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Verification of the Functional Safety Index in Technical Part of Transport Infrastructure. Railways Example

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Abstract

This paper deals with the verification of the functional safety index. Testing just only technical part. Used the data taken from Russian Railways company. Made generalization for the case of a variety of factors capable lead to failure. Proved practical applicability of the technical part of the functional safety index for railway transport infrastructure.

Keywords: functional safety index, technical safety, transport infrastructure.

1 Introduction

Functioning of technical subsystem elements is aimed to identify deviations from norms and dangerous failure of core elements (in case geometrical parameters diagnosis system of railway track, rail defectoscopy and etc.) and to recover their operability (the system of current track and locomotives maintenance).

Previously we have proposed an index of functional safety control system of the core defective elements f=1. Thus, $K_m^{(1)}$ is the probability that the core “wheel-rail” will not be in inoperable state because of the missing defective elements by control system.

$$K_m^{(1)} = 1 - \frac{Q_m}{1+2\cdot\frac{\mu_m}{\lambda_m}+Q_m}, \quad (1)$$

where Q_m is a probability of missing defective element m by monitoring device. Intensity of the core defective elements output λ_m is defined through the middle duration of non-failure operations (a middle interval in days between the possible defects appearance) $\lambda_m = 1/t_0$, where t_0 is a middle duration of non-failure operations of core elements, days. Middle duration of the core non-failure operations is defined using an index of average annual number of defects N $t_0 = 365/N$. Intensity (frequency) of the core elements control is $\mu_m = 1/t_1$, where t_1 is a middle time of detecting a defect by monitoring devices (time between adjacent verifications), days. Will then be used approaches previously applied in the works [1-10].

2 Verification of the functional safety index in technical part

Let’s verify the proposed model $K_m^{(1)}$ on the example of core state influence to functional safety with various frequency of control. Probability of missing defect element by monitoring device is $Q_m = 0{,}1$.

In order to determine λ_m one should use average annual dependence of released high-defective rails for 1 km from missed tonnage T, offered in [5], and transfer it to the core defective elements release. $N = 2{,}6285 \cdot 10^{-6} T^{2{,}07160}$.

The results of numerical example of the functional safety control system dependence from the core states at various control intensity are shown at the fig. 1. On the basis of performed calculations one can make the following conclusions.

Firstly, the increase of the released defective elements of the core “wheel-rail” decreases functional safety, provided by control system. Secondly, technical and organizational measures (control period), aimed to maintain functional safety, do not allow ensuring its constant level. Thirdly, a control system functional safety level tends to a minimum value.

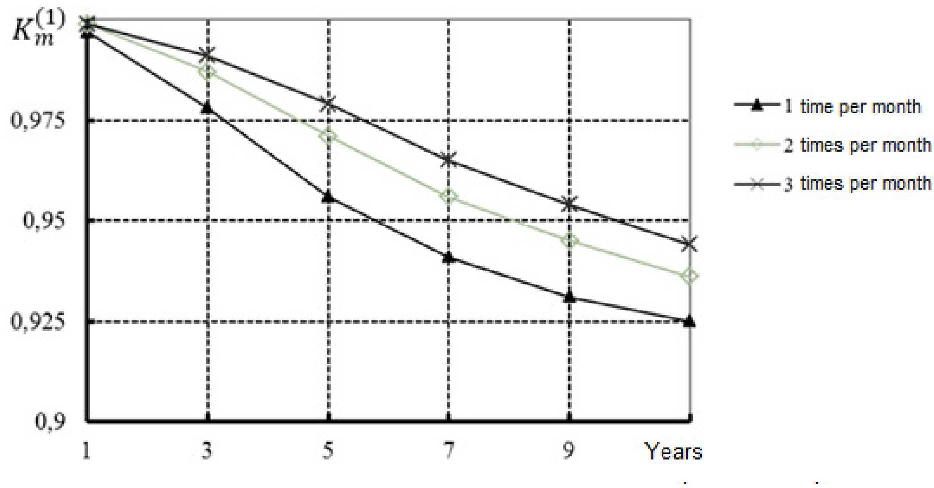

Fig 1 Dependence $K_m^{(1)}$ from the core state control period

Let's research the change of the control system functional safety level for the various core elements constructions. Let's use dependences of released high-defective rails to continuous welded and sectional rails, proposed in [11], and carry them over core elements. The results of calculation are shown at the fig. 2.

It is evident from the fig.2 that the functional safety is higher when modernized constructions of core elements are used.

