Ewelina Kwiatkowska
Dr inż. / prawnik
Adiunkt, Politechnika Wrocławska Katedra Mostów i kolei;
Prawnik Lex-Rail Kancelaria Prawna
kwiatkowskae@interia.pl

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INNOVATIVE RESEARCH METHODS OF DIAGNOSTICS TURNOUT

Abstract: This work is devoted to the process of diagnosis of railway turnouts with the use of innovative research methods. The results of tests and analyzes carried out on switches with the use of a scanner for three dimensional measurements of railway rails profiles were presented for early diagnosis of damage to spiers, resistors and crossings. The paper presents the method of testing dynamic interactions generated by railway traffic on switches with underlay pads in order to assess the impact of washers on the vibro-isolation and durability of the turnout structure.

Keywords: Research methods of railway track; Railway turnouts; Track dynamics

The development of infrastructural investments on railways contributes to the increase in the speed of traffic. The increase in the speed of rail traffic requires the railway infrastructure manager to increase expenditure on the diagnosis and maintenance of railway lines in order to ensure the safety of travelers traveling by rail. Railway infrastructure is a complex system of dependencies in which the weakest element determines the level of security of the entire system. As a result of the analysis of threats resulting from the increase in the speed of rail traffic, the technical and maintenance quality of railway turnouts is a key element of the system. Railway turnouts being a crossroads of tracks on railway lines affect safety and determine the maximum speed of railway traffic [1] [2].In order to ensure the safety of railway traffic on switches, inspections, diagnostics, and regular maintenance and repair work should be carried out. In accordance with the revised provisions of PKP PLK, instructions for visual inspection, technical tests, and maintenance of the Id-4 turnouts from 2015, the inspection is carried out in the cycle presented in Table 1. The dates of the inspections depend on the category of railway lines, the type of tracks [3].

Tab. 1. Terms of turnouts inspections [3]

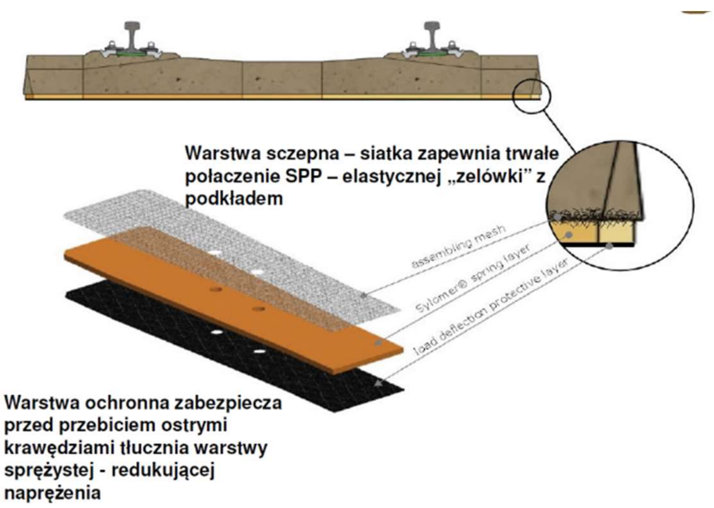
L.p.	Rodzaj toru	Kategoria linii				Infrastruktura nieczynna lub częściowo wyłączona*)
		Magistralna	Pierwszo-rzędna	Drugorzędna	Znaczenia miejscowego	
1	2	3	4	5	6	7
1	Szlakowe, główne zasadnicze i dodatkowe	1 x 1 dobę	1 x 1 dobę	1 x 1 dobę	1 x 1 dobę	1 x 6 miesięcy
2	Pozostałe	2 x 1 tydzień	2 x 1 tydzień	2 x 1 tydzień	2 x 1 tydzień	
3	Wszystkie	wg § 4 ust. 3				
*) Wykonuje pracownik dokonujący obchodów torów na obszarze swojego działania						

The frequency of conducting diagnostic tests in accordance with the Id-4 of 2015 is presented in Table 2, making the basic frequency of tests dependent on the speed of traffic and the load being transferred.

