

HIGH-SPEED TURNOUT AS PART OF THE TRACK

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Abstract – This paper presents the classification and construction of high-speed railway turnouts operated on European railway lines. The existing computer programs supporting the diagnostics of high-speed railway turnouts with the most common causes of failures originating from infrastructure elements were analyzed. The authors point to the need for integration of high-speed turnouts as a single system containing modern point machine control of switch area and swing nose crossing area with induction heating of moving turnout elements. Attention was also paid to the need to use appropriate means of transport dedicated for railway turnouts in order to improve the initial quality of the product.

Key words – turnout, diagnostics of turnouts, high-speed railways, computer diagnostic programs

JEL Classification – L62, L92, R40

INTRODUCTION

The railway turnout dedicated to the high-speed line requires presentation as a system that performs a series of complex tasks [16], [18-19], [23, 25]. It is justifiable to pay considerable attention to issues related to the availability and reliability of turnout systems, and in particular to solving technical issues that ensure the safety of rail transport in a continuous manner. The increase in the reliability parameters cooperation between steel turnout elements and point machine is the basic operational feature of the railway surface, used to ensure high availability and safety against the tendency to increase the permissible speeds of trains and increases in traffic [8-9], [12, 15, 18].

The increase in the competitiveness of the infrastructure sector entails the need for continuous development of turnout elements for the high-speed rail surface, and consequently the need to develop many fields of technical sciences, including: remote diagnostics, data acquisition and analysis systems, automation systems, driveway integration, logistic systems of turnouts in blocks and conducting simulation, experimental as well as empirical tests in railway lines. One of the examples of innovative operational tests are measurements of railway rolling

stock impact on forces occurring in the locking devices of turnouts.

The basic elements of railway traffic control devices, which should be characterized by a high degree of operational reliability, and in particular the high-speed train traffic safety depends on, is a switch-point machine used for moving the switch by means of an electric motor. The point machine ensures that both switch rails are held in the final position and enables continuous control of the position of the switch rail. Its cooperation with the turnout is one of the most important elements in the entire control process. A characteristic feature of high speed turnouts is the need to ensure that the switch rail adheres to the stock rail by increasing the number of locking devices in the switch area.

An extremely important element is also continuous diagnostics of the point machine system - turnout. As practice shows, this is a process neglected by the lack of precise definitions of forces occurring in the switch-point machine system - turnout, exact guidelines for the interpretation of results, and unclearly interpreted RAMS parameters [4] for the whole system as a high speed railway turnout.

The above considerations show how important is the management of remote railway switch diagnostics,

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including the analysis and interpretation of results in order to take appropriate preventive actions in exchange for corrective actions after the occurrence of a failure.

Still, the study of safety hazards on the rail indicate the erroneous human activity as the main cause of failures. Such an assessment indicates that if human activities were flawless, accidents would be much less frequent. For this reason, on the railway, we notice an increasing automation of devices so that human activity is reduced to the necessary minimum. Nevertheless, it must be said that in the case of many equipment failures, only man is able to prevent a catastrophe [1, 16-17].

For over 30 years, no tests has been carried out on turnouts in the railway track related to interaction between point machine - turnout in Poland.

The basic research challenge is the dynamic impact of the rolling stock on the railway track, in particular on the turnout, which is a critical element of the rail infrastructure. The problem is particularly significant in the case of high-speed rail. However, modern technical possibilities enable a significant reduction of catastrophic events on railway tracks through, among others, active track condition diagnostics. The selection of places and the measurement of important parameters for monitoring the technical condition of the turnout is known in the world literature.

In the years 2015-2019, as a result of the needs, a research program was launched entitled "Collecting operational data for the purpose of analyzing the safety and reliability of rail traffic control systems", for which was awarded of the Minister of Science and Education in 2021.

1. TURNOUT DEDICATED TO THE HIGH-SPEED RAILWAY LINE

The challenges posed on land transport engineers have always been to increase the speed of passage traffic on railway lines. Many Western European countries planned to implement technical solutions already in the mid 20th century, allowing the train to travel at speeds of up to 200 [km/h] on separate sections of the railway line. Nevertheless, it is only 1964 that it is recognized as the date of launching the high-speed railway in the world on the Tokyo-Osaka line with a passage speed of 210 [km/h].

