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PARAMETRIC ANALYSIS OF VIBRATING EQUIPMENT FOR THE INSERTION OF PILES INTO THE GROUND

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SUMMARY. *The paper presents the dynamic model for vibration insertion equipment for piles and grooved piles. For this, several constructive solutions were analysed, so that the dynamic model chosen is representative. As a consequence, the paper comprises the dynamic analysis of the system response to the action of the perturbing force generated by an inertial vibrator with four synchronized eccentric masses in-phase, to ensure a vertical unidirectional dynamic action. Finally, the paper presents the curves of variation of the amplitudes of the masses in the vibrational movement, with the optimal functional regimes.*

The dynamic model in the paper was used to analyse the dynamic response for the functional optimization of the vibrodrivers on the sites located along the Danube for the consolidation of the navigation channel bed.

Keywords: *dynamic model, vibrations, piles, grooved piles.*

1. INTRODUCTION

The vibrating equipment for the insertion of the piles into the ground are the unidirectional vibrodrivers mounted on a support plate, which are fixed on the upper end of the driving element (grooved piles, piles). Vibrodrivers are vibrating action machines intended for the grounding of some construction elements (in the case of execution and consolidation of foundation works), including grooved piles and piles, in non-cohesive, water-soaked, low and medium compaction soils, as well as in some soft cohesive soils (weak plastic clays).

Depending on the characteristics of the land, the dynamic assessment of the driving element (the working element) is performed so that the amplitude and frequency of the technological vibrations represent certain characteristics at a minimum predictable level leading to the correct execution of the pile insertion in the ground process. For this reason, it is necessary that when changing the site, the characteristics of the land shall be assessed so that the necessary adjustment of the vibrating equipment can be made in order to achieve the necessary technological vibrations.

2. FUNCTIONAL AND CONSTRUCTIVE SCHEMATIZATION

The vibrodrivers have in their composition inertial vibration generators fixed rigidly at the end of the working element (grooved pile or pile). The most commonly used construction solutions classify the vibrating equipment for inserting piles into the ground as follows:

a) Vibrodrivers with rigid fixation of the driving motor in relation to the vibration generator (fig. 1 a where: 1 – driving motor; 2 – vibration generator; 3 – support platform; 4 – pile fixing device)
b) Vibrodrivers with elastic support of the driving motor in relation to the vibration generator (fig. 1 b where: 1 – vibration generator; 2 – pile fixing device; 3 – support platform; 4 – driving motor)

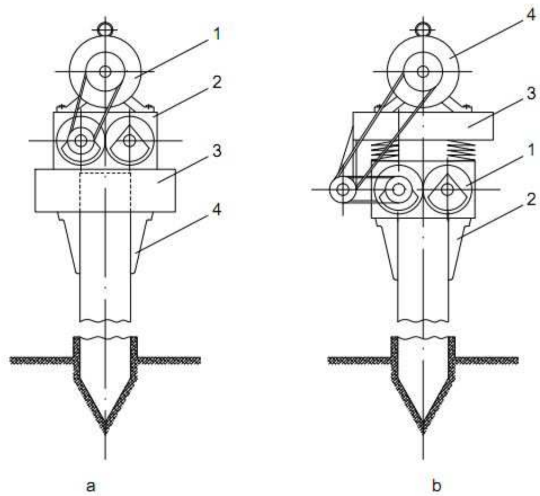

Fig. 1. Vibrodrivers for piles

The vibrodrivers with rigid fixing of the driving motor to the vibration generator have the advantage of a simple construction, but their use implies the following disadvantages:

- increasing the vibrator weight, by adding additional weights, reduces the amplitude of the vibrations and implicitly the insertion speed of the pile;
- reducing the reliability of electric motors due to the fact that the motor is subjected to the same vibrations as the driving element;
- the need to ensure the protection of the equipment carrying the vibrodriver against the transmission of the vibrations to it.

The second constructive type of vibrodriver (fig. 1 b) is composed of two parts with elastic connection through coil springs system, as follows:

- the vibrating part comprising the vibrator 1 and its gripping device to the working element 2;
- the upper part consisting of the insulation support plate 3 and the driving motor 4, the same being dynamically isolated from the elastic connection formed by the coil springs.

