Effect of Vibration Transmission in the Case of the Vibratory Roller Compactor

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Abstract: - The problem of transmitting vibrations to the driver's cabin is presented, where the level of the amplitude values must be as low as possible and the force transmitted to the ground with the highest. Thus, for such vibratory machines, the problem of isolating the vibrations transmitted in the cabin must be solved simultaneously with ensuring a maximum force transmitted to the ground when compacting the soil.

Keywords: - vibrating roller, dynamic isolation, transmitted force, soil compaction

1. INTRODUCTION

Based on the two-degree-of-freedom model, the dynamic regime of a variable-frequency vibratory roller used in soil compaction is analyzed both numerically and experimentally, the problem of isolating the vibrations transmitted to the cabin and the upper chassis as well as ensuring a maximum dynamic force during compaction is posed the land. For this, the calculation formulas for the degree of vibration isolation and the force transmitted to the ground are given [3,10,18,19].

Based on the graphically represented curves, the range of optimal frequencies for ensuring technological vibrations can be estimated.

2. EVALUATION OF THE FORCE TRANSMITTED TO SOIL

The efficiency of compaction process fundamentally depends on the force transmitted to the soil layers the vibratory roller acts on.

Considering the notations: m_1 mass of the vibratory roller, k_1 soil rigidity and A amplitude [1,2,7,13], it results:

$$F_1(t) = k_1 y_1(t)$$

or

$$F_1^{\max}(t) = \alpha k_2 A_1 \cos \omega t \tag{1}$$

The maximum transmitted force is $F_1^{\max}(t) = \alpha k_2 A_1$ and its graphical dependence on excitation pulsation ω is evidenced in Figure 4.

The mathematical relation for maximum transmitted force is

$$F_1^{\max} = \alpha k_2 \frac{m_0 r}{m_2} \cdot \frac{\omega^2\left(\upsilon_2^2 - \omega^2\right)}{\left(\alpha \upsilon_2^2 - \beta\omega^2\right)\left(\upsilon_2^2 - \omega^2\right) - \upsilon_2^2\omega^2} \tag{2}$$

in which

$$\alpha = \frac{k_1}{k_2};$$

$$\beta = \frac{m_0 + m_1}{m_2};$$

$$\upsilon_1 = \sqrt{\frac{k_2}{m_2}};$$

$$\upsilon_2 = \upsilon_1 \sqrt{\frac{\beta}{\alpha}}$$

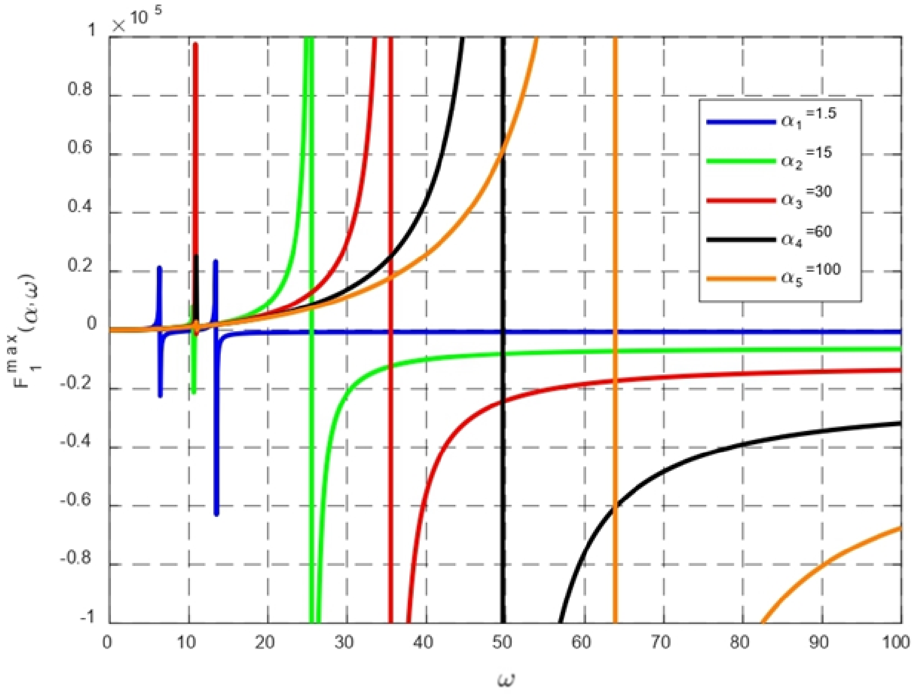


Figure 1. Graphs for variation of transmitted force F_1^{max} function of variable ω, parameters α and β=3

3. DEGREE OF VIBRATIONS ISOLATION

The upper part of the model in figure 1 (the mass m_2 and the elastic element k_2) is characterised by the fact that actuation module, motor-hydraulic pump, must be protected against the vibrations transmitted from the vibratory module (mass m_1) [4,5,16]

Under the above-mentioned assumption, the vibration isolation degree is given by relation

$$I = 1 - \frac{F_2^{\max}}{m_0 r \omega^2} \tag{3}$$

where $F_2^{\max} = k_2(A_1 - A_2)$,

so that relation (3) turns to

$$I = 1 - \frac{k_2(A_1 - A_2)}{m_0 r \omega^2} \tag{4}$$

Graphs for variation of isolation degree are shown in figure 2.

