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DIAGNOSTIC OF RAILWAY TURNOUTS CONDITION

Jacek **Paś** [1]

[1] Rzeszow University of Technology, Faculty of Civil and Environmental Engineering and Architecture, Al. Powstańców Warszawy 12, 35-959 Rzeszów, Poland, e-mail: j.pas@prz.edu.pl, https://orcid.org/0009-0002-3802-7383

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Abstract – The paper presents issues related to the process of monitoring the technical condition of railway turnouts and administration of data from measurement sensors cooperating with computer programs, enabling continuous tracking of changes and trends in the presented system, which is a railway turnout controlled by a switch point machine. The author points to the importance of remote diagnostics, mainly the moving turnout elements for appropriate intervention by the maintenance services. The paper also presents market needs in terms of the need to obtain appropriate field data, including changes in the turnout operation depending on climatic conditions and trends of changes depending on the wear of the rolling elements of the turnout. The author points to the need for monitor the condition of several most important points of the turnouts that have a direct impact on future potential: failures, damage, reduced availability of the railway line or a railway disaster. Attention was also paid to the need to use field data from the service work not only from the warranty period but also throughout the assumed whole life cycle of the turnout.
Key words – turnout, diagnostics of turnouts, high-speed railways, turnout parameter monitoring
JEL Classification – L62, L92, R40

INTRODUCTION

Railway turnouts as a railway track structure should be able to report key performance indicators in the form of diagnostic data regarding their current technical condition in the whole life cycle. Basic messages coming from the turnout should record and inform about at least two variants:
- functional-operational processes are correct,
- the intervention of maintenance services is necessary.

The approach as above is a vision of maintenance services turnouts, responsible for the operation of railway lines at all administration of railway infrastructure in the world for today. On the other hand, changes taking place in operational processes on railway lines show new tendencies, such as:
- increasing axle loads,
- increasing line availability,
- increasing the maximum speed of rail vehicles,
- limitations of the staff responsible for track maintenance processes,
- restrictions to the tracks entrance in particularly related with tunnels, high speed railway lines, bridges, etc.

New challenges in scope of: reliability, availability, maintainability, the need to calculate turnout costs throughout the whole life cycle from production to recycling and increased demand for obtaining the necessary knowledge from monitoring and remote diagnostics of turnouts and cooperating devices, such as: a point machines, heating device of movable part of turnout, obstacle detectors. In the implementation of the indicated processes, an innovative approach to managing knowledge coming from individual systems is important, namely the possibility of their direct communication, data exchange, processing and analysis without human intervention using the network commonly known as "Internet of Things". The word "Thing" in this case means a railway structure, which is the most sensitive place in the track, namely the turnout. Intelligent turnouts, despite the use of modern rail traffic control systems, are still a distant future [9-10], [15-16], [18-19]. The limitations come from a very large amount of data for communication, including outgoing and incoming from the tested turnout point, and a new threat caused by a potential cyberattack and paralysis of railway traffic. Therefore, in the first phase of implementation, diagnostic devices must perform an informative, not an executive function.

The above introduction shows how important it is to manage the continuous diagnostics of turnouts, including the analysis, calculations and interpretation of the results achieved in order to take preventive actions necessary for the operation of the system in exchange for future potential corrective actions after a failure.

The conducted research on safety hazards on the railway infrastructure shows that one of the most common causes of failures is human error. The progressive automation of railway traffic control devices and remote diagnostics of the most frequently worn elements of railway infrastructure will reduce human activity to the minimum necessary.

Currently, the challenge for those conducting the research is the dynamic impact of the rolling stock on the railway track for stochastic variable, in particular the technical condition of the turnout, including the wear of head rail profile. Permanent diagnostics of track condition allows for a significant reduction in derailments and railway accidents. Despite the abundant literature on the sensors used and measurement locations in the whole turnout, the continuous and significant development in the field of sensors, including those resistant to operation in the railway infrastructure environment, results in innovative possibilities for remote work.

1. RAILWAY TURNOUT

Rail infrastructure in Europe is responsible for about 23% of all rail accidents and about 50% worldwide [1]. Statistics show how important and necessary in the near future is to use innovative technology for monitoring and diagnostics of rail infrastructure, including mainly dedicated to turnouts through efficiently implemented IT functions.

