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A VIEW ON THE WAYS OF AUTOMATIC IDENTIFICATION THE FATIGUE PROBLEM IN PARTS OF TOWER CRANE CONSTRUCTION

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Abstract: *Contemporary intensive development of technology puts ever-increasing demands on the reliability of products. The increase in the reliability level is emphasised also in transport machines and equipment. This all requires a further improvement of the method of designing and strength checking of a construction. The methods described in this paper are the ways to reach the solution goals with the maximum use of computer technology. A practical example of loading system analysis in presented, which demonstrates use the special instrument to generally measurement of distribution random, loading parameter.*

The application of this methodology shortens knowledge of the time to failure of mobile machine components and contributes to the safety and economy of mechanical systems. The results of its application would be presented to mobile facility elements.

Keywords: f*atigue, strength reliability, random loading, probability density, statistical moment*

1. Introduction

A characteristic feature of new trends in development of new aggregates of mobile machinery is a continuous increase in manufacturing and operating costs.

Simultaneously, transmitted outputs are also higher and a sufficient reliability has to be maintained. There is a tendency towards a higher use of materials, i.e. a relatively higher stress on particular parts of the aggregate. At the same time, a real safety of operation against the maximum admissible stress decreases.

In some transportation machinery and equipment, or their elements, as e.g.. transmission groups, gear transmissions, also in tower cranes and others, the problem of strength reliability is, due to the present day, regulations conditioned by a fatigue process and by knowledge of a vibration conditions.

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.

2. The computing system

If we know the probability density of occurrence of decisive loading quantity, esq. a moment on the inlet of a transportation machine and we also know the fatigue curve for a given constructional element of unit, we can determine the total strength reliability from the point of view of fatigue strength.

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Let us suppose that the probability density of a moment parameter occurrence on the inlet is *f(M)*. The following relation can be generally written for stress:

$$\boldsymbol{\sigma_{(M)}} = \boldsymbol{\varphi(M)} \ \mathbf{x} \ \ \mathbf{M} \tag{1}$$

where φ(M) can be generally also a stochastic function.

In this way the probability density of stress $\varphi(\sigma)$ can be achieved. As we also know the fatigue curve for a particular component we can, with the help of a hypothesis of failure, determine the total service of a part *Lc* corresponding to a domain of loadings *f*(M) and functions φ *(M)*.

With regard to a probability character of the fatigue curve, where its exponents *p, q,* have a character of a random quantity, a total service life is also a random quantity characterized by a probability density. The probability that a failure might occur before a required service life *Lp* ends is given by a hatched surface in Fig. 1.

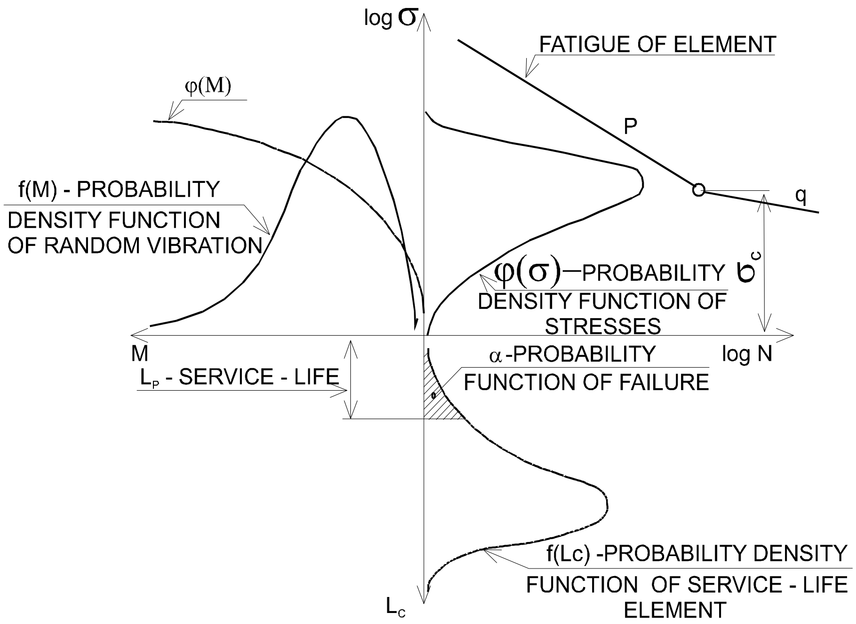

Fig. 1. In dependence on the fatigue curve

In spite of the fact that a shape of the fatigue curve is idealized to a great extent, it was chosen because of its simplicity and possible application of a majority of calculation procedures.