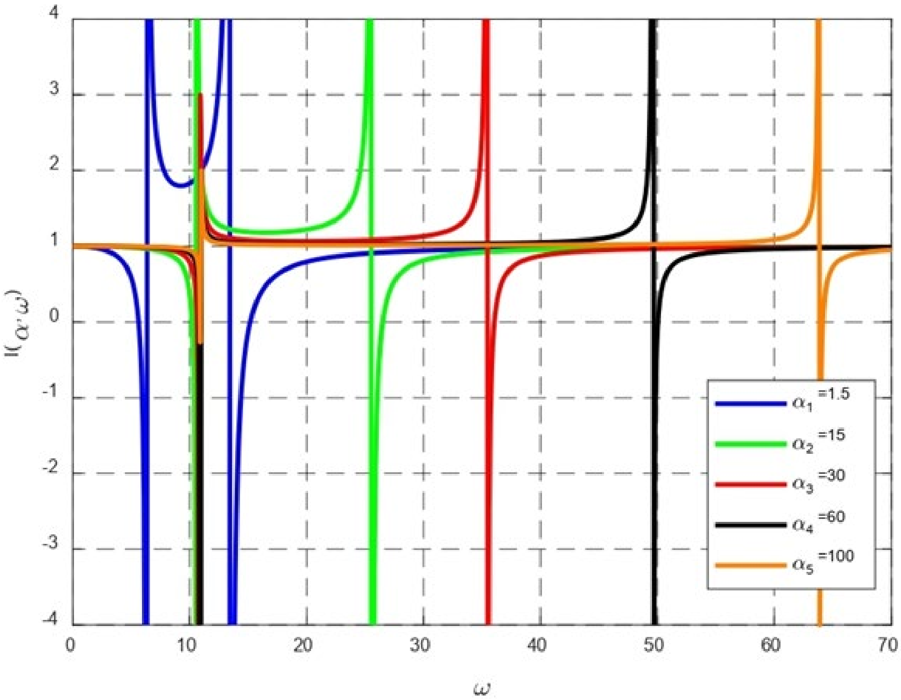


Figure 2. Graphs for variation of isolation degree I function of variable ω parameters α and β

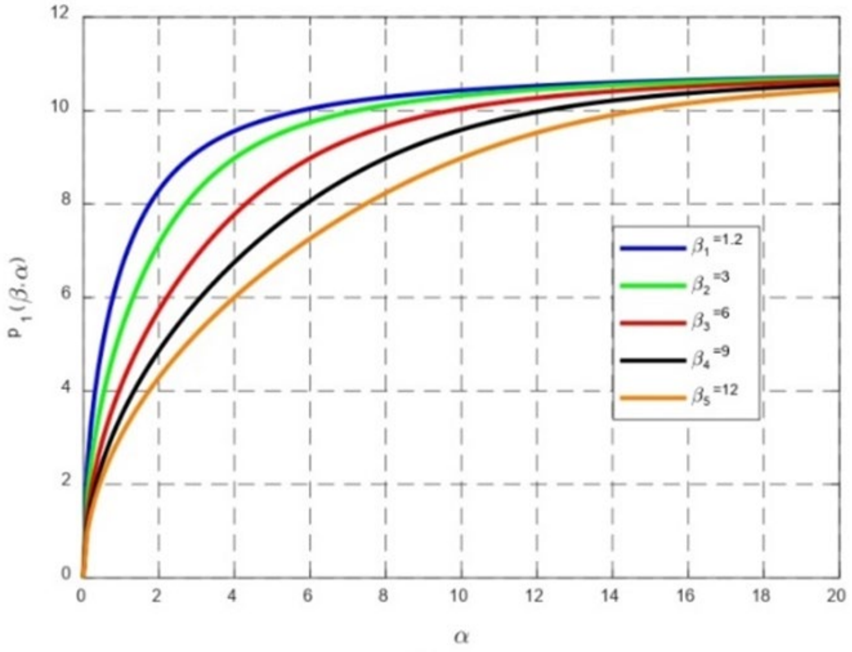
4. NUMERICAL AND EXPERIMENTAL RESULTS

The calculation formulas for the amplitudes are of the form:

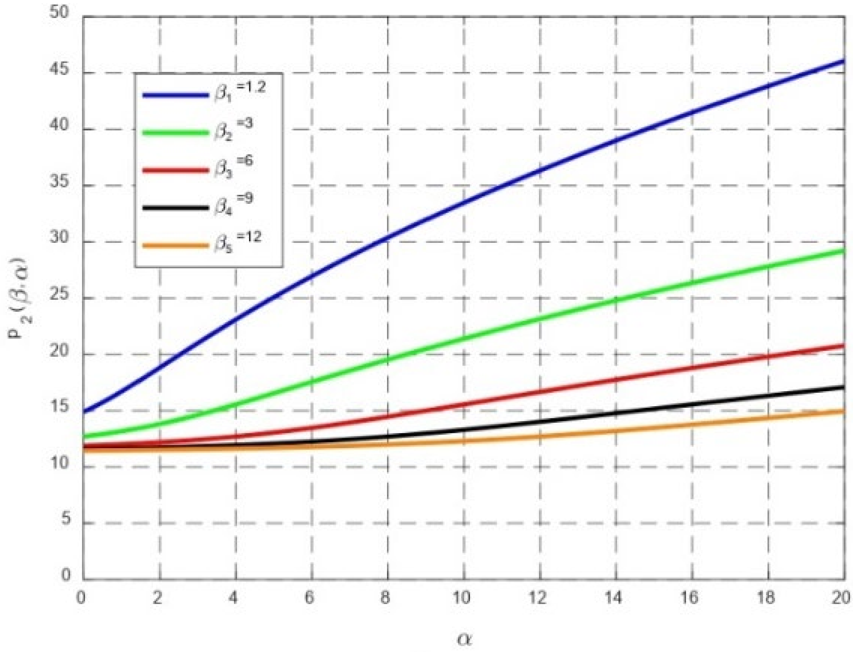
$$\begin{cases} A_1 = \dfrac{m_0 r}{m_2} \cdot \dfrac{\omega^2(\upsilon_2^2 - \omega^2)}{(\alpha\upsilon_2^2 - \beta\omega^2)(\upsilon_2^2 - \omega^2) - \upsilon_2^2\omega^2} \\ A_2 = \dfrac{m_0 r}{m_2} \cdot \dfrac{\upsilon_2^2\omega^2}{(\alpha\upsilon_2^2 - \beta\omega^2)(\upsilon_2^2 - \omega^2) - \upsilon_2^2\omega^2} \end{cases} \quad (5)$$

The graphs for variation of pulsations p_1 and p_2 function of current variable α and discrete variable β are shown in figure 3 [9,11,12,13].

The graphs for variation of amplitudes A_1 and A_2 are shown in figure 4, considering the assumption that $m_0 r = 9,49\,kgm$ [6,7,8].



(a)



(b)

Figure 3. Graphs for variation of natural pulsations p_1 and p_2 (a) variation of pulsation p_1 function of variable α and parameter β; b) variation of pulsation p_2 function of variable α and parameter β