Historically, monitoring systems have been developed and are used as a means of replacing visual inspections in rail traffic operation as well. In the past years, the responsibility for: inspection, measurements, assessment and diagnostics rested in the hands of railway experts and relied to a large extent on their experience in removing current faults [2, 12, 14]

Currently, there is an increasing demand of railway organizations for the implementation of an integrated diagnostic platform that allows them to become independent from hardware and software suppliers. The architecture of the components of individual functions together with the interactions between them will speed up the process and ensure the possibility of implementing various diagnostic applications from various manufacturing companies, as in the example of a local control center, Figure 1.

Fig. 1. Sample local control center

Information about events taking place in operational processes and the technical condition of devices is crucial in order to make effective decisions. The identification of problems occurring on railway lines in Europe confirm the need to take action to solve issues such as:

- collecting results from turnout monitoring and diagnostics,
- effective interpretation of results,
- effective decision making,
- implementing preventive actions.

All categories of railway lines require the use of innovative solutions for turnout structures. Railway logistics companies, and in particular the passenger rolling stock, require the provision of services with increasing train speeds, both on the main track and on the diverging track through the turnout, which forces the design of the radius of the diverging track with larger value. Larger values of the diverging track radius result in the use of a larger number of locking devices and depending on the turnout multipoint system, a larger number of point machines used, which is shown in Figure 2.

Fig. 2. Turnout switch on a railway line in the Czech Republic

Turnout switch works with the system of moving and controlling moving elements, which consists of: a point machine with its own system of controlling the position of the switch rail, a locking device and depending on the requirements of the railway infrastructure administration, external controllers.

2. DIAGNOSTIC OF RAILWAY TURNOUTS CONDITION

The basic criterion for the correct cooperation of the switch with the point machine is continuous diagnostics in the process of moving the movable elements of the turnout and current knowledge about the technical condition of the cooperating elements. From the point of view of the reliability of the devices, their mutual interaction in switching conditions and in static operating conditions is important. In addition, the switch point machine is responsible for keeping the switch rails in the required position and permanently controls this state during the dynamic impact coming from the wheelsets while passage of the train's [7-8], [13, 17], [25]. Diagnostic data from the turnout operation are presented in Figure 3.

Another very important element of the structure is the intelligent solution of heating the movable elements of the turnout in the event of sub-zero temperatures, snowfall or freezing rain. The subject of heating is a constant challenge for engineers also in the context of reducing electricity consumption and greenhouse gas emissions. At present, tests are being carried out with intelligent, induction heating of turnouts, which can contribute to increasing the efficiency of failure-free operation of movable elements of the turnout.

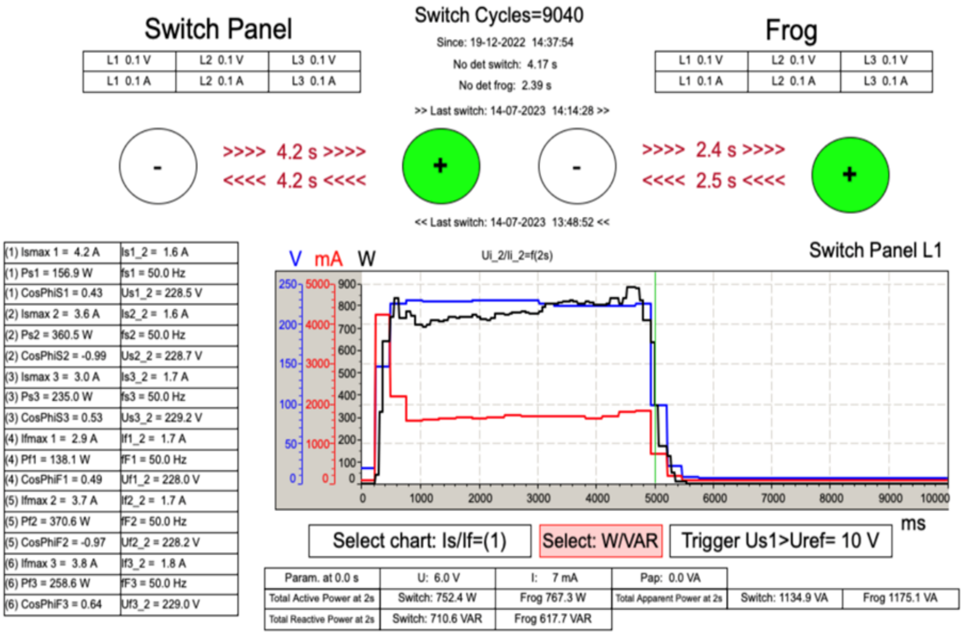

Fig. 3. Diagnostic data from the turnout operation

Essential need for implementation of diagnostic of railway turnouts condition is to increase the availability of the railway line while maintaining the highest level of system security, including minimizing the need of entry into the track for ongoing inspections of the technical condition of turnouts and