According to the theory of fatigue failure we determine a new fatigue curve, the reduced course of which would correspond to the result of the experimental test, so that a failure would occur at a failure intensity *CDC = 1,* as shown in Fig. 2.

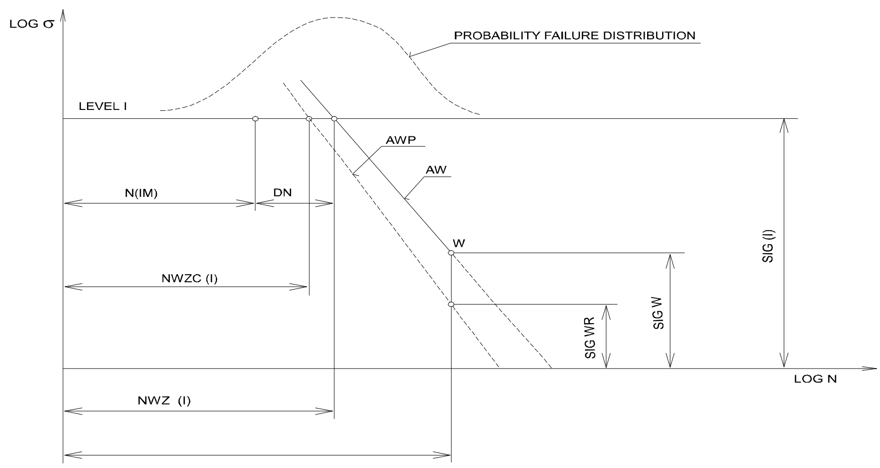

Fig. 2: An estimation of a fatigue curve and its reduction

The parameters of the fatigue curve reduced in this way are: *NWO, AWP, SIGWR* . We determined the probability for a given course of the fatigue curve. It is the probability of a failure occurrence for a deviation *SR* of a group of parts according to the relation:

2.1 On a simulated programme of an experimental test

If an assessment of some properties of constructional units on the basic of experimental destructive test is to be reliable, it requires mathematical statistics to be used. It is impossible to carry out 100% assessment of investigated properties. It would lead to a total destruction of an investigated series of components or units and it would also prevent them from being used in practice. Also another extreme, i. e. verification of service life with one specimen only is useless, especially when we realize e. q. a distribution of service life.

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* as a symbol for the service life, then individual service lives which are the results of the test will have the values of $N_1, N_2,... N_n$.

Weibull's model or regressive model can be chosen as a starting point for further solution. When solving the problems of strength reliability of transportation components and units, Weibull's model is more exact than the regressive model. Its use, however, requires more profound experimental information.

For the used Weibull's model, the function in (2) can be sufficiently approximated by the function:

$$\varphi(N) = [(N_i - a)^k] / b$$

where *a, b, k,* are parameters determined from the experimental results.

The dependence between an operating process of a constructional component and its service life N_i must be extended by a variable $R(N)$ **,** which offers a numerical guarantee in a probability form.

Let us consider that it consists of the components y_1 , y_2 , y_i , and it can be n_1 pieces of the component y_1, n_2 pieces **...** , n_j pieces of the component y_j .
The test can show that the component y_1 will be damaged with a probability $F_1(N)$, before reaching the service life N, the component y_2 will be damaged with a probability $F_2(N)$, etc. Then the probability that the whole complex unit will not be damaged before reaching the service life N**,** is given by the relation:

$$\mathbf{R(\mathit{N}) = [1 - F_1(\mathit{N})]^{n_1} \,.\, [1 - F_2(\mathit{N})]^{n_2} \ldots [1 - F_i(\mathit{N})]^{n_j}}$$

The most general form of the probable function of service life is:

$$\mathbf{R(\mathit{N}) = 1 - [\,1 - \exp\{-(\mathit{N}_i - a)^k / b\,\}\,] = \exp\{-[(\mathit{N}_i - a) / b^{1/k}\,]^k\}} \qquad (2)$$

The function in the equation (2) specifies the probability that the service life of the component will be higher than the chosen value N.

