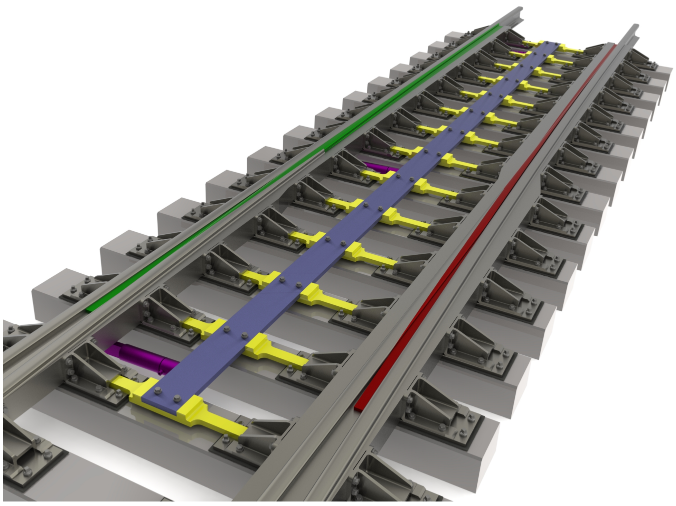
CIE4870 Structural Design of Railway Track

Winter-proof turnout



Authors:

G.Pipintakos (4635248)
R. Jan Bloem (4301919)
W.J Noca (4516990)

Supervised by

Dr. V.Markine

May 3, 2017

Contents

List of Figures

Winter-proof turnout

G. Pipintakos (4635248),W.J Noca (4516990),R. Jan Bloem (4301919)

Supervised by Dr. V.Markine

May 3, 2017

1 System description and analysis

1.1 Working Principle

For decades, the current switching mechanism has remained the same and this of course reflect the quality and the genius behind it. Among the problems that can arm this system, one of the most important is related to cold weather, in particular due to the presence of snow and ice.

In the Netherlands, NS takes into account the negative effects of winter weather, in particular they resealed a statement in which all the consequences of winter weather were described. Namely they are:

- Ice under the trains: ice and snow tend to accumulate under the cars of the trains and can breaks off over the switches in the track. This is why they use a product in order to avoid the accumulation in the first phase.
- Disruption on the electrical installation due to ice.
- Frozen Switches: as said in the first point the snow and ice can accumulate on the switches and this can froze. Nowadays ProRail heats more than 5500 switches on the network using particular heaters and this obviously can cause delays and extra costs.
- Ice on overhead power lines: this can reduce the contact between the cable and the train and cause a reduction of energy that can be not sufficient for the trains.

In order to solve the problems related to the ice and snow on switches a winterproof tournout has been invented by Richard de Roos. The idea is to have the switches not moving horizontally like it currently happen but vertically through an electronic and hydraulic systems. This system will than prevent the accumulation of snow and creation of ice blocks in the mechanicals parts of the turnout making the switches heater useless. The switching process consist in 3 different phases:

1. The blades that is down is lifted by means of an hydraulic system
2. A locking bar (see figure) than, is pushed by an hydraulic system under the lifted blades leaving free the other blade
3. The blade that now is free is pushed down from the same hydraulic system of the phase 1

The locking bar play an important role during the process because it guarantees the main safety of the system. Going below the blades it provides continuity with the base structure meanwhile the other blade that is in down position act as a lock, blocking possible movement of the bar. The hydraulic and electrical systems than provides the basic movement of the switch and determine also the “speed” of the switching process influencing than the whole infrastructure.

1.2 Design function

The main function of a turnout is to switch from one track to the other track. For this function a switch can be divided into three parts. There is the switching panel, the closure panel and the crossing panel. In the crossing panel the crossing nose is located. In this part the train crosses the track of the through direction. In the closure panel the closure rails are located. This is the part which lays in between the switch blades and the crossing nose. In the switching panel the movable parts of the switch are located. Therefore in the Winterproof turnout the switching panel will change. The closure and crossing panel of the Winterproof turnout will be the same as in the traditional turnout.

