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EXPERIMENTAL DETERMINATION OF THE VIBRATIONS OF A PLATE COMPACTOR

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Abstract: *The work principle of plate compactors is based on the effect of vibrations. The useful vibrations provided by compaction process are harmful for the human operator. The author has developed a series of mathematical models for the study of plate compactors performance. Based on these models, the author carried out a series of studies regarding the influence of some parameters on the functioning of tamping plates. The mathematical models were validated through measurements performed on a machine. In this paper are presented some of the results obtained experimentally.* ***Key words:*** *plate compactors, vibrations*

1. INTRODUCTION

The plate compactors are equipments used to compact the soil, broken stones (non-cohesive materials), concrete or asphalt coatings, as well as residuum at the ecological ramps.

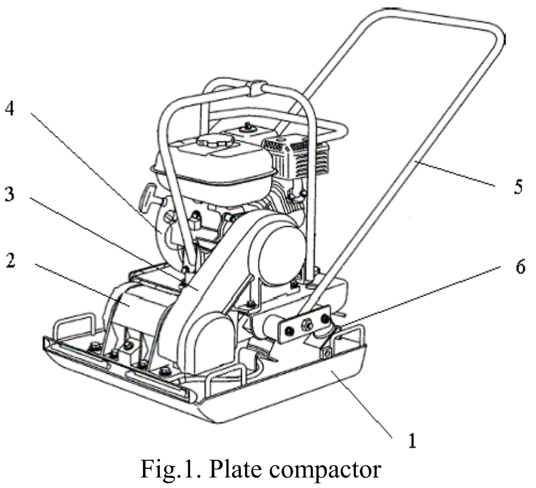

Fig.1. Plate compactor

From constructive point of view the plate compactor (Figure 1) consists of: base plate (1), vibrations generator (2) (fitted on the base plate) driven by a combustion engine (4) by means of V-belt gearing (3), the equipment being oriented by a handle (5).

The plate compactors use a mechanism (driven by motor oil or a diesel one) which creates a descending force added to the equipment's static weight. One or two eccentrically weights turning around usually form the vibrating generator. The resulted vibrations generate the equipment's advancing movement.

In order to get compaction it is necessary to reach a certain mode of operation mainly characterized by the frequency and amplitude of vibrations due by the vibration generator.

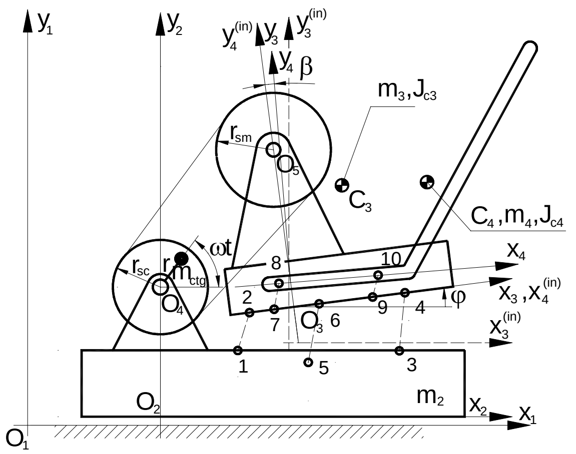

Fig. 2. Mechanical model

2. MATHEMATICAL MODEL

The mechanical model analyzed inside this work is composed of three masses (plate, frame, and handle) linked by means of rubber anti-vibrating elements. (Fig. 2)

On the basis of the mechanical model a mathematical model it was developed composed of seven non-linear differential equations corresponding to the movements performed by each component part of the mechanical system, as follows:

- an equation corresponding to the plate's movement on horizontal direction;
- three equations corresponding to the frame's horizontal, vertical and rotating movements;
- three equations corresponding to the handle's linear movements on horizontal and vertical direction, and its angular movement

Into the mechanical system the followings were considered as generalized coordinates:

- x_{O2_1} – displacement on the horizontal direction of the origin of the system referring to the vibrating plate;
- x_{O3_1}, respectively y_{O3_1} – displacements on the horizontal direction, and the vertical one respectively, of the O_3 origin of the mobile system referring to the frame;
- φ – turning angle of the frame (in trigonometrically sense) due to the horizontal line;
- x_{O4_1}, respectively y_{O4_1} - displacements on the horizontal direction, and the vertical one respectively, of the O_4 origin of the mobile system referring to the handle;
- β - turning angle of the handle (counterclockwise) due to the horizontal direction, which will be the unknown factors whose values will be found by means of system of differential equations.