The function of the probability density to the function in the equation (2) is:

$$\mathbf{f(\mathit{N}) = k/b^{1/k} .\, [\,(\mathit{N}_i - a) / b^{1/k}\,]^{k-1} .\exp\{-[\,(\mathit{N}_i - a) / b^{1/k}\,]^k\}} \qquad (3)$$

The determination of the distribution parameters in the equation (3) is carried out numerically.
The equation (2) can be written in the form:

$$\mathbf{\ln\,(-\ln R(\mathit{N})) = k\,[\,\ln(\mathit{N}_i - a) - \ln b + \ln\ln e\,]} \qquad (4)$$

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

2.2 A sequence of computation

In order to determine the distribution parameters in the equation (2) the values from Tab. 1 are to be used:

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

$$\mathbf{b^{1/2} = n^2 / \,[\,(n-1)\,(n-2)].\,[\,N_S^3 - (3\,N_S^2).N_S + 2N_S^3\,] / S_N^3} \qquad (5)$$

For the parameters *a, b*, holds by means of the moments of the function from the equation (3) :

$b^{1/2} = B(k)$, 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

$(N_i - a) / b^{1/2}$, [1], $m_n = \Gamma(1 + n/k)$.

VALUES OF FUNCTIONS

1/ k	A (k)	B (k)	C (k)	D (k)	1/ k	A (k)	B (k)	C (k)	D (k)
0,01	0,4481	-1,0813	0,9944	78,5536	0,65	0,1673	1,0279	0,9001	1,5075
0,05	0,4392	-0,8680	0,9735	16,1952	0,70	0,1416	1,1604	0,9086	1,4078
0,10	0,4250	-0,6376	0,9514	8,3119	0,75	0,1163	1,2941	0,9190	1,3201
0,15	0,4082	-0,4357	0,9331	5,6883	0,80	0,0915	1,4295	0,9314	1,2423
0,20	0,3891	-0,2541	0,9181	4,3658	0,85	0,0674	0,5674	0,9456	1,1725
0,25	0,3681	-0,0872	0,9064	3,5645	0,90	0,0441	1,7080	0,9618	1,1095
0,30	0,3455	0,0687	0,8975	3,0243	0,95	0,0216	1,8521	0,9799	1,0522
0,35	0,3217	0,2167	0,8912	2,6337	1,00	0,00	2,00	0,00	1,00
0,40	0,2669	0,3586	0,8873	2,3370	1,50	-0,1585	3,8196	1,3317	0,6454
0,45	0,2715	0,4963	0,8857	2,1040	2,00	-0,2236	6,6188	2,00	0,4472
0,50	0,2456	0,6311	0,8862	1,9131	3,00	-0,1912	10,5849	6,00	0,2294
0,55	0,2195	0,7640	0,8889	1,7554	4,00	-0,1154	60,0917	23,9880	0,1204
0,60	0,1933	0,8960	0,8935	1,6221	5,00	-0,0626	190,113	119,113	0,0068

Table 1: Values of functions

3. Tower cranes

The principle measurement of random signals is making by the special measuring instrument. The substance of construction makes up the mechanical gauge connected with the indicator. The instrument works together with photocell, which take effect to star of the recording equipment. The instrument can be installed on the critical points of the tower cranes, as shown in Fig. 1. The detail views on the specific measuring instrument shown in Fig. 2., current work [1].

Long-time tests can be run independently from climatic conditions. Very valuable results of experimental tests of the construction make for recording of signals of random loads under long-time operating state to render possible the special measuring instrument.

