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COMPUTER SYMULATION OF THE EARTHMOVING MACHINE TO PASS OVER ROUGHNESS ROAD

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ABSTRACT

In this paper the author proposed a model for computer simulation of earthmoving machine passing over the roughness roads. It's important to know the dynamic overloads into the bucket rotation system which is frecvently out of action. The results of this study putting into prominance the behaviour of earthmoving machine at the apparition of the resonance phenomenon.

1. Introduction

Investigations of vehicle dynamics nowadays mostly were done by computer simulation. When driving off the road, it is necessary to take into account the important influences of the soil surface on the dynamic behavior of the earthmoving machine. On the whole, due to the vehicles oscillations, caused by the roughness of terrain, frecvently appears defections at the bucket rotation system.

It's important to find out what parameters rule the behaviour the most, what ones that make little difference and which ones that are the most difficult to estimate. This determines the type of models that need to be done.

2. Physical model for computer simulation

The real model which was modeled in this study is the MMT 45 frontal loader, maded in PROMEX S.A. factory by Romania.

The objective of this simulation consist of the quantification the dynamic overloads and putting into prominance the factors which influences the behaviour earthmoving machine in the moment of pass over innapropiate terrains.

For computer simulation, the author propose a dynamic model which have three degree of freedom (one vertical translation and two movements consisted by angular oscilation's machine).

A vehicle suspension is required to give a good ride comfort and road handling accompanied by small motion of the vehicle body in a limited working space.

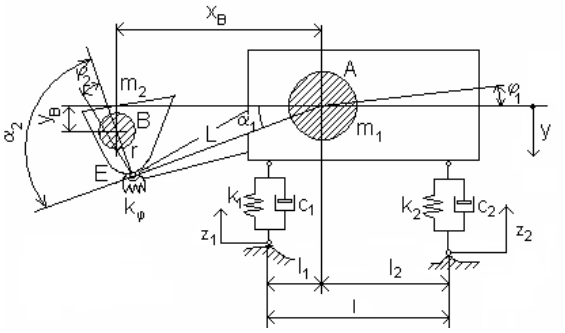

Figure 1. Physcal model for the frontal loader passing over roughness road

The mathematical model of the system presented in figure 1, writed by matriceal form, is

$$M\ddot{q} + C\dot{q} + Kq = Bz + D\dot{z} \qquad (1)$$

where q is the displacement vector for degree of freedom; z denote the excitation vector because of the inappropriate terrain; M denote the matrix of inertia; C is the dissipation matrix; K denote the stiffness matrix; B, D denote the vectors of excitations matrix.

$$\{Q(s)\} = \{G_1(s)\}Z_1(s) + \{G_2(s)\}Z_2(s) \qquad (2)$$

where $\{Q(s)\} = \{Y(s) \quad \Phi_1(s) \quad \Phi_2(s)\}^T$, $\{G_1(s)\}, \{G_2(s)\}$ are the associates vectors of the transfer functions for the external excitations of the system.

The quantification of the dynamic overloads into the drive moving system of the bucket is maded with expresion

$$\psi = 1 + \frac{k_\varphi}{M_0}\varphi_2^{max} \qquad (2)$$

where M_0 denote the moment of forces which action to the bucket joint, k_φ denote the stiffness of the bucket moving drive system.

3. Analysis of the earthmoving machine to pass over the road with roughness by the sinusoidal form

The author was considered that the excitation signal, which come across the earthmoving machine wheel, have the shape representated in Figure 2, with the next expression

$$z_1(t) = A\sin(\omega t)$$
$$z_2(t) = A\sin[\omega(t - \frac{l}{v})] \qquad (3)$$

where A denote the roughness amplitude, l denote the machine ampatament, ω denote the roughness frequency, v is the speed of the earthmoving machine.

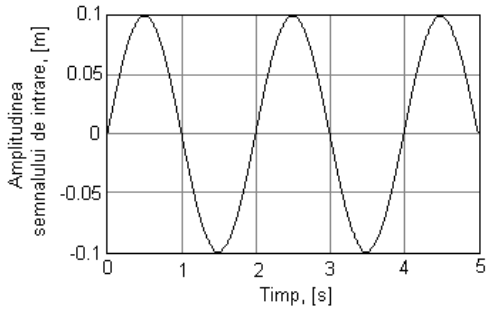

Figure 2. The excitation signals applied to the wheel.

The dynamic overloads simulation into the equipment structure of the frontal loader was maded with MATLAB/Simulink® software.

In Figures 3, 4, 5 are shows the results of simulations, when the earthmoving machine (MMT 45) are over passing an obstacle with *v=1,7 m/s*, amplitude *A=0.1m* and different pulsations.

Based on this model (figure1) the author was analysis the influence of the frequency roughness p_0 about the deplacement $\varphi_2(t)$, and was observed that at the same time of the p_0 growing and equalized the eigen frequency for angular deplacement of frontal loader's bucket, that appear the resonance phenomenon.

