THE MODELS OF DESIGNED RELIABILITIES OF TECHNICAL ELEMENTS

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Abstract: *In this paper a brief information about actions making considered mathematic models of reliability relations is given. These models have been characterized through examples. Computer simulation has been described using the presented models. Attention has been drawn to the utility of the results of the described simulation.*
The place of the presented part of the models in designing of technical objects has been shown.

1. INTRODUCTION

Designing a technical object means also the designing of its characteristics, including reliability. If we want an object to possess the required reliability in operation, we have to answer the basic question at the very stage of designing, i.e. what should be the reliability values of elements in a defined moment of time? In order to answer this question the models of relations between the required reliability of the technical object and the reliabilities of the elements should be known. These models are the very mathematical models which are the object of considerations in this paper.

Let us admit that designed object is a certain technical supersystem.

The reliability $R_s(t)$ is a feature of a technical object which defines its aptness to function correctly in a determined time t and under defined conditions $\{w_s\}$.

The reliability measure $R_s(t)$ is the probability P of non-damaging $\overline{U}_s$ of the object, so

$$R_s(t) = P\left(\overline{U}_s(0,t]\right)_{\{w_s\}} . \tag{1}$$

In the same manner the reliability $R_i(t)$ of i-kind of elements of the technical object is defined, namely

$$R_i(t) = P\left(\overline{U}_i(0,t]\right)_{\{w_i\}} , \tag{2}$$

where P is the probability of non-damaging $\overline{U}_i$ of i-kind of elements, in the time division $(0, t]$, in determined conditions $\{w_i\}$ of functioning of these elements.

The required reliability $R_s(t_z)$ of a technical object is called the value of its reliability $R_s(t = t_z)$ in a given time t_z, resulting from:

- the need of the functions to be performed by the object,
- the need of ensuring safety to the object and its surroundings (people, other technical objects and natural environment),
- the need of an effective exploitation of the object,
- needs other than the above mentioned, for example the need of meeting competition on the market.

The designing of technical objects in understood as a process in which the subjects of the process carry out the design of functioning, construction, technology of production, operation (utilization), aptness maintenance and liquidation of objects. In all the distinguished parts of the process of designing technical objects we use the information from the computer simulation of reliability relations with the utilization of models of these relations.

2. THE CONSIDERED MODELS AND ACTIONS CREATING THEM

Actions – performed by the subject (designer or a team of designers) in order to make mathematical models of reliability relations are: the decomposition of the designed technical object (supersystem) into composing elements, the abstraction of composition of elements, the idealization of reliability structures and reliability values of composing elements, the abstraction of reliability relations, the formalization of reliability relations and the verification of models of reliability relations.

It is a part of the actions (operations) of the method of fulfilling the postulate of required reliability of technical objects during the process of their designing [1-4]. Further actions of this method are simulation and analysis of the reliability relations and deductions from the properties of these relations.

3. MATHEMATICAL EXAMPLES OF RELIABILITY MODELS

The designed reliability $R_i(t_z)$ of a *i*-cylinder barrel of an Diesel engine is shown by the formula for a defined reliability structure of a ship's machinery in which the engine is, according to [2]

$$R_i(t_z)=\left\{1-\left\{1-\left\{1-\left\{1-\left[R_s(t_z)\right]^{\frac{1}{7}}\right\}^{\frac{1}{p_4}}\right\}^{\frac{1}{6}}\right\}^{\frac{1}{p_3}}\right\}^{\frac{1}{306\,y}}, \tag{3}$$

for the parameter $p_1 = 1$, and by the equation

$$R_i(t_z)=\left\{1-\left\{\frac{1-\left\{1-\left\{1-\left\{1-\left\{1-\left[R_s(t_z)\right]^{\frac{1}{7}}\right\}^{\frac{1}{p_4}}\right\}^{\frac{1}{6}}\right\}^{\frac{1}{p_3}}\right\}^{\frac{1}{18}}\right\}}{1-\left[R_s(t_z)\right]^{17y}}\right\}^{\frac{1}{p_1-1}}\right\}^{\frac{1}{17}}, \tag{4}$$

when $p_1 > 1$, where:

- $R_s(t_z)$ – is the required reliability of the machinery,
- p_1 – is the number of subsystems of the engine with series structures constituting a subsystem having a parallel structure, according to [5],
- p_3 – is the number of engines propulsing the propeller of a seaship,
- p_4 – is the number of propellers of a seaship,
- y – is the smallest number of undamaged basic subsystems of the engine which permits the engine to work on [5].

The equation (4) can be resolved through iterative methods of resolving nonlinear equations.

The designed reliability $R_i(t_z)$ of an *i*-engine shaft of a defined machinery is determine by the formula

$$R_i(t_z)=\left\{1-\left\{1-\left\{1-\left\{1-\left[R_s(t_z)\right]^{\frac{1}{7}}\right\}^{\frac{1}{p_4}}\right\}^{\frac{1}{6}}\right\}^{\frac{1}{p_3}}\right\}^{\frac{1}{126}}, \tag{5}$$

in which the same magnitudes and parameters as in the above given dependences occur.