- cost reduction throughout the whole life cycle of turnout [23],
- reduction of costs of maintenance works,
- collecting data on RAMS parameters [6], [11],
- identification of potential problems (predictive maintenance).

Wear or destruction of the rolling surfaces of turnout rail profiles in most cases are diagnosed by visual inspection and manual measurements or manual with using a profiler directly on the ground [3], [20-22].

The development of IT systems, including those responsible for analyzing large amounts of data coming directly from sensors installed in the turnout switch area, such as "Big Data Analytics" [4], seems to be necessary tool to develop a measurement system. Learning algorithms based on artificial intelligence will be used to remotely monitor the technical condition of the switch and the ability to fully analyze the collected data from the turnout, mainly from the rolling stock-turnout interaction. Changes occurring on the rolling surfaces of the turnout elements result in an increase in the forces of dynamic interactions, which are subject to trend analysis.

As part of the intelligent turnout switch, sensors were used to monitor and diagnose the parameters of the life cycle of the structure, shown in Figure 4, including those come from:

- Data coming from interaction between point machine and turnout,
- Data coming from the mechanical work of the turnout – geometry,
- Data coming from the mechanical work of the turnout - contact fatigue defect,
- Data corresponding to the rolling stock,
- Data coming from climatic factors.

Managing data coming from sensors, monitoring and diagnostics of turnout technical condition parameters, is the first step to learning and taking conclusions for Artificial Intelligence (AI) in processes such as: collected diagnostic data, analyzing and processing data for the purposes of interpreting the results and consequently, actions aimed at making the right decision. The above processes form the beginning of defining and implementing issues related to the "Intelligent Turnout".

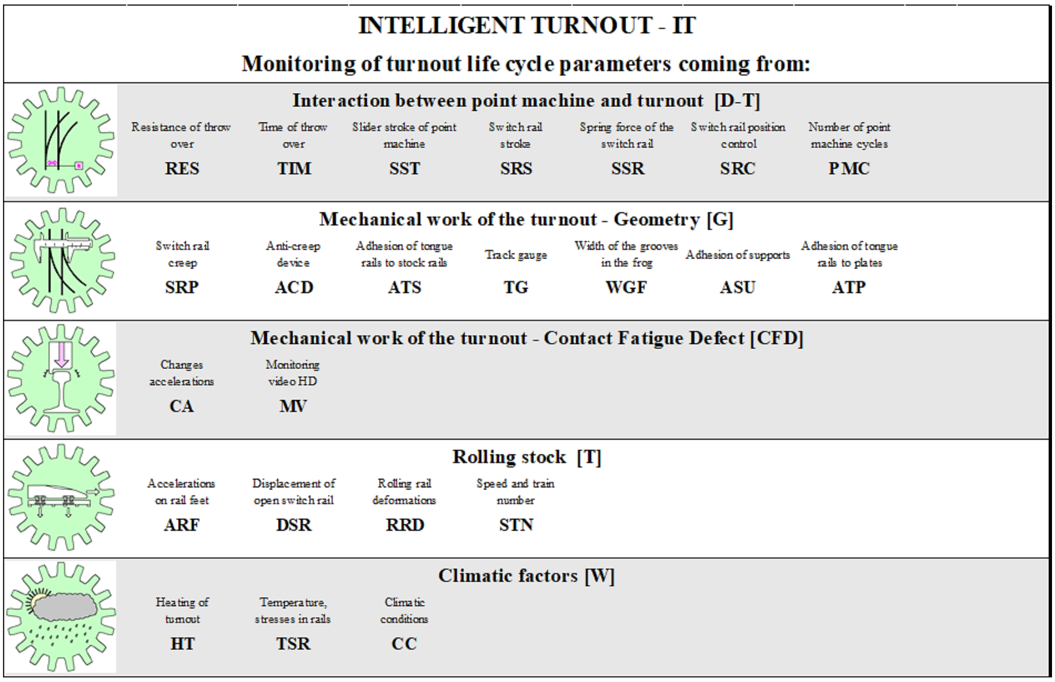

Fig. 4. Assumptions for monitoring and diagnostics of the technical condition of the turnout

