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Methods of Calculating the A_1 / A_2 Ratio According to Structural Changes

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***Abstract* - The paper presents the correlation between the physical model of a dynamic system that is in the steady state dynamic equilibrium and the computer one. The computer model follows the physical model of a dynamic system with one degree of freedom with discretely variable damping.**

***Index Terms*- amplitude ratio, computer model, dynamic system, informatic model**

I. THE PHYSICAL MODEL OF THE DYNAMIC SYSTEM

The rheological model used in the analysis is the Voigt-Kelvin model, a model characterized by spring and linear damping in parallel connection with inertial mass and excitation. This model approximates rigorously the interaction between real systems of road structures with earth and vibratory rollers. The amplitude of the motion is given by the relation

$$A = \frac{\Omega^2 A_{st}}{\sqrt{(1-\Omega^2)^2 + 4\Omega^2\zeta^2}} \qquad (1)$$

ie A = A (ω, ζ) is a function expressed in the relative angular coordinate Ω and the damping fraction ζ. A_{st} or A_{stable} is amplitude in post resonance. The E / V pattern is predominantly elastic, making the chosen layout suitable only for elastic, elastoplastic, low-viscosity landscapes.

The Dynamic Stabilized System can be analyzed by analyzing the amplitude evolution relative to the pulse for different discrete damping ratio values. Amplitude and pulsation are two parameters that can be measured during work, so points can be determined on the corresponding curves of evolution. Fig. 1 shows an example of two amplitude-versus-pulse curves for two discretionary damping ratios ζ and two points p_1 and p_2. In the compaction process, the working points will move from curves with low damping ratios to those with high values. Thus, the instantaneous value of amplitude will be initially on curve 1, corresponding to $\zeta_1 = 0{,}175$, in point 1. In the compaction process the current point will reach the point marked 2, corresponding to $\zeta_2 = 0{,}7$, ie on the curve 2.

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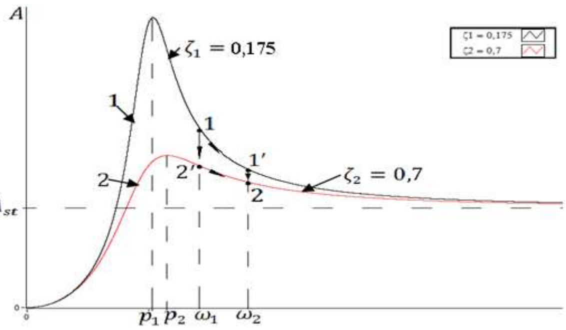

Fig. 1. Two amplitude-versus-pulse curves for two discretionary damping ratios ζ and two points p_1 and p_2

To get from point 1 to point 2, two paths can be used: 1, 1 ', 2 or 1, 2', 2. Points 1 and 1 'are on the same curve 1, corresponding to $\zeta_1 = 0{,}175$, and points 2 and 2 'is on curve 2, corresponding to $\zeta_2 = 0{,}7$. Because the route followed by the current work point is unknown to get from point 1 to point 2, it is questionable whether it is important that the route between the two points is made.

Traveling on route 1, 1 ', 2. In the formulas (2), (3) and (4), the amplitude of the corresponding points is specified. So:

- for the continuous dynamic process 1 → 1'' we have:

$$\begin{cases} A_1 = \dfrac{\Omega_1^2 A_{st}}{\sqrt{\left(1-\Omega_1^2\right)^2 + 4\Omega_1^2\zeta_1^2}} \\ A_{1'} = \dfrac{\Omega_2^2 A_{st}}{\sqrt{\left(1-\Omega_2^2\right)^2 + 4\Omega_2^2\zeta_1^2}} \end{cases} \qquad (2)$$

- for the dynamic jump process 1'→ 2 we have:

$$\begin{cases} A_{1'} = \dfrac{\Omega_2^2 A_{st}}{\sqrt{\left(1-\Omega_2^2\right)^2 + 4\Omega_2^2\zeta_1^2}} \\ A_2 = \dfrac{\Omega_2^2 A_{st}}{\sqrt{\left(1-\Omega_2^2\right)^2 + 4\Omega_2^2\zeta_2^2}} \end{cases} \qquad (3)$$

