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DIAGNOSIS OF STRUCTURAL INTEGRITY USING THE NON-LINEAR VIBRATION TEHNIQUE

Lecturer Drd.Eng. LEOPA ADRIAN
“Dunarea de Jos” University of Galati

ABSTRACT

The aim of the work presented here was to investigate the possibility of using hangs in the non-linear vibration characteristics to detect damage in mechanical structure. The nonlinearities were detected by examining the changes in time and frequency response, in over time (and hence over amplitude of vibration).

1. General view

In the world exist functionally system for integrity of the structure diagnoses, like bridge, trough nonlinear vibration technique. The non-linearity are identified trough monitoring in time the fundamentally frequency of the studies system. Base on this information, can elaborate a theoretical model capable that include structural modify of the system in the mathematical approach. This model was developed and validates experimentally, to become a very important and helpful instrument, for certify integrity system with dynamical loading.

This work, approach the influence of nonlinearities behavior of the viscoelastic system toward dynamical response of the machines foundation.

2. The physical and mathematical model

For this study we consider phisical model with tree degree of freedom [2], Figure 1, who characterized the technological equipment behavior like forging hammer and press with eccentric.

For this model the following sequences hypothesis [4]:

- the mass will considerate concentrate in the centre of mass
- will be neglected the turn round of the frame of press
- will be take into consideration only moves on Ox direction
- will be neglected the friction forces in time of press functioning
- the cutting force is the shock tip
- the frame of the press will be two-part considerate M_1 and M_2
- the elastic and damping forces are linear expression.

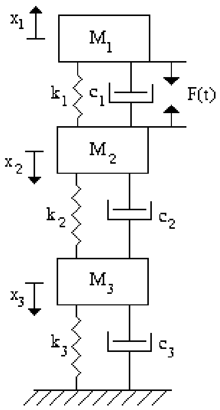

Figure 1. The phisical model

The mathematical model can be written:

$$\begin{aligned} & M_1 \cdot \ddot{x}_1 + c_1 \cdot (\dot{x}_1 + \dot{x}_2) + k_1 \cdot (x_1 + x_2) = F(t) \\ & M_2 \cdot \ddot{x}_2 + c_1 \cdot (\dot{x}_1 + \dot{x}_2) + c_2 \cdot (\dot{x}_2 - \dot{x}_3) + \\ & \quad + k_1 \cdot (x_1 + x_2) + k_2 \cdot (x_2 - x_3) = F(t) \\ & M_3 \cdot \ddot{x}_3 + c_2 \cdot (\dot{x}_3 - \dot{x}_2) + c_3 \cdot \dot{x}_3 + \\ & \quad + k_2 \cdot (x_3 - x_2) + k_3 \cdot x_3 = 0 \end{aligned} \tag{1}$$

where:

x_1 – displacement of the mass M_1; $\dot{x}_1$ - speed of the mass M_1; $\ddot{x}_1$- acceleration of the mass M_1; x_2 – displacement of the mass M_2; $\dot{x}_2$- speed of the mass M_2; $\ddot{x}_2$ - acceleration of the mass M_2; x_3 – displacement of the mass M_3; $\dot{x}_3$ - speed of the mass M_3; $\ddot{x}_3$ - acceleration of the mass M_3. The numerical solution of the system equation (1) is made by known algorithm, or by method Runge - Kutta, the stability solution and the precision of the results depend only the value of the time - increment who has to be little than 0.001 seconds. The solving system has made in hypothesis of the next numerical value: $k_1=7400000\cdot10^3$ [N/m]; $c_1=17000\cdot10^3$ [Ns/m]; $m_1=16\cdot10^3$ kg; $k_2=7500000\cdot10^3$ [N/m]; $c_2=15000\cdot10^3$ [Ns/m]; $m_2=25\cdot10^3$ kg; $k_3=8000000\cdot10^3$ [N/m]; $c_3=18000\cdot10^3$ [Ns/m]; $m_3=80\cdot10^3$ kg; $P=4000\cdot10^3$ N; $\beta=3\cdot10^9$ 1/m^2