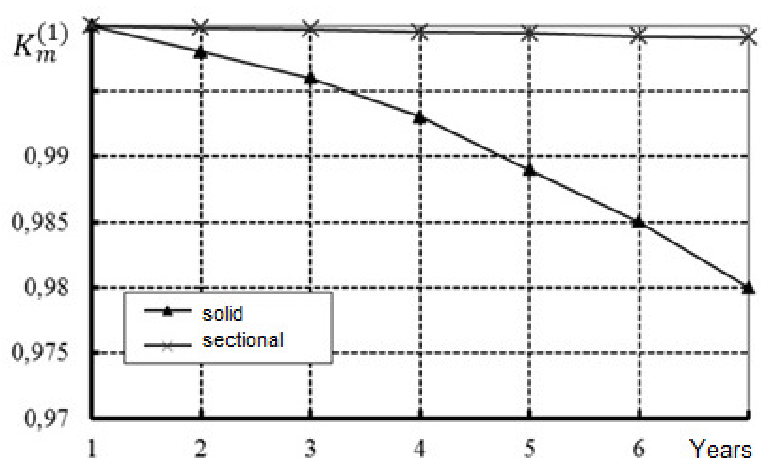

Fig.2 Dependence $K_m^{(1)}$ from a kind of core elements construction

Expression (1) allows considering one kind of destabilizing factor (dangerous mistakes of personnel or monitoring devices failures). Thus, the functional safety index of the core “wheel-rail” defective elements of the control system with presence of some destabilizing factors is determined by their direct product:

$$K_m^{(1)} = \prod_{i=1}^{N_q} (K_m^{(1)})_i,$$

where q is an index of one kind destabilizing factor; N_q is a total amount of dangerous destabilizing factors capable to transfer core to inoperable state.

Let’s divide the whole set of dangerous destabilizing factors into several subsets according to classification given in [61]. Hence, $N_q = N_1 + N_2$, where N_1 is the total amount of technical devices dangerous failures transferring the core to inoperable state; N_2 is the total amount of technicians’ dangerous mistakes transferring the core to inoperable state. So, $K_m^{(1)} = (K_m^{(1)})_1 \cdot (K_m^{(1)})_2$, where $(K_m^{(1)})_1 = \prod_{i=1}^{N_1} (K_m^{(1)})_i$, is the probability that the core will not be in inoperable state for the estimated time because of control system dangerous failures; $(K_m^{(1)})_2 = \prod_{i=N_1+1}^{N1+N2} (K_m^{(1)})_i$, is the probability that the core will not be in inoperable state for the estimated time because of dangerous actions (mistakes) of technicians performing the control.

Let’s consider the influence of the number of destabilizing factors to the functional safety. The initial data for calculation is $K_m^{(1)} = 0{,}98$. The results of calculation are shown at the fig. 3.

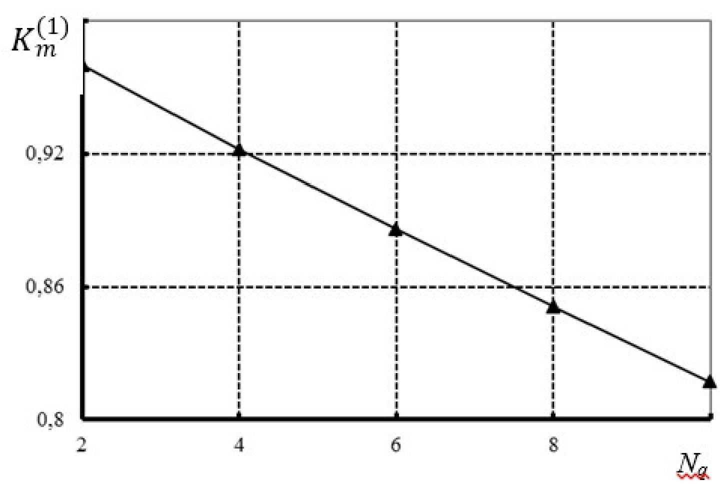

Fig. 3. Dependence $K_m^{(1)}$ from the number of destabilizing factors N_q

Thus, increase of destabilizing factors leads to decrease of control system functional safety.

Conclusion

For instance, decrease of influence of such destabilizing factor like technical personnel mistakes, is achieved by means of organizational and technological measures, by means of introduction automatic management systems. Technological operations automation completely excludes human factor in some cases.

On the basis of calculations it can be concluded that the proposed model for the control devices functional security of defective core elements adequately reflects the processes occurring in practice. Methodology for quantifying the functional safety of technical personnel $K_m^{(2)}$ is an actual topic for further research.

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