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Functional Testing of Railway Traffic Control Devices

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Summary
The article presents the problems of functional tests of railway traffic control devices. The purpose and scope of the tests as well as the impact of testing on the SRK devices are presented. The methodology of selecting tests depending on the scope of research is proposed. For this purpose, the SRK devices were analyzed for functional and diagnostic properties.

Keywords: functional tests, railway traffic control devices, tests

1. Introduction

The functional testing of railway traffic control devices is time-consuming, particularly at large stations. Additionally, the performance of tests involves the reduced availability of the devices in question. In reality, the use of traffic control devices is impossible or substantially hindered during testing. To conduct a test, the initial status of devices must be restored and this requires suitable technical means and human resources. In effect, there is a need to find optimal sets of checks (tests) required to make a proper diagnosis regarding the functional condition of the devices. In the process of diagnosing, optimization methods are adopted and, thanks to them, we can have ordered test programs [2]. Their order is specified as a result of the criterion adopted. The cost criteria, likelihood of damage or rise in entropy regarding the facility in question restrict the program in terms of quantity and absorption (time, human resources, equipment, etc.) of testing. It is necessary to analyze whether the use of methods known for technical diagnostics during functional tests will translate into the broader availability of traffic control devices and whether it is possible to implement additional devices as well as signals other than natural ones [6, 9, 10].

When it comes to testing simple facilities, the experience and intuition of well-qualified personnel should be sufficient and this is usually how tests are performed. As for large facilities, it is necessary to introduce generalizations and formalize issues required to elaborate an optimal testing program. As opposed to small configurations, it is difficult to develop a proper and full testing program for complex facilities [9, 10].

2. Purpose and scope of functional tests

The functional testing of devices is a form of checks aimed at assessing the compliance with the specification of the system reaction to the following:

- forced commands generated by the operator,
- systemic environment,
- random incidents in the form of disturbance or damage.

The purpose of these tests is to check all functions of the system in terms of compliance with the principles of railway traffic control and signaling. Additionally, the tests are carried out with a view to checking compliance with the safety rules included in normative documents, the so-called certification tests [3, 4, 11].

Another purpose is related to tests performed under the acceptance of application as well as commissioning [12]. Such tests are conducted for newly developed devices, after the modernization of devices, or the modernization of devices at neighboring stations (impact on functionality) as well as in the case of repair or replacement of components.

The newly developed devices must be tested in terms of all functions implemented in the specific facility. This is connected with testing the specific application adapted solely to the specific train service

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stations. As part of the tests, the compliance of application software and proper assembly with the design and infrastructure manager's requirements are verified. The tests are performed for satisfied and non-satisfied conditions of orders, yet contrary to certification tests, safety tests are not included. Tests after the modernization of devices at the station and modernized devices at neighboring stations and tangent lines are carried out in order to confirm the correct cooperation of devices and the proper operation of interfaces.

The last group of tests are those performed in the process of exploitation under the periodical diagnostics of devices. In this group, all functions adopted in devices in terms of their availability are checked and these checks are performed when fulfilling the diagnostic plan in accordance with diagnostic and inspection guidelines [7, 8]. When performing tasks at the train service station, some system functions are used very rarely or not used at all, and may be not included in the diagnostic program for the station. Functional tests are carried out:

- in the process of certifying devices and assessing the compliance of newly marketed devices;
- when taking over devices and networks (commissioning):
  - newly developed,
  - modernized,
  - reconstructed (e.g. in the case of the track system of the station, adding new functions in devices),
  - temporarily inactive, before their use is restored;
- in the process of using:
  - cyclically at fixed time intervals, in accordance with maintenance guidelines,
  - after identifying disturbed operation of devices,
  - after removing defects, replacement of damaged elements and adjustment,
  - after rail accidents under proceedings of the rail accident commission.