The transition from state 1 to state 2 can be done as follows:

$$\frac{A_1}{A_{1'}} \cdot \frac{A_{1'}}{A_2} = \frac{A_1}{A_2}$$

The parameter ratio is:

$$\frac{A_1}{A_2} = \left(\frac{\Omega_1}{\Omega_2}\right)^2 \sqrt{\frac{(1-\Omega_2^2)^2 + 4\Omega_2^2\zeta_2^2}{(1-\Omega_1^2)^2 + 4\Omega_1^2\zeta_1^2}} \qquad (4)$$

Evolution by conditions 1, 2 ', 2. In the formulas (5), (6) and (7), the amplitude of the corresponding points is specified. Thus we have:

- for the dynamic jump process 1 → 2', we have:

$$A_1 = \frac{\Omega_1^2 A_{st}}{\sqrt{(1-\Omega_1^2)^2 + 4\Omega_1^2\zeta_1^2}} \qquad A_{2'} = \frac{\Omega_1^2 A_{st}}{\sqrt{(1-\Omega_1^2)^2 + 4\Omega_1^2\zeta_2^2}} \quad (5)$$

- for continuous dynamic process 2'→ 2, we have:

$$\begin{cases} A_{2'} = \dfrac{\Omega_1^2 A_{st}}{\sqrt{(1-\Omega_1^2)^2 + 4\Omega_1^2\zeta_2^2}} \\ A_2 = \dfrac{\Omega_2^2 A_{st}}{\sqrt{(1-\Omega_2^2)^2 + 4\Omega_2^2\zeta_2^2}} \end{cases} \quad (6)$$

The evolution relationship from state 1 to state 2 is demonstrated as follows:

$$\frac{A_1}{A_{2'}} \cdot \frac{A_{2'}}{A_2} = \frac{A_1}{A_2}$$

At the end

$$\frac{A_1}{A_2} = \left(\frac{\Omega_1}{\Omega_2}\right)^2 \sqrt{\frac{(1-\Omega_2^2)^2 + 4\Omega_2^2\zeta_2^2}{(1-\Omega_1^2)^2 + 4\Omega_1^2\zeta_1^2}} \quad (7)$$

It can be concluded from the formulas (4) and (7) that the transition between two distinct states depends only on the state parameters (A, Ω) and does not depend on the shape and nature of the road between states.

For the study of the laws of variation of the amplitudes ratio according to the structural changes, three methods have been developed. For each method, a separate program was created.

II. METHOD 1

In this method, the evolution of the ratio of amplitudes is monitored, depending on the constant ζ_1 and Ω_1. Different values of parameter r are given.

a) Change r = 1, 2, ..., 10. Keep constant ζ_1 = 0,2 and Ω_1 = 1,05, and λ values in the range 1-20. Curves are given in Fig. 2.

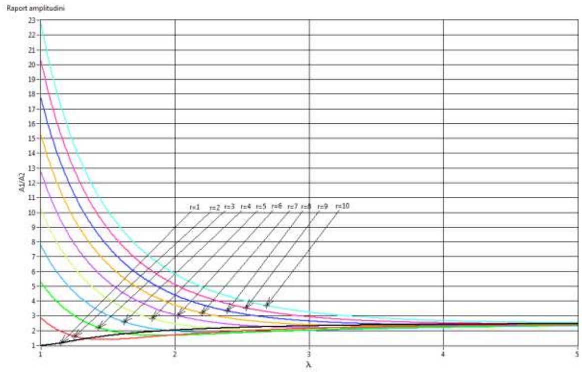

Fig. 2. Detailed method 1, r = 1, 2, …, 10

b) Change r = 0.25..2.00 in step 0.25. The curves in Fig. 3 are obtained.