In the field of railway infrastructure, high-speed rail, the critical element determining the actual maximum speed is the turnout. Turnout should be treated as the most vulnerable element requiring special supervision and maintenance. In connection with the above, it is necessary to design integrated

high-speed turnouts with remote diagnostics, supporting the work of the railway diagnostician in the field of decision-making and the accuracy of the preventive work being carried out. The integrated turnout dedicated to high-speed railway lines consists three basic areas: switch, swing nose crossing, closure rails in which there are: switch locking devices, point machines, control systems, concrete sleepers, heating of moving parts of turnout, remote monitoring of technical condition [5-7], [13-14], [21-22], [24].



Fig. 1. Turnout for high speed trains in Spain
[Source: Authors library]

High-speed railway lines require innovative solutions of turnout constructions. Turnouts are constructed with a larger radius, which consequently makes it necessary to use a large number of locking devices and, depending on the switch position, a large number of switch point machines. The basic task of the turnout is to change the direction of travel of the rail vehicle from the main track to the turning track, this is accomplished by the moving elements of the turnout, such as the arched switch rail and the straight switch rail, controlled by a switch point machine through the elements of the adjusting closure [6], [10-11], [19-20].

In high-speed railway turnouts, swing nose crossing are used. The bow of the frog is adjusted by means of setting devices and adheres to the wing rail of the required direction of travel. The above structural solutions ensure continuity of rail tracks, and thus continuous contact between the wheel and rail, which eliminates the need to use guardrails and significant changes in dynamic impacts on the train composition.



Fig. 2. Swing nose crossing [Source: Authors library]

Swing nose crossing in comparison to the frogs with a fixed nose has a significant differences in the introduction of an additional adjustment device controlling the operation of the frog. Additionally, an extremely important element is designing an intelligent solution for heating moving switch elements in order to increase the availability of the railway line in situations of negative temperatures, snowfall or freezing rain.

Steel parts of railway turnouts dedicated for high-speed railway lines interact with the controlling and steering system of movable elements of turnouts including: point machines with their own control system of position of the switch rails, adjustment closures, force transmission system, point machine bed, control rods, setting rods [1, 5]. In the case of using more than one actuator in multi-point machine systems as well as in a single-point machine system, equipped with elements for transferring forces to successive closures (coupling of locking devices), the used electrical energy cooperates with mechanical and hydraulic point machine constructions as well as electromechanical and electronic position control points.

The point machine in the field of railway traffic control devices is one of the most important elements of the railway turnout. It plays an important role and has a direct impact on the safety of rail vehicle traffic. Because of cooperation between the point machine and railway turnout, the necessary criterion for the correctness of the system is the diagnostics of the process of moving the movable parts of the turnout and the up-to-date knowledge of the technical condition of the cooperating elements.

The examples of solutions of switch point machines used on high speed lines are:

- The L826H electro-hydraulic point machine, manufactured by Thales, is a device for adjusting the control of the switch area and the switch nose crossing area. The point machine can be built outside as well as inside the tracks. The point machine in trailable version and non-trailable version can work in multi-point machine systems because the adjustable throwing force time is independent of the stroke.



Fig. 3. Multi point control of swing nose crossing [Source: Authors library]

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- The Alstom Hy-Drive system is an integrated, modular solution for high-speed railway turnouts, responsible for switching and locking the turnout with a large number of locking devices. It is characterized by hydraulic power transmission and the ability to manually change the switch in the event of breakdown.



Fig. 4. Switch area [Source: Authors library]

Depending on the requirements of the railway infrastructure manager, there are several basic cooperation systems in the field of turnouts dedicated to high-speed lines and control system, switching support and control. Turnouts configured in a multi-

point machine system with the number of locking devices equal to the number of point machines and in a single-point machine control system with a mechanical or hydraulic coupling are used.

The basic model, the most common, dedicated to high-speed railway is the switch area in a multi-point machine system, characterized by the same number of point machines as the locking devices. A characteristic feature of turnouts with a large number of locking devices is the need to control the position of the switch rail both in the direction of the turnout switch as well as in the area of a crossing with a moving nose. The above control occurs through the use of point machines with its own control system, carried out by means of control rods connecting the point machine control sliders with the moving elements of the switch.

Another model dedicated to high-speed rail is a railway switch in a single-point machine system, characterized by the need to use additional elements to transfer power from the point machine to subsequent closures. A characteristic feature of turnouts with many closures is the need to control the position of the switch rail. In the case of a single-point machine system, the control is carried out only by external systems (not integrated with the point machine) of the position controllers.

An example of such solution is the previously mentioned Hy-Drive system installed in the turnout on the central trunk railway line in Poland.

