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Peculiarities of technical object's safety level evaluation

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Abstract

In this work is developed method of evaluation safety level, which decreases with floating intensity functioning during technical object. Factors, condition such changes were reviewed. Basing on proposed methodic of detection of various types of risks exists possibility to form constructive algorithms of evaluation of safety level, which allows forming adequate danger counteraction means. One of basic factors, representing dangers, is malfunctions, appearing on technical object.

Introduction

Most technical objects (TO), aimed on service, for example, transportation, can be dangerous for environment. Such threats are artificial and are not natural for the environment. Environment adapts to threats by forming counteraction processes.

In this paper there is not characterize the threats of such type in spite of possibility of initiate negative events in TO. Let us accept that TO is designed and produced taking in consideration all possible external factors. Reason for creation of any safety means, not required by technological process, could be evaluation result of safety level of relevant TO during each current moment functioning of TO. Necessity of conduction of evaluation is justified by following factors. During TO design it is not necessary to create means, counteracting threats which may appear in some lap of time of TO functioning, if the last ones will activate due to the natural processes of ageing of TO components. With increase of complexity of TO and with increase of uptime, not depending on projected conditions, ways of use and service of TO, processes of its use and service may change. Such modification is mostly initiated by the environment, in which TO functions and is conditioned by a number of external to TO factors. For example, functioning mode of TO changes or separate fragments of TO are modified etc. Beside functional threats, initiated by technological processes, TO can have threats, initiated in cases when TO stops functioning. This is characteristic to those TO, which use substances, dangerous for environment or which propose services, connected to them. The most common reasons for changing character of new threats are changes of parameters, characterizing TO. Such reasons have wide range of factors, leading to them. Examples of such factors could be:

- extension of hardware resource of TO;
- absence of alternative services;
- arise of unpredicted external factors, negatively influencing TO etc.

Analysis of risk estimation tasks

The most common way of evaluation of TO danger level is calculation of risk value. Calculation of risk value can be performed basing on various approaches and methods. The most common method is based on use of statistic modelling [1]. Quite wide for safety evaluation are spread logical probability systems. Those systems are based on continuous monitoring of all events, taking place in complex system and according to the logic of connection of those events are calculated current values of probability of arise of relevant threats [2]. Weakness of those approaches is a need to perform continuous monitoring of TO. In both cases such monitoring ensures increase of evaluation preciseness due to the increase of statistic data about changes in TO. Continuous monitoring leads to decrease of TO efficiency in framework of main technological process and leads to complication of TO. Therefore, arises the task of creation of more efficient monitoring strategy, and simplification of procedures of monitoring data analysis.

Modern standards regulating development processes of complex TO requires including into main devices list also diagnostic systems for it [3]. While the primary purpose of diagnostics systems is detection of malfunctions, arising during functioning of TO and are physical factors, leading to the safety level decrease. Results of diagnostics could be basic data for calculation of safety level of TO, so methodic of calculation of safety level can be formed in close relation to diagnostics systems. As a result of function of diagnostic system (DS) are formed data on malfunctions. In most cases, DS function in such way that malfunctions, detected by DS, are rated by the level of their influence on technological process and environment. The appearance of malfunctions is one of the main reasons for TO safety level decrease. So, it is worth to synchronize calculation of TO safety value with work of DS. Obviously, evaluation of the safety level is necessary only in case of its decrease. The appearance of malfunctions is one of the reasons for such decrease. To form methodic of calculation of safety value it is necessary to review following tasks:

– determine interpretation of risk evaluation and accordingly with risk value unit;
– select scale of measurement of relevant parameter, interpreted as a risk;
– to form TO safety models which will help to calculate its value.

Safety level evaluation tasks

To evaluate the safety level, independent of object of evaluation are widely spread risk values *R* [4, 5]. Interpretation of concept of risk in different works is widely analyzed and mostly depend on the subject area. So, let us stop on the interpretation which will be used in this case. For risk value we will determine following ranges of its measurement:

1. Range in which risk determines decrease of efficiency of processes of functioning of TO (*RE*).
2. Range in which risk determines level of harmful influence of TO on environment (*RN*).
3. Range in which risk determines threat for services consumers, staff and population, located in the environment (*RL*).
4. Range in which risk determines catastrophic impact on TO and the environment of relevant negative factors (*RK*).

