TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 62, Issue I, March, 2019

ANALYSIS OF THE DYNAMIC REGIME OF FORCED VIBRATIONS IN THE DYNAMIC COMPACTING PROCESS WITH VIBRATING ROLLERS

Cornelia Florentina DOBRESCU

Abstract: *In order to increase efficiency and work speed, in the process of dynamic compaction, mixed compactors are used. The adjustment of the vibrations regime of the compactor roller with the travel speed, is made based on the real-time monitoring of the dynamic response. Thus, the instantaneous movement of the vibrations of the compactor rollers is captured in the form of an analog signal and then converted to digital system until the occurrence of some supra-harmonics specific to the transition of the field into the plastic field.*
This article presents the dynamic scheme of a mixed self-propelled vibratory compactor. Thus, based on the dynamic analysis, it is presented the variation of machine and of technological amplitude with compactor rollers, including the force transmitted in the compaction field.
Key words: *dynamic compaction, mixed self-propelled vibratory compactor*

1. INTRODUCTION

For the dynamic study, there was adopted the construction and functional scheme of a 20t self-propelled mixed compactor and the maximum disturbance force of 800 kN at the frequency of 50 Hz with the amplitude of the 2 mm vibratory roller. The dynamic system can be schematized as a linear-elastic model with three degrees of freedom. The flat roto-translation movement of the chassis with all the equipment has been transformed into inertially coupled translational movements to two equivalent mass concentrations m_2 and m_3 placed above the leaning points of the chassis to the roller, respectively to the axles of the wheels with tires.

Based on the mass data, of rigidity and dynamic excitation, there were determined the calculation relations for amplitude and their representation in relation to the continuous variation of the excitation pulse ω in order to identify the dynamic regimes.

Compaction is a process to increase density of soil bymechanical means, which usually involves rolling, vibrating,tamping or combination of these processes. In this process particles are rearranged by application of external force and air in the voids is expelled out. This external force is applied in the form of rolling, vibrating, tamping or combination of these processes.

In the study of the compaction process the following three categories of variables have to be considered: - parameters regarding the compacted material: initial density, granularity, material humidity etc.; machine parameters: the mass of the machine, the frequency and the amplitude of the vibrations that are generated and transmitted to the compacted material; compaction method (machine type, number of passes, speed of the vibratory compactor etc.).

2. DYNAMIC ANALYSIS

The construction solution (image 1) shows that the vibratory roller 1 is elastically bonded with rubber pads 2 to the chassis of the machine 3 so that the vibrations transmitted to the cab 4 be reduced to the permissible limit. Tire wheels

5 are located behind the machine serving only for traction.

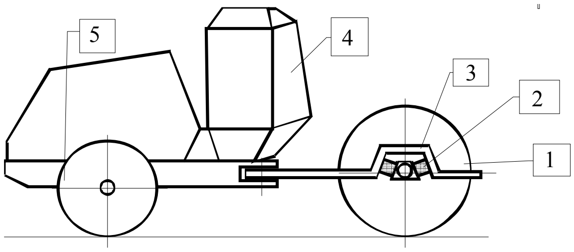

Fig. 1. Constructive scheme

The dynamic scheme shapes the dynamic behavior of the compactor by mass elements m_1 for the vibratory roller; m, J for the chassis of the machine with all the equipment (motor-pump group, cab, accessories) and m_p for the pair of tire wheels, as well as for the k_1 and k_3 rigidities for the land subject to compaction and k_2 for the elastic system of isolation of the vibration transmitted from the roll to the chassis.

Figure 2 shows the dynamic model of the self-propelled mixed compactor with one vibratory roller, with the following notations:

- x_1 (A_1) is the instantaneous movement (elongation) of the technological vibration of the vibratory roller and A_1 is the amplitude of the vibrations;
- x_2 (A_2) - the instantaneous movement (elongation) of the vibrations transmitted to the chassis at the connection point A, and A_2 is the amplitude;
- x_3 (A_3) - the instantaneous movement (elongation) of the vibrations transmitted to the chassis in the connection point B, which is located on the axis of the tire wheel pairs;
- $P = P(t) = m_0 r\omega^2$ - the vertical disruptive force of the vibrator placed inside the roller, and $m_0 r$ is the static momentum of the dynamic unbalance masses, ω is the pulse of the disruptive force;
- C - the mass center of the chassis assembly fully equipped with a hydraulic pumping group, thermal engine, control cabin, accessories;
- a, b the distances between mass center C and points A and respectively B.

