instead of transmitting the force of the point machine by means of transmission, cost-efficiency has been sought after by using a spring-actuated setting device. They are fully mechanical devices which do not require to be run, nor do they have any power source of their own. When the point machine moves the switch blade of the turnout, it causes a certain bending moment on the switch blade which acts as a stimulus for the springs of the setting device. This is a markedly simpler and, above all, cheaper solution than an entire point machine or the transmission mechanisms mentioned above [6]. The acquisition cost of a spring setting device is only about one third of the point machine, which, in Finnish circumstances, has so far provided savings of €10 million in the acquisition cost of the devices when half of the point machines can also be replaced with spring setting devices in long turnouts.

However, the structure of the spring setting device known as Railex, which is used in Finland today, has been noted to contain certain properties that may add to the vibration in the switch area and transmission of forces from one switch blade to another. Similar behaviour has also been observed in other countries [5]. It has been seen that these properties, together with the trailable point machines, which are still mainly used in Finland, have contributed to two derailment accidents [7,8] in Finland recently. In those accidents, the switch blades suddenly opened during the passage of the train. For this reason, there is a need to investigate whether the functioning of the device is sufficiently reliable in order to determine whether to replace the actual point machine.

These issues have not been studied before, because these devices are still, globally, very rarely used. Therefore, it is very important to bring these security issues into knowledge if these kinds of fully mechanical spring devices become more common in the future. This article focuses mainly just on those security issues. The primary target is to use laboratory tests to investigate the basic operating principle of the setting device, which may serve as a starting point for the potential vibration behaviour. Another target is to investigate the behaviour of the device under train load, which will give us the final understanding about the reliability of the device in actual situations.

2 Structural functioning of the spring setting device

The functioning of Railex is based on a continuous throw rod attached from the switch blades to the spring mechanism that turns with the throw rod according to Figure 1. The length of the throw rod can be adjusted from both sides with shroud nuts, allowing symmetrical operation in both movement directions.

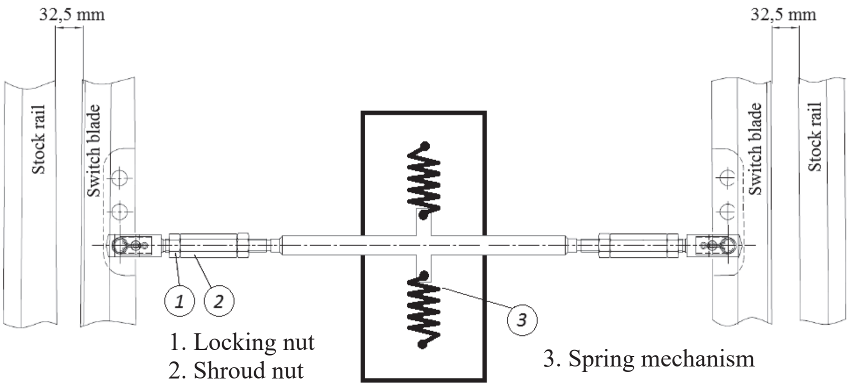

Figure 1: The basic structure of Railex and its attachment to the track

The basic principle of Railex is to press the switch blade in use with its spring force against the stock rail and, above all, to hold it in place during the passage of the train. The springs inside the device will possess some compression, even after the movement, and they will never reach their nominal length. Again, there is some tension between Railex and the open switch blade which ensures that the width of the flangeway between the stock rail and the switch blade remains adequate.

When the turning procedure starts, the spring setting device has a certain holding force and the point machine has to overcome that holding force and move the springs over the centre position, which is shown in Figure 1. The spring force is resisting the movement before this phase, but after the centre point has passed, the spring setting device starts to assist the point machine to move the switch blades towards the end position and secures the end position with a compression force.

Since the spring setting device is a wholly independent structure, it does not provide any signal about its operation to the traffic controllers. Therefore, a separate switch blade position detection device is always mounted in the immediate proximity of the spring setting device.

Despite its low-cost and simple structure, the use of Railex is causing some problems as well. The biggest problem occurs during tamping. The device is mounted in the middle of a bearer, whereas its throw rod gets settled in the middle of two bearers and blocks the tamping picks of the tamping machine. This is why the turnout cannot be mechanically tamped at the location of Railex. This problem, however, is not directly caused by the device itself, but rather by its bad positioning. In the current turnout structure, the attachment point of Railex is located between the two bearers in order that the rods of the detection device can be directed from under the rail and switch blade structure to the same attachment point. In modern turnout structures, the rods can be placed inside a hollow bearer, which solves the tamping problem.

Another weakness has to do with the continuous throw rod. The continuous throw rod, between the closed and open switch blade, is capable of transmitting the vibration in the turnout during train passage from one switch blade to the other. Because of that there can be a risk that the increased vibration in the switch blades poses a problem for the operation of the actual point machine. Therefore, for safe use of Railex, it is essential to investigate its vibration properties more closely. This way we can rest assured that the functioning of Railex is, at least, not adding to the lateral vibration, which is very harmful to the functioning of the turnout.

During the movement of the switch, the spring path forms, together with the throw rod, a triangle geometry which can be used to determine the theoretical force levels of Railex. As illustrated in Figure 2, the final throwing force consists of the spring forces which are in parallel with the rod. These force component values can be computationally determined when we know the perpendicular distances of the attachment points of the Railex spring mechanism and the spring constant of the springs within the mechanism.

