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Development of logistic services in rail transport

Abstract: An important factor for the safe operation of the high speed railway lines is proper choice of turnouts and their drives. The article includes information about presently used turnouts on the CMK Central Trunk Line together with their classification in regards of switch machine applied. New challenges were identified which manufacturers of superstructure and certification bodies have to cope. Technologies increasing the quality of turnouts as sold were discussed as well as parameters defining their technical availability and maintainability. The authors presented a proposal of remote diagnostics allowing undertaking the preventive or corrective actions in right time.

Keywords: Turnout; High speed railway line; RAMS

Introduction

The construction of high-speed railway lines in Poland will be based on operational experience of the European Union countries as well as the use and maintenance of rail infrastructure on line No. 4 - Central Trunk Line. The results of railway turn tests, implemented by the organizational unit referred to in art. 22g par. 9 [14], as well as user's operating opinions (PKP Polish Railway Lines S.A.) and technical standards [13], determine the selection of geometry and the construction of railway turnouts.

Another important factor is the fact that the Manufacturer has a Building Release Certificate issued by the Office of Rail Transport [5]. In view of the plans to build new high-speed lines (including the so-called Y), it will be necessary to implement new turnout constructions with new geometry, which may be a serious decision problem for a potential supplier.

Central Trunk Line

Currently, the only high-speed railway line in Poland is the Central Trunk Line (CMK), with a total length of 224 km. There are 11 railway stations and 3 branch checkpoints on the line [3]. In the last few years, the infrastructure manager in Poland has taken appropriate measures aimed at adapting the Central Trunk Line (CMK) along the entire length to the standard of moving rail vehicles at a maximum speed of 200 - 250 km/h. In order to achieve the indicated goal, it was necessary to define the construction requirements of the turnout and conduct operational tests. A feature that distinguishes turnouts dedicated to high-speed railway lines from those destined for conventional lines is the length of this structure, and consequently a greater number of adjusting closures both within the crossover and the frog with a moving bow. More than 1 number of closing closures, it is necessary to define the drive system for

setting the turnout. Currently, we distinguish single-drive systems with hydraulic or mechanical coupling and multi-drive system. Another requirement for the KDP line is the use of frogs with a movable bow. A frog with a movable bow(Fig. **1**) ensures continuous contact between the wheel and rail, reducing the mutual dynamic interaction between turnout and rolling stock [9].

1. A frog with a movable bow of TrackTec KolTram production. Turnout No. 30 at Psary station. Source: Track Tec

For reasons related historically to the CMK line, the dominant solution for moving the turnout nowadays is the single-drive system, which accounts for approximately 70% of all turnouts; including:

- out 20% with mechanical coupling of the locking devices;
- approx. 50% with hydraulic coupling of adjustments;
- the remaining 30% are turnouts with a multi-drive conversion system.

This is shown exhaustively for the main tracks in Table **1**.

Table **1.** Specification of regular turnouts in track No. 1 and 2 on CMK [9]

Stacja	Rozjazdy wielonapędowe	Rozjazdy jednonapędowe	Krzyżownica
Grodzisk Mazowiecki	8	0	Stała
Korytów	10	0	Stała
Szeligi	0	13	Ruchoma
Biała Rawska	0	4	Ruchoma
Strzałki	1	11	Ruchoma
Idzikowice	0	20	Ruchoma
Opoczno Południe	0	12	Ruchoma
Pilichowice	0	4	Ruchoma
Olszamowice	0	12	Ruchoma
Włoszczowa Północ	0	14	Ruchoma
Knapówka	5	0	Ruchoma
Psary	5	8	Ruchoma
Góra Włodowska	12	0	Ruchoma
Zawiercie		x	Stała

None of the manufacturers in Poland has an indefinite certificate of admission to the operation of a type of buildings for railway turnouts intended for rail traffic at a maximum speed of 250 km/h on the main track. Many of these turnouts, integrated with drives, have been ordered, manufactured and built on railway tracks based only on the EC declaration of conformity for the interoperability constituent, infrastructure subsystem, according to the no longer binding Commission Decision of 20 December 2008 concerning the technical specification for interoperability of the infrastructure subsystem of the trans-European high-speed rail system 2008/217/EC. In the Decision at that time, crossovers and crossings (point 5.2) were indicated as interoperability constituents. While the EC declaration of conformity could then be accepted as lawful in relation to the switch, this cannot be done for drive or crossover. The drive is also a part of the railway signaling system and is subject to testing and assessment of compatibility with existing station systems of traffic control in the area of a given infrastructure manager.