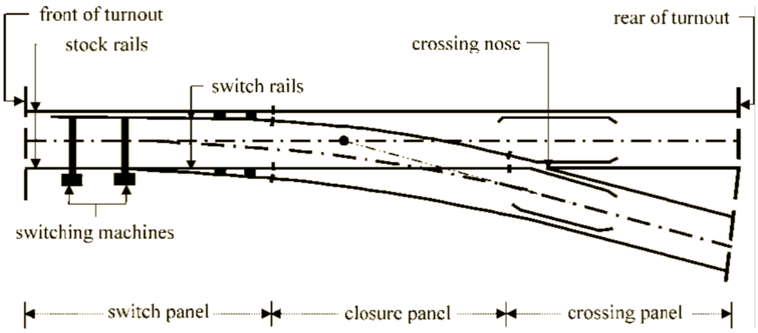


Figure 1: traditional switch

In the traditional switch the blades of the switch move horizontally. Both switch blades are connected with each other, so that the blades can guide the train only in one direction. The winter-proof turnout has two blades which move independently of each other. Also, the switch blades move vertically instead of horizontally. When one of the blades is moved upwards, the locking-bars will move and will lock the blade to prevent it to lower. When the locking-bars have moved, and are in the right position, the other blade will be lowered.
Despite the differences in both design the main function of both switches is the same. Both designs let a train switch from one track to the other. Furthermore, both design ensure that only one direction is possible. In a traditional switch both switch blades are connected which each other and move simultaneously. However, in the winter-proof turnout the blades move independently of each other, but the locking-bars prevent the switch blade which is in the upper position to lower due to the weight of the train.

1.3 Advantage and disadvantages of the proposed solution

The innovative idea of Richard van Roos using vertically movable blades instead of the traditional horizontal, that are used through the last centuries, is analyzed below in terms of the positive and negative aspects that will have in the train operation system. First of all it is crucial to highlight that the main advantage is considered the lack of heaters that the common turnout is using and simultaneously the energy reduction that will result by this. However, the turnout is still in experimental stage and further need of testing about the dynamical behavior of forces and thinking of maintenance is needed.

1.3.1 Benefits

- Saving energy – Since the heaters hare not necessary anymore
- Reduction of CO_2 - Lower Environmental Impact Indicator
- Cheap solution – Low energy bills and simple mechanical setup
- No need of expertizing employees
- No disturbing of track from ice and snow
- Eliminate train delays due to possible extraordinary works due to ice on the rails
- Function of the turnout 24/365 in every weather condition
- No maintenance for heating systems is required

- Less risk of derailment
- Climate change is reality – Sufficient solution for more severe winters

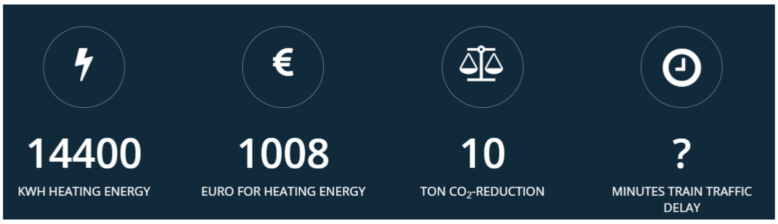


Figure 2: Actual facts of energy and environmental savings of the waterproof turnout

1.3.2 Drawbacks

Probably the most important issue is related to the difficulty to install a passive system to provide the possibility for a train coming from the wrong direction to not derail. The list of all the drawnback is listed here and it has to be considered that this system is still under development so some possible negative sides cannot be predicted properly. Mainly we can underline:

- Lack of real application and potential problems
- Possible derailment in the trailing direction due to wrong position of the vertical blades
- Lack of knowledge about maintenance
- Possible impact in the switching part
- Damage of connecting strip
- Unwillingness of acceptation from the existed companies and need of certification
- Need of mechanical testing in high speeds trains
- Difficulties of change the worldwide accepted used turnout

1.4 Suggestions for improvements of the design using numerical optimization.

First of all to formulate numerically the optimization problem someone has to think which part of the turnout will take into account in order to optimize the function of winter poof turnout totally. For the need of the task it is decided to consider the blades of the turnout as our optimization issue. Initially the requirements that are taking into account are the safety barriers and maintenance aspects.