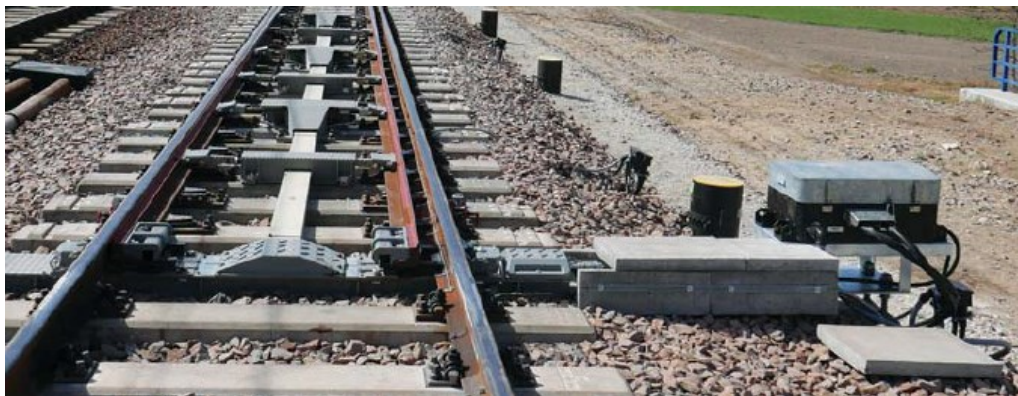


Fig. 5. Turnout in single-point machine steering system process [Source: Authors library]

From the point of view of safety, a very important parameter of cooperation between the point machine and turnout is the interaction of these elements in the switching conditions and in static conditions. Adjusting the turnout is not the only liability of the point machine - movable elements of the turnout, it is also responsible for keeping the switch blade and

swing nose crossing in the assumed position and controls this state during the interaction of dynamic wheelsets during the train passage [10-11], [19-20]. The system of interaction between point machine and turnout is a critical component of the system and has a decisive impact on the maximum possible speed of the rolling stock. The basic condition for the

correct operation of the point machine with turnout is proper maintenance of both elements, regular inspections and maintenance work in accordance with the manufacturer's guidelines.

2. DYNAMIC IMPACT BETWEEN THE ROLLING STOCK AND TURNOUT

Due to the complexity of the whole system, which is a railway turnout with trackside infrastructure, interacting with railway rolling stock, mainly for passenger traffic, the authors examined the impact parameters of the forces coming from the rail vehicle to the turnout and in particular on the locking device in the switch area and the open switch blade from

the stock rail. The purpose of the research was to analyze the impact of a passenger vehicle on the turnout in two control systems: multi-point machine and single-point machine with mechanical coupling of locking devices.

The tests were carried out while driving a traction vehicle Pendolino series ED250 through the turnout on the main track with speeds $V = 200$ [km/h].

Exemplary test results and phenomena that takes place in the open switch blade from the stock rail are shown in Figure 6 (turnout in a multi-point machine control system) and Figure 7 (turnout in a single-point machine control system with mechanical coupling).