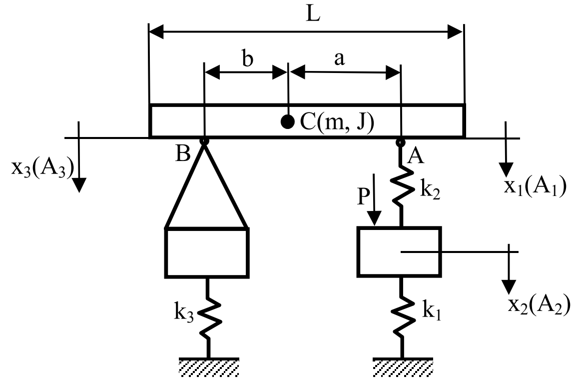

Fig. 2. Scheme of the dynamic model

The differential movement equations for the model in image 2, in the linear-elastic domain, may be written as:

$$\begin{cases} m_1\ddot{x}_1 + (k_1 + k_2)x_1 - k_2 x_2 = m_0 r\omega^2 \sin\omega t \\ m_2\ddot{x}_2 + m_{23}\ddot{x}_3 - k_2 x_1 + k_2 x_2 = 0 \\ m_3\ddot{x}_3 + m_{23}\ddot{x}_2 + k_3 x_3 = 0 \end{cases} \qquad (1)$$

The reduced masses m_2, m_3 and m_{23}, conformed only to the vertical translational instantaneous displacements corresponding to "material points" with displacements x_1, x_2 and x_3 are given by the relations:

$$\begin{cases} m_2 = \dfrac{1}{l^2}\left(mb^2 + J\right) \\ m_3 = \dfrac{1}{l^2}\left(ma^2 + J\right) + m_p \\ m_{23} = \dfrac{1}{l^2}\left(mab - J\right) \end{cases} \qquad (2)$$

where $l = a+b$

The function of own pulse for the linear-elastic system with three degrees of freedom is as

$$D(\omega) = a_6\,\omega^6 + a_4\,\omega^4 + a_2\,\omega^2 + a_0 \qquad (3)$$

whose coefficients a_{2j}, j =0, 1, 2, 3 are

$$a_0 = k_1\, k_2\, k_3$$
$$a_2 = k_2\,(k_2\, m_3 - k_3\, m_1) - (k_1 + k_2)\,(k_3\, m_2 + k_2\, m_3)$$
$$a_4 = (k_1 + k_2)\,(m_2\, m_3 - m^2_{23}) + (k_2\, m_3 + k_3\, m_2)m_1$$
$$a_6 = m_1\,(m^2_{23} - m_2\, m_3) \qquad (4)$$

The amplitudes of the vibrations for system (1) emerge as follows:

$$A_1 = \frac{m_0 r\omega^2}{D(\omega)}\left[\left(k_2 - m_2\omega^2\right)\left(k_3 - m_3\omega^2\right) - m_{23}^2\omega^4\right] \qquad (5)$$

$$A_2 = \frac{m_0 r\omega^2}{D(\omega)}\left(k_3 - m_3\omega^2\right)k_2 \qquad (6)$$

$$A_3 = \frac{m_0 r\omega^2}{D(\omega)} k_2 m_{23} \qquad (7)$$

3. PARAMETRIC ANALYSIS

For the dynamic scheme in Figure 2, the parametric constructive (mass and dimensional) values as well as the values of the rigidities for the soil and the elastic dynamic isolation step were determined.