Normal turnouts installed on CMK are operated in three geometries:

a) Rz 60E1-2500-1:26,5 sbS 1:40.
b) Rz 60E1-1200-1:18,5 sbS 1:40,
c) Rz 60E1-500-1:12 sbS 1:40,

Turnouts with radius return path R2500 and R1200m are the interconnection of main tracks and are referred to as trivial connections [13]. On the other hand, turnouts with a radius of the reversing track R500, which are a combination of main tracks with additional main tracks, are referred to as basic main turnouts [13].

The structure of the "drive-and-turn" system in a multi-drive conversion system is characterized by a serial reliability model, for example, composed of 5 drives of the same type - fig.**2**. In such a system, damage to one element makes it impossible to change the whole turnout.

2. Reliable driving turnout control model in a multi-drive system.
PM1-PM5 - switch drives. INT - means the setting system. Source**:** [15]

Failure events in individual drives are independent, so the reliability of the serial system, assuming that the drives are identical, is:

$$R_s(t) = [R_{PM}(t)]^5$$

To achieve the satisfactory reliability of a system consisting of 5 drives, the reliability of individual drives must be sufficiently high. The reliability of a system consisting of 1 to 5 drives is given in Table 2. It is worth noting that when the reliability of a single point machine drops to 0.9, the reliability of the entire system in the serial structure drops to 0.59. (sic!).

Table **2.** Reliability of a system consisting of 1 to 5 turnout drives. Source: [15]

The number of drives in the system	System reliability				
1	0.995	0.99	0.98	0.95	0.90
2	0.990	0.98	0.96	0.90	0.81
3	0.985	0.97	0.94	0.86	0.73
4	0.980	0.96	0.92	0.81	0.66
5	0.975	0.95	0.90	0.77	0.59

Another example is the Rz60E1-1200-1: 18.5 railway turnout in a single-drive Alstom SmartDrive (HyDrive) conversion system with hydraulic coupling - Figures **1** and **3**.

3. Turnout switch Rz60E1-1200 with Alstom SmartDrive hydraulic drive.
Source: Track Tec.

The construction of this turnout completely meets the requirements set by the Infrastructure Manager in the rail PKP PLK. According to the latest technical standards [13], both in the scope of: "single-drive control system with special coupling guaranteeing high availability" as well as "(...) guaranteeing manual adjustment of turnout/ moving bead for 1 person in 4 minutes to ensure availability turnout in emergency situations ".In the case of a switch equipped with one drive cooperating with hydraulic force transmission elements for subsequent closures, the event consisting of the failure of one element is dependent on the

failure of the next element. The elements are connected hydraulically with each other, so the probability of a breakdown (immobilization of the turnout) will depend on the degree of correlation of events consisting in the occurrence of faults at certain points of the crossover. The presented solution with the Alstom HyDrive system, however, has the redundancy of changing all points in parallel. The pressure created by the pump in the hydraulic line causes that the actuator starts at the point with the least resistance to movement. The adjustment process ends the actuator located at the point with the greatest resistance to movement, however, all the force generated by the pump is then intended to change only this point. The hydraulic aggregate (HPU) has a very simple design, which means very high reliability. In connection with the philosophy of the parallel system of moving all points in the manner described above, it allows obtaining very high-reliability parameters.

Choosing the right turnout adjustment system is an extremely important decision-making process based on the RAMS analysis, as the "drive-and-go" system is critical and determines the safety of train movement, and therefore the maximum permissible speed at the junction [9].

Current legal regulations for the operation of turnouts on national railway lines

The railway crossing is fully verified as a product in accordance with national legal regulations. The current Regulation No. 720 of the Minister of Infrastructure and Development of 13 May 2014 requires obtaining for the turnout certificate of permission to operate a type of building issued by the President of the Office of Rail Transport confirming the compatibility of the type of turnout with the requirements specified in the so-called "The list of the President of UTK on the relevant national technical specifications and standardization documents, the use of which makes it possible to meet the essential requirements regarding the interoperability of the railway system", in force under the Polish Minister's Regulation of 2013 [11]. A challenge for the Railway Infrastructure Manager in Poland, in the light of the above, it is possible to carry out technical tests of turnouts for producers operating on the domestic market, so that they can meet the legal regulations for safe operation of railway traffic. The type examination of the building (here: railway turnout) takes place on the testing ground, which is necessary to carry out the complete admission procedure in accordance with the above-mentioned List of the President of the Rail Transport Office, as well as the procedures of PKP PLK SMS-PW-17. Polygons are also used to verify current and shape future technical standards of railway systems.