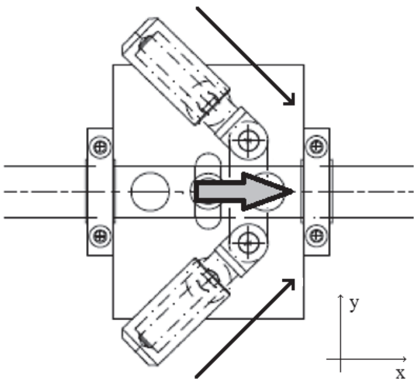

Figure 2: Turning of the spring structure towards end position. The thin arrows represent the force generated by the springs, and the thick arrow, the sum of the components in parallel with the rod

Figure 2 shows that the value of the force in parallel with the rod changes as a function of the angle between the springs and the throw rod. The final throwing force of the rod F_x can be derived from Equation (1).

$$F_x = 2k\Delta \sin\theta \tag{1}$$

In Equation (1), k is the spring constant of a single spring (61,1 N/mm), which was defined using a separate load test. Variable Δ is the change of the spring length, and variable θ represents the angle between the springs and the throw rod. These variables can be defined from Equations (2), (3) and (4).

$$\Delta = R_0 - R \tag{2}$$

$$\sin\theta = \frac{x}{R} \tag{3}$$

$$R = \sqrt{x^2 + y^2} \tag{4}$$

In Equation (2), R_0 is the nominal length of the spring at rest (115 mm) and R is the actual spring length in use. Variable x is the displacement from the centre position of the throw rod, and y is the perpendicular distance between the attachment points of the spring structure (34 mm). The constants and all the calculations are based on the Railex R102 -structure, which is used in Finland for turning the heel of the short 60E1-300-1:9 -turnout.

Based on these values, a displacement-force diagram is illustrated in Figure 3, which, in practice, shows the theoretical resisting force for the displacement x in the whole movement range.

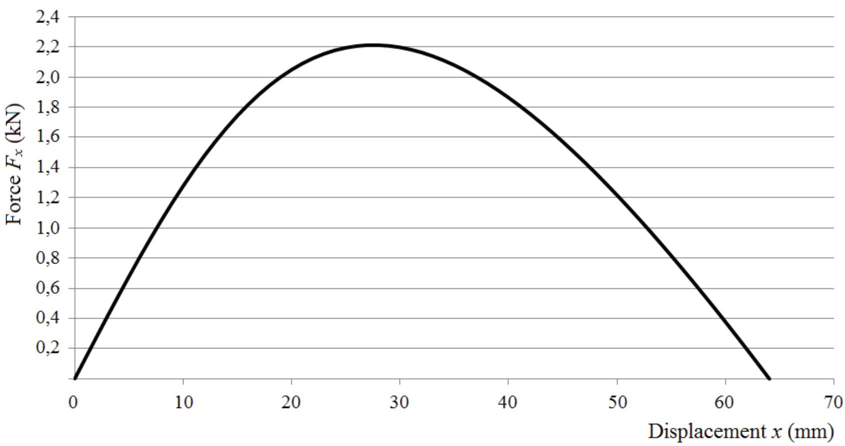

Figure 3: Displacement-force diagram of Railex (R102)

Equation 1 and Figure 3 shows that the final force F_x is impacted by two properties, the change of spring length Δ and the angle of springs θ, which are effecting crosswise. The springs are lengthening in motion reducing the actual spring force, yet at the same time the angle θ is increasing, which means that the springs are more parallel in relation to the Railex throw rod and the force is transferred better. This property makes the final force diagram parabolic shape, and the maximum value is reached when the joint impact of the spring length and the angle θ is optimal. The maximum value of the force F_x is reached with a displacement of 28 mm. Before this point, the angle has a greater impact than the spring length, increasing the force in the direction of the x-axis. After the maximum point, the reducing spring force becomes the more dominant property, also reducing the final force. This end section of the parabola, however, is somewhat insignificant after all, because the nominal value of the flangeway between the stock rail and the switch blade is 65 mm, according to current instructions [9]. This means, in practise, that the throw rod of the spring setting device is moving exactly 32,5 mm in both directions during use (see Figure **1**). In other words, the maximum force generated by the device is reached near a functional position. According to Figure 3, the maximum force in a R102-type Railex is approximately 2,2 kN, which can be compared to the values derived from the static loads presented later on in this article.

After defining the force F_x, in parallel with the rod, it is possible to also define the spring constant k_a of the whole device for motion in parallel with the rod, as well as the natural frequency f derived from it. This can be derived using Equations (2) and (3).

$$k_a = \frac{dF_x}{dx} \tag{5}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{k_a}{m}} \tag{6}$$

In these Equations, (5) and (6), x is the displacement of the rod from centre position and m is the mass of the rod (15,33 kg).

Natural frequency f is a useful piece of information for determining the dynamic properties of the spring setting device. By taking a closer look at Equations (1) and (5), it can be seen that there is not just a single spring constant for the device. Changes in the angle of the spring mechanism θ change the forces in parallel with the throw rod. In reality, this means that both the spring constant k_a and the natural frequency f are functions of the displacement x. The changing natural frequency of the throw rod allows us to quickly understand that it is very difficult to make the device resonate. The potential resonation of the spring setting device is discussed separately, in connection with dynamic test loads.