The first requirement for the design of the blades that is examined is safety. We need a to have a sufficient function of the blades for that reason we need constraints for the deflection of the blades separately. For the blade that is up, we need an extreme value which the deflection should smaller than this in order to prevent derailment and for the blade that is down we need a sufficient value that prevents the contact of the flange with the blade,

we have

$$u_{top,x} \leq u_{top,allowable,x}$$

and also

$$u_{bottom,x} \geq u_{bottom,allowable,x}$$

The second requirement for the design of the switch blades is that the stress of the interface should be smaller than the allowable stress, to prevent failure of the switch. Furthermore, the stress of the interface should be larger than a specific value, because otherwise the switch blade can be over dimensioned. When the switch is over dimensioned the design of the switch is not cost efficient.

$$\sigma_{Ed,interface,x} \geq 0.8 * \sigma_{interface,allowable,x}$$

$$\sigma_{Ed,interface,x} \leq \sigma_{interface,allowable,x}$$

Another requirement for the design is the maintenance of the blades of the new turnout.The service life in terms of number of cycles of the blades affects the maintenance and we can express it as

$$N_{cycles} \leq N_{deterioration}$$

Where $N_{deterioration}$ is a fixed value that represent the lifetime of the material. When this value is exceeded severe damages occurs.

The variables that are taking into account are the thickness of the blade **t** and the height of the blades **h**.

The next step is to formulate the optimization problem in order to improve the design. In order to proceed with this, we first have to choose which requirement will choose as our objective. For the general acceptance of the new type of turnout in the market it is considered crucial to minimize the maintenance and through it potential cost aspects. We will combine the aforementioned aspects into a multi-criteria function using weighted coefficients depending on the importance of each requirement in the final improvement. We will have in this function finally,

$$F_{improved} = a_1 * \frac{N_{deterioration}}{N_{cycles}} \Rightarrow Min$$

which will be subject to the above constraints:

for the deflection of the up blade

$$\frac{u_{top,x}}{u_{top,allowable,x}} \leq 1$$

for the deflection of the blade down

$$\frac{u_{low,x}}{u_{bottom,allowable,x}} \geq 1$$

for the allowable stress

$$0.8 \leq \frac{\sigma_{Ed,interface,x}}{\sigma_{interface,allowable,x}} \leq 1$$

2 Emergency system to face a wrong direction switch configuration

2.1 Running through a traditional switch

[van Houvelingen, 1984, onderzoeksraad, a, onderzoeksraad, b, verkeer en waterstaat, 2007]

When a train drives from the rear of the slip to the front of the slip, also called trailing direction, a problem can occur. If the train is coming from one direction, while the direction of the switch blades is the other direction, the switch blades are in the wrong position. This result in a problem in which the train could derail. However, this problem is prevented due to horizontal movement of the switch blades. When a train comes from the wrong direction, the flange of the wheel introduces a horizontal force on the switch blades. This horizontal force moves the switch blades to the right position for the train to drive over the switch. As a result of this passive system, also known as "running through a switch", the train is prevented to derail.

