CALCULATION OF FATIGUE DAMAGES UPBUILDING FOR COMPLICATING LOADING PROCESSES

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Abstract: *The method of representation of stochastic processes of loading called by a method of the inserted cycles is offered. The method enables to allow both influencing of a succession of amplitudes of cycles of loading, and complication of pattern of the process. The calculated model of upbuilding of fatigue damages in conditions of random loading is designed. The model grounded on the given method of representation, and also on a hypothesis about possibility of the separate registration of complication of pattern and succession of amplitudes of the process of loading.*

Key words: representation of stochastic process, random loading, upbuilding of fatigue damages, durability

1. Introduction

The abatement of specific consumption of materials of parts of machines at fullest usage of their resource is the actual problem of a modern machine industry. This tendency is foregone result in limitation of durability in connection with beefing-up of influencing of fatigue processes. It is known that most of parts of machines and constructive elements in exploitative conditions are subjected to random loading.

In such conditions durability of parts calculate according to the equation [1, 2]:

$$L = \left(\sum_{i=1}^{n} p_i \lambda_i \right)^{-1}, \qquad (1)$$

where L – calculated durability;

λ_i – upbuilding of fatigue damage in i external environments for a reference stand of durability (km of run, amount of cycles, time in use etc.);

p_i – relative duration of maintenance in i conditions

n – amount of representative external environments (for example, acceleration, operating duty, braking, repair etc.).

The meaning of p_i has not the complicate solving. It is enough to have the statistical information on external environments of the given machine or of analog. Thus the condition $\sum_{i=1}^{n} p_i = 1$ should be executed.

The description of λ_i is more composite. It demands a solution of the all-up task of toting of fatigue damages.

At the present stage advancements of science make toting of fatigue damages by means of the kinetic equations of damage more often. These equations look like [3]

$$dz/dt=F\,[z\,(t),\, s\,(t),\, R\,(t),\, C\,(t)], \qquad (2)$$

Where z – measure of damage, which one contents to such dependences:

$$z\,(t=0);\; z\,(t=T_{kr})=1, \qquad (3)$$

where T_{kr} – time before breaking down;

F[..] – determined non-negative scalar function (the cumulative model of damages);

R(t) – vector of arguments of baseline dependences, which one allows for geometry, stuff, surface quality etc.

C(t) – vector of arguments of an environment (corrosion, temperature etc.).

The classification of the equations such as (2) is made depending on used model of toting of damages. So, *Miner's* linear model [4] is described by the equation

$$\frac{\partial z}{dt} = c(\sigma)\cdot\sigma^{r(\sigma)},$$

(4)

where c and r are step functions.

The equations of an aspect (4) will be used now very much often. But the linear model is poor at many conditions of loading. It is confirmed by outcomes of jobs [1, 2, 5].

Therefore great many of studies were directional on mining of the method of applications of upbuilding of fatigue damages. The most known method of applications has elaborated *Bolotin* [3], *Kogaev* [6, 7], *Pochtenny* [8-10]. The vast browse of hypotheses of upbuilding is in *Birger's* job [5]. But also these methods of applications not are a universal resource of upbuilding.

Now there is no conventional method of application of calculation of durability in conditions of random loading, especially for broadband stochastic processes. Therefore mining of the method of application for the registration of complication of the process of loading is the actual task.

2. Discussion

The principal attention in the equation (2) at random loading should be given to influencing $\sigma(t)$. The influencing of vectors $R(t)$ and $C(t)$ on upbuilding of damages depends on contingency of loading a little.

Definition of the function $F[\sigma(t)]$ in the equation (2) there is very difficult task. So, the influencing has not only amplitude σ_i, but also definite amount of the previous amplitudes σ_{i-1}, σ_{i-2}, σ_{i-k}. In some cases $k=10^2$.. 10^3 cycles [11, 12].

On our view, the solution of the task for the registration of complication of the process should have such stages.

2.1. Representation of stochastic process

The representation is the maiden and important stage, on which one the representation of random loads with reduction them to equivalent at damage objective or blocked, is reduced. At the present stage while that there is no generally accepted technique of the solution of this problem.

Existing methods of representation (extremes, scopes, lets, complete cycles, "rain-flow" etc) give different distributions of loadings, so and of λ_i.

A reason of it is the poor registration of histories of loading and the complexities of the process [1, 2, 5-12]. The count at simultaneous histories of loading and the complexities of the process by conventional methods of representation are impossible through their orientation to distribution of values of amplitudes without definition of their sequence (method of complete cycles, whether "rain-flow") disregarding complexities of process (method of scopes, method of extremes, method of lets).

