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SOME PROBLEMS OF ESTIMATION THE RELIABILITY OF SAFETY IN MAN-MACHINE-ENVIRONMENT SYSTEMS

Summary. Assurrance of the high reliability of safety is very important problem in construction and utilization of the contemporary technical systems. Problems of safety are particularly important in these cases, when the failures of system generate danger for human life, environment, cooperating systems and for the system itself as well.

In this paper has been assumed the proposition, that for estimation the reliability of safety of such a system, it is necessary, besides considering reliability of technical devices, to take into account influence of the man-operator of system and influence of environment, to its functioning.

The proposed coefficients of estimation the system reliability of safety may be source of information, how to assure the possibly high safety of man-machines-environment systems.

1. INTRODUCTION

The permanent extension of tasks performed by the man-machine-environment systems, and higher and higher level of their complexity, in the technical structure and in the operational as well, require to define coefficients of estimation their reliability of safety.

Basing on the fundamental concepts connected with system safety, it is possible to identify the functional and reliability structure of such a system. Usually the safety or efficiency of realization the system's tasks was considered in aspect of it's technical part. In the contemporary systems it is necessary to notice the influence of man-operator of the system for each stage of the realization tasks process.

Man-operator is engaged to fulfil the control and inspection tasks as well. His activity must be considered in two real aspects. On the one hand man-operator is able to interfere with difficult situations, when the occurrence of an event causing a dangerous situation is possible - in these cases his activity may be the source of functional or time safety or efficiency surplus. On the other hand an error commited by the man-operator or his failure may be the reason of occurrence unreliability of safety or unreliability of efficiency.

In some cases it is necessary to take into account influence of the environment to the system's functioning, for example in transportation or mining systems.

Therefore for qualitative, and than quantitative analysis of man-machine-environment systems reliability of safety, it is necessary to the complex methods, which allow to estimate reliability of safety of all elementary components of the system. It is indispensable to determine such a technical-operational-environmental structure of the exploitationed systems, which allows to identify the systems reliability of safety states, with including the role and influence of man-operator and environment on this safety.

2. DEFINITIONS OF BASIC CONCEPTS CONNECTED WITH SYSTEM SAFETY

The concept - reliability of system safety, or in short - the system safety, in the descriptive sense means that the system is resistant to its failure or errors generating danger for the system itself, for cooperating systems, for environment and for human life as well.

The second concept, which together with the safety term makes part of the system reliability concept is the reliability of system functioning (system efficiency). In the descriptive sense it is the system resistance to the failures or errors of its operation, causing only breaks in the functioning of the system or its incomplete functioning.

The opposite terms of the safety and the efficiency are the unreliability of safety and unreliability of efficiency, respectively. These unreliabilities are defined in the descriptive sense as the susceptibilities of the system for the kinds of failures or errors stated in the definitions of safety and efficiency.

In all these definitions above, failures or errors of system are understood as the failures of object (of the technical part of the system), failures or errors in the system's controlling (caused by man-operator) and "failures" - influences of the environment.

The measure of the system safety unreliability is the probability Q_B of occurrence of an event causing a dangerous situation. The measure of the system efficiency unreliability is the probability Q_S of occurrence of an event causing nonefficient work of the system.

Assuming that events of failures causing unreliabilities of safety and unreliabilities of efficiency, respectively, exclude each other, the total unreliability of system appointed by the probability Q of its failure, may be determine by the sum of probabilities Q_B and Q_S.

According to the kind of reasons causing occurrence of the state of the system safety unreliability we can consider:

- technical unreliability of safety, caused by the operational failure or fault of the technical elements of system, with probability of occurrence $Q_{Bt}(t)$;
- operational unreliability of safety caused by the control error of the system's operator, with probability of occurrence $Q_{Bo}(t)$;
- biological unreliability of safety caused by the operator's "failure" (faintness, illness, sleep), with probability of occurrence $Q_{Bb}(t)$;
- environmental unreliability of safety caused by the catastrophism action (influence) of the system's environment, with probability of occurrence $Q_{Be}(t)$.

It seems to be reasonable considering the states of unreliability of safety caused by the simultaneous occurrence failures or errors of the technical elements and system's operators and the influence of system's environment.