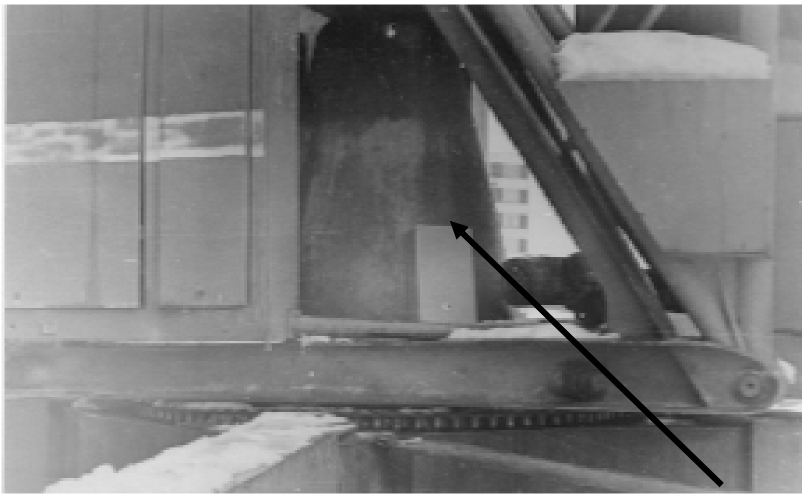

Fig. 1. The general view on the specific measuring instrument

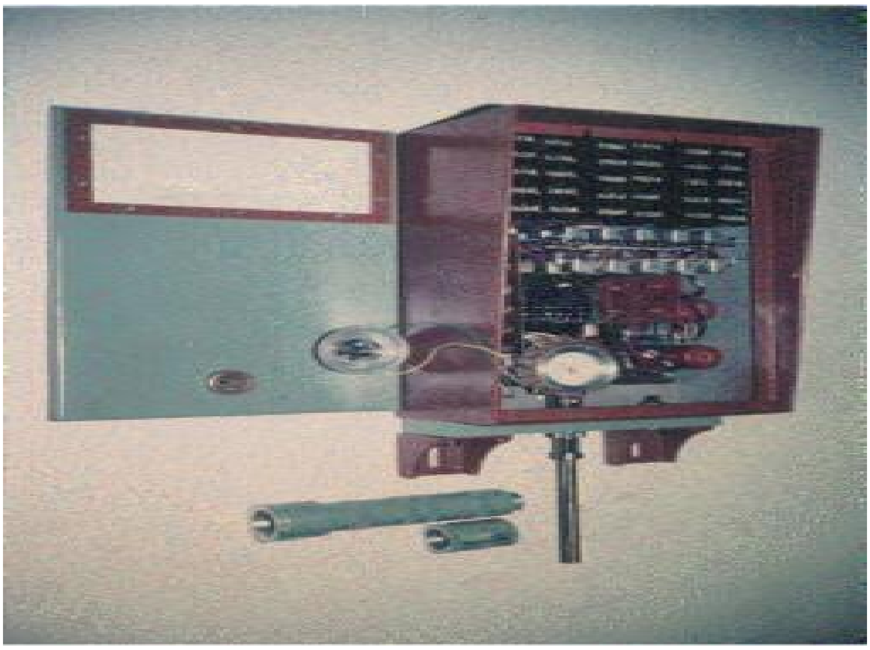

Fig. 2. The detail view of the specific measuring instrument

3. Analysis and Solutions

The signal of response may be analysed by statistical characteristic of stochastic function. The output data expressing one of the statistical characteristics of loading in a graphical way.

The dependence between random loads and life, N_f , of components must be completed by a variable, $R(N_f)$, which expresses digital guarantee in the probability form.
Parameter distribution may be expressed from equation (2) as

$$\mathbf{R(N_f) = exp. - (N_f - N_{min} / N_{sig} - N_{min})^k} \tag{6}$$

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

The determination of the parameters of this distribution are achieved by the moments of function numerically, current work [2].
The basic scheme of a development diagram can be seen in Fig. 3. It is based on an assumed dependence of a failure on he intensity of damage.