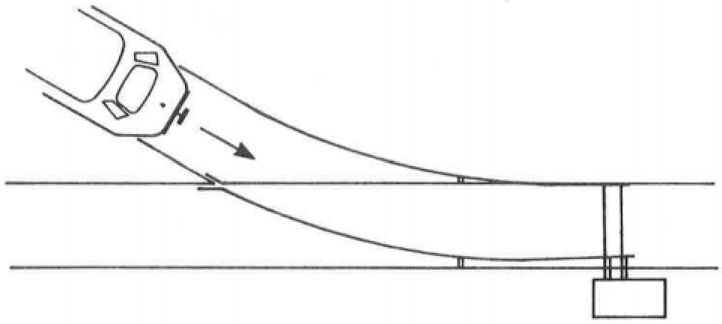


Figure 3: Running in wrong direction of a traditional switch

However, when this occur the switching mechanism is damaged. In fact, in normal conditions the switch blades are locked in their position to prevent them to move when a train passes and therefore preventing a derailment. But, when a train comes from the wrong direction the switch blades are forced to move, so a safety mechanism in the control system of the switch brakes unlocking the blades. This safety mechanism prevents the switch engine to get broken. However, due to this breaking the controller cannot control the switch anymore. Therefore, there is no traffic possible on this broken switch.
Because of this in the Netherlands it is not allowed to run through a switch. Every switch must be in the right direction and is protected with a signal. Therefore, a train only can run through a switch, when the driver ignores a red signal and run through a switch. However, due to the passive movement of the switch, the train will not derail but it will damage the switch.

2.2 Disadvantages of current solution

[G.Grudning and C.Pucher, 2014, ERTMS, 2013, Corporation and TranSmart Technologies, 2005]

The problem existing with the trains coming from the wrong trailing direction is suggested to be solved with ERTMS signalling system. The ERTMS has two basic components: an automatic train protection system to replace the existing national ATP systems and a radio system to provide communication between the track and the train based on GSM frequencies. The ERTMS is proposed as a solution to the problem because it will increase the capacity of the existing lines and provide the waterproof turnout with a greater ability to respond to growing transport demands, keeping in mind the continuous communication-based signaling system.
Moreover, when a train comes from the wrong trailing direction it will be able through this continuous communication to recognize beforehand with a simple wheel detection system if a change of the blades is needed. The train detection system is working by gathering the information of direction speed and initiate the operational sequences.
In this situation the closure and opening sequences are interrelated with the signaling system and are triggered by train movements. This enables the change of the blades in case they are positioned in the wrong direction. However, one have to think about the time needed for this change of the blades and the possible location of these wheel sensors in order to avoid possible derailment or at least.

So the system that will be used will not be the common passive system adopted nowadays but an interactive system with full co-operation of the train movement and the position of the crossing blades. An active system tends to be prone to wrong estimation of the wheel position and speed due to malfunction of incorrect setting by the operator. Obviously, this kind of mistake can cause derailment and put in danger the passengers. Another possible problem can come from a lack of electricity due to a malfunction of the system or the main electric network. This is why a backup electrical system is considered necessary in order to have a continuous undisturbed source of energy to be safe against black-outs. Moreover, it has to be kept in mind that the cost of such advanced electronic radio/GSM based system is comparatively high with the passive system.

Finally for underground turnouts the sensors frequencies can highly be affected by the ambient conditions like tunnels or areas with weak GPS signal coverage.

2.3 Alternatives

Although the idea is simple, the structure is still quite complex and is strongly depended on electrical systems. This is the reason why it gets complicated to intervene with a mechanical system in case of electrical malfunction, or human mistakes. A rough idea will be proposed here but is clear that need some work and deep research to be proposed to the designer.