Significance of the quantities in the mathematical system is as follows: m_0 – eccentric mass; m_2 – plate mass; m_3 – mass of the frame and motor; m_4 – handle mass; k_1, k_3 – stiffness's; k_2 – axial factor of rigidity; x_{A_B}, respectively y_{A_B} – distances on the axis O_1x_1, respectively O_1y_1 between points A and B.

The equations corresponding to the mathematical model are [1][8]:

$$\frac{d^2x_{O2\_1}}{dt^2}=\frac{1}{m_2+m_0}\left[m_0 r\,\omega^2\cos\omega t-\mu N\,sign\left(\frac{dx_{O2\_1}}{dt}\right)+x_{2\_1}\cdot k_1++x_{4\_3}\cdot k_1+T\cos\psi\right] \tag{1}$$

$$m_3\left[\frac{d^2x_{O3\_1}}{dt^2}+\left(-x_{C3\_3}\sin\varphi-y_{C3\_3}\cos\varphi\right)\frac{d^2\varphi}{dt^2}+\left(-x_{C3\_3}\cos\varphi+y_{C3\_3}\sin\varphi\right)\left(\frac{d\varphi}{dt}\right)^2\right]= \\ =-x_{2\_1}\cdot k_1-x_{4\_3}\cdot k_1-T\cos\psi-x_{8\_7}\cdot k_3-x_{10\_9}\cdot k_3 \tag{2}$$

$$m_3\left[\frac{d^2y_{O3\_1}}{dt^2}+\left(x_{C3\_3}\cos\varphi-y_{C3\_3}\sin\varphi\right)\frac{d^2\varphi}{dt^2}+\left(-x_{C3\_3}\sin\varphi-y_{C3\_3}\cos\varphi\right)\left(\frac{d\varphi}{dt}\right)^2\right]= \\ =-y_{2\_1}\cdot k_1-y_{4\_3}\cdot k_1-T\sin\psi-m_3\,g+y_{6\_5}\cdot k_2-y_{8\_7}\cdot k_3-y_{10\_9}\cdot k_3 \tag{3}$$

$$J_{C3}\frac{d^2\varphi}{dt^2}=\left(-x_{2\_C3}\cdot y_{2\_1}+y_{2\_C3}\cdot x_{2\_1}\right)k_1+\left(-x_{4\_C3}\cdot y_{4\_3}+y_{4\_C3}\cdot x_{4\_3}\right)k_1+\ldots+ \\ +\left(-x_{8\_C3}\cdot y_{8\_7}+y_{8\_C3}\cdot x_{8\_7}\right)k_3+\left(-x_{10\_C3}\cdot y_{L10\_9}+y_{10\_C3}\cdot x_{10\_9}\right)k_3 \tag{4}$$

$$m_4\left[\frac{d^2x_{O4\_1}}{dt^2}+\left(-x_{C4\_4}\sin\beta-y_{C4\_4}\cos\beta\right)\frac{d^2\beta}{dt^2}+\left(-x_{C4\_4}\cos\beta+y_{C4\_4}\sin\beta\right)\left(\frac{d\beta}{dt}\right)^2\right]= \tag{5}$$

$$=x_{8\_7}\cdot\cdot k_3+x_{10\_9}\cdot k_3$$

$$m_4\left[\frac{d^2y_{O4\_1}}{dt^2}+\left(x_{C4\_4}\cos\beta-y_{C4\_4}\sin\beta\right)\frac{d^2\beta}{dt^2}+\left(-x_{C4\_4}\sin\beta-y_{C4\_4}\cos\beta\right)\left(\frac{d\beta}{dt}\right)^2\right]= \tag{6}$$

$$=+y_{8\_7}\cdot k_3+y_{10\_9}k_3-m_4\,g$$

$$J_{C4}\,\frac{d^2\beta}{dt^2}=\left[+x_{7\_C4}\cdot y_{8\_7}-y_{7\_C4}\cdot x_{8\_7}\right]k_3+\left[+x_{9\_C4}\cdot y_{10\_9}-y_{9\_C4}\cdot x_{10\_9}\right]k_3 \tag{7}$$