Tab. 2. Frequency of railroad turnout tests [3]

L.p.	Parametr	Częstotliwość badań przy określonych parametrach eksploatacyjnych				
1	2	3	4	5	6	7
1	Prędkość [km/h]	V ≤ 40	40 < V ≤ 120		120 < V ≤ 160	160 < V ≤ 200
2	Obciążenie [Tg/rok]*)	-	≤ 10	> 10	-	-
3	Częstotliwość podstawowa	6 m-cy	6 m-cy	3 m-ce	3-m-ce	2 m-ce
4	Częstotliwość wydłużona	max 12 m-cy	max 9 m-cy	max 6 m-cy	max 6 m-cy	max 3 m-ce
*) Obciążenie – sumaryczne obciążenie przewozami wszystkich kierunków w rozjeździe 1)						

The applicable diagnostic procedures for turnouts are based on classic measuring equipment for measuring the position of the track in the plan and profile, among others track gauges, profile gauge, feeler gauge, arrow gauges, measuring draisines, geodetic devices. Classic diagnostics provide the ability to detect the resulting damage to the switch and plan its repair. However, in the process of modernization and introduction of the latest standards in maintaining railway turnouts, it is advisable to introduce research procedures allowing to detect defects at their early stage, ensuring the safety of traffic and maintaining maximum railway traffic speed, by preventing damages causing the need to reduce the speed of crossing. One of the methods of early detection of turnout damage is the use of optical scanners for three-dimensional diagnostics of the examined elements, the second research method allowing early detection of damages is the analysis of dynamic impacts caused by railway traffic. At the Wrocław University of Technology in the Cathedral of Bridges and Railways since 2016, it is run by PhD Eng. Ewelina Kwiatkowska, a railway turnout study program using innovative research methods. The tests are conducted on two test sites, the first polygon is located at the Siedlce station, Fig. 2 and 3 on two turnouts type Rz 1: 12-500-60E1 in the construction of the first tested crossover, anti-vibration panels are used in prestressed concrete turnout sleepers. underlay pads (PPP) fig. 1, PPP was not used in the second travel. The second research area is located at the station Krakow Towarowy in the type Rz-60E1-1: 9-300 from PPP and the Kraków Łobzów station at Rz-60E1-1: 9-300 without PPP. The structures of the tested turnouts belong to two Polish producers of turnouts at the Siedlce station to Trac Tec KolTram in Zawadzkie, at the Kraków Łobzów station and Towarowy to KZN Bieżanów station.



1. Mats for undercoat use in prestressed concrete turnout sleepers

The polygonal tests of turnouts are divided into two parts. The first part of the research program includes turnout geometry tests in plan and profile carried out with classical measurement techniques in accordance with the instructions of the manager of PKP PLK Id-4 and using the innovative 3D optical scanner produced by Graw. Classical tests of turnout geometry measurements in the plan and profile were made using a profilometer, a track gauge, a shooter, an arrow machine, and surveying devices, measurements are made every 3 months in a cycle and the range is consistent with Id-4.

In the diagnostics of turnouts, an innovative measuring device in the form of an optical scanner for measuring the profile of rails was also used, used for three-dimensional imaging diagnostics of crossings, spiers, and resistors. Measurements using the scanner are carried out every 3 months on crossings, spiers, and resistors. The tests are aimed at assessing the wear of turnout elements as a result of exploitation and early diagnostics of the damage of the turnout structure. The innovative methods used to measure the rails are compared with classical diagnostic methods to assess the research potential.

The second stage of the study of turnouts at the training grounds is characterized by the research of dynamic interactions [4]. The research is aimed at measuring dynamic interactions generated by railway traffic in the area of crossroads and transferred by crossover on the track. Studies on the dynamics of turnouts include the measurement of noise, vibration in turnout sleepers, track bedding and examination of the deflections of turnouts caused by train passing. Dynamic tests are carried out every 6 months on switches in the Siedlce, Kraków Towarowy and Kraków Łobzów stations. Dynamic analyzes are aimed at assessing the flow of application of underlay pads on the propagation of vibrations in the junction, bedstead, noise emission, and track deflection.

