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Estimation of the Maximum Permissible Polyfactor Action Load on a Living Organism

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ABSTRACT. One of the basic objectives of the modern biological research is to study the influence of multifactor action on a living organism and to estimate organism resistance to this action. The mentioned research requires significant resource including the object of experiments that complicates identification of efficient directions and their realization. Application of mathematical modelling with respect to body resistance, especially in the process of studying multifactor action, considerably reduces the volume of research maintaining prospective directions. The paper represents a schematic plot of modelling and basic accents, which are adequate for estimation of the limits of the resistance and potential life of the biological system in conditions of multifactor action. *© 2016 Bull. Georg. Natl. Acad. Sci.*

Key words: multifactor action, resistance of a live system, modelling

For estimation of different factors acting on a living body it is necessary to define the relationship among number factors of the so-called external power ($P_{extern.}$) and the factors stimulating resistance to them (R). For the organism resistance factors it is reasonable to define external factors. In order to ensure safety or the probability of $P(A)$ functioning on a living organism or a part of it, the following relation is necessary:

$$P(t)= P(R_{resist.} > P_{extern.}) > 0\ldots \tag{1}$$

With account of taken measures it means that it should exceed the power of action of all the external factors. In both cases these factors refer to the law of distribution of random values in the form of $f_{Pextern.}$ and $f_{P\,resist..}$. Then negative function on a living organism or a part of it for any value of $f_{Pextern.}$ and $f_{Rresist.}$ can be given as follows:

$$P(t)=\int_{-\infty}^{\infty} f_{P_{extern}}(P_{extern})\left[\int_{-\infty}^{\infty} f_{resist}(R)dR\right]dR_{extern} \tag{2}$$

with limits of $-\infty < P_{extern.} < \infty$ and

$$P(t)=\int_{-\infty}^{\infty} f_{resist.}(P_{resist.})\left[\int_{-\infty}^{\infty} f_{P_{extern.}}(P_{extern.})\times dP_{extern.}\right]dR_{resist.} \tag{3}$$

with limits $-\infty < R < \infty$.

To achieve the result it is necessary to describe the law of distribution of random values of $f_{\text{Pextern.}}$ and $f_{\text{Rresist.}}$, which may have normal, exponential, empirical, gama-distribution. The mentioned methods are well developed and described in literature [1-3]. For the given case let us consider the law of normal distribution, as far as it is known as the law of precision, because with the increase of the data in any order the law still tends to the law of normal distribution.

In this case the density of normal distribution of data will be given by:

$$f(P_{\text{extern.}}) = \frac{1}{\sigma_{P_{\text{extern.}}}\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{P_{\text{extern.}} - M_{P_{\text{extern.}}}}{\sigma_{P_{\text{extern.}}}}\right)\right] \tag{4}$$

within the limits $-\infty < P_{\text{extern.}} < \infty$.

In the case of a living organism the density of normal distribution of data will be given as:

$$f(R_{\text{resist.}}) = \frac{1}{\sigma_{P_{\text{resist.}}}\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{R_{\text{resist.}} - M_{P_{\text{resist.}}}}{\sigma_{P_{\text{resist.}}}}\right)\right], \tag{5}$$

where $\sigma_{P_{\text{extern.}}}$, $\sigma_{P_{\text{resist.}}}$, $M_{P_{\text{extern.}}}$, $M_{R_{\text{resist.}}}$ are the average square deviations and their mathematical expectation, respectively.

To prove the main theory it is reasonable to introduce the difference of the random values:

$$Y = R_{\text{resist.}} - P_{\text{extern.}}. \tag{6}$$

Resistance will exceed the acton caused by external factors.

According to equation (6) an average square deviation of these values and their mathematical expectation will be:

$$\sigma_Y = \sqrt{\sigma^2_{\text{resist.}} - \sigma^2_{\text{extern.}}}, \tag{7}$$

$$M_Y = M_{R_{\text{resist.}}} - M_{P_{\text{extern.}}} \tag{8}$$

and the probability of reliability can be given by:

$$P(Y > 0) = \int_0^\infty \frac{1}{\sigma_Y\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{Y - M_Y}{\sigma_Y}\right)\right] dY. \tag{9}$$

The deviation will take place after a period of time T in case if the limited admissible resource W_0 gradually decreasing will become equal or less, than W_T. Suppose the mentioned process W_T corresponds to the law of normal distribution, then estimation of average value of reliability of the object will be possible. Instead of the index of reliability P the term "risk" very often is used. It means the possibility of system's destruction. Between the risk r and reliability P the following ratio exists: $2r = 1 - P$.