To distinguish between both cases linear and nonlinear elastic characteristic, the equation system will be resolved take into consideration two hipothesis [3]:

- the stiffnes coeficient are constantly;
- the stiffnes coeficient k_2 have expresion:

$$F_{el} = k_2(\dot{x} + \beta \dot{x}^3) \qquad (2)$$

3. Comparative analyze of the dynamical response systems for two considered case

Througt equation system resolve, obtain the kinematic parameters behavior in time and in frequency: acceleration, speed and movement [1]. These changes in timp of the kinematic parameters bring information about transmited vibration to environment The excitation stresses are semi-sinusoidal shocks, rectangle shocks or triangle shocks. In this paper will study only semi-sinusoidal excitation shocks case Figure 2.

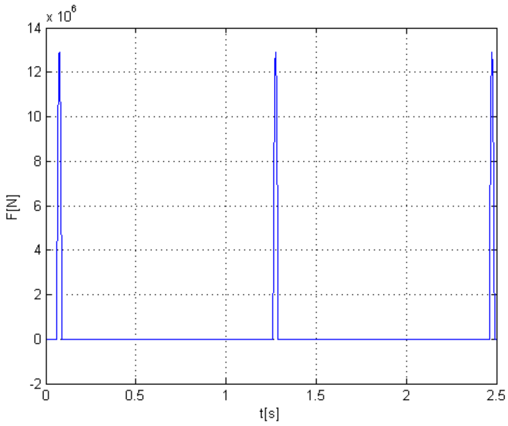

Figure 2. The Semi sinusoidal excitation

In the next figure will be represented the dynamical responses in time and in frequency for m_3 mass, in two considered hypothesis.