3. THEORETICAL CONSIDERATIONS

The vibrations provided by the vibrating machines and transmitted the human operator can be perceived at the level of some parts of the body but they can affect the entire organism of the human operator. The vibrations produced by the tamping rammers and plate compactors are transmitted to the human operator's hands.

The harmful effects of vibrations on human operator can be summarized as follows:

- the excitation of the nervous system and hormonal activity which results in the alteration of some metabolic processes;
- the emergence of tactile perceptiveness disorders, painful or thermal;
- the emergence of fatigue and sleepiness conditions which can affect the intellectual performances and visual acuity;
- the emergence of emotional conditions of fear and anxiety;
- the emergence of vascular disorders accompanied by excessive cooling of the extremities which come into contact with vibrating parts of machinery;
- osteoarticular and muscle lesions.

Taking into account the effect of vibrations on human operator and on his work capacity, there were established some permissible exposure limits in which the human body is not affected by the harmful vibrations.

Due to the fact that during the usage of construction equipments the physico-pathological effects and subjective human-caused doesn’t have always a decisive influence on the operator health, made possible the graphical representation of exposure limits curves (harmfulness threshold or health hazard).

4. EXPERIMENTAL STUDY

The study was conducted for the case of a compacting plate having the following characteristics (figure 3): the mass of the bed plate: m_1 = 70 [kg], the total mass of the frame and driving engine: m_2 = 55 [kg], the mass of the eccentric: m_0 = 3,465 [kg], the eccentricity r = 0,0134 [m], the elasticity constant k_1 = 58110*2 [N/m] and k_2 = 608250 [N/m], the friction coefficient between the base plate and ground is: μ = 0,35.

Fig. 3. The plate compactor

On the designed and built equipment were made a series of measurements of vibration on the vertical direction, the results being illustrated by means of table 1.

Table 1.

The measured values of the vibrations at the level of machine components

Component	Unit	No	Average value	Minimum value	Maximum value
Vibrating plate	mm	1	1.245	0.895	2.114
	mm	2	3.090	2.661	3.802
	mm	3	2.156	1.784	2.896
	mm/s	1	0.462	0.398	0.569
	mm/s	2	6.383	5.309	7.413
	mm/s	3	2.382	1.984	3.015
	m/s^2	1	0.266	0.219	0.569
	m/s^2	2	1.640	0.040	2.260
	m/s^2	3	0.995	0.568	2.713
Frame	mm	1	1.122	0.944	1.318
	mm	2	1.648	1.115	2.043
	mm	3	1.236	0.985	1.656
	mm/s	1	0.672	0.491	0.983
	mm/s	2	1.950	1.585	2.265
	mm/s	3	1.096	0.871	1.274
	m/s^2	1	0.379	0.221	0.313
	m/s^2	2	0.343	0.251	0.407
	m/s^2	3	0.214	0.180	0.243
Handle	m/s^2	1	0.151	0.114	0.200
	m/s^2	2	0.305	0.257	0.359
	m/s^2	3	0.100	0.086	0.111

The measurements were performed on a track of land characterized by a 90% compaction degree, with maximum speed and the vibrator at full speed.

By analyzing the experimental data, it results that the equipment falls into the cycle of operation with an exposure time of four hours.

Fig. 4. The measurement of vibration at the level of plate compactor's components

The antivibration rubber elements allow vibration reduction delivered to the frame (and to the motor drive) but also to the human operator.