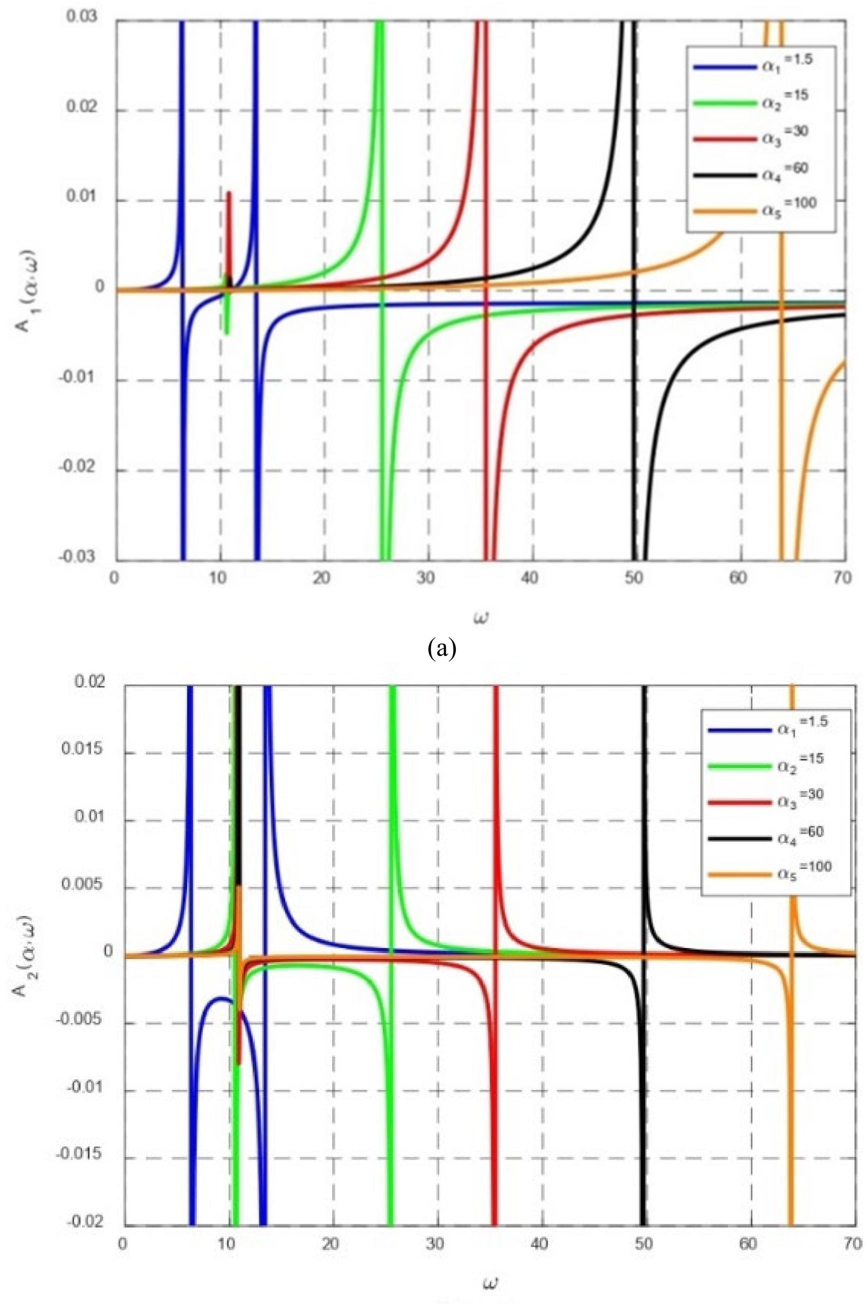


Figure 4. Graphs for variation of amplitudes A_1 and A_2 – with the assumption $m_0 r = 9,49\,Kgm$ (a) variation of amplitude vibration A_1 function of variable ω and parameters α , β ; (b) variation of amplitude vibration A_2 function of variable ω and parameters α , β

At the research institute, ICECON Bucharest, Romania there were carried on experiments for vibratory compaction roller process with CV10 equipment. Some relevant characteristics are [20,21,22,23]:

$m_1 - m_0 = 3150$ kg;

$m_2 = 2650$ kg;

$m_0 = 390,6$ kg;

$r_I = 24,3$ mm – for first speed (I),

$r_{II} = 53,16$ mm – for second speed (II) and

$r_{III} = 94,27 mm$ – for the third speed (III);

- excitation pulsation $\omega = 75$ rad/s;
- elasticity coefficients $k_1 = 50 \cdot 10^4$ N/m; and $k_2 = 33 \cdot 10^4$ N/m.

The exeprimental results are presented in Table 1 (in comparison to the calculated ones) [7,8,11].

Table 1 Experimental results

Parameter		**Value**	
		calculation	experimental
Natural pulsation [rad/s]	p_1	7,76	6,81
	p_2	18,1	19,5
Static torque m_0r [Kgm]	m_0r_I	9,49	9,41
	m_0r_{II}	20,76	20,62
	m_0r_{III}	36,82	36,76
Amplitude A_1 [mm]	A_1^I	3,16	3,12
	A_1^{II}	6,92	6,86
	A_1^{III}	12,27	12,18
Rigidity x10^4 [N/m]	k_1	50	52
	k_2	33	38
Isolation degree, %		98	92

5. CONCLUSIONS

For the linear dynamic model of the vibratory roller have been set p_1 and p_2 parameters that define the resonance for the two modes, amplitudes in stable regime for different values of discrete increase in rigidity k_1 and of vibratory roller mass m_1 [14,15,16].

Relevant conclusion can be synthetized as mentioned next:

a) compaction efficiency is represented by the force transmitted to soil, $F_1^{\max}$;

c) vibration isolation at ω=75 rad/s for the actuation module, results in calculated value of, at least, 90% and experimentally determined value of 92%;

d) experimental values have low deviations, at about 5÷12% when compared to the calculated ones, proving that the linear dynamic model chosen is adequate and fit for further specific evaluation.

As conclusion of all the above, it is to be stated that the elastic linear model for vibratory roller is in complete accordance with the hypotheses and dynamic calculi presented in this paper.

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