3 Load tests for the spring setting device

3.1 Laboratory test arrangements for the spring setting device

As the force diagram, described above, is only theoretical, it must be compared with the functioning of a real structure. To obtain some reference values, a spring setting device, detached from the track, was loaded in laboratory conditions with both static and dynamic load. In both of the tests, the spring setting device was loaded according to Figure 4 using a movement-controlled hydraulic cylinder attached to a firm loading frame.

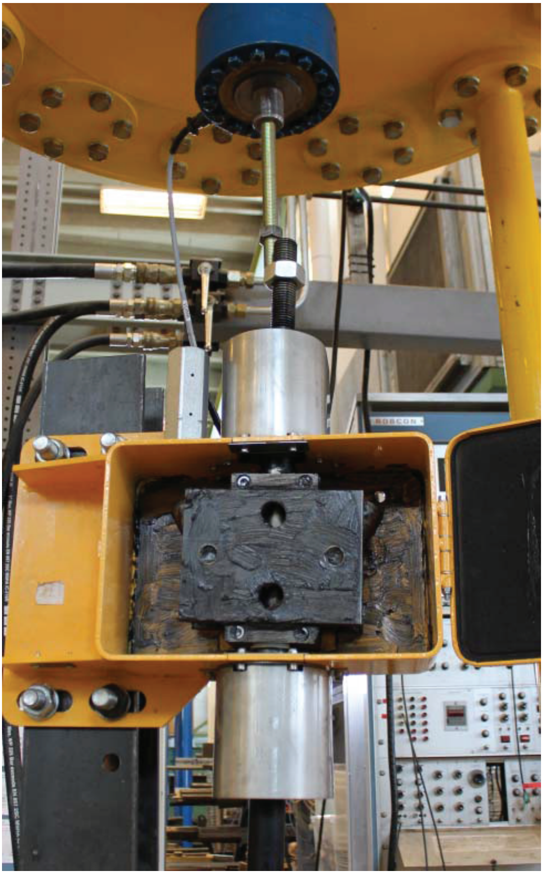

Figure 4: Equipment used for loading the Railex throw rod

The purpose of the static load tests was merely to measure the movements of the Railex rod and the forces generated by it. By using two displacement sensors and two strain gauges it was possible to measure these two quantities separately from the hydraulic cylinder used as a load source and from the Railex throw rod exposed to load. The force loading the Railex throw rod was measured using strain gauges attached to the shroud nuts, which is seen in Figure 5. Strain gauges were easy to calibrate just by compressing the shroud nut with a known load.

The idea of the static tests was to load the throw rod very gently from one end of the movement range to the other. This gave us the opportunity to measure the forces resisting the movement of the spring mechanism over the whole movement range without dynamism.

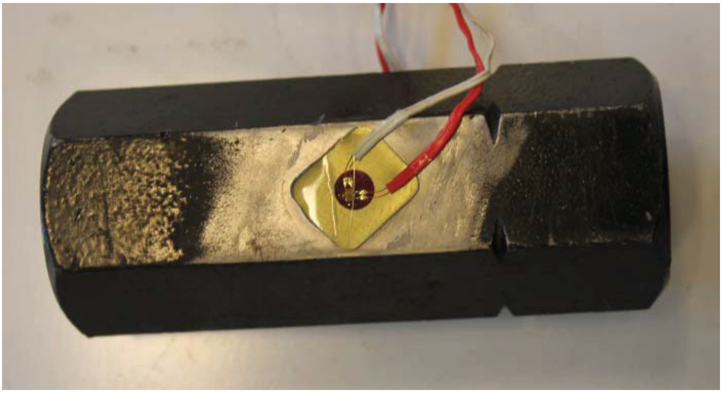

Figure 5: The strain gauge attached to a shroud nut used for measuring the force loading the nut

The control system for the cylinder and the measurement system for the sensors was implemented using DasyLab software. The static control of the cylinder was implemented in a control system in a displacement-controlled way by generating a saw-tooth wave with a very low frequency (f = 0,05 Hz). The displacement amplitude was selected, bearing in mind the 45 mm movement of the Railex throw rod on both sides of its centre position, which is more than the movement length required on the track.

In addition to the static tests, the hydraulic cylinders were also used as a hammer, giving us the opportunity to search for the potential resonance frequencies of the device. At the same time, it was also tested whether the Railex spring mechanism will follow if the loading frequency of the hammering is increased. The resonation of the device, or the inertia of the springs, could weaken the functioning of Railex under train loads and inflict uncontrolled turning of the switch blades.

Vibration measurements [10] implemented in the aftermath of a derailment accident [7] that took place in 2009 in Toijala, Finland, made us realize that the most significant forces loading the Railex throw rod emerge at the propagation frequency of a train wheelset. On the basis of the bogie frame and speed of the trains moving in Finland, we can calculate that in short 1:9-turnouts the load frequencies caused by train wheelsets are in the range of 0-12 Hz, and so the resonation was investigated at 0,5 Hz increments in this range. At the same time, it was concluded that the selected maximum frequency of 12 Hz is sufficient for testing the potential inertia of the rod.

3.2 Vibration measurements in Toijala field side

In addition to the laboratory tests for Railex, the functioning of the device and its impact on other railway structures were measured in 2012 in Toijala, Finland, under real train loads [10]. As mentioned earlier, the measurements were related to investigating the reasons for the derailment accident that had taken place at the same location. From the viewpoint of Railex, the most essential measurements made in Toijala concentrated on investigating the lateral vibrations of the switch blades and the force levels of the throw rod. The mounting locations of the displacement and force sensors in a short 1:9-turnout are shown in Figure 6.

