THE ANNALS OF “DUNAREA DE JOS” UNIVERSITY OF GALATI
FASCICLE XIV MECHANICAL ENGINEERING, ISSN 1224-5615
2004

ANALYSIS OF THE DYNAMIC RESPONSE TO STOCHASTIC ACTIONS ON THE TILTING SYSTEM OF THE LOADER BUCKET WITH HYDRAULIC CORRELATOR

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ABSTRACT

The resistance encountered by the active organ – the bucket – of the loader when digging into the material pile is part of the category of external influences applied to the equipment. Generally this force is not constant due to the non-homogeneity of the material or to the dislevelments of the railway.

1. Introduction

Because of the non-uniformity of the ground, material size, various moistures etc. during the digging process of the bucket in the material, the resistance force has a random character.
In the calculations for the definition of the constructive elements of the working equipment and obviously of the resistance structure of the basic equipment, an average value of this resistance force may be used.
Because in most cases the stress of the bucket is random, we shall further on study the dynamics of the tilting system from this point of view.
Also, within the following, it shall be assumed that the elastic structure of the working equipment is a linear system, the dynamics of the tilting system presupposing the analysis of two essential aspects: the study of the equipment elements as well as the provision of the traction condition for the equipment.

2. Theoretical assumptions

On the grounds of d’Alembert principle, the dynamic equilibrium equation for all the moments acting upon the assembly bucket – arm – tilting system, leads to the following motion equation (fig.1)

$$M_i + M_a + M_e - l_2 \cdot f(t) = 0$$

Respectively

$$J \cdot \ddot{\theta}(t) + c \cdot l_1^2 \cdot \dot{\theta}(t) + k \cdot l_1^2 \cdot \theta(t) - l_2 \cdot f(t) = 0$$

Where: $M_i = J \cdot \ddot{\theta}(t)$ is the inertial couple proportional to the motion acceleration $\ddot{\theta}(t)$, and J is the inertial moment of the bucket against the articulation point (O) with the arm.

$M_a = c \cdot l_1^2 \cdot \dot{\theta}(t)$ – resistance couple due to amortization, which is proportional to the motion velocity $\dot{\theta}(t)$, c being the viscous amortization coefficient;

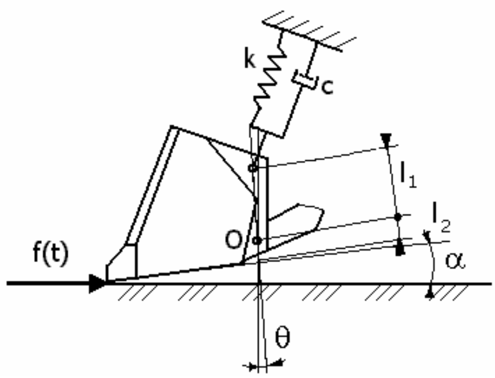

Figure 1

$M_e = k \cdot l_1^2 \cdot \theta(t)$– elastic couple proportional to the displacement θ(t), k being the rigidity of the tilting system;
f(t) – external perturbing force applied directly on the bucket cutting edge:

$$\omega_0^2 \frac{k \cdot l_1^2}{J};\ \xi = \frac{c \cdot l_1^2}{2J \cdot \omega_0}$$

With the known notations:
the motion equation is brought to the standard form:

$$\ddot{\theta}(t) + 2 \cdot \xi \cdot \omega_0 \cdot \dot{\theta}(t) + \omega_0^2 \cdot \theta(t) = \frac{l_2 \cdot f(t)}{\xi}$$

In which:
ω_0 is the own pulsation of the bucket vibrations without considering the amortization,

$$\omega_0 = 2\pi \cdot n = \frac{2\pi}{T};$$

ξ - fraction of the critical amortization, defined as the ratio between the effective amortization c and the critical amortization c_{cr}, $\xi = \frac{c}{c_{cr}}$. The critical amortization is the amortization for which the bucket goes back into equilibrium position after an arbitrary excitation without any oscillation,

$$c_{cr} = 2m \cdot \omega_0 = \frac{2J}{l_1^2}\omega.$$

Equation has a solution in the form of:

$$\theta(t) = \theta_0 + \theta_1(t)$$

where :
θ_0 is the solution corresponding to the constant component f_0 of material resistance.
θ_1 (t) – the solution corresponding to the random component $f_1(t)$ material resistance

($\bar{f} = \bar{f}_0 + \bar{f}_1(t)$)

By using relation, the motion equation around the average value $\theta_0 = \frac{l_2 \cdot f_0}{\omega_0^2 \cdot J}$ is

$$\ddot{\theta}_1(t) + 2 \cdot \xi \cdot \omega_0 \cdot \dot{\theta}_1(t) + \omega_0^2 \cdot \theta_1(t) = \frac{l_2 \cdot f_1(t)}{J}$$