The constructive solution with elastic supported motor allows additional pressing of the driving element, thus leading to a combined vibration-pressing effect with good results when introducing the piles in non-cohesive and poorly cohesive soils.

The elastic constant of the springs is chosen so that the pulse of the plate 3 is lower than the one of the vibrator, in which case the springs play the role of dynamic isolator.

From the comparative analysis, it results that the amplitude of the vibrations and the loading pressure cannot be varied and separated, because the two sizes are in an inverse proportional ratio.

3. ANALYSIS OF THE DYNAMIC RESPONSE

Taking into consideration the aspects presented above as well as the fact that the vibrodrivers with elastic suspension have a wider range of use (they allow to increase the static weight of the machines without reducing the amplitude of the vibrations), the paper shall hereafter present the dynamic modelling for the vibrating equipment with elastic supported driving motor.

The model used for modelling most of the vibrating equipment for driving the grooved piles and piles into the ground is the one of the linear vibrating system with 2 concentrated masses as in figure 2 a.

For the study of this model, the dynamic calculation scheme represented in fig. 2 b has been adopted.

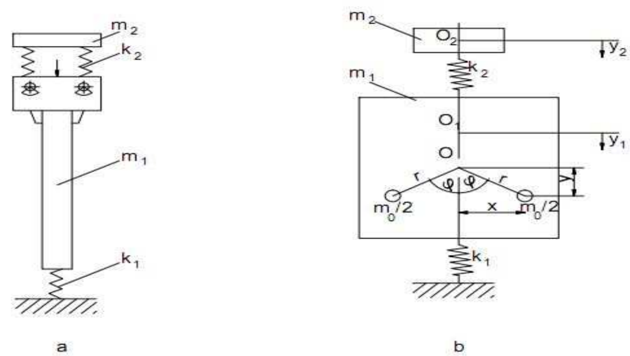

Fig. 2. Dynamic calculation model and scheme

The defining parameters for the dynamic model in figure 2 are as follows:

m_1 is the total mass of the vibrator with the gripping system and the working element;

m_2 – the mass of the driving motor together with the setting platform;

k_2 – the stiffness coefficient of the elastic elements on which the motor platform rests;

k_1 – the stiffness coefficient of the soil;

m_0 – the total mass of the eccentric elements of inertial imbalance in the vibrator component;

r – the eccentricity of the imbalance elements.

The position of the masses m_1, m_2 and m_0 is given by the instantaneous coordinates y_1, y_2 and φ.

The differential equations of the movement of the mechanical system are of the following form:

$$(m_1 + m_0) \cdot \ddot{y}_1 - m_0 r \ddot{\phi} \sin\phi - m_0 r \dot{\phi}^2 \cos\phi \quad (1)$$
$$+ k_1 y_1 + k_2(y_1 - y_2) = 0 \quad (2)$$
$$m_2 \ddot{y}_2 - k_2(y_1 - y_2) = 0 \; - m_0 r \ddot{y}_1 \sin\phi + \quad (3)$$
$$(J_0 + m_0 r^2)\ddot{\phi} + m_0 g r \sin\phi = M$$

where:

J_0 is the moment of total inertia of the eccentric imbalance masses reduced to the rotation axis of the vibrator motor wheel;

M – the moment of the driver torque corresponding to the vibrator motor shaft;

φ - the position angle of the eccentric masses.

For the stabilized operating regime, that is $\varphi = \omega \cdot t$; $\dot{\phi} = \omega$ and $\ddot{\phi} = 0$, the differential equations of movement shall have the following form:

$$(m_1 + m_0)\ddot{y}_1 + k_1 y_1 + k_2(y_1 - \quad (4)$$
$$y_2) = m_0 r \omega^2 \cos\omega t \quad (5)$$
$$m_2 \ddot{y}_2 - k_2(y_1 - y_2) = 0 \quad (6)$$
$$-m_0 r \ddot{y}_1 \sin\omega t + m_0 g r \sin\omega t$$
$$= M_\omega$$