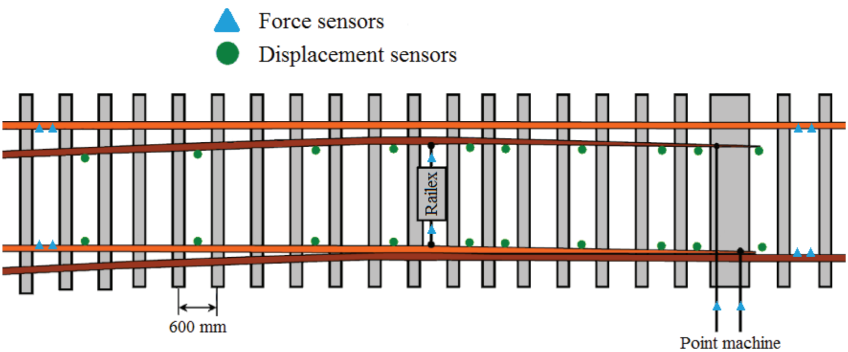

Figure 6: Displacement and force sensors used for measurements in Toijala, Finland

Prior to the measurements, little was known about the potential forms of vibration in this kind of structure. Therefore, to gather as much data as possible, the idea was to mount the sensors, evenly distributed, over the whole switch area. The sensor bodies were attached to the bearers, which in this case were considered to act as static reference points. The forces loading the actuators were defined indirectly using strain gauges glued to the rods.

3.3. Load test results

3.3.1 Laboratory test results

All static laboratory tests for the spring setting device were performed as described in Section 3.1, measuring the displacement of the rod and the force generated by the spring mechanism. One single test cycle consisted of the movement of the rod from the centre position to one end, and then to the other end and back to the centre. To ensure the reliability of the measurements, this cycle was repeated five times. Displacement-force diagrams, such as those shown in Figure 3, were generated on the basis of force and displacement measurements. One of the diagrams is presented in Figure 7.

Figure 7 allows us to immediately see that the behaviour of Railex is fully symmetrical around the centre position, even in reality. However, the forces measured from the Railex throw rod deviate slightly from the mathematical values presented earlier in Figure 3. This is quite understandable, since the mathematical values describe an entirely theoretical situation without any friction or clearances in the structure. The shape of the measured force curve still demonstrates that the operating principle of the device is, in fact, fully in accordance with what has been described theoretically.

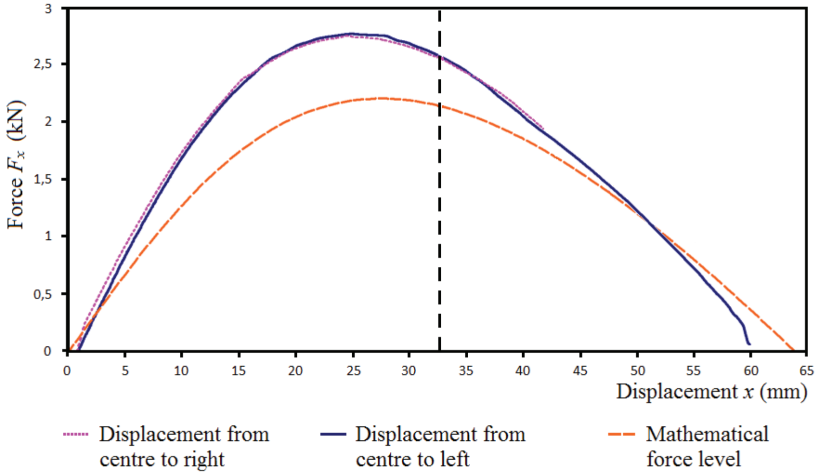

Figure 7: Displacement-force diagrams of Railex R 102. The black dotted line illustrates the location in which Railex gets settled if correctly aligned. Load directions were defined by viewing the turnout from the tip towards the heel

The actual Railex structure reaches its highest resisting force to motion at approximately 2,7 kN, when Railex has been deviated about 25 mm from its centre position. On the basis of the Railex structure and Finnish Transport Agency's instructions [9], it is known that the rod is moving about 65 mm altogether during one turn of the turnout which, if correctly aligned, corresponds to a motion of 32,5 mm on both sides of the centre position. The black dotted line in Figure 7 illustrates this location. In other words, the Railex rod moves during the turn normally over the maximum force point (25 mm), which means that realizing the movement requires a load equalling at least the maximum force.

Dynamic tests were made in three different initial positions to see whether the vibration was stronger in certain areas. Just as in the static tests, the analysis of the dynamic test results was based on investigating the displacement and force values. Thus, the displacement and force values were measured from both the loading cylinder and the Railex rod. This being the case, the dynamic behaviour of the Railex structure can be investigated simply by comparing the displacement and force signals. Figure 8 shows the displacement comparisons in the first test in which the

Railex rod was loaded with 12 Hz frequency in the vicinity of the rods centre position.

