APLIKÁCIA POČÍTAČOVEJ ANALÝZY KRITÉRII ŽIVOTNOSTI PRE ŠPECIÁLNE DOPRAVNÉ PRVKY

APPLIED COMPUTER ANALYSIS THE SERVICE LIFE CRITERIA TO SPECIAL TRANSPORT ELEMENTS

Miroslav KOPECKÝ, Ján VAVRO[1]

Abstrakt

Problém únavovej pevnosti a životnosti, ako veľmi dôležitý jav v pevnostnej spoľahlivosti je spojený viac alebo menej s určitými hodnotami neistoty. Metódy, ktoré sú obsahom príspevku sú cesty dosiahnuť riešenie prostriedkami charakteristickej krivky únavovej pevnosti a redukovanej únavovej krivky s maximálnym využitím počítačovej technológie.

Kľúčové slová: Dynamické porušenie, únava, nelineárny dynamický systém, numerická metóda.

Abstract

The problem of fatigue strength and service-life, as the most important phenomena of strength reliability under those conditions is connected more or less with a certain degree of uncertainty. The methods described in this paper are the ways to reach the solution goals by means of a characteristic curve of fatigue strength and reduced fatigue curve with the maximum use of computer technology.

Keywords: Dynamic failure, fatigue, non linear dynamic systems, numerical method.

INTRODUCTION

In some transportation machinery and equipment, or their elements, the problem of strength reliability is conditioned by a fatigue process and by knowledge of a fatigue curve. A considerable part of dynamically loaded components in mechanical engineering and in transport is loaded with time-variable strength. In the case of the means of transport, competitiveness leads to weight reduction savings and extreme operational situations cause high overloading. A demand to guarantee strength reliability is more important predominantly in case when a failure-free operation of a constructional element can influence the safety of human lives or when an eventual failure can bring about considerable economic losses. Random operational loading creates a stochastic process of excitation forces. A successful reproduction of the response of this random loading depends on the technical facilities

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THEORY

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A course of the damage intensity for different loading levels can be a criterion for elimination of insignificant loading levels and for a proper choice of loading levels. Determining the total failure intensity we can get a basic orientation concerning loading and possible failures in particular elements. We determined the probability for a given course of the fatigue curve. It is the probability of a failure occurrence for a deviation of a group of parts.

The basic scheme of a development diagram can be seen in Fig.1. It is based on an assumed dependence of a failure on he intensity of damage.

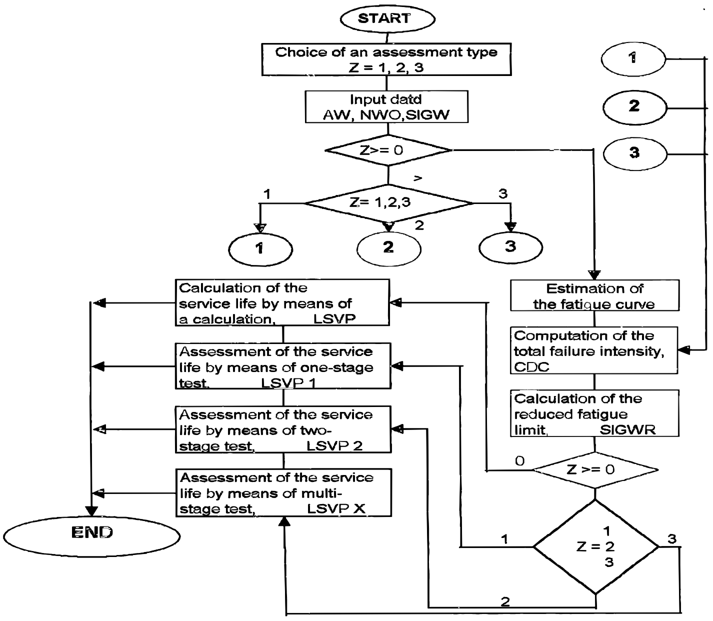

Fig.1 A basic scheme of the development diagram

An analysis of stochastic loading for transport machines and equipment by means of statistic characteristics.

To work out a method of reliability assessment to transport elements and equipment by means of a characteristic curve of strength reliability with the maximum use of computer technology.

To define an equality amplitude and a frequency of harmonic excitation to a spectrum of random loading by means of functions statistic moments of power spectral density, as shown in Fig. 2.

An identification of dynamic properties in an operational random excitation and an analysis of a signal with the help of statistical characteristics of stochastic excitation.

For a random stationary and Gaussian distribution time series several parameters describing the time evolution of the quantity can be expressed by the function of the statistical moments of the power spectral density in relation to the zero frequency axis is defined as follows

$$m_n = \int_{-\infty}^{\infty} f^n . S(f)\, df \qquad (1)$$

The mean number of crossings in time unit N_k through k-level is

$$N_k = \left((m_2 / m_0)\,.\exp(-k / 2m_0) \right)^{1/2} \qquad (2)$$

An equivalent frequency of the phenomenon can be obtained taking k=0 :

$$f = \left((m_2 / m_0) \right)^{1/2} \qquad (3)$$

In this case one should consider the equivalent amplitude sinusoid of a random loading equal to the mean square value of the random evolution with zero mean value

$$\sigma^2_{amp} = 1 / T \int_0^T (\sigma)^2 (t)\, dt \qquad (4)$$

and

$$\sigma_{red} = \sigma_{amp} + \sigma_s \qquad (5)$$

where

$$\sigma_s = 1 / n \sum_{i=1}^{n} \sigma_i \qquad (6)$$

An expression of a dependence between a stochastic loading of a given constructional element and its reliability by means of an extension with a new magnitude which will express a numerical guarantee in a form of probability.