Probabilities of ocurrence such events and states are denoted respectively by:

$Q_{Bto}(t)$ - for the state of technical-operational unreliability of system safety;

$Q_{Btb}(t)$ - for the state of technical-biological unreliability of system safety;

$Q_{Bob}(t)$ - for the state of operational-biological unreliability of system safety;

$Q_{Bte}(t)$ - for the state of technical-environmental unreliability of system safety;

$Q_{Bbe}(t)$ - for the state of biological-environmental unreliability of system safety;

$Q_{Boe}(t)$ - for the state of operational-environmental unreliability of system safety;

$Q_{Btob}(t)$ - for the state of technical-operational-biological unreliability of system safety;

$Q_{Btoe}(t)$ - for the state of technical-operational-environmental unreliability of system safety;

$Q_{Bobe}(t)$ - for the state of operational-biological-environmental unreliability of system safety;

$Q_{Btbe}(t)$ - for the state of technical-biological-environmental unreliability of system safety;

$Q_{Btobe}(t)$ - for the state of technical-operational-biological-environmental unreliability of system safety.

3. IDENTIFICATION MODEL OF MAN-MACHINE-ENVIRONMENT SYSTEM

Let us assume, that any considered man-machine-environment system is the system of activity, in which the object of activity is realization of the specified tasks, subject of activity are the system operators, and mediums of activity are the technical devices. System works in a determined environment.

Analysing course of the task realization in the each stages of the system exploitation process, it is possible to precise the probabilities staying of the system in the each reliability states, from the point of view of task realization safety.

Operational algorithm allowing to secure such an object consists of:

- identification of the considered system as the man-machine-environment activity system;
- qualification of the technical-operational-environmental functional structure of the system;
- explicitness of the system reliability structure;
- identification of the system reliability states;
- construction of the stochastic model of the system exploitation process;
- construction of the probabilistic safety reliability model of the system task realization;
- explicitness of the probabilities occurrence of the system task realization safety reliability states.

In general case set of the system task realization safety reliability states may be determine by the probabilities:

$R_{r\ int}(t)$ - probability of occurrence the state of intentional, safe realization of the task;

$R_{r\ Bi}(t)$ - probability of occurrence the quasi-safe state realization of the task (when occur the temporary states of unreliability of safety),
where index "i" $\Rightarrow$ t, o, b, e, to, tb, ob, te, be, oe, tob, toe, obe, tbe, tobe, precises the states mentioned above;

$R_r(t)$ - probability of occurrence the state of task realization

$$R_r(t) = R_{r\ int}(t) + \sum_{i=1}^{n} R_{r\ Bi}(t) \tag{1}$$

n - amount of states;

$Q_S(t)$ - probability of occurrence the state of unreliability of efficiency;

$Q_{Bj}(t)$ - probability of occurrence the state of j-th unreliability of safety, where index "j" is defined in the same way as index "i";

$Q_B(t)$ - probability of occurrence the state of unreliability of safety

$$Q_B(t) = \sum_{j=1}^{m} Q_{Bj}(t) \tag{2}$$

m - amount of states;

$R_{NS}(t)$ - probability of occurrence the state of efficiency surplus;

$R_{NBk}(t)$ - probability of occurrence the state of k-th safety surplus, where index "k"→ t,o,to - precises respectively technical, operational or technical-operational safety surplus;

$R_{NB}(t)$ - probability of occurrence the state of safety surplus

$$R_{NB}(t) = \sum_{k=1}^{s} R_{NBk}(t) \tag{3}$$

s - amount of states.

The probabilities defined above satisfy an equation:

$$R_r(t) + Q_S(t) + Q_B(t) + R_{NS}(t) + R_{NB}(t) = 1 \tag{4}$$

These probabilities, which numerical values may be statistically calculated basing on the exploitation investigations of the system, make the ground to define the coefficients of estimation the safety reliability of realization the task.

4. COEFFICIENTS OF ESTIMATION THE RELIABILITY OF SAFETY OF REALIZATION THE TASKS

From the point of view of the possibility of estimation the reliability of safety in accomplishing the tasks by the man-machine-environment system of activity, as the simplest coefficients may be accepted the values of the probabilitis $R_{r\ int}(t)$, $Q_B(t)$ and $R_{NB}(t)$, which have respectively meaning:

$R_{r\ int}(t)$ - probability of intentional, safe realization of the task;

$Q_B(t)$ - probability of occurrence impendancy over safety;

$R_{NB}(t)$ - probability of occurrence the system safety surplus.