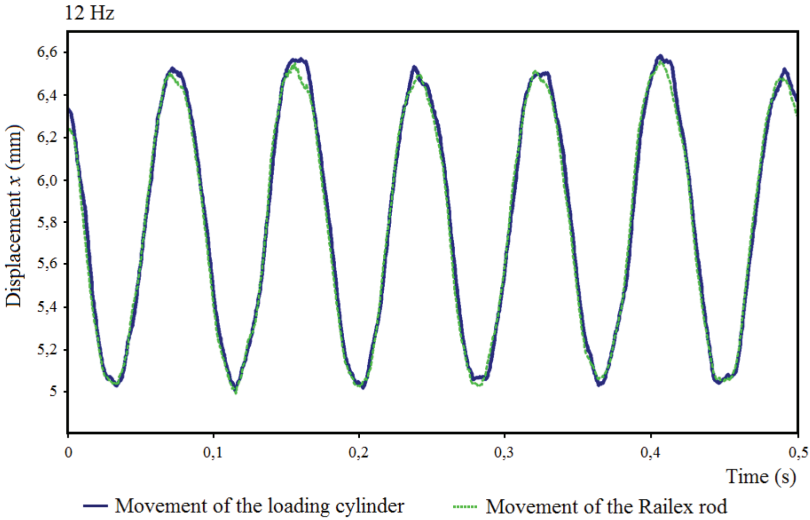

Figure 8: Displacements of the loading cylinder and Railex throw rod during 12 Hz dynamic load when the rod is located very close to the centre position

Figure 8 tells a lot about the dynamic properties of the Railex structure. The Railex throw rod follows the movements of the loading cylinder very well, even at high frequencies. This allows us to directly conclude that the Railex spring mechanism does not have any inertia properties which would weaken the functioning of Railex during fast loads. A similar analysis was made for the other frequencies and no changes were noted in the vibration behaviour. Thus, to conclude, there are no resonating frequencies in the Railex throw rod between 0-12 Hz.

3.3.2 Results of the measurements in Toijala field side

From the viewpoint of the safe operation of Railex, it is of the utmost importance to test the device in real situations, in addition to the laboratory tests. This way, we can rest assured that the force generated by the device, presented in Figure 7, is sufficient for holding the switch blade in place during the passage of the train. The actual operation of Railex and the switch blades have been measured in 2011 in Toijala, Finland, as described in Section 3.1., Figure 9 illustrates the compression of the throw rod and the displacement of the closed switch blade when the Sr2-locomotive and the first vehicle unit, following, passes the turnout.

Figure 9 shows how the passage of the train does not cause any significant lateral movements in the switch blade. As the maximum momentary displacements are approximately 0,4 mm, the order of magnitude is totally meaningless. Thus, during the passage of the train, the switch blade stays firmly in place at the location of Railex as well.

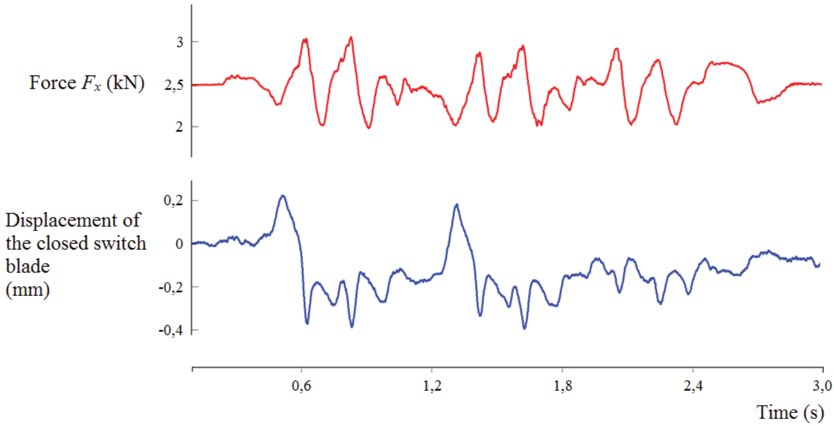

Figure 9: Change of compression in the Railex throw rod and the displacement of the closed switch blade next to the attachment point of the Railex rod when the Sr2-locomotive and the first vehicle unit, following it, passes the turnout. The negative displacement values refer to displacement away from the stock rail

However, it is important to note that the throw rod still shows signs of clear strain change. Thus, the switch blade tends to move under train load, but the spring force and the friction between the switch and baseplates manage to hold it in place. The impact of friction can be identified from the fact that the forces impacting the throw rod are, momentarily, even greater than the maximum force of 2,7 kN generated by the Railex springs. It is also noticeable that the compression force is changing very rapidly, which means that the throw rod does not have time to move significantly. These kinds of forces could, perhaps, cause problems if they last longer.

4 Adjusting the throw rod of the spring setting device

The results presented above clearly indicate that in a normal situation the spring setting device functions steadily and is safe for railway traffic. However, the situation may markedly change if the length of the throw rod is wrong or it is non-symmetrically aligned. Non-symmetrical alignment means that the length of the rod on both sides of the spring structure is not the same, and the movement of the rod is no longer symmetrical from one side to the other.

The length of the rod can be adjusted from both sides of the device using the shroud nuts (see Figure 1). Two adjustment points make it possible to adjust the device non-symmetrically which can be helpful when the switch blade is moved from the side of the longer rod to that of the shorter one, because the springs reach the centre position ($F_x = 0$) earlier and begin to push the switch blade towards a new position. However, the long throwing of the springs on the other side of the centre reduces the compressive force remaining in the rod, which makes it harder to hold the switch blade in place during train passage.

In the old adjustment instructions, the non-symmetrical adjustment was not restricted enough, because the only defined adjustment value was the 65 mm flangeway clearance, which defines the total length of the rod, but can also be reached with a non-symmetrical adjustment.