Thus, for the constructive model in Figure 1, we have the following parameters:

$m_0\, r = 8$ kg.m
$a = 2{,}4$ m
$b = 1{,}1$ m
$k_1 = 5 \cdot 10^7$ N/m
$k_2 = 10^6$ N/m
$k_3 = 1{,}5 \cdot 10^7$ N/m
$m_1 = 4000$ Kg
$m = 14000$ Kg
$m_p = 2000$ Kg
$J_c = J = 16200$ Kg m^2

On the basis of the previous data, there were established the values of the masses in vibratory movement, as follows:

$m_1 = 4000$ Kg
$m_2 = 2700$ Kg
$m_3 = 9900$ Kg
$m_{23} = 1690$ Kg

In order to assess the efficiency of the vibrations transmitted in the soil to be compacted, the maximum force transmitted in the field shall be established $Q_{max} = k_1 A_1$, and the $T_{12} = k(|A_2| - |A_1|)/(m_0\, r\, \omega^2)$ transmissibility for the degree of isolation of vibrations.

Based on the initial data and the calculated values, the variation curves of parameters A_1, A_2, A_3, Q_{max}, T_{12}, may be represented as in Images 3…7.

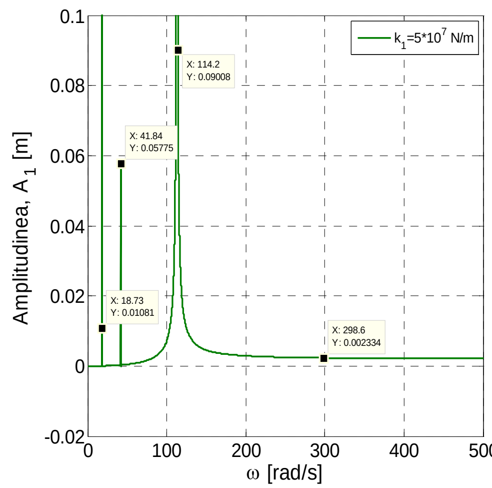

Fig. 3. Variation of amplitude A_1 according to pulse ω

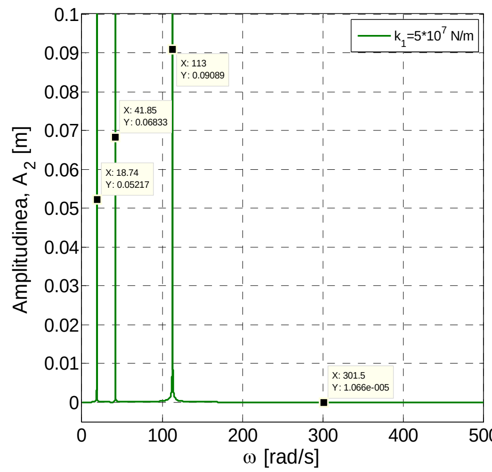

Fig. 4. Variation of amplitude A_2 according to pulse ω

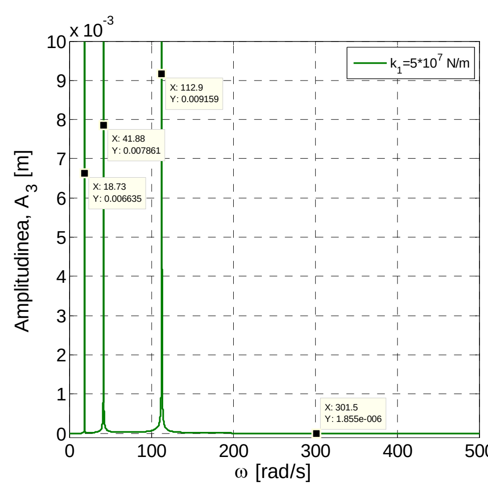

Fig. 5. Variation of amplitude A_3 according to pulse ω

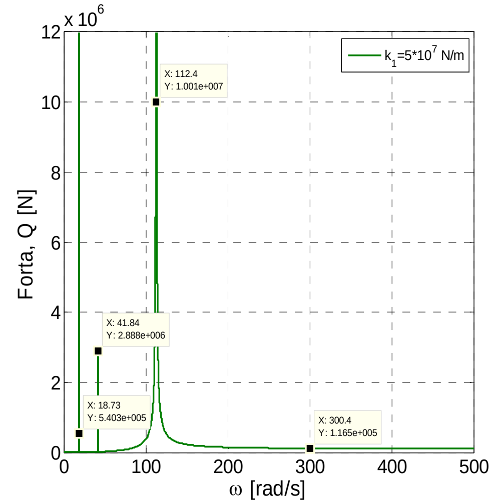

Fig. 6. Variation of maximum compaction force Q_{max} according to pulse ω

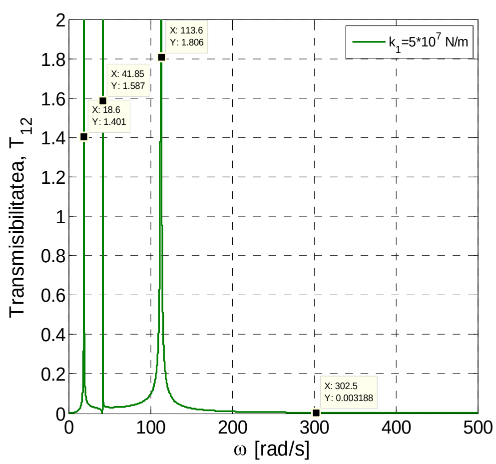

Fig. 7. Variation transmissibility of vibration T_{12} with pulse ω

It is found that the system has three critical zones at resonance, and in the post-resonance amplitude A_1 of the technological vibrations is maintained constant and stable. Amplitudes A_1 in the resonance areas have high values with negative effects on the cab comfort and the durability of the motor-pump group.

In post-resonance, they have low values which make the degree of isolation high.

4. CONCLUSIONS

The compaction of natural and stabilized soil with mixed self-propelled compacting (vibrating roller and tire wheels) can be achieved through an effective approach to real-time monitoring of the compaction process. Thus, in a first stage, the initiation parametric sizes of the technological compaction process must be evaluated. For this purpose, there are necessary the values of the vibratory roller amplitude are required in various dynamic regimes, delimited by intervals of the disturbing pulse variation with avoidance of the critical resonance areas.

This stage is the feasible variant preceding the adjustments required for "real-time control" of the dynamic compacting process.