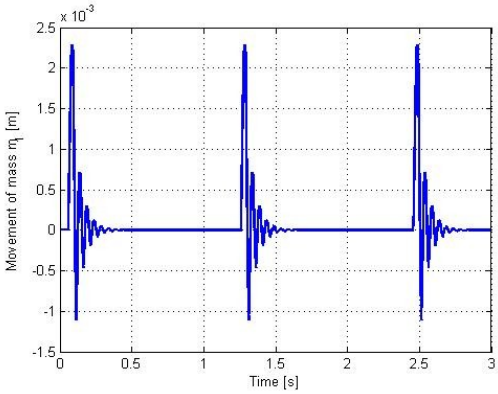

Figure 3 Displacement of mass m_3 - linear case

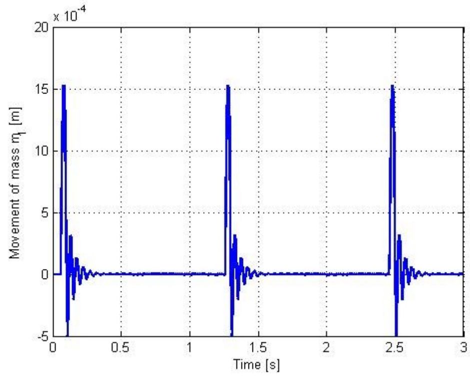

Figure 4. Displacement of mass m_3 - nonlinear case

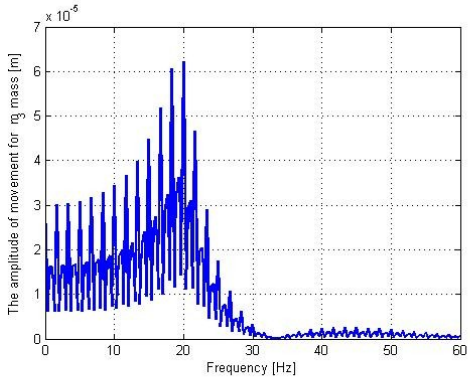

Figure 5. Fourier spectra vibration displacement m_3 – linear case

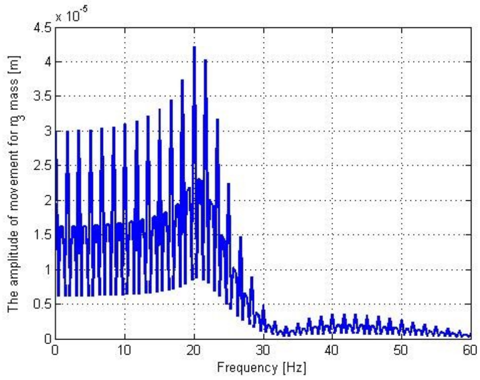

Figure 6. Fourier spectra vibration displacement m_3 – nonlinear case

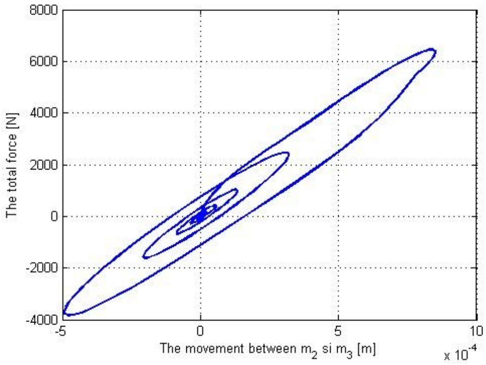

Figure 7. Hysteretic loop – linear case

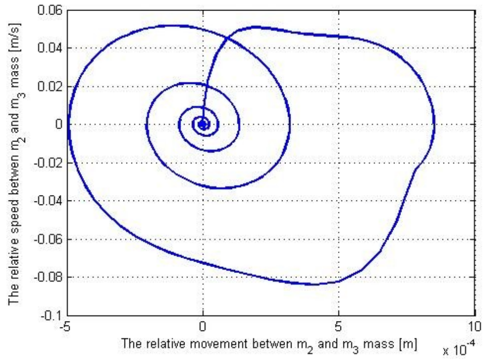

Figure 8. Movement trajectory – linear case

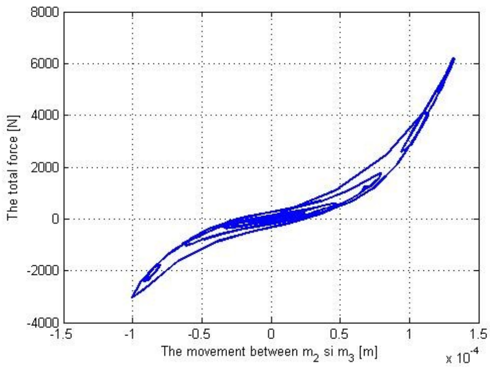

Figure 9. Hysteretic loop – nonlinear case

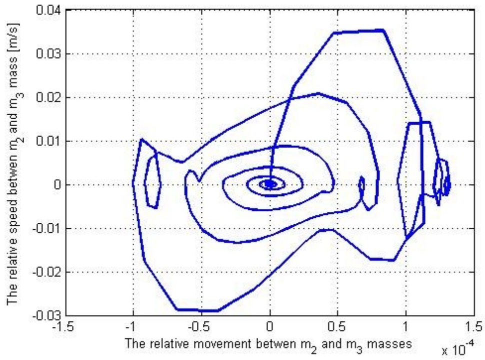

Figure 10. Movement trajectory – nonlinear case

4. Conclusions

The nonlinear caracteristic of the stiffnes coeficient of the viscoelastic elements react on dynamical behavior of the system in time and frequency responces follow as:

- the differences between responces in time and in frquency are not significant;
- in the hysteresis loop representation, we observ a diminish of the dissipate energy in the nonlinear stiffnes coeficient hypothesis wich mean that a biger cantity of energy will be transmited to the environment;
- the movement trajectory in nonlinear case, present a semnificativ instability.

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