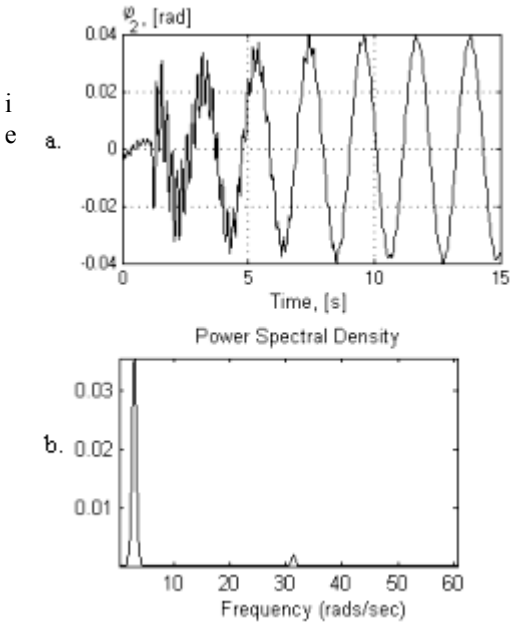

Figure 3. Results of computer simulation for the angular deplacement of the loader's bucket
p_0= 2.97 rad/sec
a. Temporal evolution
b. Frequency spectrum

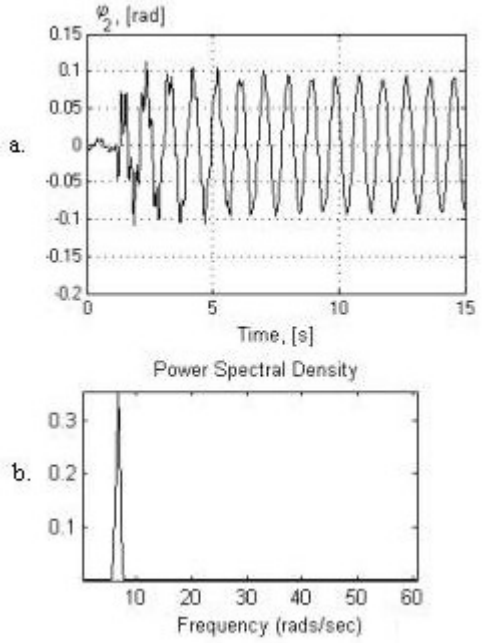

Figure 4. Results of computer simulation for the angular deplacement of the loader's bucket
p_0= 6.64 rad/sec
a. Temporal evolution
b. Frequency spectrum

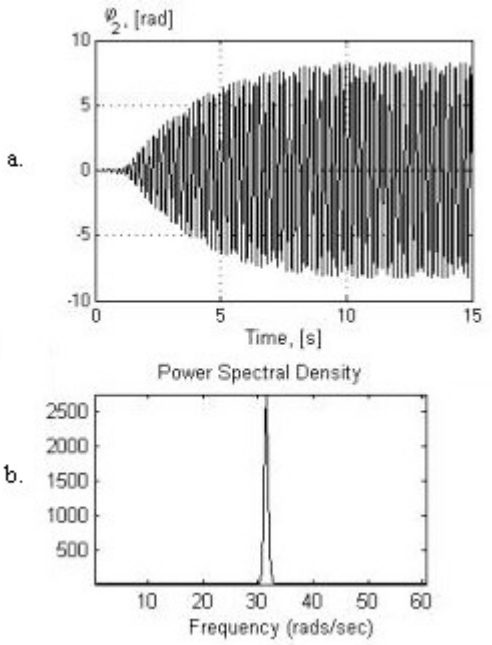

Figure 5. Results of computer simulation for the angular deplacement of the loader's bucket
p_0= 30.9 rad/sec
a. Temporal evolution; b. Frequency spectrum

4. Analysis of the earthmoving machine to pass over the road with the singular roughness

In this case, the author was considered that the excitation signal, which come across the earthmoving machine wheel, have the form representated in Figure 6, with the next expresion

$$z_1(t) = \begin{cases} A\sin(\omega t), & 0 \le t \le T \\ 0, & t > T \end{cases}$$

$$z_2(t) = \begin{cases} A\sin(\omega t), & \frac{l}{v} \le t \le T + \frac{l}{v} \\ 0, & t \in \left(0, \frac{l}{v}\right) \cup \left(T + \frac{l}{v}, \infty\right) \end{cases} \quad (4)$$

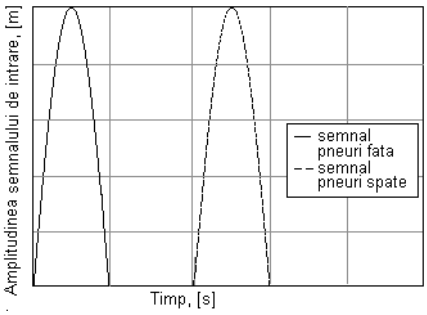

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Figure 6. The excitation signals applied to the wheel.

In Figure 7 are show the results of the computer simulation, when the eartmoving machine (MMT 45) over pass an obstacle with *v=1,7 m/s*, with amplitude *A=0.1m* and p_0= = 30.9 rad/sec.