Besides of them it sensible to define the sets of coefficients, which determine the groups of characteristics of the system reliability of safety:

i) proportional coefficient of the safe realization the task:

$$\beta(t) = \frac{R_{r\ int}(t)}{R_r(t)}\ 100\% \tag{5}$$

precising, which is the percentage of the safe accomplished tasks by the exploitationed system;

ii) proportional coefficient of the quasi-safe realization the task:

$$\beta i(t) = \frac{R_{r\ Bi}(t)}{R_r(t)}\ 100\% \tag{6}$$

(where index "i" is defined as mentioned above),
precising respectively the percentage causal influence of the particular elements of the considered system on the occurrence the quasi-safe states realization the tasks;

iii) proportional causal coefficient of the unreliability of safety:

$$\beta_B^{f}(t) = \frac{Q_{Bj}(t)}{Q_B(t)}\ 100\% \tag{7}$$

(where index "j" is defined as mentioned above),
precising quantitatively reasons of the occurrence unreliability of system safety;

iv) coefficient of the efficacy of safety surplus:

$$w_{SNB}(t) = \frac{R_{NB}(t)}{Q_B(t)} \tag{8}$$

which may be interpreted as the factor of the system safety, according to the "fail-safe" method, used during designing of some classes of systems.

5. CONCLUSIONS

The analysis of system safety ought to be treated very complex. In most cases it is necessary to take into account the technical structure of the system, the way of it's controlling and influence of the environment as well. It is particularly important in these cases, when in the point of view of the system reliability there is difference of two fundamental kinds of failures or errors. Occurrence one of them causing a dangerous situation leads to unreliability of safety, the othar one causes only unreliability of efficiency.

In general it is rather simple to estimate the unreliability of safety of technical part of system. For its determination we need only collection of information about work of devices in exploitation. Much more complicated are problems of estimation the man-operator's reliability and influence of environment. To obtain the credible data in these domain, special systems of collecting information must be describe. These problems require further investigations.

The further investigations requires too the problem of stochastic relations between technical, operational and environmental parts of systems of activity. In practice failures in technical devices, faults and failures in the control of system and influence of the environment are not absolutely independent.

In this paper only some selected problems, which are actually investigated have been presented.

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PROBLEMY OCENY NIEZAWODNOŚCI BEZPIECZEŃSTWA
SYSTEMU CZŁOWIEK - MASZYNA - ŚRODOWISKO

S t r e s z c z e n i e

Zapewnienie wysokiej niezawodności bezpieczeństwa jest bardzo ważnym zagadnieniem w procesie konstruowania i zastosowania współczesnych systemów technicznych. Zagadnienie bezpieczeństwa jest szczególnie ważne gdy niezdatność systemu stwarza zagrożenie dla życia ludzkiego, środowiska, systemów współpracujących oraz samego analizowanego systemu. W tym artykule założono, że dla oceny niezawodności bezpieczeństwa takiego systemu niezbędne jest rozpatrywanie, oprócz niezawodności technicznych elementów, także system człowiek - operator oraz wpływu środowiska na ten system. Proponowany współczynnik estymacyjny niezawodności bezpieczeństwa systemu może być źródłem informacji jak zabezpieczyć wysokie bezpieczeństwo systemu człowiek - maszyna - środowisko.

ПРОБЛЕМЫ ОЦЕНКИ НАДЁЖНОСТИ БЕЗОПАСНОСТИ
СИСТЕМЫ ЧЕЛОВЕК - МАШИНА - СРЕДА

Р е з ю м е

Обеспечение высокой надёжности безопасности является важнейшей проблемой в процессе конструирования и применения современных технических систем.

Проблема безопасности особенно важна тогда, когда непригодность системы создаёт угрозу человеческой жизни, среде связанным с ней системам, а также и самой анализируемой системе. В данной статье предполагается, что для оценки надёжности безопасности такой системы необходимо рассматривать, кроме надёжности технических элементов, системы человек - оператор, а также влияние среды на эту систему. Предлагаемый коэффициент оценки надёжности безопасности системы может быть источником информации о том, как обеспечить высокую безопасность системы человек - машина - среда.