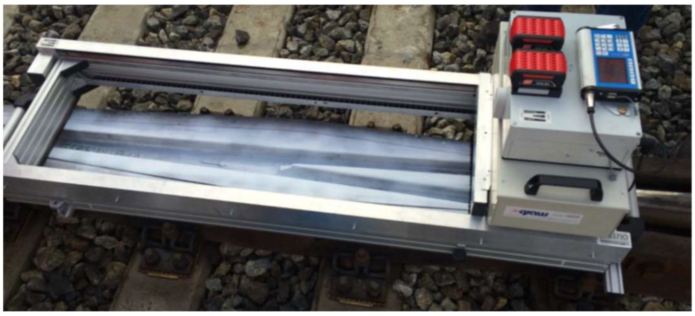
2. Turnout PPP RZP 1: 12-500-60 E1

3. Turnout without PPP Rzl 1: 12-500-60E1

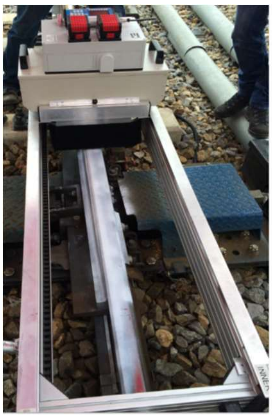
The results of geometry tests, turnout profile from the first stage are compared with the results of dynamic tests from the second stage of the research program being carried out. A comparative analysis of test results aims to evaluate the applied research methods for early diagnosis of turnout damage.

Research using a rail scanner

Laser measuring device Skorpion produced by Graw Sp. z o.o. is designed for periodic measurements of rail profiles and turnouts. Fig. 4. The device consists of a support frame, which is a rigid reference beam, laser measuring head, allowing the measurement of the shape of the measured object and the drive system allowing the automatic travel of the head over the tested object. After setting the device over the tested object, the measurement is performed fully automatically. The result of the measurement is the 3D model of the measured object, i.e. the exact representation of the object in both transverse and longitudinal direction. The measurement is made by reading the tested element every 1 mm. The device is laid on the tested element coated with white matting preparation fig. 4. The scanner was tested on switches made of PPP fig. 4 and fig. 5 and switches without PPP and on the new needle, resistors, and cross-links at the manufacturer of turnouts.



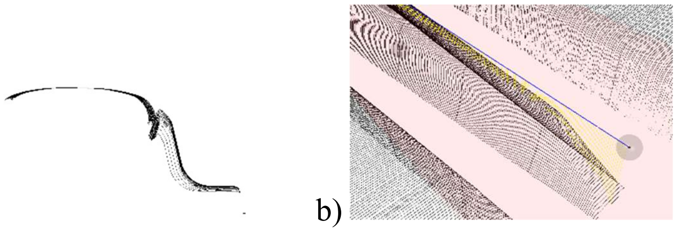
4. 3D Scorpion scanner - intersection in a PPP turnout



5. Scorpion 3D scanner - spiers and resistors in a PPP turnout

6. 3D Scorpion scanner - new spire and resistor

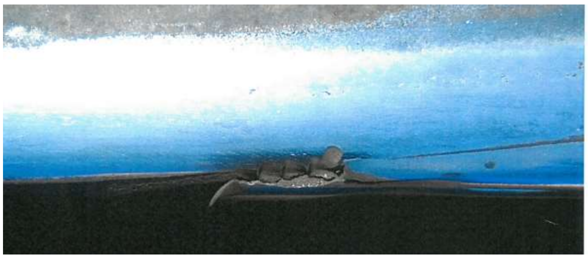
Sample results of the measurement of the profile of the spire and intersection are shown in Fig. 7, the measurement was made in 1 mm step. The comparison of measurement results for the PPP turnout and without PPP and new elements showed wear at the bow of the zero intersection markers without PPP, amounting to 0.52 mm, and in the PPP turnout 0.35 mm in comparison with the new intersection. When measuring the needle in a non-PPP switch, the consumption was 0.32 mm compared to the new needle. When testing the needle in the PPP switch, the consumption was 0.28 mm compared to the new needle. An example image from the scanner is shown in Fig. 7.



a) b)