For 0 < ξ < 1, the general solution of the equation is of the form:

$$\theta_1(t) = \theta^*(t) + \theta^{**}(t)$$

Where:

$$\theta^*(t) = e^{-\xi\omega_0 t}(A\cos\omega_0\sqrt{1-\xi^2}t + B\sin\omega_0\sqrt{1-\xi^2}t)$$

In which A and B are constants that depend on the initial conditions

$$\theta^{**}(t) = -\frac{l_2}{J \cdot \omega_0 \cdot \sqrt{1-\xi^2}} \int_0^{\infty} f_1(t-t') \cdot e^{-\xi\omega_0 t'} \cdot \sin\omega_0 t\sqrt{1-\xi^2}\, t' \cdot dt'$$

The solution given by relation is asymptotically stable, in square average and the variable change t' =t-τ has been done because the random process is considered stationary.
In order to determine the mathematical expectancy $m_{\theta^{**}}(t)$, the auto correlation function $k_{\theta^{**}}(t)$ and the spectral density $S_{\theta^{**}}(t)$ for the response of the system, we need the mathematical expectancy and the auto correlation function of the input signal, as well as the frequency features of the system.
Because $f_1(t)$ is a stationary centered random function, $m_{\theta_1(t)}$= 0.
The auto correlation function pf the stationary processes of excitation and response is given by the relation:

$$k_{\theta^{**}}(\tau) = \int_{-\infty}^{+\infty} k_{f_1}(\tau - t_2' + t_1') h(t_1') h(t_2') dt_1' dt_2'$$

Where the pondering function is given by the relation:

$$h(t) = \begin{cases} 0, pentru\ t \in (-\infty, 0) \\ -\frac{e^{-\xi\omega_0 t} \sin\omega_0\sqrt{1-\xi^2} \cdot t}{\omega_0\sqrt{1-\xi^2}}, t \in (0,1) \end{cases}$$

The spectral density of the power of the response function of the excitation response power and the transfer function is given by the relation:

$$S_{\theta^{**}}(\omega) = |H(i\omega)|^2 \cdot S_{f_1}(\omega)$$

Where:

$$H(i\omega) = \frac{1}{\omega_0^2 - \omega^2 - 2i\xi\omega_0}$$

$$S_{f_1}(\omega)=\frac{1}{2\pi}\int_{-\infty}^{+\infty} k_{f_1}(\tau-t_2'+t_1')\cdot e^{-i\omega(\tau-t_2'+t_1')}d\tau$$

Further on we shall determine the square averages of the system response function of the square average $\sigma_{f_1}^2$ of the random excitation $f_1(t)$. The auto correlation function of the excitation is of the same type with that of the terrain the equipment is moving upon.

If the approximation relation of the excitation auto correlation function $f_1(t)$ is known, which is given by the relation:

$$k_{f_1}(\tau)=\sigma_{f_1}^2\cdot e^{-\alpha|\tau|}\cdot \cos\beta\tau$$

The square averages are calculated with the relations:

$$\sigma_{\theta_1}^2=\frac{2\alpha\cdot\sigma_{f_1}^2}{\pi}\int_0^v\frac{v^4\cdot dv}{(\alpha^2+v^2)[(\omega_0^2-v^2)+4\xi^2\omega_0^2v^2]}$$

$$\sigma_{\dot\theta_1}^2=\frac{2\alpha\cdot\sigma_{f_1}^2}{\pi}\int_0^v\frac{v^6\cdot dv}{(\alpha^2+v^2)[(\omega_0^2-v^2)+4\xi^2\omega_0^2v^2]}$$

$$\sigma_{\ddot\theta_1}^2=\frac{2\alpha\cdot\sigma_{f_1}^2}{\pi}\int_0^v\frac{v^8\cdot dv}{(\alpha^2+v^2)[(\omega_0^2-v^2)+4\xi^2\omega_0^2v^2]}$$

Constants α and β depend on the equipment motion velocity, v and of parameters a and b la which values are obtained function of terrain dislevelments:

$\alpha = a\cdot v$; $\beta = b\cdot v$.

3. Conclusions

Achieving a numerical study of the behaviour of the functions given in presenting relation,.

constructive solutions may be obtained so that the motions, velocities and accelerations exceeding the limit levels considered as acceptable, be minimum

Thus it is extremely important that function of the angular motion obtained after the random excitation of the active organ of the equipment to determine the accelerations, the random forces and couples respectively.Consequently, the acceleration peaks correspond to the random shocks to which the bucket is subject to, a study of their taking over by the equipment, namely by the basic machine through the connection points being necessary in order to analyze the effect on the entire machine.

4. References:

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