While the primary purpose of risk as some value is measured continuously, then it is logical to assume that mentioned above ranges are sequent which can be described by correlation:

$$RE \rightarrow RN \rightarrow RL \rightarrow RK.$$

It is proposed to use different measurement units of risk value in different ranges. This is because the risk as a parameter is closely related to processes, which it characterizes. The risk as some value is abstraction and isn't interesting. Its use makes sense only when value of risk gets interpretation in subject area, where risk is used. Subject area can be variable, but risk will have different interpretation depending on state of the TO. Let us accept that change of value of one parameter, or number of parameters, characterizing service or number of services on preset value δp_i corresponds to change in service. In first case, risk for TO is interpreted as TO functioning in different modes. As risk determines possibility of decrease of efficiency functioning of TO, then the last one in general case we will evaluate by intensity of the service level change and by number of available services. If we have x services and some lap of time for them Δt_i then velocity will be written down by known correlation:

$$v(x) = \frac{x}{\Delta t} v(x) \text{ or } v(x) = \frac{\mathrm{d}x}{\mathrm{d}t}.$$

If we review intensity of services as uninterrupted value, then risk RE will be determined by following correlation:

$$RE = \alpha - \frac{\mathrm{d}v(x)}{\mathrm{d}t} = \alpha - \frac{\mathrm{d}^2 x}{\mathrm{d}t^2}.$$

Minus sign means that intensity of services decrease, because if correlation:

$$RE = \alpha + \frac{\mathrm{d}^2 x}{\mathrm{d}t^2},$$

takes place, then interpretation *RE* loses its semantic value. Let us review interpretation of range thresholds, where *RE* is calculated. If correlation takes place:

$$[(v(x) = \mathrm{const}) \& (v(x) = \max)] \rightarrow (RE = 0),$$

then it means that inside range $D(RE)$ top point for value of *RE* is equal to zero and $v(x) = \max$. With decrease of $v(x)$, or with decrease of $\mathrm{d}v(x) / \mathrm{d}t$, velocity $v(x) \rightarrow 0$, and takes place correlation:

$$\left[\left|\left(\frac{\mathrm{d}\,v(x)}{\mathrm{d}\,t}\right)\right| > 0\right] \rightarrow \left(\lim_{x\rightarrow 0} v(x) = 0\right).$$

So, *RE* at lower edge point of variable *x* of the range *D*(*RE*) has maximum value. As far as decrease *v*(*x*) can be caused by various reasons, function $RE = f^{RE}$ (d*v*(*x*)/d*t*) can be different. Such function describes current value of *RE*. During change of *v*(*x*), the last one not only can be decreased, but at some Δt_i can be constant or even increase. This means that in general case f^{RE} is a function uninterrupted on the lap of its definition and also uninterrupted in area of edge points of lap *D*(*RE*). In that case, f^{RE} must have such structure, that in cases when *v*(*x*) = 0, f^{RE} (d*v*(*x*)/d*t*) = 0 takes place. Function f^{RE}(d*v*(*x*)/d*t*) can be formed basing on models, describing *v*(*x*) for preset TO. This approach in most cases is used for building models for determination risk value. Intensity of functioning of TO can be conditioned by separate key factors which belong to various types:

– physical nature of technological process;
– economical nature, conditioned by request for service on the market;
– evolution nature [6, 7].

The physical nature is formed by physical sources basing on which TO is created. The economical nature is formed by economical sources, for example it could be request from consumers for some kind of service. Evolution factor is determined first of all by changes, taking place in TO. Those changes can be caused by resource parameters, change of which can lead to change of efficiency of functioning of TO. Evolution factors can be caused by natural changes in environment, for example, change of trajectory in case of transportation services which can cause the need to change TO, which could not be forecasted during TO design. Risk of the second type of *RN*, is determined basing on analysis of level of harmful influence of relevant processes in TO on environment. Classic approach to resolve such kind of tasks of determination of that type of risk is based on study of interaction of key factors of environment and factors of technological processes, taking place in TO. In framework of this work are accepted following provisions.

1. Any kind of interaction of technological processes or consequences of their implementation with environment, not forecasted in technical documentation of TO, is harmful for environment.
2. Environment has limited resources.
3. Amount of harm to the environment (OS) is determined by following factors:
   – speed of changes in OS, to which leads influence of technological processes (TP), formally written down as following correlation:
   $$S^H = f^v\left[V^{OS}(y_1,\ldots,y_k)\right];$$
   – volume of residual effect, arising due to the inability of OS for complete self-recovery, described by correlation:
   $$S^{Ho} = f^o\left(\gamma^{OS}\right);$$
   – level of ability for self-recovery of OS, which represents itself as a speed of recovery and is described by correlation:
   $$S^{Hw} = f^w\left(C^W\right).$$
4. Interaction of processes of TO with OS, which means negative influence of TO on OS, takes place only in case of deviation of TO from regular functioning.
5. Deviation of functioning processes of TO from regular is caused by malfunctions in hardware and structure of TO.
6. Any malfunction is projected and is detected by diagnostic system.

Provision about interaction of TP with OS means that the last one can be reviewed as a part of natural processes in OS. Limitedness of resources in OS is a natural condition for any OS.