In order to apply equation (9) the responce of the living organism will be: it would be better to represent it as follows:

$$P = \int_0^\infty \frac{1}{\sigma_W\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{W_0 - W_T}{2\sigma_{W_T}}\right)\right] dW. \tag{10}$$

The problem requires to define the lower limit of the static resource [1], i.e., the lower limit of the random value. If we denote the right hand-side relation (9) by:

$$\frac{(Y - M_Y)}{\sigma_Y} = Z \tag{11}$$

then $\sigma_y dz = dy$. and for Y=0 that corresponds to the complete exhaustion of resource we have:

$$Z = \frac{W_0 - W_T}{\sqrt{\sigma_{W_0}^2 - \sigma_{W_T}^2}}. \tag{12}$$

In this case the reliability will be defined by:

$$P = \Phi(z) = \Phi\left[\frac{W_0 - W_T}{\sigma_{W_0}^2 - \sigma_{W_T}^2}\right]. \tag{13}$$

Concrete values of the reliability can be obtained by means of the normed Table of the values of normal distribution function [2].

Table 1. Distribution function of normed, normal data

z	0	0.5	1	1.5	2	2.5	3	3.5	4
Φ(*z*)	0.5	0.691	0. 841	0. 933	0.977	0.993	0.998	0.999	0.999

The resource of a living organism $W(T)$ for any value of T gradually decreasing is as follows:

$$W(T) = W_0 - YT, \tag{14}$$

where Y is the intensity in any interval of time.

Taking into consideration equation (14) and primary resource of the organism W_0 is constant or $\sigma_{W_0} = 0$, equation (12) will be given as follows:

$$z = \frac{W_0 - YT - W_T}{\sigma_{W_0}}. \tag{15}$$

From this equation the intensity of the process can be defined:

$$Y = \frac{W_0 - \sigma_{W_0} Z W_0 - W_T}{T}. \tag{16}$$

The recovery resource is described as:

$$T = \frac{W_0 - \sigma_{W_0} Z W_0 - W_T}{Y}. \tag{17}$$

Using the rule of three-sigma and 20% admissible limit of the average value of W_0 the equations (16) and (17) will be significantly simplified:

$$Y = \frac{W_0 - 0.033 Z W_0 - W_T}{T}, \tag{18}$$

$$T = \frac{W_0 - 0.033 Z W_0 - W_T}{Y}. \tag{19}$$

If to define earlier chosen limit, then

$$W_0 = \frac{YT + -W_T}{1 - 0.033T}. \tag{20}$$

The obtained equation can define the efficiency of the complex of curative and profilaxes measures inside the limit.

ფსიქოლოგია

ცოცხალ ორგანიზმზე ზემოქმედების ზღვრულად დასაშვები დატვირთვის შეფასება

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თანამედროვე ბიოლოგიური კვლევის ერთ-ერთ ძირითად ამოცანას წარმოადგენს მრავალფაქტორიანი მოქმედების შესწავლა და ორგანიზმის მდგრადობის დადგენა ამ ზეგავლენის პირობებში. აღნიშნული კვლევა მოითხოვს მნიშვნელოვან რესურსს, მათ შორის ექსპერიმენტალურ ობიექტებს, რაც ძალზე ართულებს ეფექტური მიმართულებების გამოყოფას და მათ რეალიზაციას. შესაბამისად, მათემატიკური მოდელირების გამოყენება ორგანიზმის მდგრადობის თვალსაზრისით (განსაკუთრებით პოლიფაქტორული ზეგავლენის შესწავლის პროცესში), მკვეთრად ამცირებს კვლევის მოცულობას პერსპექტიული მიმართულებების შენარჩუნების ფონზე. ნაშრომში წარმოდგენილია მოდელირების სქემატური ჩარჩო და ძირითადი აქცენტები, რაც ადეკვატურია ბიოლოგიური სისტემის მდგრადობის და სასიცოცხლო პოტენციალის საზღვრების შესაფასებლად პოლიფაქტორული ზეგავლენის დროს.

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