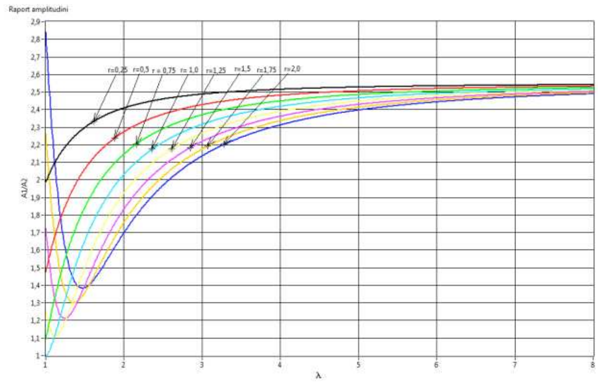

Fig. 3. Detailed method 1, r = 0,25; 0,50...2,00

III. METHOD 2

In this method, the evolution of the ratio of amplitudes is observed, depending on λ with the constant r and Ω_1. Different values of the parameter ζ_1 are given.

a) represents the synthesis of the curves for r = 4, Ω_1 = 1,05 and the discrete change of ζ_1 = 0,1; 0.2; 0.3; 0.4, with the continuous variation of λ, which takes values in the range 1-20. The curves in Fig. 4 are obtained.

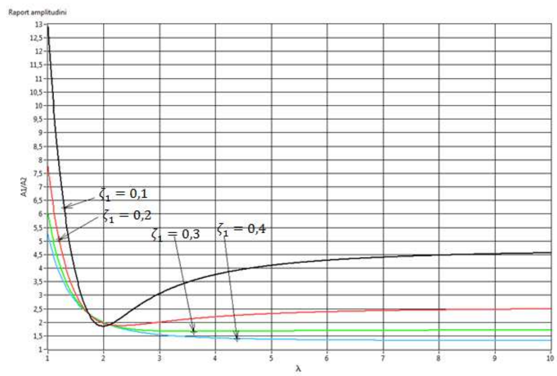

Fig. 4. Detailed method 2, ζ_1 = 0,1; 0,2; 0,3; 0,4

b) for the values of ζ_1 = 0.001; 0.021 0.041; 0.061; 0.081; 0.101, the graphs in Fig. 5 are obtained.

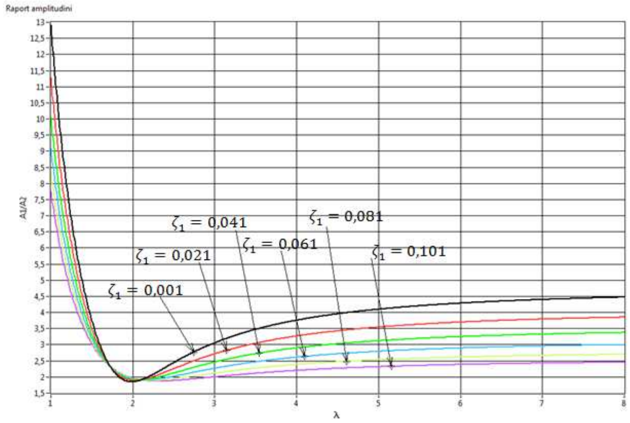

Fig. 5. Detailed method 2, ζ_1 = 0,001; 0,021 0,041; 0,061; 0,081; 0,101

c) For ζ_1 = 0,2; 0.3; 0.4; 0.5; 0.6 and 0.7 are the graphs in Fig. 6.