Each case presented above is associated with the performance of a specific set of tests. Depending on the functional configuration of devices and purpose of testing, it can differ in terms of the number of test cases. It is necessary to emphasize that tests are carried out on active devices which are the basis for traffic control and, at the time of testing, the tracks are closed while part of the track system is excluded from traffic. It is also necessary to engage the personnel on duty to perform tests for the operation of devices (establishing route sections, setting the direction of linear interlock, simulation of occupancy, etc.). These actions limit the availability of traffic control devices and influence the traffic of the station, which may lead to the disturbance of train movement. Train traffic is certainly a priority, which also influences the performance of tests. At the time when a scheduled train is to run, the tests must be suspended. One positive aspect is the fact that performance of the task – establishing the route section, running of the train, releasing the route section – also serves as a test which checks the functional configuration of the route section. To sum up, in the process of conducting SRK functional testing, the following problems arise:

- impact of the test on traffic at the station or on the route,
- limited availability of the SRK system to traffic control,
- commitment of the traffic controller in the operation of devices related to testing,
- influence of traffic on the performance of tests,
- lack of a formalized method of setting tests for specific facilities.

Therefore we must raise some questions: Is it possible to minimize the negative results of functional tests? What available signals can be used to test devices without new and additional equipment? To answer these questions, it is necessary to analyze SRK devices, functional and diagnostic properties, as well as define the conditions of devices and available tasks and orders.

3. Analysis of srk devices in terms of functional and diagnostic properties

The railway traffic control system is a collection of controlling and controlled devices (elements) and its operation applies to a specific field of control [1, 5]. These devices form the technical structure of the control system and their connections serve as a functional structure of the SRK system. The system structure is unique for each field of control. Control and inspection of the condition of elements are based on dedicated control cards. The aforesaid cards are programmed with dedicated software along with relevant control and inspection algorithms. In computerized SRK devices, all controlled elements are reflected in the system in the form of logical objects. These objects are identified with their so-called status, which can be as follows:

- physical condition of the object, e.g. current location of a switch, occupancy of the track section;
- logical state of the object (assigned by the interlocking unit):
  - arising from performance of the traffic control task, e.g. locking,
  - arising from fulfillment of the operator's order (command), e.g. stoppage,
  - arising from fulfillment of the maintenance process, disturbance or damage.

In order to introduce the notion of status, examples of potential physical and logical conditions which the switch can be in are presented below.

Physical conditions of the switch

- location:
  - switch in a right direction (straight),
  - switch in a left direction (switched),
  - switch in the indirect position (is being switched);
- occupancy by rolling stock (controlled by a separate occupancy control system):
  - non occupied,
  - occupied;
- control:
  - switch being switched (no inspection),
  - no inspection of switch location due to disturbance / failure;

Logical conditions (states) of the switch

- no data on the controlled element;
- logical occupancy (arising from the section of axle counter reset procedure);
- stoppage for switching;
- closed for establishment of the route section;
- locked (on train route, shunting route):
  - overlap,
  - flank protection,
  - route body.

All the conditions which the *N* switch can be in may be presented in the form of the matrix:

$$N = \begin{bmatrix} n_1 \\ n_2 \\ \dots \\ n_n \end{bmatrix}.$$

To have the “left position” of the *i* switch, it is necessary to adopt the control algorithm a_{i2}. Analogically, to have other statuses for other elements of the task configuration in the matrix, it is required to use a dedicated algorithm of this element.

$$N_i = \begin{bmatrix} a_{i1}^N \\ a_{i2}^N \\ a_{i3}^N \\ a_{i4}^N \\ a_{i5}^N \\ a_{i6}^N \\ a_{i7}^N \end{bmatrix}.$$

For other configuration devices: the occupancy control system for tracks and turnouts *T* and semaphore device *S*, the matrix record with the use of control algorithms remains analogical (for adequate statuses of devices to the type of device).

$$T_i = \begin{bmatrix} a_{i1}^T \\ a_{i2}^T \\ \dots \\ a_{in}^T \end{bmatrix}, \quad S_i = \begin{bmatrix} a_{i1}^S \\ a_{i2}^S \\ \dots \\ a_{in}^S \end{bmatrix}.$$

Entrance into a specific condition is forced by the setting order issued from the setting panel by the train dispatcher. The setting order can take the form of an individual command concerning one or a few elements of the system configuration. Handling the individual order will cause a reaction of the element addressed, not others. To establish the route under semaphore, it is necessary to select the beginning and end of the route as well as to select the type of route section to be set (train or shunting route). This is concerned with selecting the specific route section, inspecting the availability of elements, restoring the required condition of elements, closing before switching and locking, and then a proceed signal authorizing movement is displayed.

The elements are controlled with the use of strictly defined algorithms which control information and signals, on the basis of which the following are fulfilled:

- commands:
  - route-oriented, e.g. establishing the route section;
  - individual, e.g. turning (switching) the switch:
- information from track-side devices on their condition and predisposition to fulfill the order,
- information on traffic in the control area and its systemic surrounding.