The length of service life of one component or unit is conditioned by a series of factors, as e.g. inner microscopic defects of material, manufacture irregularities, ways of use, impact of the environment, etc. A range and occurrence of such factors is incidental and, therefore, individual service lives generally differ and it is impossible to determine exactly a service life for a given component. If we use N_f as a symbol for the service life, then individual service lives which are the results of the test will have the values of N_1 , N_2 ,... N_n . The dependence between an operating process of a constructional component and its service life, N_f , must be expended a variable component, $R(N_f)$, which offers a numerical guarantee in a probability form.

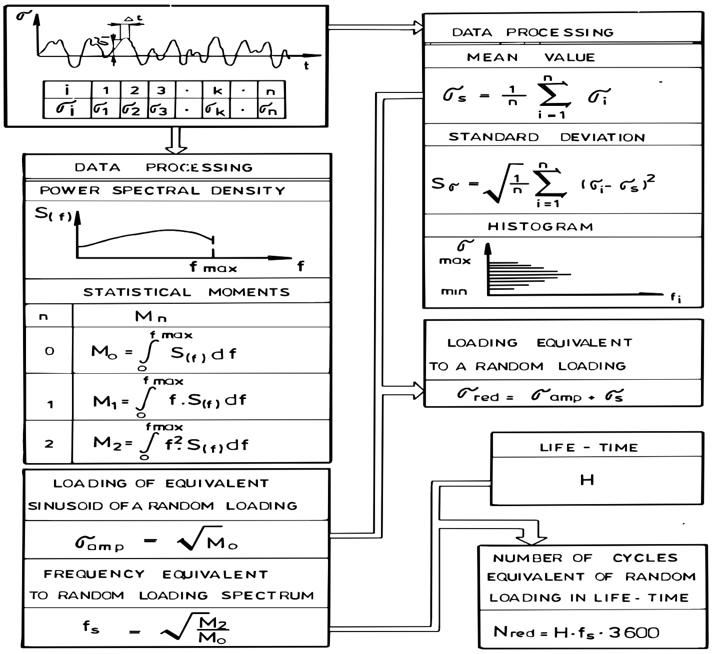

Fig.2 Scheme of method

A parameters distribution may be expressed as

$$R\,(N_f) = \exp\,(-(N_f - N_{min}) / (N_{sig} - N_{min})\,)^{k} \qquad (7)$$

where N_{min} is a minimum of the longevity,
N_{sig} is a modal value of the longevity,
k is a parameter of distribution.

With parameters of distribution, we may define the result by the statistical curve of longevity, which in a form of probability characterized the longevity from eq.(7)

$$\ln(-\ln R(N_f\,)) = k\,[\,\ln(N_f\, - a) - \ln b + \ln\ln e\,] \qquad (8)$$

which is the equation of characteristic curve of the strength reliability found for a tested constructional component.

A SEQUENCE OF COMPUTATION

In order to determine the distribution parameters in the equation (7) the values are to be used:

Let n constructional components or units be tested, and the results of service life tests be N_1 , N_2 ,..... N_m .

We calculate the mean value of service life N_S.

We calculate a standard deviation of service life S_N .

We determine a degree of slope by means of the relation

$$b^{1/2} = n^2 / [(n-1)(n-2)].\,[N_S^3\; -(3N_S^2\,).N_S + 2N_S^3\;\,] / S_N^3$$

For the parameters a, b, holds by means of the moments of the function from the equation (8):

$b^{1/2} = B(k)$,	from which $1/k$ is determined,
$S_N\,.\,D(k) = b^{1/2}$,	from which b is determined,
$N_S\; -[S_N\,.\,D(k)].\,C(k) = a$,	from which a is determined.

The functions B(k), C(k), D(k) are determined numerically from a general k-th moment for the variable $(N\text{-}a) / b^{1/2}$, [1]

$$m_n = \Gamma\,(1 + n/k)$$

APPLICATIONS

The applications of this method in this paper are restricted to load-carrying parts of some transport elements. For illustration are shown the results of laboratory tests for a part of construction (Fig.3).

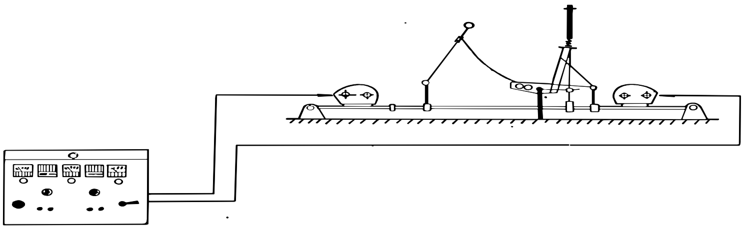

Fig.3 The scheme of the special-purpose testing for frame construction

The test of simulation regime for frame construction has been made upon the special purpose machine, as shown the scheme in Fig. 3.