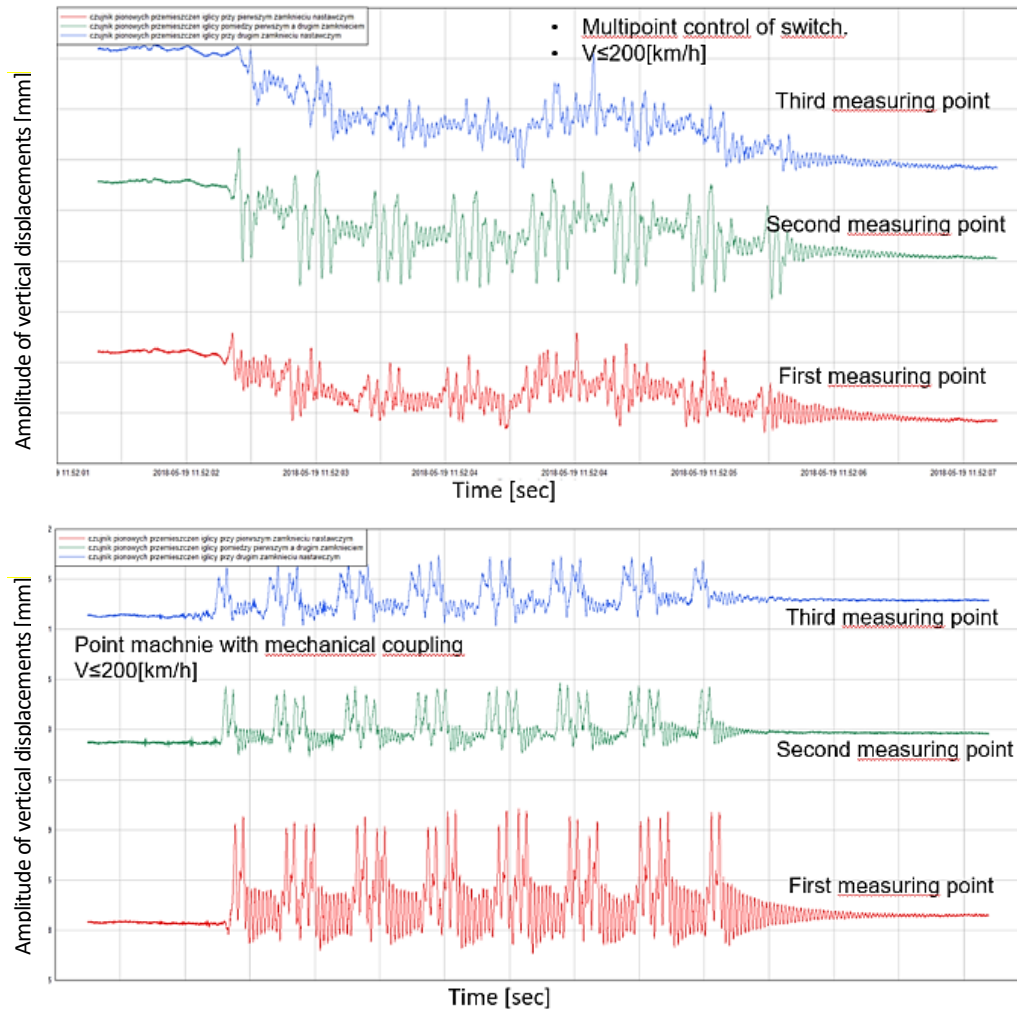


Fig. 6. Vertical displacements open switch blade from the stock rail

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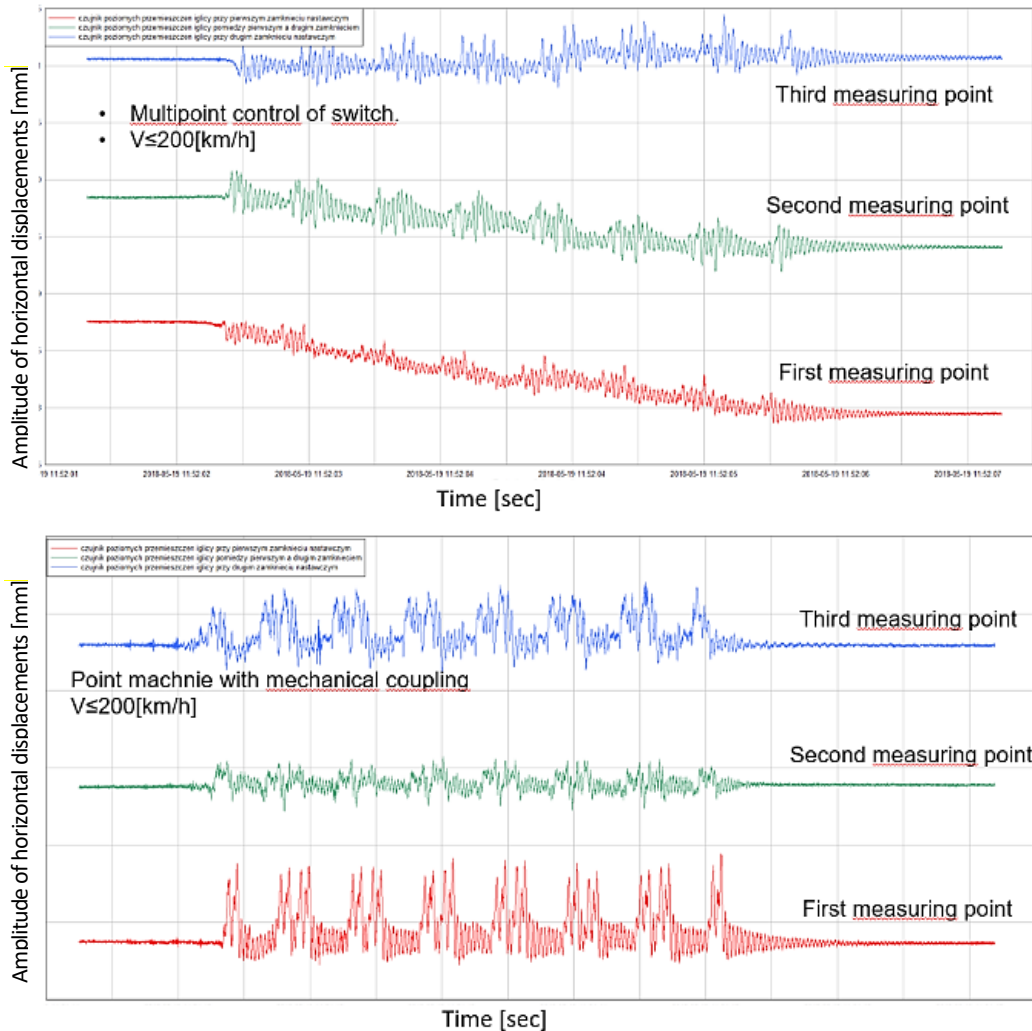