7. Image from the Scorpio type 3D scanner, a - spire, b-intersection

The conducted research with the use of the scanner allowed early diagnostics of turnout damage in the part of the nose of the cross-brace. The results of the measurements carried out in February 2016 showed damage to the beak bow 4 mm, 4 mm damage was observed while analyzing the results on the computer. Due to the 4 mm damage, scratches during field tests were not diagnosed. The proliferation of the damage caused the crack of the cross of the cross which occurred in August 2016. Fig. 8**.**

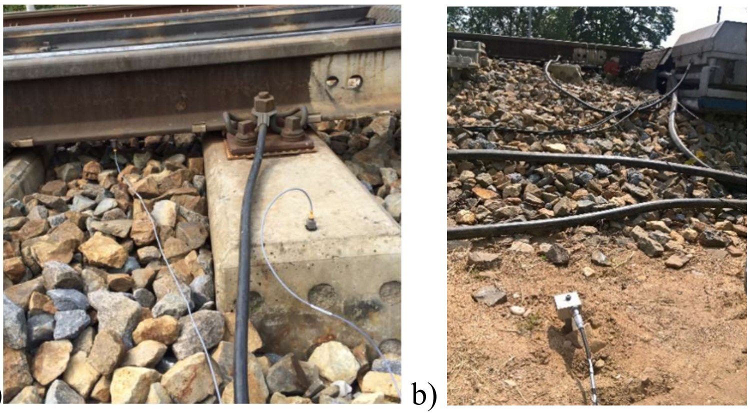


8. Damaged bow of the intersection

The results of the tests carried out with the Skorpion scanner demonstrate the desirability of conducting regular diagnostic imaging using three-dimensional imaging diagnostics allowing for early identification of defects and enabling the introduction of maintenance works to prevent further damage. Extending the diagnostics of turnouts with 3D testing of rail profiles is indicated on the bus lines with the highest traffic volume in order to increase the safety and reliability of the conducted railway traffic.

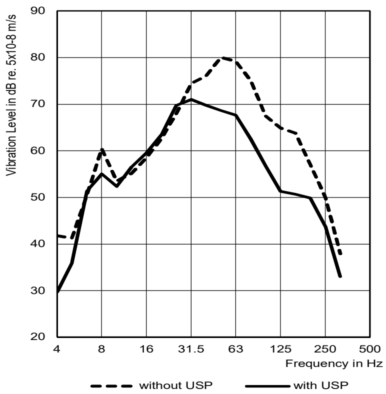
Vibration propagation research

The dynamic impact study was carried out using Photon Brüel & Kjaer photographic equipment. The test was carried out at the Siedlce station when the train was traveling at a speed of 70 km/h in the main direction at the crossover with PPP and without PPP. The measuring sensors are laid on the rail, the traveling wheel in the switch zone and in the track bed at a distance of 5 m from the track axis Fig. 9**.**

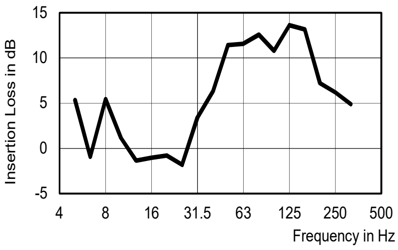


a) b)

9. Measuring apparatus and location of measuring sensors in the junction, a- sensors on the rail and sleepers, b- sensors in the substructure



10. Results of vibration measurements in the railway track bed at a distance of 5 meters from the axis of the main track. The continuous line marked test results for a switch with PPP, dashed line indicates test results for a switch without PPP



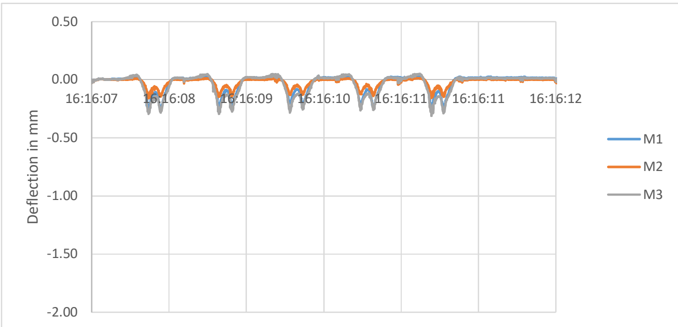
11. Reduction of vibrations in the railway substructure as a result of using PPP in the junction as compared to the junction without PPP

