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Numerical Monitoring of the Dynamic Behavior in Frequency of the Parametric Systems in Forced Vibration Regime

The aim of the paper is to present a consistent monitoring method which can be used on construction sites for a rapid assessment of the work quality. The starting point is represented by the evolution processes with forced vibrations considering a system with one degree of freedom and the rheological model of Voigt-Kelvin whose elastic and viscous values can change during the technological process, in real time. Response functions are analyzed at the passing of the dynamic system from one state to another and the resulted families of curves are plotted.

Keywords*: damping, response functions, parameterization*

1. Introduction

The present issue constitutes the subject of a study based on which criteria and dynamic analysis methods of the technological processes with forced vibrations, in real time, are established.

During the processing with technological vibrations changes of the rigidity, damping and mass are possible as a consequence of the modification of the process parameters.

In this case, the defined functional state in the system of axes amplitude-pulsation or in the frequency domain is given by the point I of coordinates (ω, A)/ ζ on the curve with the damping ratio such that it can be individualized through the index of order j: $I_j(\omega_j, A_j)/ \zeta_j$. The evolution of the state I_j on the same curve as well as the jump on another curve, in a different point on the vertical, $I_k(\omega_j, A_k)/ \zeta_k$, at the same pulsation ω_j, can be evaluated in real time through specialized instrumentation and an appropriate computer system [1].

The response functions through the amplitude can be defined as A_j/A_1 with j=2, 3…and with W_j/W_i, meaning the ratio of the amplitudes $R_j=A_j/A_1$ and the ratio of the dissipated energy $E_j=W_j/W_i$.

2. The Physical Model of the Dynamic System

The dynamic system of order II, complete with m, c, k in which the structural parameters c and k are discretely variable, has one degree of freedom and the rheological model of Voigt-Kelvin whose elastic and viscous values can change during the technological process [6].

In Figure 1 the dynamic response amplitude-pulsation-damping is presented for two distinct curves with the positioning of the functional states 1 and 2 through successive tracing along two evolution paths 1-1`-2 or 1-2`-2.

Curve 1 has $\zeta_1=0.175$ and curve 2 has $\zeta_2=0.7$ such that, as an example, it is observed that state 2 can be reached from state 1 as a result of the parametric modification of the stiffness, damping and excitation pulsation. From the variation of the amplitudes ratio, the dynamic behavior when passing from a system in equilibrium to another one results, as a consequence of the parametric change [2].

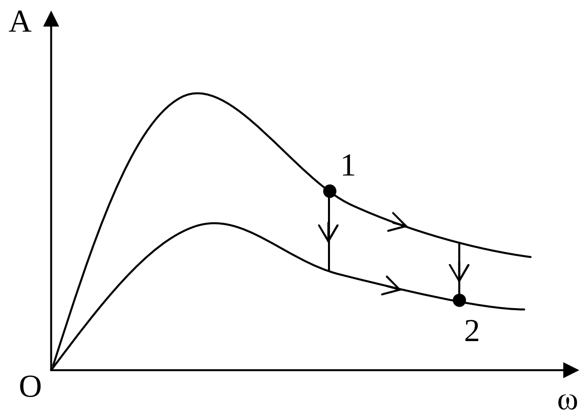

Figure 1.

Noting the parameters ratio between those from state j and those from the initial state 1, one has [5]:

$$\lambda_j = \frac{k_j}{k_1} \tag{1}$$

where λ_j represents the stiffness ratio,

$$\upsilon_j = \frac{c_j}{c_1} \tag{2}$$

where υ_j represents the linear viscous damping ratio,

$$\Phi_j = \frac{\omega_j}{\omega_1} \tag{3}$$

where Φ_j represents excitation pulsation ratio,

$$\Omega_j = \frac{\omega_j}{p_j} \tag{4}$$

where Ω_j represents the relative pulsation of order j,

$$p_j = \sqrt{\frac{k_j}{m}} = \sqrt{\lambda_j} p_1 \tag{5}$$

where p_j represents the eigenpusaltion for mode j,

$$\zeta_j = \frac{c_j}{2\sqrt{k_j m}} = \frac{\upsilon_j c_1}{2\sqrt{\lambda_j k_1 m}} \tag{6}$$

or

$$\zeta_j = \upsilon_j \frac{\zeta_1}{\sqrt{\lambda_j}} \tag{6`}$$

in which ζ_j represents the damping ratio of order j.