It is essential to study this issue because, in the investigations [7] made of the derailment accident in Toijala in 2009, it was found that the Railex rod had probably been aligned 17 mm non-symmetrically. A similar accident took place in Vammala in 2013, and false adjustments were also noticed there [8]. To conclude, the adjustment values of the throw rod clearly contributed to the occurrence of these accidents.

Figure 10 presents the force curve of the spring setting device, as shown in Figure 7, yet, with the change of the holding force triggered by non-symmetrical alignment of 17 mm on different sides of the device.

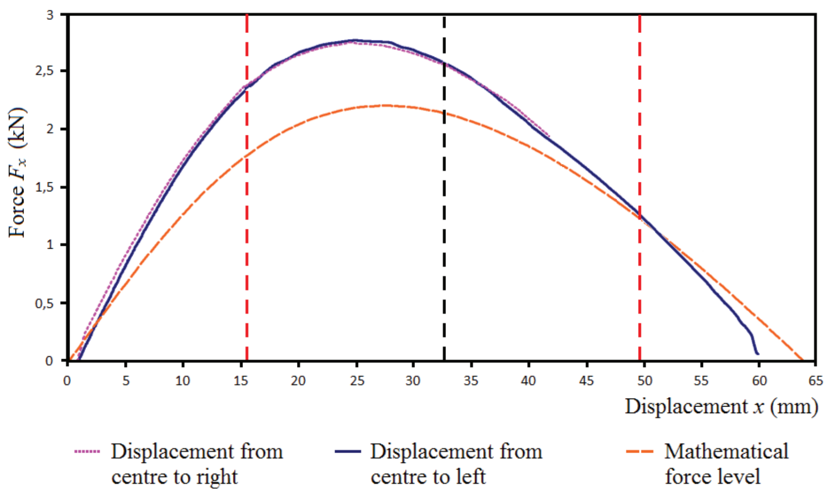

Figure 10: Displacement-force diagram of Railex R102. The dotted vertical line in the centre describes the section where Railex gets settled when correctly adjusted as in Figure 8. The dotted vertical lines closer to the edges illustrate the locations where Railex gets settled if the rod is aligned 17 mm non-symmetrically, as was noted to be the case when investigating the accident in Toijala, Finland

The dotted vertical lines, closer to the edges in Figure 10, describe how great the resisting forces Railex could generate are in this 17 mm non-symmetrical position. In this situation, the Railex throw rod can move 49,5 mm (32,5 + 17) from centre position in one direction, but only 15,5 mm (32,5 – 17) in the other. This being the case, both positions could cause problems to the functioning of the device.

When the rod is deviated by 15,5 mm, the holding force of the device is practically at the same level compared to a normal situation, but the difference is that the maximum force point has not been exceeded. If Railex is, for one reason or another, loaded by higher forces than the above-mentioned 2,5 kN, the turning begins, and the resisting force reduces as the motion continues. In other words, the risk of sudden turning increases significantly.

According to these tests, by deviating the rod 49,5 mm from its centre position, the holding force is only 1,1 kN. As the compression reduces by this much, the switch blade may move more easily at the location of Railex during train passage, which increases vibration in the switch blade structure. As the sudden turning of the turnout at the location of Railex still requires exceeding the maximum force (2,7 kN), this adjustment does not directly help the Railex throw rod to turn to the other end position. The increased lateral movement of the switch blade is, however, always unfavourable for the functioning of the turnout, because it stresses the point machine and may result in breaking it. Therefore, according to these studies, the Finnish Transport Agency's adjustment instructions was updated in 2015 so that only 2 mm non-symmetric adjustment is allowed in future.

In the above mentioned example, it is assumed that the non-symmetrical alignment has been made precisely so that the total length of the throw rod does not change. Normally, however, the non-symmetrical alignment also impacts the total length of the throw rod, causing even bigger problems in practice. The total length of the Railex throw rod directly determines the size of the flangeway between the stock rail and the open switch blade, and this, naturally, has a major impact on the safe use of the turnout. If the total length of the throw rod has been adjusted to be too long, the flangeway becomes smaller. In this case, the inner surface of the flange of the wheel may hit the open switch blade slightly behind Railex where the flangeway is at its smallest. A potential hit would generate very high forces on the open switch blade and make an effort to enlarge the flangeway. The continuous throw rod does, however, prevent the flangeway from widening at the position of Railex, and so the Railex rod forms, in fact, a supporting point for the lateral bending of the switch blade. The rough drawing about the situation after the wheel impact is shown in

Figure **11**.

On the other side of the supporting point, *i.e.* close to the tip of the switch blade, the flangeway naturally tends to become smaller, which can result in the opening of the trailable point machine, or even breaking of the whole point machine and derailment. It is quite possible that the two derailment accidents mentioned above were caused by this very scenario.