The conducted measurements were subjected to frequency analysis in the comparative range for the PPP turnout and without PPP. As a result of the use of sub-base washers in the turnout sleepers, there was a reduction of vibrations in the rail by 20% compared with the switch without PPP, in the turnout sleepers by 30%, and in the track substructure by 40% in the frequency range from 5 to 40 Hz. In the frequency range from 40 to 240 Hz there was a reduction of vibrations in the rail by 25%, in the turnout sleepers by 35%, and in the trackbed by 60% in the travel with underlay washers in comparison to the switch without PPP. The results of the tests were presented on the example of Fig. 10 and 11 show the level of vibrations registered in the railway track bed in turnouts with PPP and without PPP. The test results showed the highest level of vibration reduction at a vibration frequency above 31 Hz.

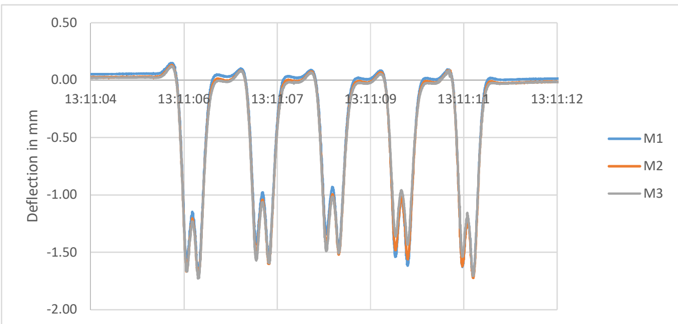
Studies on vertical deflections of PPP foundations and without PPP were presented for the access section to the tested turnouts from PPP and without PP at the Kraków Łobzów and Kraków Towarowy stations. The measuring stand with installed sensors is shown in Fig. 12. The test was carried out at the train speed of 70 km/h.

12. Studies on deflection of PPP primers

Fig. 13 shows vertical deflections of the foundation on the section without PPP, Fig. 14 shows the deflection of the foundation on the PPP section.



13. Vertical deflection of the sleeper without PPP



14. Vertical deflection of PPP sleeper

Measurements of the deflection of the sleepers showed very rigid support of the railway track on the section without PPP. The vertical deflections of the undercoat were 0.3 mm, on the section equipped with PPP, more flexible pavement behavior with vertical base deflections of about 1.5 mm was demonstrated. Deflection of sleepers as a result of the use of under-deck washers confirm the results of propagation of vibrations generated by the passing train on sleepers and track bed, increase of deflection shows increased vibroisolatility of the crossover area and reduction of vibrational impacts of the studied area. Measured diagnostics of profiles and turnout geometry as well as the dynamics of turnout structures showed the relationship of reduction of vibrations in the junction with the reduction of dynamic impacts as a result of the use of underlay washers and reducing the wear of the profile of the intersection, spire, and resistor.

Summary

The results of diagnostic and dynamic tests showed the desirability of conducting research aimed at early detection of turnout damage. Research has shown that 3D imaging diagnostics allow early identification of lesions, which is not diagnosable by classical measurement methods. Three-dimensional diagnostics of profiles of spiers, resistors, and crossings on main lines should be introduced as a permanent stage in the process of maintenance of the railway surface at turnouts. Investigations of dynamic interactions in switches with pads under undercuts and without PPP have shown a positive effect of the application of the elastic layer on the reduction of vibrations in the rail, turnout sleepers and track bed. The study of crossover dynamics is confirmed by the results of tests using 3D diagnostics of turnouts positive impact of PPP on the reduction of rail wear and reduction of generated vibrations by railway traffic.

Source materials

[1] Bałuch H.: Trwałość i niezawodności eksploatacyjna nawierzchni kolejowej WKiŁ, Warszawa 1980 r.
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[4] Kwiatkowska E. Wpływ wibroizolacji podkładów strunobetonowych na pracę podtorza kolejowego, Raport serii PRE nr 8 /2015, Politechnika Wrocławska