By solving the above system, it results two own forms of vibration with the own pulsations p1 and p2 given by the following relation:

$$p_{1,2} = \left[\frac{1}{2}\left(\frac{k_2}{m_2} + \frac{k_1 + k_2}{m_1 + m_0} \right) \pm \frac{1}{2}\sqrt{\left(\frac{k_2}{m_2} + \frac{k_1 + k_2}{m_1 + m_0} \right)^2 - 4\frac{k_1 k_2}{(m_1 + m_0)m_2}} \right] \quad (7)$$

The dislocations y_1, y_2 are of harmonic form with the amplitudes:

$$A_1 = \frac{m_0 r\omega^2 (k_2 - m_2\omega^2)}{D} \quad (8)$$

$$A_2 = \frac{m_0 r\omega^2 k_2}{D} \quad (9)$$

where

$$D = \left[k_1 - (m_1 + m_0)\omega^2\right]\left(k_2 - m_2\omega^2\right) - m_2 k_2 \omega^2 \quad (10)$$

The way in which the amplitudes A_1 and A_2 vary depending on the ω current variable is shown in the graphs in figures 3, 4, 5.

The working hypothesis is established based on experimental determinations performed within ICECON. Thus, the experimental results obtained by direct laboratory determinations are presented in table 1:

Table 1

Eccentric mass positions	**m_1+m_0(kg)**	**m_2(kg)**	**m_0(kg)**	**r(mm)**
Position1	3150	2650	390,6	24,3
Position2	3150	2650	390,6	53,16
Position3	3150	2650	390,6	94,27

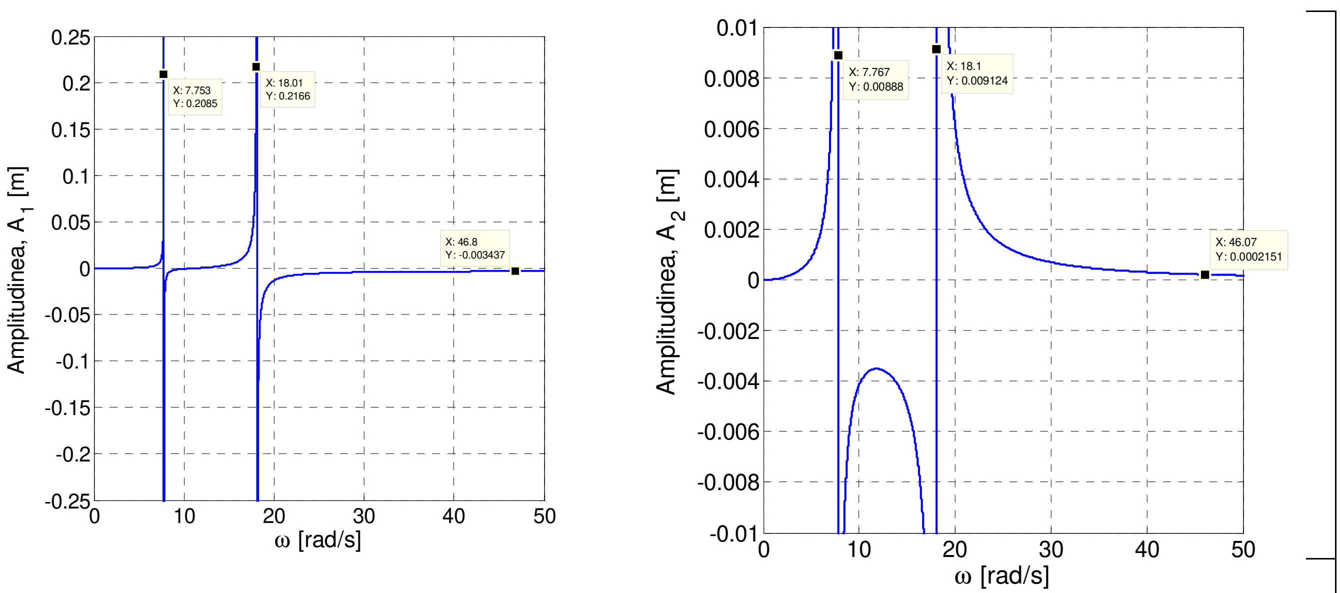

Fig.3. The variation of amplitudes A_1 and A_2 for position 1 of the eccentric masses