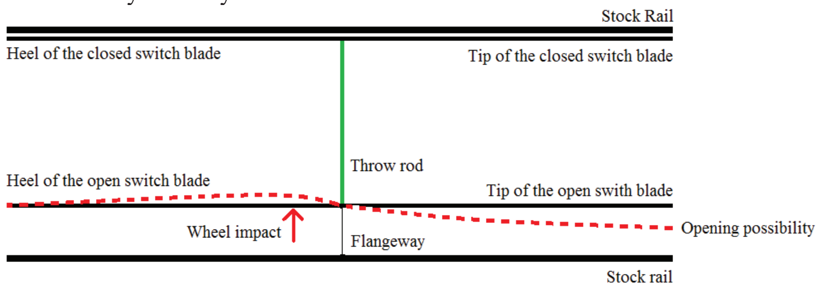

Figure 11: Opening possibility of switch blade after wheel impact force

If the width of the flangeway has changed, it is always a pronounced problem in Finland, because there are two types of rolling stock moving on the Finnish rail network. In addition to the normal Finnish rolling stock, there are also the freight wagons that are moving between Finland and Russia, which are built in accordance with the GOST standard. In the GOST standard, the distance between the outer surfaces of the flanges is 4 mm shorter than in the Finnish rolling stock, which calls for the need of a wider flangeway. Therefore, the Finnish turnout geometry has been designed to function as a compromise between these two wheelset widths. As a result, the flangeway width range 63-68 mm, defined in the Finnish Transport Agency's official maintenance instructions [11], is somewhat tight, having no room for the false alignments presented above. The Tampere University of Technology has made calculations about the actual flangeway width in different wearing situations [12] and, in those calculations, it has been revealed that the nominal flangeway width of 65 mm is not even sufficient in utmost situations where the switch blades of the turnout have worn out to their limit and a wheelset, which is in accordance with the GOST standard, has a barely acceptable amount of wear.

These facts point out that the total length is the utmost important thing when adjusting the Railex throw rod. Nevertheless, these deviations in throw rod length have been noted in many maintenance areas. In the inspections made for spring setting devices in the autumn of 2013, it was discovered that out of the 470 inspected devices some kind of false alignment occurred in 17% of all cases. This means that the expertise of the maintenance personnel required for aligning this device seems to vary.

5 Evolution of the spring setting device in Finland

The Railex spring setting device, presented in Figure 1, is the only one that is actively used in Finland today. However, other kinds of spring setting devices have also been manufactured in other countries. For this reason, the Finnish Transport Agency decided, in connection with other development of the turnout structure, to pilot a new spring setting device structure. This new structure is presented in Figure 12.

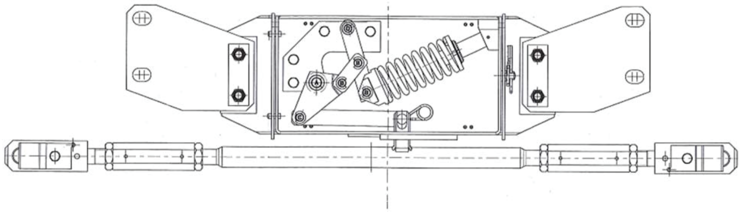

Figure 12: The new spring setting device structure piloted in Finland. [13]

As we can see from Figure 12, there is an entirely different mechanism in use for transferring the spring force to the throw rod. Contrary to Railex, this mechanism allows the generation of force in parallel with the throw rod by using only one spring. Figure 13 indicates how the force is transmitted through the mechanism in different situations.

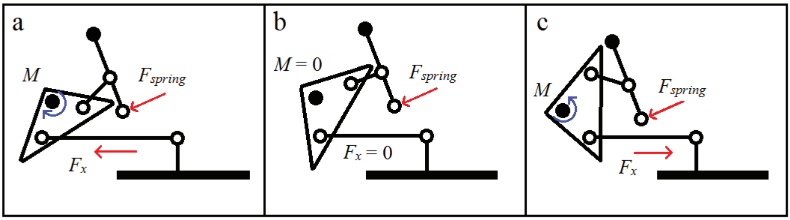

Figure 13: Force transmission from a spring to throw rod. The device in its a) left end position, b) centre position, c) right end position

Since the spring mechanism is distinctly different from the current Railex structure, it is essential to test what kind of a force curve this device can generate. The static force curve of the new device was created by loading the throw rod, as presented in Section 3.1., slowly from edge to edge in the whole movement range. Figure 14 presents the force curves of Railex and the new spring setting device next to one another.

The static force curve of the new device proved to be very linear, which means that the mechanism distributes the force evenly over the whole movement range. Arising from the mechanism, the force generation is not fully symmetrical, but, in the position at the time of using the turnout (32,5 mm), the force holding the switch blade, approximately 3 kN, is the same on both sides. At the same time, the behaviour of the device is compared with the currently used Railex. The most important thing is the level of the compression force during turnout use, which is very similar in both cases. There is a difference in the shape of the curve, but it is of importance only when the length of the throw rod has been aligned non-symmetrically and its end position deviates from 32,5 mm. The length adjustment solution is very similar to that of the current Railex structure, which means that the false alignments presented in the previous chapter are possible in the new structure as well. Arising from the linearity of the force, the non-symmetrical alignment affects the force levels of the new spring setting device much more than that of Railex. When the new device is used, it is all the more important to avoid non-symmetrical length alignment of the throw rod.