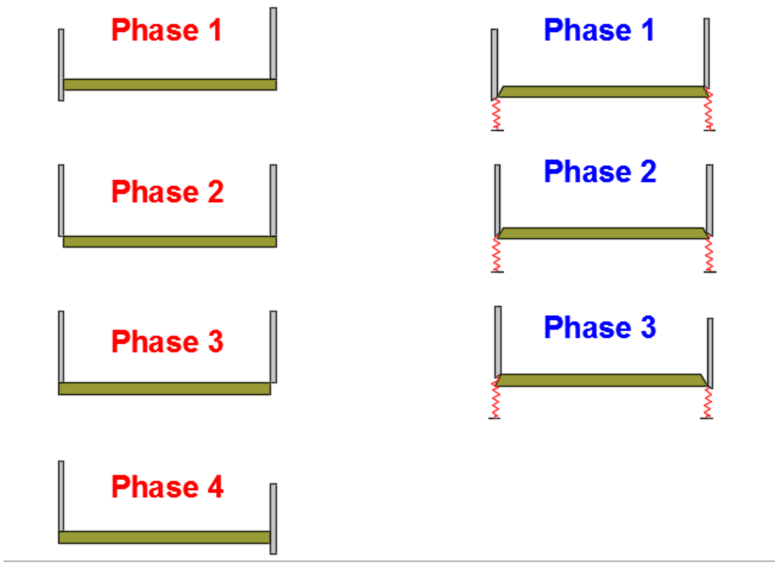


Figure 4: step process of possible alternative

Need to be remembered that we have unlighted 3 main phases in the switching of the direction it appear clear that in such kind of emergency situation this process cannot happen in 10-20 seconds but need to be almost instantaneous, so the first problem is to unlock mechanically the system in order to not depend on electric system than it is possible to work on the switching process.
The main idea is to modify the lifting system and the locking bar and blades design. The mechanism is really stiff and strongly locked so the main principle is to modify the lifting system mechanically when the train comes from the wrong direction allowing the two blades to go up and down freely. Of course, one of the two blade will be carried by the switching bar meanwhile the other one will go down. So now that the blades are free to move the idea is to change the shape of the switching plate and blades on the edges so when the train approach to the switch with his weight it will push down the blade that is sustained by the plate that will be pushed in the opposite direction. Doing this movement the switching blade that is down will be lifted and the train will be able to overcome the few meters of the switch.
Obviously also the second blade will push down the plate so in static equilibrium with perfect horizontal track the switch would be both half lifted and the switching plate in the middle. This problem could be overcome providing a little inclination so reducing the weight on one side and increasing the one that need to push down totally the blade.

It appears clear that this proposal need a lot of work, all the mechanism need to be studied and properly designed but we believe that there is an open window to work on this idea.
At the moment, the principal solution remain the electric security system that could just be improved with backup energy system in case of malfunction of the electrical network or general blackout.

3 Secondary risks

Among others possible derailment is possible due to the wrong function of the locking bars. More specifically, the ballast or additive dust can be located in between the rigid locking bars preventing consequently the blades to shift up and down. This will prevent the normal function of the turnout and increase the wear or in the worst scenario results in derailment. Furthermore, the potential severe winters when temperatures below zero are observed with combination with snow can result in a layer of ice, especially if the blade is down for a sufficient time. This will make trouble and need high force to lift the blade and maybe the thickness of the layer will malfunction this upward movement.

3.1 Other issues

A critical part in the design of the winterproof turnout is the alignment of the vertical moving blades and the normal rails. Even when there is a small height difference between the switch blade and the through rail, impact forces will develop. Due to the impact forces are generated by the inertia of the rail system, the forces on the rails and blades will be larger than the static forces which are applied on the rails due to the train weight. Due to the higher forces the stresses and wear of the rails and blades will be higher. This will result in increased maintenance of the switch and a shorter life time. Therefore, the blades should be at exactly the same height as the trough rails. Furthermore, in the design also impact forces have to be considered.
Also failure of the hydraulic mechanism should be considered. When due to the a failure in the hydraulic system the locking-bars cannot move or the switch blades cannot be raised or lowered the controller should be notified that the switch is not safe for the train to drive over it.
When the locking-bars are not in their final position danger exist for derailment of the train, because the switch blade is not fully supported by the locking-bars. Also when a switch blade is not lowered or not supported by the locking-bars damage will occur in the hydraulic system. This will be difficult to replace and therefore should be avoided.

References

[Corporation and TranSmart Technologies, 2005] Corporation, U. and TranSmart Technologies, I. (2005). Low-cost highway-rail intersection active warning system field operational test.

[ERTMS, 2013] ERTMS (2013). The european rail traffic management system.

[G.Grudning and C.Pucher, 2014] G.Grudning and C.Pucher (2014). Various application of wheel detection system with inductive wheel sensor.

[onderzoeksraad, a] onderzoeksraad.

[onderzoeksraad, b] onderzoeksraad.

[van Houvelingen, 1984] van Houvelingen, A. (1984). Opleiding en vorming. *NS*.

[verkeer en waterstaat, 2007] verkeer en waterstaat, I. (2007). Onderzoeksrapport.