The values for the elastic constants corresponding to antivibration rubber elements, for the first stage (of the plate and frame) as well as for the second (of the frame and handle) were obtained using some software applications developed by the main author, application that also allows the analysis of the equipment behavior and the calculus of handle vibrations.

The constructive variant of handle finally selected (the one with rubber nozzles), allows the substantial reduction of the vibration transmitted to operator's hands.

In the figure 4 it was immortalized a moment during the measurements on components of the equipment.

In figure 5 and 7 are represented the variation in time of plate's acceleration, respectively spectral representation of the obtained signal.

Similar representations were obtained during all the measurements for the frame as well, (see figures 6 and 8).

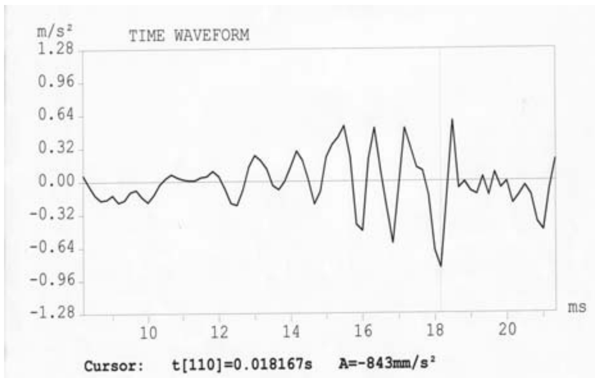

Fig. 5. The time variation of plate's acceleration

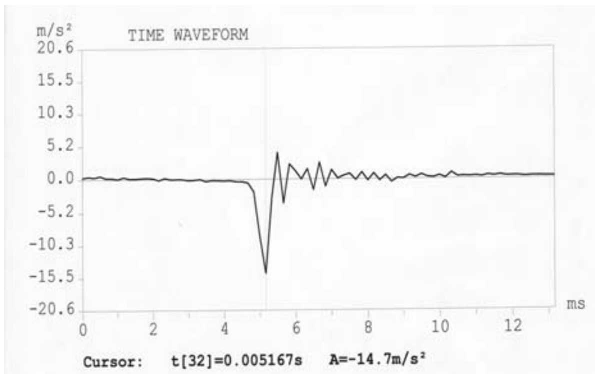

Fig. 6. The time variation of frame's acceleration

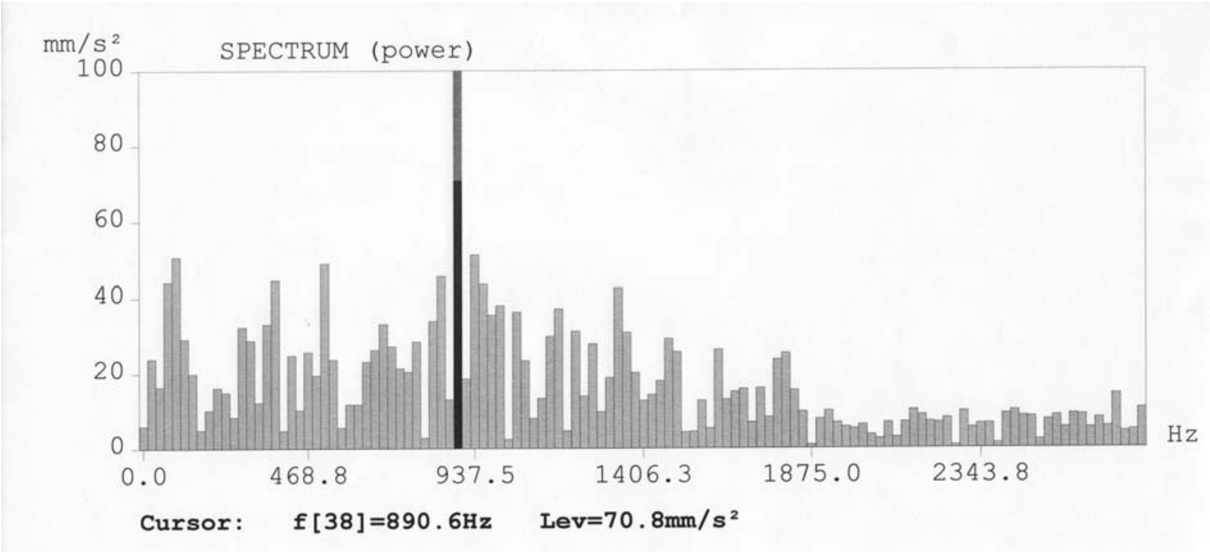

Fig. 7. Spectral representation of the signal obtained for the plate

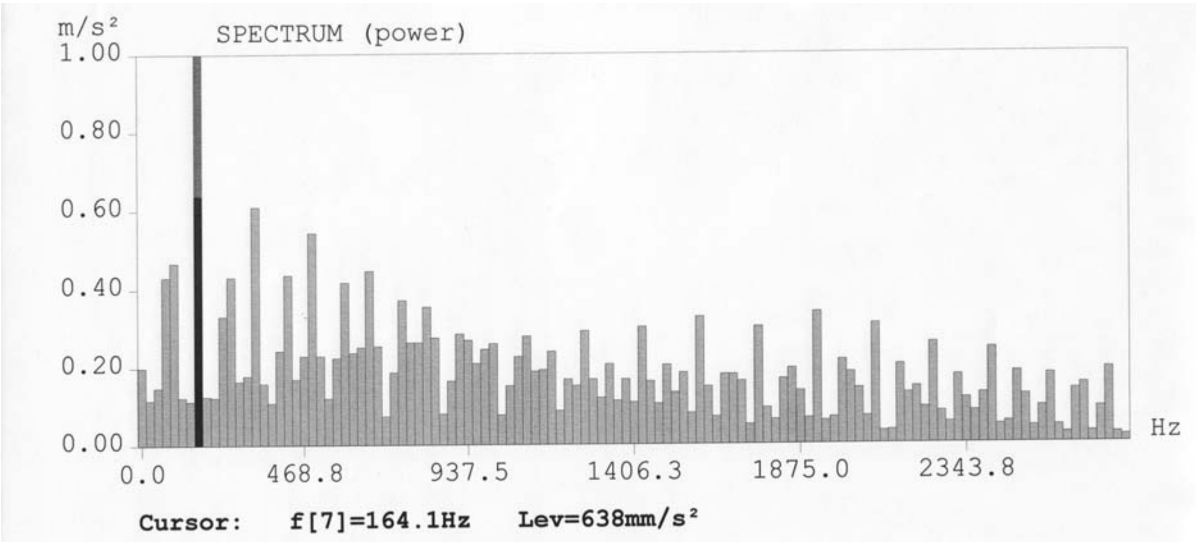

Fig. 8. Spectral representation of the signal in case of the frame

5. CONCLUSIONS

The author has developed a mathematical model for studying the vibrations of plate compactors (including the handle).

Based on theoretical analysis it was found that the vibrations measured for the handle are beyond admissible limits, so the handle's vibration absorbers were replaced, action that have as effect the diminishing of vibration of the handle.

For the validation of the mathematical model, were performed a series of vibration measurements, the results being presented in this paper.

Data analysis shows that the equipment falls into the cycle of operation with duration of exposure of four hours.

The vibrations transmitted to the frame as well as to the human operator are relatively small and fits within the allowable limits.

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DETERMINAREA EXPERIMENTALA A VIBRAȚIILOR UNEI PLĂCI COMPACTOARE

Rezumat: Principiul de lucru al plăcilor compactoare se bazează pe utilizarea vibrațiilor. Vibrațiile utile procesului de compactare sunt dăunătoare operatorului uman. Autorul a dezvoltat o serie de modele matematice pentru studiul funcționării plăcilor compactoare. Cu ajutorul acestor modele s-au realizat o serie de studii privind influența unor parametri asupra funcționării plăcilor compactoare. Validarea modelelor matematice s-a realizat prin măsurători efectuate asupra unui utilaj. În lucrare sunt prezentate o parte din rezultatele obținute experimental.

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