Third provision has direct relation to the task of determination of risk like *RN* [8, 9]. Let us accept that value of risk is measured by following components:

– amount of harm, that could be done to OS;
– time lap, needed to neutralize this harm;
– type of reason of arise of this harm in OS.

Formally, risk like *RN* is described by correlation:

$$RN = F\left(S^H, \Delta t_i, P^R\right),$$

where S^H – is total amount of harm to OS, caused by all factors, Δt_i – time lap needed to neutralize S^H, P^R – reasons of arise of S^H. Value S^H we will accept as dependent from speed of negative changes in OS, described as $V^{OS}(y_1,\ldots,y_k)$, and γ^{OS}, which are remaining changes in OS. Speed of change of OS state is determined by models of technological processes, taking place in TO and models of processes, taking place in OS. We will not review those models in details, as they are different for different technological processes (TP). Same situation takes place relevantly to models of processes in OS. Value of residual effect of influence of TP on OS depends on processes, taking place in OS. Relevant processes are also described by models of interaction of OS with TP. As far as processes in OS are natural, so relevant models are substituted with approximated descriptions, which in most cases are systems of evaluation of changes in OS, connected to system of evaluation of state of TP [10, 11]. So, in that case, f^o represents itself as the statistics models, preciseness of which depends on data volume and its evaluation.

According to provisions 4, 5 and 6, interaction of TO with OS is caused by arise of malfunction *NP*, which is projected. That means that arise of relevant malfunction can be detected and described by following correlation:

$$NP^k_{i \neq j} = f^N \left[R(\mathrm{TO}), L\left(NP^P_j\right), \tau_j \right]$$

where R(TO) – is resource of TO, NP_j^P – malfunctions which raised during [0, τ_j], L – logical formula, describing relations between functional parameters and diagnostic parameters. Existence of such relation is caused by fact that any malfunction causes some consequences which in TO can be interpreted as malfunctions.

In that case are not reviewed non-projected malfunctions, which are different from projected ones by factors, based on following provisions:

- malfunction is a process, consisting of steps: arise of malfunction, development of malfunction, influence of malfunction on functional parameters and influence of malfunctions on TO functioning;
- for projected malfunction all its steps are known, which allows in framework of DS to detect them at different stages and relevantly there is a possibility in security system to counteract it;
- for non-projected malfunction TO functioning mode.

Let us introduce a concept of resource R(OS), which is contrary to concept of ability level of OS to counteract process of doing harm to OS, by TO which is characterized by parameter S^H. Value *RN* can be reviewed as one, that characterizes risk of decrease of resource R(OS). Like the concept of resource of TO, which is in fact that after decrease of resource of TO to zero it is getting out of order or stop functioning, can be accepted that after some resource consumption R(OS) as a result of harmful influence on OS of factors of TO, arises risk of type *RL*, which determines the range of harmful influence of TO on health of humans, located in relevant OS, or transition $RN \rightarrow RL$ takes place. Then we can write down following correlation:

$$RN = f^Z \left[R(\mathrm{OS}), F\left(P_j^{NP}, \ldots, P_{j+m}^{NP}\right), \tau_j \right].$$

In this correlation values P_k^{NP} represent themselves as parameters, characterizing influence of unusual values of functional parameters of TO on OS and are determined because all NP_i are projected. Projection of NP_i means that there exists methodology of prediction and detection of relevant malfunction. Because NP_i are projected, formula $F_j^{NP},\ldots,P_{j+m}^{NP}$ describes dependencies between malfunctions in TO, which can be determined during TO design and parameters P_k^{NP}. So, we can limit ourselves by logical approximation for *F*, to calculate value of *RN*.

Risks like *RL* and *RK* significantly are different from risks *RE* and *RN*, so we will not review them in this work.

Conclusions

In this work is described methodic of determination of risk, used to evaluate level of safety of TO, which could be a vehicle. Proposed methodic is based on concept of various types of risks, defined by consequences of decrease of safety level of TO. Proposed methodic is reviewed in framework of limitations, defined by types of malfunctions which could lead to decrease of safety level and correspondingly to increase the level of risk for TO functioning. In the work is defined and analyzed interpretation of risk and its value, basing on value of influence or changes, taking place as a result of negative influence on TO functioning efficiency of external and internal factors.

Due to the use of the proposed methodic of forming tasks of detection of changes of safety level of some TO, it is possible not only to connect one or another safety level of TO, but also take into account processes and parameters, causing decrease of safety of TO. This gives possibility to unify methods of determination of value of risk and to develop constructive methods of detection of sources of safety level change. So, in framework of this work, there are processes causing projected malfunctions. As malfunctions are presented as some processes in TO, then appears possibility to implement effective methods of counteraction to the last ones.

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