Actual requirement of mining of such method of representation therefore has ripened, which one would give distribution of amplitudes in time with the simultaneous count of actual complexity of the frame of process. According to our view, such method can be an offered below method of installment allocation of average values of amplitudes called by us by a method of the putted in cycles [13].

The essence of a method consists in following. The first stage of representation is, as well as for other methods, definition of extremes of process $\sigma_{extr.i}$. Then for any of adjacent half circles the amplitude σ_{ai}^{1} and average value σ_{mi}^{1} is determined. It enables to determine sequence of amplitudes on maiden most to high frequency of process.

At the second stage the process is esteemed, where by points act computed before average value σ_{mi}^{1}.

For this process the extreme values are determined, and other points of process from further consideration disclaimed.

There are again determined, as well as for the maiden stage, σ_{ai}^{2} and σ_{mi}^{2}. Thus, we receive distribution of amplitudes and their sequence on second, more low frequency.

Such procedure repeats by then, while at any stage:

At first, the difference between maximum and minimum value of process does not become smaller for any certainly defined value $[\Delta\sigma]$, for example, $[\Delta\sigma]$ =0,3 σ_{-1}.

Or, secondly, 2 extreme points will not stay.

Then after representation of process the reducing of stresses with different circle ratio *R* to symmetric or pulsate circles recommends for reliability calculations. Such reducing to a marked degree decreased the volume of necessary information for next calculation. It is especially valuable for random loading processes. In such case we have been decreasing quantity of parameters for determination of loading circles, namely two-degree massive [$\sigma_{max\ i}$, R_i] is reduced to one-degree equivalent massive [$\sigma_{eq\ i}$] with *R*=const (*R* =-1 or *R*=0). It gives opportunity to assess the law of random stresses distributing and then to account randomize of loading under fatigue reliability calculations, for examples, using *Veybull's* distribution [8, 10, 12]. The reducing of amplitudes is circumscribed in job [14].

The following stage is calculation of upbuilding of damages from the equivalent block of loading.

2.2. Model of upbuilding of fatigue damage

The general damage at all stages of implementation is instituted from the equation

$$Z_t = \sum_{j=1}^{s} K_{j1} \sum_{i=1}^{p} K_{j2} \frac{n_{ij}}{N_{ij}} = \sum_{j=1}^{s} K_{j1} \sum_{i=1}^{p} K_{j2} \frac{\overline{\omega_j}}{2\pi N_0}\left(\frac{\sigma_{ij}}{\sigma_{-1}}\right)^m \qquad (5)$$

under condition of $\sigma_{ij} > \sigma_{-1\ kin}$;

S – amount of levels of representation;

N_0 – the number of cycles to point of low break of fatigue curve;

σ_{-1} – fatigue limit for symmetric circle;

m – inclination characteristic of a *Veller's* curve;

K_j – influence coefficient of complication of the process.

If K_j=1, the given equation will be to the equivalent equation (4) and *Miner's* linear upbuilding of damages. The essence K_j is a simplification of the process simultaneously with selection of its features. Besides, we tender to section K_j into two parts:

$$K_j = K_{j1} \cdot K_{j2}, \qquad (6)$$

where K_{j1} – influence coefficient of efforts of the previous level on given;

K_{j2} – influence coefficient of irregularity of efforts inside a level. K_{11}=1.

The definition K_{j1} can be conducted by means of analysis of two-frequency processes of loading, where there are many observational data. For a definite stuff $K_{j1}=F\left(\frac{\overline{\omega_j}}{\overline{\overline{\omega_{j-1}}}}, \frac{\overline{\sigma_j}}{\overline{\overline{\sigma_{j-1}}}}\right)$.

We tender for definition K_{j2} the equation $K_{j2}=F\left(\overline{\sigma_j}, D\,\sigma_j\right)$. His influencing first of all depends on a value of a deviation of the process $\frac{D_\sigma}{\overline{\overline{\sigma}}}$.

3. Conclusions

The calculation of upbuilding of fatigue damages is made with allowance for complications of the process of an offloading. It became possible due to a designed method of representation of stochastic process, its reduction to a symmetrical equivalent offloading, and also hypothesis about possibility of the separate registration of complication of pattern and succession of amplitudes at separate levels. Doubtlessly, the proposed equation (5) will be exact only at a precise estimation of K_j. Therefore definition of K_j is the future task for studies of combined processes of an offloading.

4. Bibliography

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