Frame construction **Table 1**

Reliability Number of cycles to failure	Alternative	
	A	B
	x 10^6	
N_1	3,65125	3,9
N_2	1,8915	4,1536
N_3	1,1545	2,236
N_4	2,275	5,7135
N_5	1,412	

For the frame constructions is required value of service life $N_f = 2{,}55803.10^6$ cycles. Alternative B in Tab. 1 is seen to be the most reliable. Then the probability that the frame construction will not be damaged before reaching the service life N_f in % is $R(N_f) = 80{,}91$, as shown in Fig.4.

The statistical curve of longevity for B alternative frame construction from eq.(7) is shown in Fig. 4. Eq.(8) is answer to the curves of probability density from Fig.5 in our case for frame constructions.

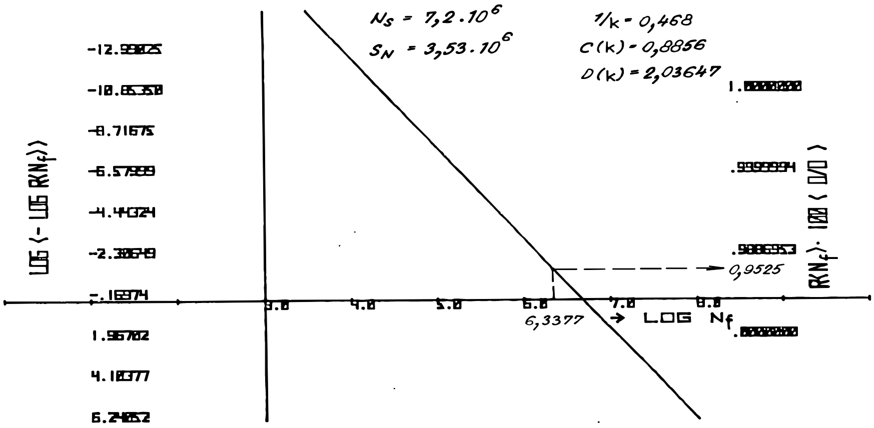

Fig.4 Statistical curve of the longevity for B-alternative of frame construction

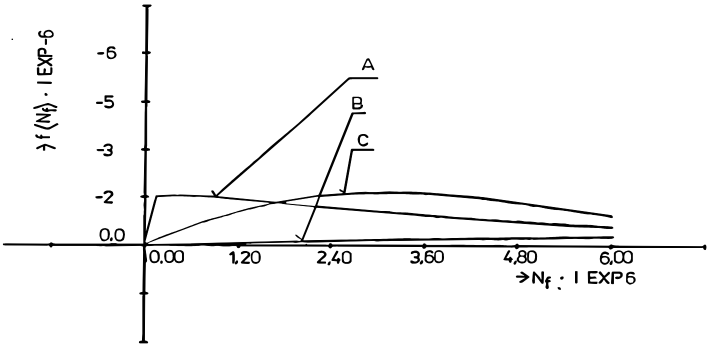

Fig.5 Curves of probability density distribution of damage for frame construction

Tests are frequently completed on construction subassemblies, as they are shown in Fig.6.

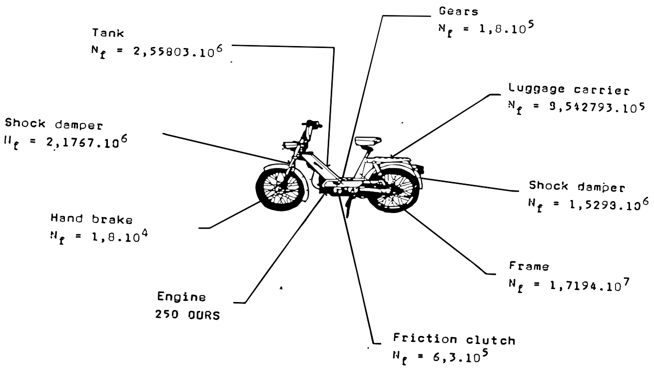

Fig.6 View of the load-carrying parts of motor-cycles of small capacity

CONCLUDING REMARKS

Tests of the longevity of load-carrying parts of motor-cycles at laboratory make variable extreme condition of random excitation in operating state possible.

Mechanical systems of transportation machinery and equipment differ considerably from the point of view of a possibility of simulation procedures. When assessing properties of a construction model in the stage of its design and prototype test, or innovation and experiment verification, the question of economy is also important. The presented system of assessment of strength reliability has been applied in many concrete situations and verified within cooperation with manufacturing enterprises. It enables a simulation of an operating process of loading in laboratory conditions and also a full use of computers.

The results gathered so far have shown that the system of assessment of the strength reliability in mechanical sets of transportation machinery and equipment is good and offers a possibility of generalization.

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