The diagnostic and monitoring system, for which the primary goal is the actual analysis of the state of wear of all components included in the railway turnout and those affecting direct cooperation with the rolling stock, is shown in Figure 5. Although the monitoring and alarming functions are still basic requirements for decision making, the entire diagnostic system included in the intelligent turnout has further goals:

a) integration of various diagnostic systems from different manufacturers,
b) alarm and intervention (use of colors, e.g. green/yellow/red),
c) keeping minimum stocks of spare parts,
d) commissioning diagnostic processes and maintenance of devices not only during the warranty period but also throughout the product life cycle.

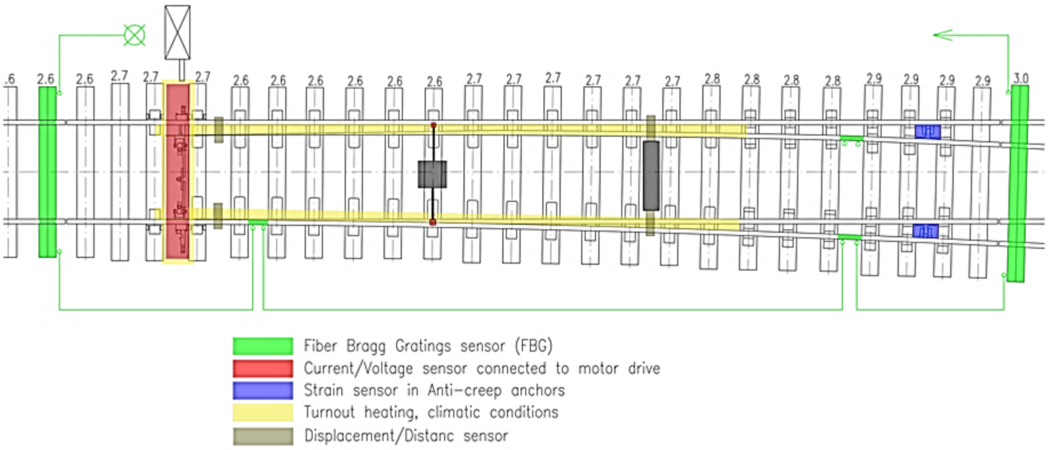

Fig. 5. A model of using sensors for remote diagnostics of a turnout

Due to the complexity of the entire system, which is a railway turnout cooperating with the rolling stock, the author conducted tests of the parameters of the impact of forces coming from the train on the turnout, and in particular on the locking device in the switch and the switch rail distant from the resistance.

3. FUTURE DEVELOPMENT OF THE INTELLIGENT TURNOUT

One of the important issues for the development of an intelligent turnout is the correct definition of what we really want to monitor and what information we expect from the turnout [5], including the determination of key performance indicators with the relevant parameters responsible for the functional activities of the turnout. Another important issue is the decision whether the digital-graphic data obtained from the diagnostic process will be sufficient for the user and maintenance services in the future, or whether the intelligent turnout should make decisions in the form of a report to take the necessary preventive actions. The collected data will be subject to verification and analysis from the process of monitoring the deteriorating technical condition of the railway infrastructure over the next years of operation. Using consistent field data and wear trends in a project of intelligent turnout, subsequent evaluation of measurement data in various analytical models and prediction of progressive degradation will contribute to the development of the product design through efficient management of change and configuration of the devices used, as shown in Figure 6, using the FRACAS (Failure Reporting, Analysis, and Corrective Action System) loop as an example [24].