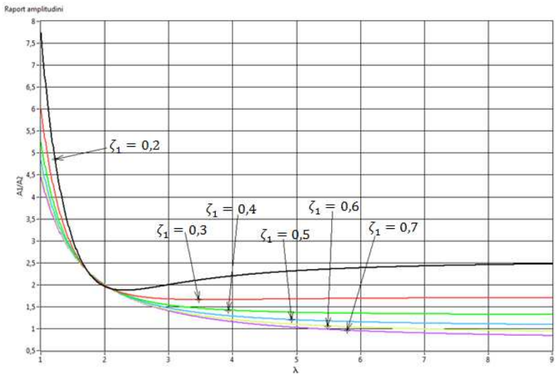

Fig. 6. Detailed method 2, ζ_1 = 0,2; 0,3; 0,4; 0,5; 0,6; 0,7

IV. METHOD 3

In this method, the evolution of the ratio of amplitudes, depending on r, is obtained, with constant ζ_1 and Ω_1. Different values of parameter λ are given.

a) For : λ = 3, 4, 5, 6, 7, 8, 9, 10; ζ_1 = 0,2; Ω_1 = 1.05, with r taking values in the range 1-10, the curves in Fig. 7 are obtained.

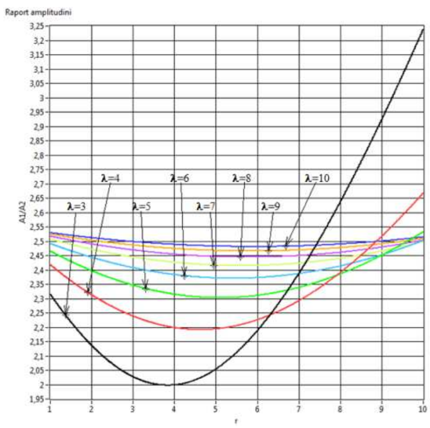

Fig. 7. Detailed method 3, λ = 3, 4, 5, 6, 7, 8, 9, 10

b) For:
λ = 0,25; 0,50; 0,75, 1,00; 1,25; 1,50; 1,75; 2,00, the curves in Fig. 8 are obtained.

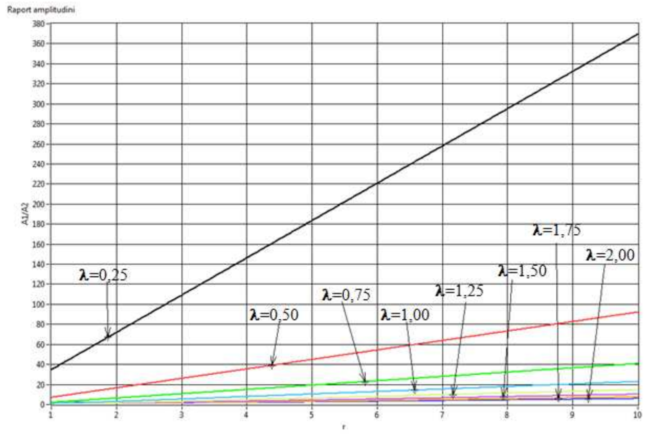

Fig. 8. Detailed method 3,
λ = 0,25; 0,50; 0,75, 1,00; 1,25; 1,50; 1,75; 2,00

V. CONCLUSION

The variation of the A_1 / A_2 ratio according to discrete or continuous values of physico-mechanical parameters highlights the following:

- functional behavior after smooth curves and monotone evolutions on intervals;
- families of curves show that all parameters are in a functional and structural correlation;
- analysis of evolutions is deterministic and predictable for machine-to-field interaction.

These studies open up significant perspectives for the foundation of an informational and instrumental model for assessing machine operation. In the compaction process, in the first stage, with each pass of the compaction machine, there is an increase in the rigidity of the ground. Depending on the recorded pulse value and the magnitude of the amplitude corresponding to the moment of reading, which is the coordinates of the current working point, the value of the damping ratio can be determined. The coordinates of these current working points can be stored. When the variation of the damping ratio is asymptotic to the line of the A_{st} value (Fig. 1), the compaction process must be stopped. Finally, by the processing of the coordinates of the stored current points, it is possible to draw the curves of the variation of the damping ratio depending on the pulsation. This way we can observe the evolution of the increase of the rigidity of the terrain. By storing all the data corresponding to the respective ground and the characteristics of the compaction machine, criteria for starting, stopping and adjusting the compaction process for that type of field can be developed.

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