A characteristic feature of the given mathematical models is that the reliabilities of the engine elements are a function of the required reliability of the machinery (considered as a technical supersystem), where the engine is.

It is practical also to reckon the average durabilities of elements answering the designed values of elements reliability. For example the average durability $E(T_i)$ of an *i*-engine shaft (of a defined machinery) when the distribution of the probability of this shaft durability is a Weibull distribution is defined by the formula

$$E(T_i) = \frac{t_z \Gamma\left(\frac{1}{q_i}+1\right)}{\left[-lnR_i(t_z)\right]^{\frac{1}{q_i}}} \quad , \tag{6}$$

where:

t_z – given time value,

$R_s(t_z)$ – reliability defined by the formula (5),

q_i – parameter of Weibull distribution,

$\left\{\frac{1}{q_i}+1\right\}$ – Euler gamma function.

The average durabilities of elements may be an information more perceived by the objects (engines) producers than the values of elements reliability because the average durabilities of elements are often known to producers from the investigations of the processes of elements wear.

The exemplary model of relation between the designed reliability $R_i(t_z)$ of *i*-(*i*-kind of) element (of *s*-supersystem) and the average life (durability) $E(T_i)$ of this element, when the distribution of the probability of life T_i of *i*-kind of elements is a gamma distribution, is defined by the equation

$$\xi_i = R_i(t_z) - \sum_{k=0}^{g_i-1} \frac{\left[\frac{g_i t_z}{E(T_i)}\right]^k exp\left[-\frac{g_i t_z}{E(T_i)}\right]}{k!} \quad , \tag{7}$$

where g_i is the parametr of gamma distribution; the value $E(T_i)$ of this equation is reckoned iteratively by making use of the condition

$$\zeta_i \le \zeta_{i\,adm} \quad , \tag{8}$$

where $\zeta_{i\,adm}$ constitutes the admissable value of the difference in equation (7).

It should be stressed that, when the reliability values of the produced elements are smaller than the designed reliability values of elements, then the postulate of required reliability of a technical supersystem is fulfilled through reservation of machines and gears or (and) prophylactic exchanges of elements. These problems are treated in papers [1-3].

Formula (9) is the model of relation between the real average life (lifetime) $E^*(T_i)$ of *i*-kind of elements and the designed reliability $R_i(t_z)$ of the same kind of elements, and period $t_{m,i}$, $m = 1, 2, ... , n$, utilization of *i*-kind of elements to their *m*-prophylactic exchanges, when the distribution life probability T_i of *i*-kind of elements is a Weibull distribution

$$t_{m,i} = \frac{E^*(T_i)\left[-lnR_i(t_z)\right]^{\frac{1}{q_i}}}{\Gamma\left(\frac{1}{q_i}+1\right)} \quad , \tag{9}$$

where q_i is the parameter of Weibull distribution, $\Gamma\left(\frac{1}{q_i}+1\right)$ a Euler gamma function and the other symbols – as previously; the number *n* of prophylactic exchanges of elements is obtained form the condition:

$$t_{n+1} \ge t_z \,, \tag{10}$$

then

$$R_i^*(t_z) \ge R_i(t_z) \,, \tag{11}$$

where $R_i^*(t_z)$ is the reliability value corresponding to $E^*(T_i)$ of *i*-kind produced elements.

4. COMPUTER AIDED RELIABILITY SIMULATIONS

The design computer aided reliability simulation is carried out with the use of mathematical models of reliability relations. The result of this simulation are valued reliability relations, among others reliability values of elements are obtained according to the required reliability of an object for its various designs, so for various reliability structures of an object. Simulation includes algorithmization (i.e. creation of a mathematical models system of reliability relations consisting of these models and relations of their arrangement with regard to the defined target), programming of algorithms, current verification of the correctness of formalization of reliability relations and the computer representation of these relations in the form of tables of variable values and diagrams. An important feature of simulation is the creation of such mathematical models system of reliability relations so that a "dialogue" between the designer and the computer in searching a complex solution of the execution of the required object reliability postulate might exist.

Designed reliability values and average durabilities of elements corresponding to these values constitute useful information for subjects forming the reliabilities of elements through research on the influence of various factors on the reliabilities of elements and such a selection of these factors so that the elements have (as far as possible) designed reliability values and ultimately (through the above mentioned research) for the makers of technical objects. Then it will be known to which reliability values of elements one should tend in the above mentioned research as well as in the production of elements and objects by the same.

5. CONCLUSION

The above presented usefulness of mathematical models of selected reliability relations is in general connected with the assurance of the objects required reliability during operation. We deal with a part – i.e. designing of objects reliability – which belongs to a whole: designing of objects and constitutes an essential link coupling valuing of technics (and here the postulate of required objects reliability) with the forming of elements reliability and the production of technical objects.

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