Historically, turnouts for high-speed rail were tested at the following stations:

a) Psary: 1998-2002
b) Korytów: 2007-2010
c) Grodzisk Mazowiecki: 2013-2018
d) Strzałki: 2013-2019[1]
e) Psary: 2018-2019[2]

In order to carry out a full admission procedure, in Poland, technical inspections of turnouts at the Strzałka and Psary stations are currently being conducted in Poland.

Types of turnouts on the CMK line

Presented requirements with national legal regulations are currently implemented by the Track Tec KolTram company, which installed the turnout Rz 60E1-1200-1: 18.5 sbS 1:40 with the moving bead of the frog in a single-drive Alstom SmartDrive adjustment system with hydraulic coupling at the Psary station [2] based on a timely release certificate. In the first half

[1] expected date of completion of technical tests
[2] expected date of completion of technical tests

of 2019, it is planned to carry out dynamic tests on the impact of rolling stock on turnouts, in accordance with the approved test program, prepared by the organizational unit referred to in art. 22g par. 9 [14], being the basis for the issue of the Type Approval Certificate and the component of the application to UTK for issuing an indefinite certificate of release for exploitation. The register of type approval certificates for use is published in the electronic database of the Office of Rail Transport.

As of today, the only criterion determining the choice of the turnout structure are the provisions in technical standards [13]. The Infrastructure Manager has not defined any requirements in the field of the RAMS standard [12] for steel parts of railway turnouts. Lack of requirements regarding the reliability, availability, and maintenance susceptibility parameters causes that the production plants do not carry out activities to collect RAMS data for manufactured turnouts, including those dedicated to high-speed railway lines. In the future, it will be advisable to take the necessary actions to collect and analyze the actual parameters of RAMS, which among others is required by the IRIS railway standard [8] for the assessment of product construction. These data should provide the possibility of defining the requirements by the ordering party in the future, also as a consequence of the continuous improvement of the quality of railway turnouts. Work on increasing the quality of the initial turnout construction takes place through the application and observance of the requirements of the Instruction [6] and the implementation by the manufacturers of block transport technology and turnout development using the specialist Crossroads Train (PZR) - Fig.**4**. For example, PZR was used to replace the turnout with station number 30 on the Psary station.

4. Carriage of turnouts in blocks. Source Track Tec

Regardless of the steel parts of the railway turnout, companies producing rail traffic control systems, including drives, position controllers, collect RAMS data and their numerical values in order to define the reliability parameters, i.e. availability and susceptibility of maintenance to meet the requirements indicated in the Instruction [7]. 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 and handling railroad turnouts in the future.

Technical data for the turnout with the station number 30 on the Psary station integrated with the Alstom Hy-Drive hydraulic drive is given in table **4**.

Table **4.** Technical data of the MOT turnout. Source: [4]

Czas przestawiania napędu	≤ 10 sec
Siła nastawcza	1,2 ÷ 3,8 kN
Siła trzymania	>40 kN
Tolerancja pozyskania elektrycznej kontroli położenia	≤ 2 mm-kontrola położenia
	≥ 4 mm-brak kontroli położenia
Skok suwaka	215 mm
Skok iglicowy	115 mm
Zasilanie elektrycznego obwodu kontrolnego	48 Vcc ±10%
Temperatura otoczenia	-40°C÷ +70°C
Stopień ochrony	IP54 zgodnie z normą EN 60529
Ciężar	450 kg
Żywotność	20 lat/500 000 przestawić
MTBF	24 933 h
MTTR	1.4275 h
MTBM	0,5 roku
MRT	30 min.

All reliability parameters of the device meet the requirements of the Instruction [7]. Whereas the average time between failures declared at 24,933 [h], it exceeds the requirements almost twice.

Conclusions

The basic task for railway turnout manufacturers will be to skillfully monitor the state of technical readiness, detect potential hazards and take necessary preventive actions to detect potential defects early. The turnout constructions are designed for maintenance-free operation for up to 6 months, in accordance with the manufacturer's declaration. Therefore, it seems reasonable to implement two processes: an observation process and a warning process [1], which compares the data from the observation process with the assumed limit values and provides information about the state of the system for decision-making activities. Tasks carried out according to the pattern originating from aviation or motorization are the beginnings of work on the project "Intelligent turnout" [10], including remote diagnostics and continuous acquisition of data on the technical condition of the monitored system.

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