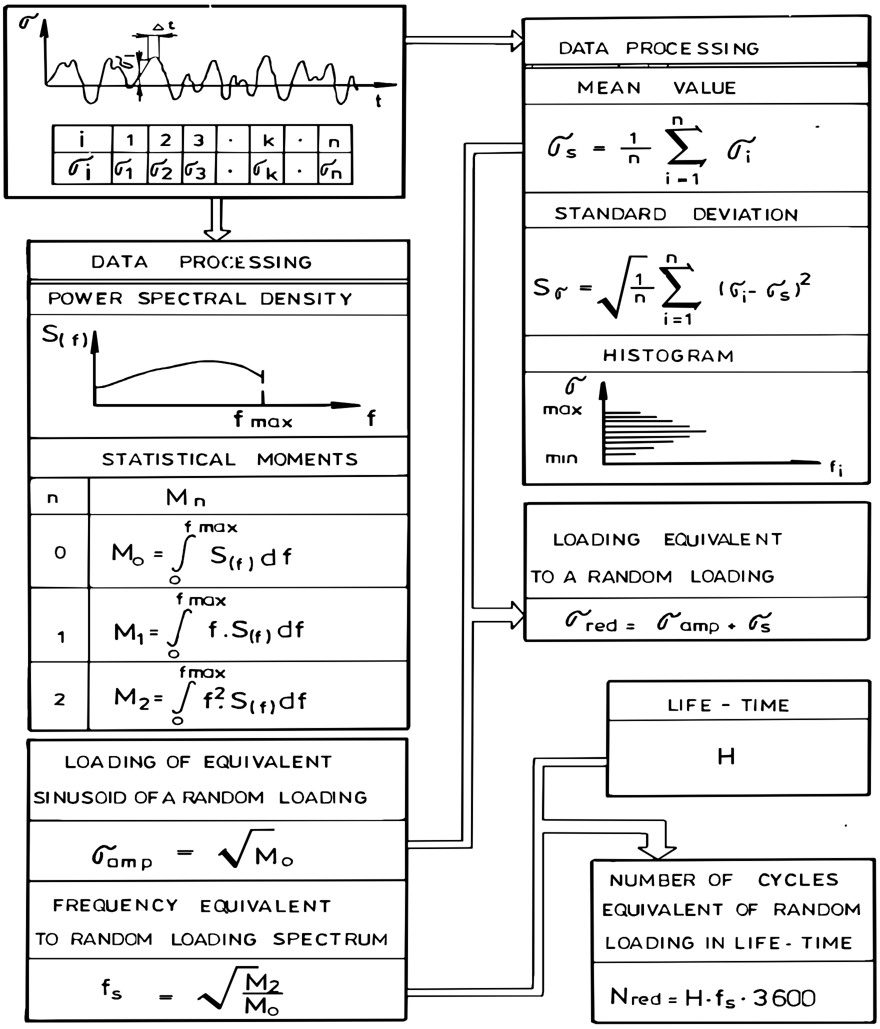

Fig. 3. A basic scheme of the development diagram

Results of the measurement of tower crane have expressed the reduced fatigue curve, as shown in Fig. 4.

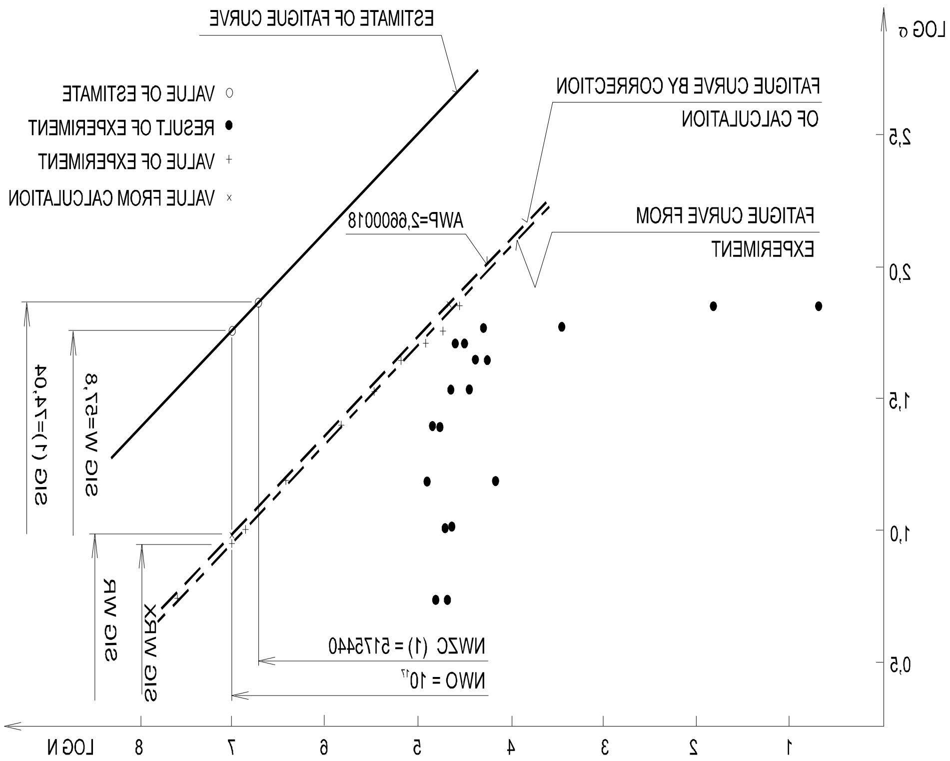

Fig. 4. Fatigue curve reduced for tower crane

The values of functions *B(k)*, *C(k)* and *D(k)* , are introduced for the practical application in Eq.(6) for variables *1 / k* .
With parameters of distribution, we may define the result by the statistical curve of longevity, which in a form of probability characterised the longevity form Eq.(6):

$$\mathbf{ln\ (-ln\ R\ (\ N_f\ ))= k\ [\ ln\ (\ N_f - a\ ) - ln\ b + lnln\ e\ ]} \qquad (7)$$

4. Conclusions

The applications of these methods, which this paper will be showed, have been made upon the special-purpose machine in a laboratory and in industrial conditions directly.

This system control has been conceived independently of climatic conditions.

Conditions can be exactly reproduced to compare and to evaluate new designs or redesigns and good approximation to system control was expected and achieved.

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References

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