Fig. 7. Horizontal displacements open switch blade from the stock rail

Interpretations of test results of the experiment and comparative conclusions of two turnout in the same geometry equipped with a multiple of locking device points on the central trunk line in Poland leads to conclusions about the need to implement diagnostics and monitor the parameters of drive-turnout cooperation, in particular the impact of the rolling stock on the movable elements of the turnout. In one system of horizontal displacements, there is a noticeable tendency for the open switch blade to close under the influence of dynamic impact from the high-speed railway rolling stock which can lead to the risk of switch point break. As a result of the

research, it was indicated that in the implementation of subsequent works and studies on the phenomena occurring in the system, steel railway switch elements - point machine, it is crucial to pay special attention to the ability to provide data on the technical condition of the system remotely without the need for direct diagnostics.

3. INTEGRATED HIGH-SPEED TURNOUT

As of today, the main criteria determining the choice of turnout structure are the technical standards in a given country. Infrastructure managers do not define any requirements in the field of the RAMS

standard [4] for steel parts of railway turnouts. Lack of requirements regarding the reliability, availability and maintenance parameters means that production plants do not collect (or do it in a limited scope) RAMS data for manufactured turnouts, including those dedicated to high-speed railway lines. In the future, it is advisable to take the necessary actions to collect and analyze the actual parameters of RAMS, which is required by the ISO / TS 22163 (IRIS) railway standard [2] for the assessment of product construction. These data should provide the possibility of defining the requirements by the ordering party in the future, also continuously improving the quality of railway turnouts produced.

Regardless of the steel parts of the railway turnouts, companies producing rail traffic control systems collect RAMS data and their numerical values in order to define the reliability parameters, i.e. availability and susceptibility to meet the requirements. The manufacturer's quality declaration is a guarantee of carrying out all necessary laboratory and field tests and can be treated as a basis for warranty claims or refusal to issue references for devices that do not meet the required reliability indexes. Parameters in all indicated areas have a direct impact on the total costs throughout the entire life cycle of the product. Higher parameters of reliability and maintenance susceptibility have a direct impact on improving the system's readiness, which in turn translates into lower operating costs in future.

The basic task for railway turnout manufacturers is to skillfully monitor the state of technical readiness, detect potential hazards and take necessary preventive actions to detect potential faults as early as possible. The turnout constructions are adapted to maintenance-free operation within a period of up to 6 months, in accordance with the manufacturer's declaration. In view of the above, it seems reasonable to implement two processes: an observation process and a warning process that compares data from the observation process with the assumed limit values and provides information on the state of the system for decision-making [1, 8], [16-18].

In connection with the above, it is necessary to implement continuous, automatic and preferably remote monitoring of turnout parameters, mainly in the area of cooperation of steel turnout elements with switching point machines [13-14], [21-22], [24] so as to minimize the occurrence of failure. High-speed railway lines limit the possibility of entry into the track for technical inspections and the basic benefits of a well-prepared database of the occurrence of potential system failures are:

- Cost reduction throughout the product's life cycle,

- Reduction of time and costs of maintenance works,
- Collecting RAMS parameter data for turnout work,
- Early identification of potential problems (predictive maintenance).