In this case the rheological model can be represented with discretely variable quantities like in Figure 2.

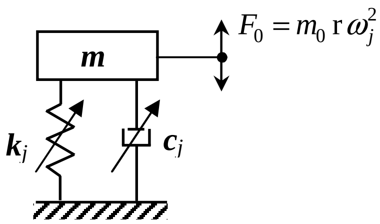

Figure 2.

Thus, for the stationary regime with known excitation pulsation, the response curves parameterized with respect to the damping ζ_1 respectively ζ_j will be defined. The functional states of the technological vibrations regime are [4]:

- State 1 defined by the amplitude $A_1(\Omega_1, \zeta_1)$;
- State j defined by the amplitude $A_j(\Omega_j, \Phi_j, \lambda_j, \upsilon_j)$.

The function S_j which defines the passing, in steps, from one initial state to a final one can be written as:

$$S_j = \frac{A_j}{A_1} = \frac{1}{R_j} \tag{7}$$

or as an analytical expression [3]:

$$S_j = \sqrt{\frac{(\lambda_j - \Omega_1^2 \Phi_j^2)^2 + (2\zeta_1 \Omega_1 \Phi_j)^2 \upsilon_j^2}{(1-\Omega_1^2)^2 + (2\zeta_1 \Omega_1)^2}} \, . \tag{7`}$$

The dissipative function D_j at the modification of the functional state, for the evolution j-1, is:

$$D_j = \frac{W_j}{W_1} \tag{8}$$

or

$$D_j = \upsilon_j \Phi_j S_j^2 \tag{8`}$$

3. The Functional Evolution with Respect to the Parametric Variations of the Dynamic System

In the cases of earth compacting process, fillings for foundations, mineral aggregates and bituminous mixtures, the functional evolution can be followed by:

- The initial parameters which are constant, as follows: $\Omega_1 = 1$; $\zeta_1 = 0.316$; $\upsilon_j = 1$;
- The variable parameters which modify the evolution from state 1 to state j. These are discretely variable in steps, namely for the specific supra-unitary increasing stiffness: $\lambda_j = 1, 2, 3, 4, 5$ and for the excitation ratio: $\Phi_j = 1..5$, considering a very small step which ranges between 0.01 and 0.5;
- The variable parameters for the sub-unitary specific increasing stiffness, namely: $\lambda_j = 0.2, 0.4, 0.6, 0.8, 1$ with the same variation for the ratio of the excitation pulsations as in the previous case;

In Figure 3 the family of curves $S_j = \frac{A_j}{A_1}$ is represented only for the discrete and increasing variation of the λ_j, meaning $\lambda_j = 1, 2, 3, 4, 5$ with $\Phi_j = 1..5$ and a step of 0.1. It can be observed that for higher stiffness values the maximum ratio decreases and that for any value of the ground stiffness for $\Phi_j \geq 4$ the ratio S_j remains constant.

In Figure 4 the same S_j curves are shown but for the case in which the values of λ_j are sub-unitary, namely $\lambda_j = 0.2, 0.4, 0.6, 0.8, 1$.