These are natural systemic signals on the basis of which the system performs tasks. These data, being an integral part of the technical structure, are subject to processing by the SRK system on the basis of specific control algorithms, and output data are generated. The output data for an efficient system is fulfillment of the order, e.g. establishment of the route section by calibrating relevant devices, turning the switch, etc. The use of railway traffic control devices and their functionality, and in particular inviolable structure, limit the introduction of other signals than the ones which occur naturally during control. Additionally, the introduction of additional equipment is not recommended due to potential violation of the structure of devices as well as the impact on reliability of the test and traffic safety.

The setting orders are listed in the design documentation for SRK devices in the form of a locking sheet (Fig. 1) or route sheet. The basic information included in these documents contains the following:

- list of train routes and shunting routes feasible at the station;
- list of directional interlocking and exclusions;
- list of controlled track and switch sections which belong to the specific route section;
- list of conditions and statuses of switches and derails on the route;
- list of conditions of elements of the systemic environment:
  - condition of line block,
  - condition of level crossing signaling in case of dependence on connection.

Individual commands and routes defined in the locking sheet are available from the operator's panel and can be used when inspecting the functioning. The availability of setting and individual orders allows tests to be conducted without the need to implement additional external signals and use additional equipment. The signals from the systemic environment are also available and required for correct fulfillment of the function. These are natural input signals and the system reaction is real, which raises the credibility of the test and does not require additional analyses.

Correct fulfillment of orders confirms the functional efficiency. The functional efficiency of SRK devices will be concerned with the system's ability to switch between defined conditions and restoration of the specific condition and its maintenance at the time when the task is performed. Configuration of elements and their status depends on the task performed and is unique for each of them.

4. Selection of tests

The number and type of functional tests are dependent upon the purpose of testing. During tests performed in the aftermath of repairing a device subassembly, the trials can be limited to include only the element repaired and its functional connections. It is necessary to consider the functions in which the repaired element is involved, that is, on which routes and orders it is assigned for functional configuration of the task.

Each task, e.g. setting of the route, can be recorded in the form of functional configuration of the task. An example of functional configuration of the task *Zj* (including n switches, semaphores, track/switch sections) will take the following form:

$$K_j = \{(N_i, N_{i+1}, N_{i+n}), (S_i, S_{i+1}, S_{i+n}), (T_i, T_{i+1}, T_{i+n})\},$$

where:
K_j – *j* functional configuration of the task,
N_i – *i* switch,
S_i – *i* semaphore,
T_i – *i* track (switch) section.

Each task is performed in a specific functional configuration in which particular elements must have a suitable status. Restoration of the required status of the configuration element is fulfilled through the control algorithm. The same task configuration can be recorded using the collection of control algorithms of particular elements involved in the task:

$$K_j = \left\{\left(a^N_{i_k}, a^N_{i+1_k}, a^N_{i+n_k}\right), \left(a^S_{i_k}, a^S_{i+1_k}, a^S_{i+n_k}\right), \left(a^T_{i_k}, a^T_{i+1_k}, a^T_{i+n_k}\right)\right\}.$$

The configuration does not include elements of the functionally associated system being in the systemic environment. Its control algorithms are not tested during functional tests of station configuration elements. However, it is necessary to remember that the actual condition of elements of a systemic environment influence the performance of tasks at the station. For example, a failure to set the line block system will prevent the exit route being set, similarly to inactive connected / locked.

The collection commands (route-related and individual) along with functional configuration can be

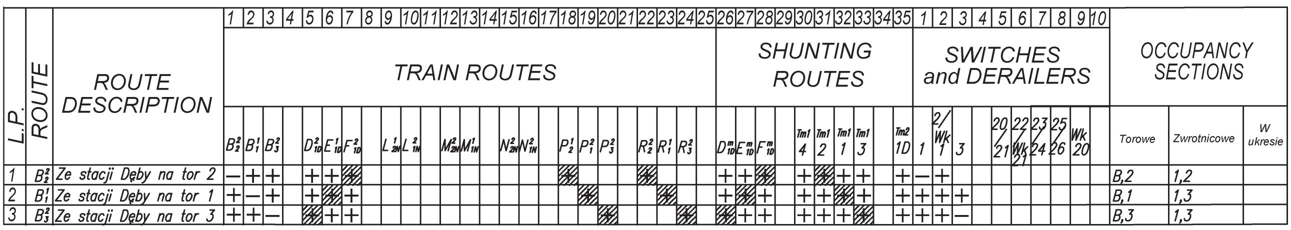

Fig. 1. Part of sample locking sheet [own elaboration]

presented in tabular form (Table 1). For route-related commands, when recording with the use of control algorithms, it is possible to use the locking sheet because it specifies devices used in the route section and their required status. The individual orders concern only those elements for which they are intended. The table is simultaneously the set of all tasks which the system can perform.