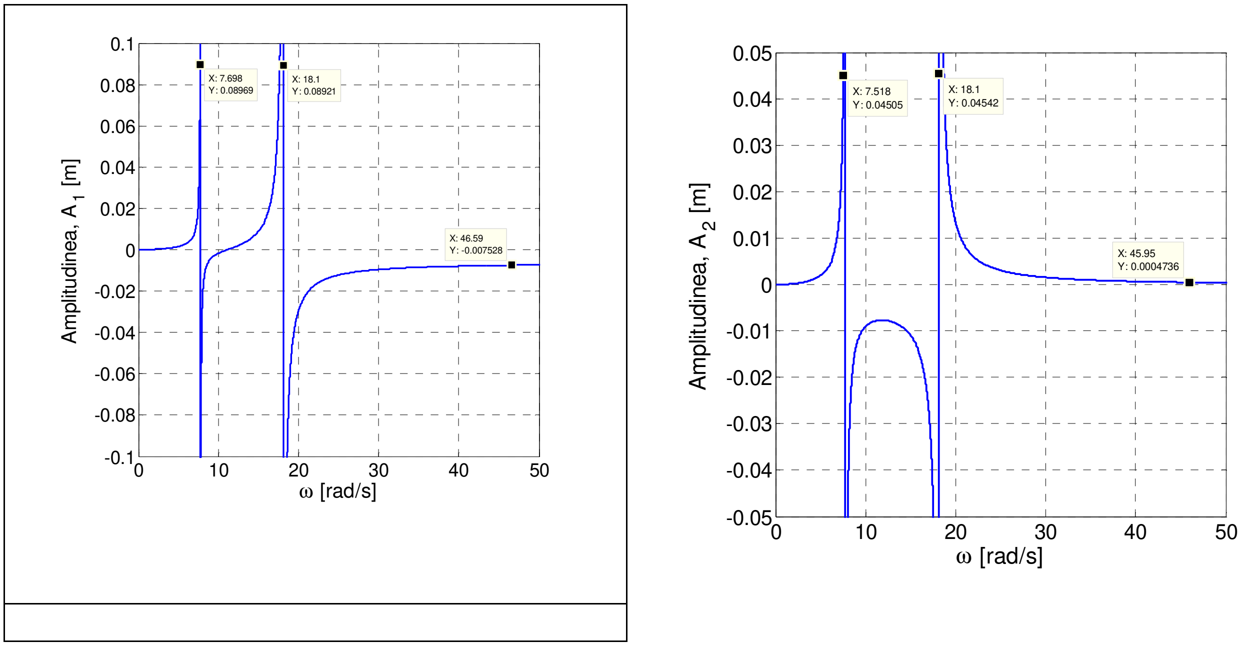

Fig.4. The variation of amplitudes A_1 and A_2 for position 2 of the eccentric masses