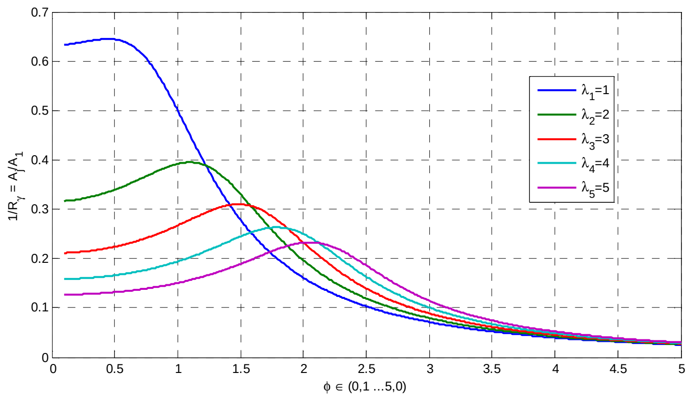

Figure 3.

The dissipation function D_j for the case of $\lambda_j = 1, 2, 3, 4, 5$ is given in Figure 5 and for $\lambda_j = 0.2, 0.4, 0.6, 0.8, 1$ in Figure 6.

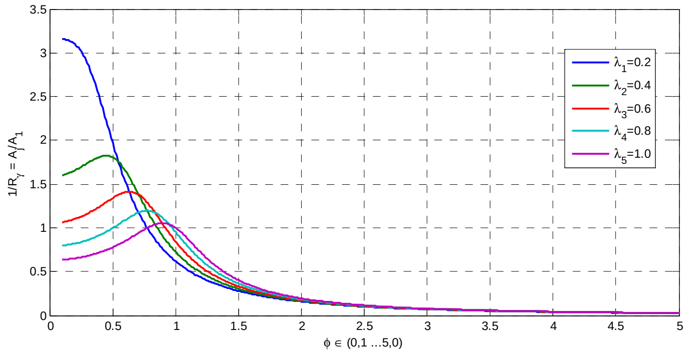

Figure 4.

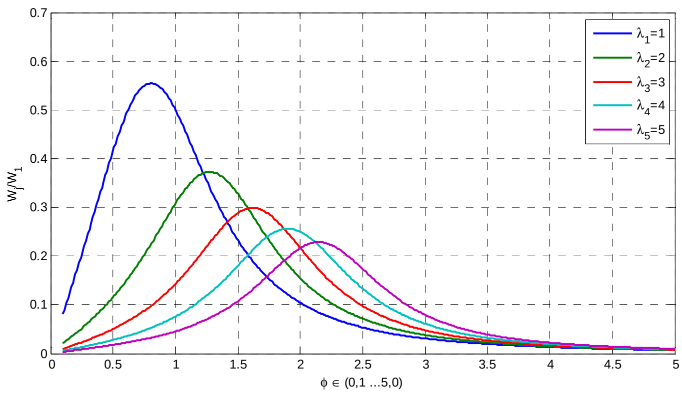

Figure 5.

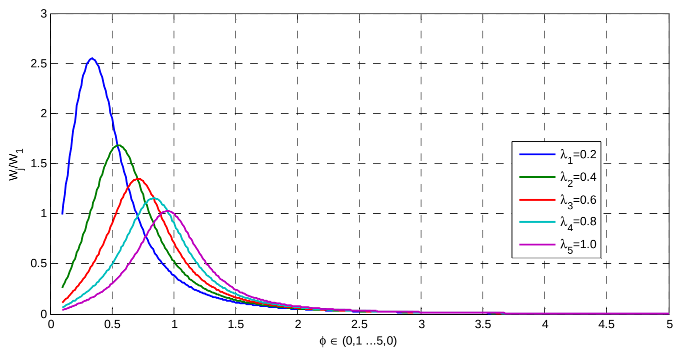

Figure 6.

4. Conclusions

For the evolution processes caused by the discrete modification of both the physical and mechanical parameters of the material as well as the excitation ones, functions S and D reflect the influence of the passing from one state to another thusly:

a) The modification of the stiffness in compaction steps which leads to a decrease in the ratio (ratios) S having significant technological consequences;
b) The variation of the ratio D at parametric changes highlights the fact that for each passing step the energy dissipated by the compacted layers depends on the amplitude modification with consequences which can be taken into consideration in calculus.

The present monitoring method can be used on construction sites for a rapid assessment of the work quality.

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