In principle remote diagnostics of damage and weariness of the steel parts of the turnout is not possible directly. It is necessary to identify damage or weariness by some mechanical parameters that can be transformed into voltage or electricity. The weariness or destruction of the rolling surfaces of the turnout profiles have been diagnosed so far by visual inspection or manual measurements using a profilometer directly on the ground.

In the era of advance IT systems, in particular "Big Data Analytics", it seems necessary to develop a measuring system that analyzes large amounts of data coming directly from the metered areas of the crossroads and the crossing crossroads [3]. Artificial Intelligence algorithms (machine learning, neural networks) should be used to remotely monitor the technical condition of turnouts. In order to effectively collect the data, various sensors should be embedded in the turnout (using the concept on Internet of Things – IoT).

It is assumed that the changes of the rolling surfaces in the turnout elements cause an increase in dynamic forces, which can be assessed by trend analysis. Thus, the measuring system consists of pairs of sensors that measure the parameters of dynamic forces applied on rail profiles, both in the zone of the turnout as well as in the zone of the crossing with the moving nose.

The system uses sensors to monitor the parameters of the turnout life cycle, including:

- a) Data coming from interaction between point machine and turnout
 - Resistances of setting the turnout and crossing with movable nose,
 - Time of setting the turnout,
 - Switch blade stroke,
 - Spring forces of the switch blade,
 - Control the position of the switch blade,
 - Number of adjustments.
- b) Data coming from the mechanical work of the turnout - geometry
 - Creeping of the switch blade,
 - Impact forces of the anti-creeping device,
 - Minimum distance of the open switch blade from the stock rail,
 - Width of the track in the axis of the locking device,
 - Width of grooves in the crossing area,
 - Technical condition of switch rollers.
- c) Data coming from the mechanical work of turnout - contact fatigue defect
 - Changes of accelerations on: stock rails,

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- connecting rails, frogs,
- Video monitoring of HD (high definition) cameras.
- d) Data corresponding to the rolling stock
 - Measurements of accelerations on the rail feet,
 - Measuring the displacement of the open switch blade from the stock rail,
 - Measurements of deformation, deflections of rolling rails, using an FBG type optical fiber.
- e) Data coming from climatic factors.
 - A weather station, installed at a railway station or in a direct switch position, to measure air temperature, humidity, wind speed and snow detection, etc.
 - Video monitoring, in particular in the first phase of installation of remote diagnostics devices is intended to link the behavior of the turnouts with passing rolling stock.

Skillful management of data from the above sensors for monitoring the technical parameters of the turnout will allow the implementation of Artificial Intelligence (AI) in research processes and, as a consequence, further developments towards "Intelligent Turnout".

CONCLUSIONS

The remote collection of complete, accurate data on the technical condition of the track structure being used and the possibility of taking appropriate preventive actions in a timely manner becomes extremely important for engineers and people responsible for the maintenance processes of rail infrastructure with concentration on railway turnouts. Skillful and correct data analysis from "intelligent turnout" will also allow to determine the average values of RAMS parameters not only for electrical devices including: point machines and railway heating systems but also steel parts of the turnouts depending on the railway line used and the load affecting them by the annual movement of passenger and cargo vehicles. The above data will allow to create simulation of life-span of the product and costs incurred throughout the life cycle. Further activities are aimed at clarifying the management of the "Intelligent Turnout" processes, also in the perspective of turnouts for conventional surface and creating maintenance-free rail lines with limited service in the life cycle of the product.

ROZJAZDY DUŻYCH PRĘDKOŚCI JAKO CZĘŚĆ TORU

W artykule przedstawiono klasyfikację i budowę rozjazdów kolejowych dużych prędkości eksploatowanych na europejskich liniach kolejowych. Przeanalizowano istniejące programy komputerowe wspomagające diagnostykę rozjazdów kolei dużych prędkości z najczęstszymi przyczynami awarii pochodzących

z elementów infrastruktury. Autorzy zwracają uwagę na potrzebę integracji rozjazdów dla linii kolejowych dużych prędkości jako jednego systemu zawierającego nowoczesne napędy zwrotnicowe oraz napędy dla krzyżownic z ruchomym dziobem z indukcyjnym ogrzewaniem ruchomych elementów rozjazdów. Zwrócono również uwagę na konieczność zastosowania odpowiednich środków transportu dedykowanych dla rozjazdów kolejowych w celu poprawy wyjściowej jakości produktu.

Słowa kluczowe: rozjazd, diagnostyka rozjazdów, koleje dużych prędkości, programy komputerowe wspomagające diagnostykę rozjazdów

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