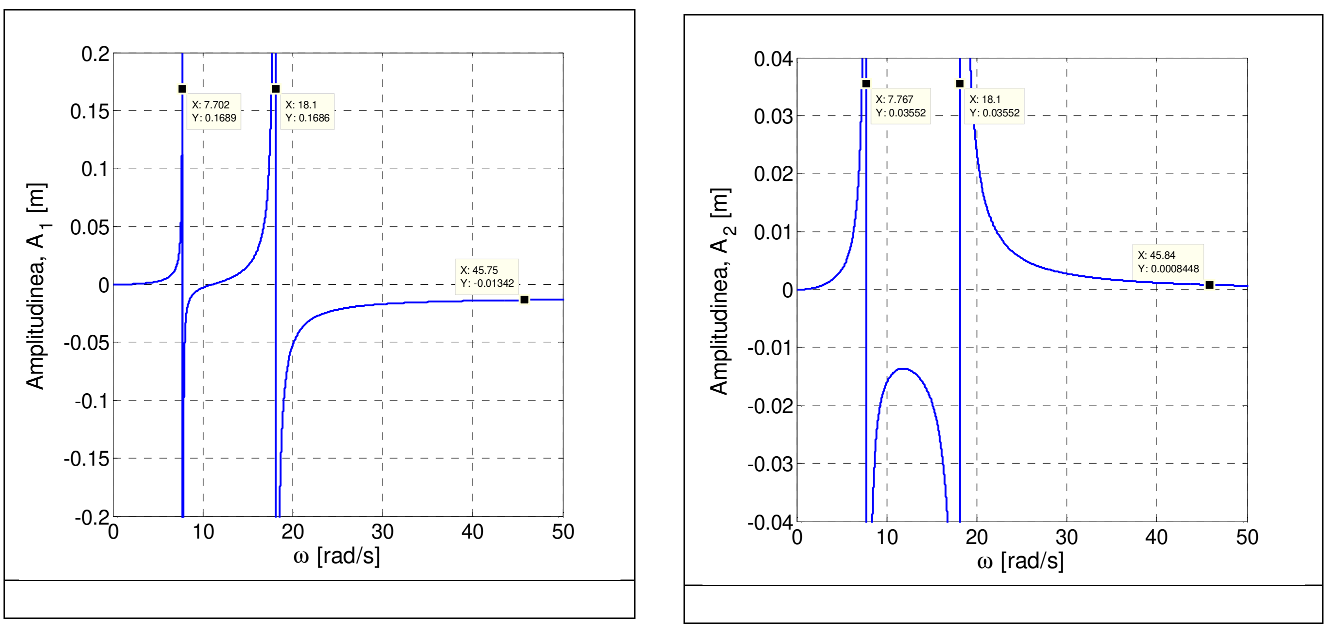

Fig.5. The variation of amplitudes A_1 and A_2 for position 3 of the eccentric masses

4. CONCLUSIONS

Following the dynamic analysis of the model with two degrees of freedom that schematizes the behaviour of the vibrating equipment for inserting piles into the ground, the following conclusions are drawn:

1) the amplitudes of the two masses are represented in the graphs of figures 3, 4 and 5 for three positions of the eccentric masses.
2) the amplitude in the resonance points (p_1 respectively p_2) tends towards very large values, asymptotically. These areas should be avoided so that the system works in a stable regime.

3) for the amplitudes A_1 and A_2 it is found that in steady regime to post-resonance, the amplitude A_1 for the three analysed situations has a constant and stable value, so that the assessment of the technological process can be carried out effectively. The amplitude A_2 (the one of the support platform) tends to zero so that the dynamic isolation of the motor can be ensured in a proportion of 95 %.
4) the experimental results obtained within ICECON confirm that the graphical representation is correct and significant. It can be considered that the model with two degrees of freedom is plausible, consistent and realistically reflects the dynamic behaviour of the system.
5) compared to the above, the presented dynamic analysis can be a preliminary basis for assessing the ability of the vibrating insertion equipment for characteristics of the land in a given location, so that the insertion speed and depth set in the process design stage can be reached.

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ANALIZA PARAMETRICĂ A ECHIPAMENTELOR VIBRATOARE DE ÎNFIGERE A PILOȚILOR ÎN PĂMÂNT

REZUMAT. În lucrare se prezintă modelul dinamic pentru echipamentele de înfigere prin vibrare pentru piloţi şi palplanşe. Pentru aceasta au fost analizate mai multe soluţii constructive, astfel încât modelul dinamic ales să fie reprezentativ. În conseecinţă, lucrarea cuprinde analiza dinamică a răspunsului sistemului la acţiunea forţei perturbatoare generată cu un vibrator inerţial cu patru mase excentrice sincronizate în fază, pentru asigurarea unei acţiuni dinamice unidirecţionale pe verticală. În final se prezintă curbele de variaţie a amplitudinilor maselor în mişcarea vibratorie, cu regimurile optime funcţionale. Modelul dinamic din lucrare a fost utilizat la analiza răspunsului dinamic pentru optimizarea funcțională a vibroînfigătoarelor pe șantierele situate în lungul Dunării pentru consolidarea albiei șenalului navigabil.

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