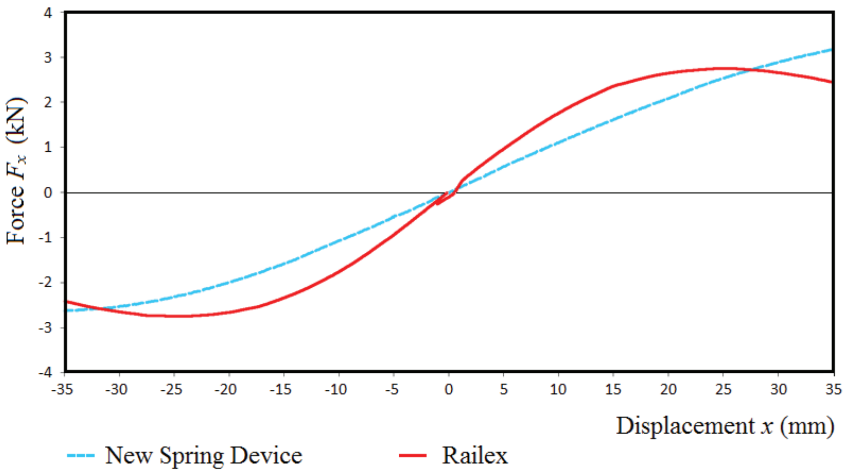

Figure 14: The static force curves of both spring setting device types

The new structure does, however, also provide some advantages in comparison to Railex. First, the device is notably smaller by its outside measures than Railex, and it can be fully mounted on top of a single bearer if desired, for example. This way, it does not disturb the tamping work in any way, which has been considered a major problem in the current structure. The small size also decreases the risk of hit from the ice blocks which are dismounting from the boogies.

Second, a markedly clearer benefit of the new structure is the adjustability of the spring force. The precompression of the spring is fully adjustable by turning the screw on its heel. This is a considerable difference in relation to the currently used Railex in which the springs are mounted inside a standard-length bracket without the possibility for adjustment. As a result, currently, we have two different springs in use in Finland because turning the long turnout needs bigger force. Adjustable precompression makes it possible to shape up the force curve of the new device, and so the same device is suitable for both short and long turnouts where a different level of turning force is required. The impact of the precompression of the spring is presented in Figure 15.

Figure 15 indicates that changing the precompression length is in linear proportion to the slope of the force curve. This property makes it possible to use one and the same device to generate any desired compression force at a desired location. The only limiting factor for the use of the device is the maximum movement length, which is approximately 90 mm in this prototype. Therefore, this prototype device cannot be used in the tip of the long turnout, where the required movement length is 110 mm. The maximum movement length can, however, be modified by lengthening the rods of the linkage and the distance between the attachment points of the triangular piece (see Figure 12).

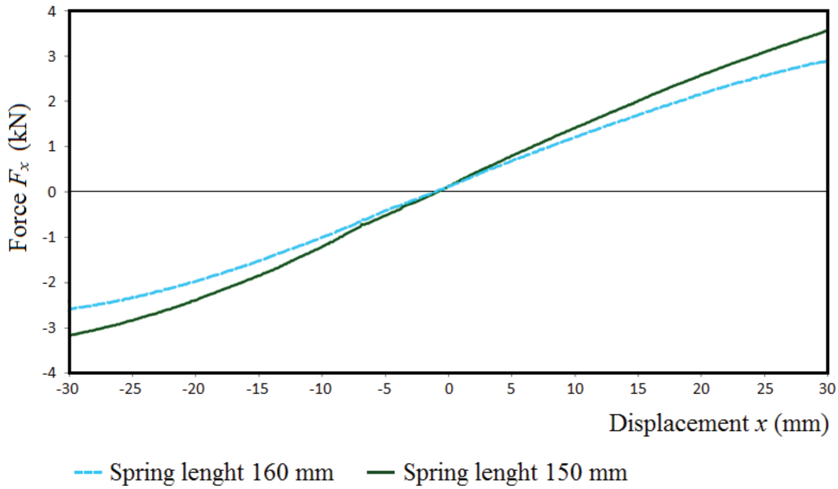

Figure 15: The static force curve of the new spring setting device with two different precompression lengths. The default value of 160 mm for the spring is presented in the diagram

The adjustment of the precompression force is an important factor, especially in cold conditions like in Finland. In winter, the temperature of switch blades can be quite low, which will increase the tensions in the steel. To overcome these extra tensions in the switch blade, the spring device will need little bit more force in winter time. The precompression force settled in the factory should be enough to overcome these changes, but it is still convenient to have the possibility to increase the precompression on site, if problems are arising. But, in order to avoid any new false alignments, adjusting the precompression length of the spring must be the responsibility of the device manufacturer or the assembly phase, and it should be changed only in special situations after manufacturers command.

In addition to this development work in Finland, the aim in the future is to test a new spring setting device in which both of the switch blades would be moved with their own throw rods. The benefit then would be that when the flange of the wheel hits the switch blade, the loads would not be transmitted on the point machine as radically as before. Instead, the switch blade would back down slightly at the location of the spring setting device. This would markedly reduce the risk of opening the actual point machine.

6 Conclusion

The calculations and measurements presented here shows that the properties of the Railex spring setting device are sufficient for holding the switch blades securely in place during the passage of the train. This being the case, the Railex spring setting device can be used in situations where there is the need to replace part of the actual point machines with more cost-effective alternatives. In addition to Railex, there are other spring force based spring setting devices on the market, one of which is in pilot use in Finland. This solution has proven to be at least as effective as Railex.

The unconditional prerequisite for the safe use of the tested devices is that the throw rod must be carefully adjusted, because false alignments may result in a marked loss of compression force holding the switch blade, and so leads to a lack of safety. False alignments of the rod may also lead to the narrowing of the flangeway between the open switch blade and the stock rail, causing a yet higher risk of accidents. If the flangeway width is changed, it is always a pronounced problem in Finland, because there is a lot of rolling stock, in accordance with the GOST standard, moving on the Finnish rail network with a narrower distance between the flanges than in the Finnish rolling stock.

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