The table of tasks specified through control algorithms includes all control and inspection algorithms implemented in the system. They are recorded in the heading of Table 1. The algorithms are used to fulfill route-related and/or individual commands. There is a set of algorithms used solely during route-related or individual orders. If an algorithm is used in a specific task, there is "1" in the cell, when it is not – "0".

The number and scope of tests depend on the purpose of testing. With regard to certification tests, acceptance tests and cyclical diagnostics, it is necessary to test all functions of the system but also limit oneself to cover each function once only. They apply to logically correct and verified application, so there is no need to study functions many times in other task configurations. To inspect functions during the exploitation of devices after repairs or disturbances, the tests must be narrowed down to inspect specific functions. To inspect the performance of a specific function, it is necessary to find the tasks in which the algorithm that performs this function occurs. If the inspected algorithm emerges in one task only, this task is an indispensable check. For instance, a failured card of an external controller of point machine no. 1 has been replaced. To check if the repair was correct and the function was performed, it is necessary to find tasks in the table in which switch 1 is included in the task configuration. These are the following tasks: ZP_1, ZP_2, ZI_1, ZI_2. By performing these tasks, we receive information on the correctness of fulfillment of the function by the element in question, and therefore on the functional condition of devices.

5. Conclusion

The performance of functional tests involves the restricted availability of devices and infrastructure for the performance of tasks at the traffic station, costs, and the commitment of the station's personnel. This negative influence of tests can be minimized while selecting tests for performance. The selection is related to the purpose of testing and its scope. It is logical that a broader scope of tests, that is certification

Table 1

Table of tasks performed by the SRK system in the record of control algorithms [own elaboration]

			Control and inspection algorithms											
			Switches						Semaphores			Track and switch sections		
			a^N_{11}	a^N_{12}	a^N_{1n}	a^N_{21}	a^N_{22}	a^N_{2n}	a^S_{A1}	a^S_{A2}	a^S_{An}	a^T_{A1}	a^T_{A2}	a^T_{An}
Task	Route-related orders	ZP_1	1	0	0	0	0	0	0	1	0	1	1	0
		ZP_2	0	1	0	1	0	0	0	0	1	1	0	1
		ZP_3	…	…	…	…	…	…	…	…	…	…	…	…
		…	…	…	…	…	…	…	…	…	…	…	…	…
		ZP_n	…	…	…	…	…	…	…	…	…	…	…	…
	Individual orders	ZI_1	1	0	0	0	0	0	–	–	–	–	–	–
		ZI_2	0	1	0	0	0	0	–	–	–	–	–	–
		ZI_3	…	…	…	…	…	…	…	…	…	…	…	…
		…	…	…	…	…	…	…	…	…	…	…	…	…
		ZI_n	–	–	–	–	–	–	–	–	0	0	0	1

where:
ZP, ZI – tasks: route-related commands ZP, individual commands ZI,
ZP_1, ZP_2, ZP_n – tasks in the form of routes – route-related commands in accordance with the locking sheet,
ZI_1 – command to turn a switch in +,
ZI_2 – command to turn a switch in –,
ZI_n – command to reset LO.

tests, requires a bigger number of tests than the study of a function after the simple repair of one of the subassemblies of the configuration. The methodology presented is concerned with using available tasks defined in the design documentation and natural systemic signals. It is a recommended approach because we do not introduce foreign signals and additional equipment, and we also receive a real response of the devices in question, which can be correlated with the design documentation directly and it is possible to specify the functional condition of the system. The very selection of tests should substantially limit the negative impact of testing. Further works related to the subject will be concerned with analyzing the cost of tests and the possibility of using the minimization of test sets known from device diagnostics. The use of cost criteria will let us organize the collection of tests and select those checks which have the lowest impact on the availability of SRK devices during testing.

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