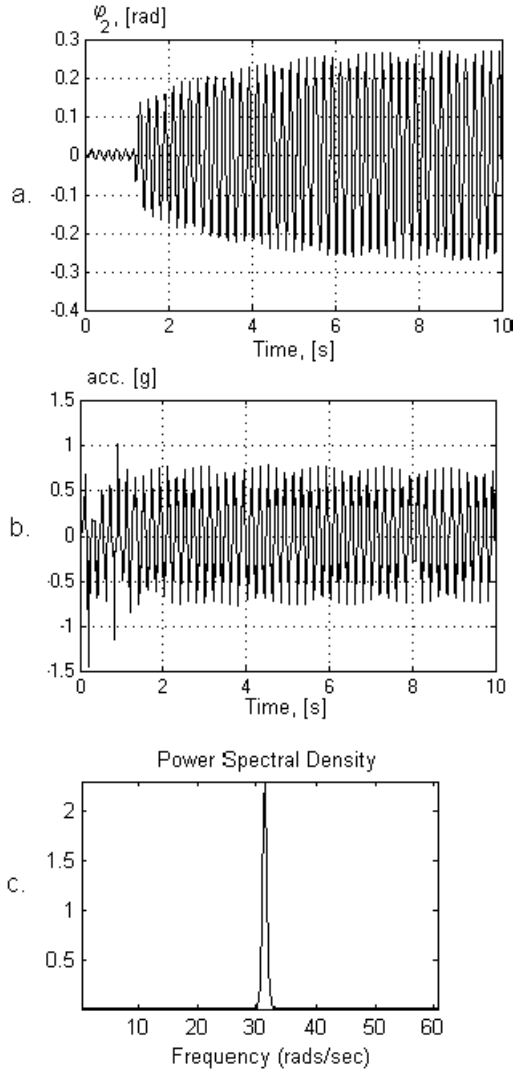

Figure 7. Results of computer simulation
a. Angular deplacement for the bucket $\varphi_2(t)$
b. Temporal evolution of the vertical acceleration
c. Frequency spectrum for $\varphi_2(t)$

5. Conclusions

The disturbing actions on the vehicle suspension system includes road irregularities, braking forces, acceleration forces, inertial forces on a curved track, and payload changes. Among them, road roughness is the most important disturbance, to the either of the rider or the vehicle structure itself. Many roads surface profiles have been measured, and several road models have been discussed in the literature.

Analysing the figure 7, it could be said that, in case of resonance phenomenon apparition, the dynamic overloads growing over the ten value (Ψ > 10).

The consequences of this phenomenon involve to the dynamic overloads apparition, at the working equipment of the earthmoving machine, and leads to the functional parameters modifications.

An important factor which produce the discomfort to the human operator is the acceleration on vertical direction of the base machine, at the over passing the roughness, both of these with the singular distribution, and, especially, of these with the lowest apparition frequency.

References

[1] **Axinti, G., Axinti, A. S.** - *Modelarea comportarii dinamice a utilajelor pe pneuri ce ruleaza pe terenuri denivelate*, A XXVIII-a Conferinta de Mecanica Aplicata, Targoviste, 2004.
[2] **Bausic, Fl**. - *Dinamica masinilor de constructii. Bazele modelarii,* Editura Matrixrom.
[3] **Bratu, P.** - *Evaluarea solicitarii dinamice in structura de rezistenta a echipamentelor incarcatoarelor frontale ca urmare a oscilatiilor transversale*, Revista "Mecanizarea Constructiilor", nr. 4/1984.
[4] **Bratu, P.** - *Vibratiile sistemelor elastice*, Editura Tehnica, Bucuresti, 2000.
[5] **Debeleac, C**. - *Analiza comportarii dinamice a incarcatoarelor frontale in vederea stabilirii performantelor de calitate tinand seama de interactiunea cupa-material in procesul de incarcare*, Grant CNCSIS, 2002-2003.
[6] **Debeleac, C., Leopa, A., Nastac, S.** -*Vibratii in echipamente tehnologice la deplasarea pe teren denivelat*, Conferinta Stiintifica Internationala TMCR 2005, Chisinau, 19-21 mai, 2005, vol. 3, pag. 264-267.
[7] **Debeleac, C.** - *The Reducing Of The Balance Vibrations For The Technological Equipments Movement On the Unarranged Ways,* Simpozionul International "Disiparea energiei. Procese acustice, vibratorii si seismice", Bucuresti, Romania, noiembrie, 2005.
[8] **Debeleac, C.** - *Analiza regimului dinamic la incarcatoarele frontale rapide in vederea stabilirii performantelor de calitate,* Teza de doctorat, mai 2006.
[9] **Falkner, A., Reinaler, W.** - *The effect of road-excited vibrations on the load spectrum, the required space and the ride comfort*, ATZ worldwide 6/2005.
[10] **Oproescu, Gh., Nastac, S.** - *Elemente de modelare numerica,* Editura Libertatea, Braila, 2000.
[11] **Sireteanu, T., Gundisch, O., Paraian, S.** - *Vibratiile aleatoare ale automobilelor*, Ed. Tehnica, Bucuresti, 1981.