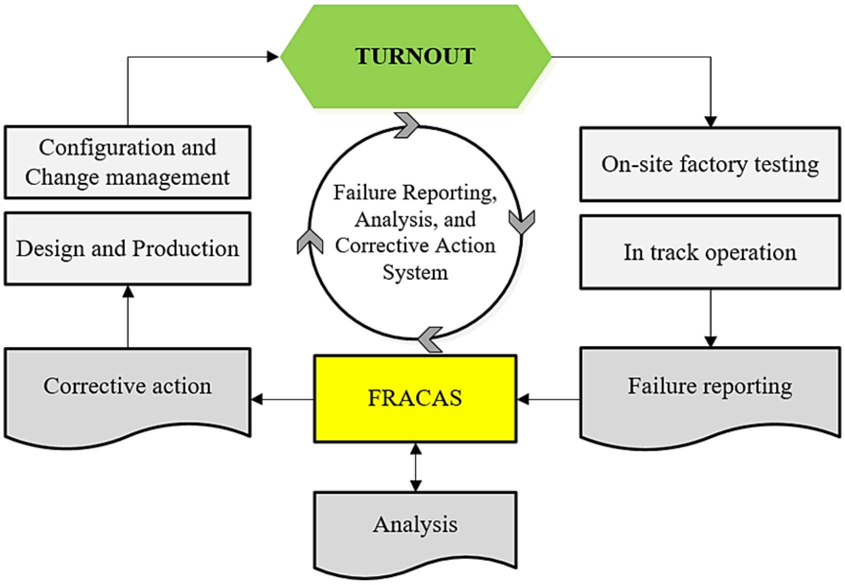

Fig. 6. Failure reporting, analysis, and corrective action system

CONCLUSIONS

Rail transport is the safest means of land transport. Regardless of the above, implementation of remote diagnostics of integrated turnout devices can have a decisive impact on reducing the costs associated with maintaining a safe level of technical condition and reducing the risk of limited availability of the railway line caused by a failure. The novelty of the article is the indication of critical places in the railway track, especially in the scope of mechanical operation of the turnout (Fig. 4), which should be subject to continuous monitoring in the future. The data will contribute to the prediction of the product wear in its further operation. The author is conducting research on the operational wear of the turnout, which will be continued in terms of durability and reliability of work. Collecting data from monitoring, their correct analysis will contribute to correct decision-making in the future.

As a result of the analysis of technical solutions and operational tests conducted, it should be stated that the implementation of remote diagnostics of turnouts will enable:

- collection of diagnostic data and their analysis using IT tools,
- decision-making management of the process of maintaining the technical condition of turnouts with data on: state of fitness, ongoing destructive processes, necessary maintenance, replacement or possible rejected,
- reduction of human and equipment resources needed for the maintenance of railway turnouts,
- positive impact on the development of new turnout designs through the use of knowledge about the actual weaknesses of previous configurations of solutions,
- extending the time to the next repair cycle by making them dependent on the actual wear of the turnout,
- significant impact on the improvement of rail traffic safety,
- improving the management of the turnout configuration and obtaining reliable RAMS parameters in operation.

DIAGNOSTYKA STANU TECHNICZNEGO ROZJAZDÓW

W artykule przedstawiono zagadnienia związane z procesem monitorowania stanu technicznego rozjazdów kolejowych oraz administrowaniem danymi, pochodzących z czujników pomiarowych współpracujących z programami komputerowymi. Proces monitorowania i diagnostyki umożliwia śledzenie zmian i trendów w prezentowanym podsystemie, jakim jest rozjazd kolejowy, sterowany napędem zwrotnicowym. Autor wskazuje na znaczenie diagnostyki zdalnej, głównie ruchomych elementów rozjazdu, dla ułatwienia podjęcia decyzji o właściwej interwencji służb utrzymania ruchu kolejowego. Przedstawiono również potrzeby rynku w zakresie konieczności pozyskiwania odpowiednich danych terenowych, w tym zmian w eksploatacji rozjazdu w zależności od warunków klimatycznych i zmian w zależności od zużycia elementów tocznych rozjazdu. Zwrócono uwagę na potrzebę monitorowania stanu technicznego kilku najważniejszych punktów rozjazdu. Poprawna analiza wyników monitorowania rozjazdów powoduje redukcję potencjalnych awarii i uszkodzeń co w konsekwencji zmierza do zachowania najwyższego poziomu dyspozycyjność linii kolejowej i ograniczeniu katastrofy kolejowej. Zwrócono również uwagę na konieczność wykorzystania danych terenowych z prac serwisowych nie tylko z okresu gwarancji, ale także w całym cyklu życia rozjazdu.

Słowa kluczowe: rozjazd, diagnostyka rozjazdów, koleje dużych prędkości, monitorowanie parametrów rozjazdów.

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