In essence, the following conclusions are drawn from this study:

a) the dynamic calculation model can be used to initiate and complete the initial dynamic analysis data;

b) the mass, rigidity and dimensional parameters are in direct correlation with the functional regime of the vibratory compactor;

c) the Dynamic response performance can be assessed based on the calculation relations given in the work which have been verified and validated on a large number of machines and categories of land;

d) the dynamic compaction efficiency can be determined by assessing the maximum force transmitted to the compaction field;

e) the curve families are plotted on the basis of the discrete variation of the rigidity of soil, which after each pass the plastic-field pressing up is made until completion;

f) the land rigidity values, consisting of poorly cohesive soils or sandy clay soils stabilized with ecological substances, are experimentally determined on bathes and specially designed test polygons.

In essence, the data contained in this paper provides the possibility of a dynamic analysis of the vibratory roll-compacting soil system. Thus, in the initial phase it is possible to complete the compaction technology by vibration of oil, in "total monitoring" regime with decisions imposed by parametric values thresholds.

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ANALIZA REGIMULUI DINAMIC AL VIBRATIILOR FORTATE IN PROCESUL DE COMPACTARE DINAMICĂ CU RULOURI VIBRATOARE

Rezumat: *Pentru a crește eficiența și viteza de lucru, în procesul compactării dinamice se utilizează compactoare mixte. Reglarea regimului de vibrații al tamburului compactorului, cu viteza de deplasare, se face pe baza monitorizării în timp real a răspunsului dinamic. Astfel, mișcarea instantanee a vibrațiilor tamburului compactorului este captată sub forma unui semnal analogic și apoi convertită în sistemul digital până la apariția unor supra-armonici specifice tranziției în domeniul plastic. Acest articol prezintă schema dinamică a unui compactor mixt cu vibrații autopropulsate. Astfel, pe baza analizei dinamice, se prezintă variația mașinii și a amplitudinii tehnologice cu rolele de compactor, inclusiv forța transmisă în suprafața de compactare.*

Cornelia Florentina DOBRESCU, Senior researcher, PhD. Eng, National Institute for Research and Development in Construction, Urban Planning and Sustainable Spatial Development, Bucharest Branch, 266 Pantelimon Street, Bucharest, Romania, cornelia.dobrescu@incd.ro, corneliadobrescu@yahoo.com, +4021 255.73.14