11th International Research/Expert Conference
"Trends in the Development of Machinery and Associated Technology"
TMT 2007, Hammamet, Tunisia, 05-09 September, 2007.

ANALYSIS OF INVERTER-ELECTROMAGNETIC VIBRATOR SYSTEM USED IN VIBROCOMPACTING TECHNOLOGY

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ABSTRACT
Vibrocompacting method is technology through the agency of this realize intractable pieces, abrasive pieces, a sintering powder and represent advantages: in vibration field, powders flow much easy, action who permit foundering of pieces with complex configuration, also friction forces between powder and stamping wall are removed.
Following aspects emphasized in case of this application: interested parameters are frequency and amplitude, single restriction assessed vibration force is periodic nature of this force.
Authors are orientated toward a system composed from electromagnetic vibrator, driving by inverter with variable frequency. Because is non-interested problem of harmonic response, for this application vibrator is supplied by inverter with a voltage single modulated.
Keywords: inverter, vibrator, vibrocompacting

1. INTRODUCTION
Vibrocompacting method is a non conventional technology used for realizes sintering pieces, fuses, power resistors or to warm double of pipe filled with sand. In the situation of equipment by vibrocompacting used for any applications, execution element, an electromagnetic vibrator, must power supplied with a voltage with variable frequency and amplitude, for may determine optimal parameters for vibration. Because inverter load is non linear, for the inverter is a problem for generation the shape of power supply voltage. Possible solutions are supply with no modulate voltage or with voltages generated by PWM techniques (pulse width modulation).

2. EXPRESION OF CURRENT THROUGH MOBILE COIL
Used equipment by the authors for vibrocompacting applications, have in constitution one electromagnetic vibrator with tact, one inverter supplied with simple modulated voltage and a device for measuring vibration amplitude and frequency.
In this technology the interesting problems are systems energetic parameters, the authors are orientated to inverter who generating a voltage simple modulated, which have advantage of a better voltage efficaciousness.
Towards difference by other applications of electromagnetic vibrators, in this case it isn't possible to consider invariable alternative current coil, because increase report between maxim amplitude of vibration x and work air l_0:

This work was supported by Romanian Ministry of Education and Research, the CEEX project 153/2006

$$x \le x / l_0 \le 0{,}4\,, \tag{1}$$

Must underlined for this application, vibration frequency is twice frequency of power supply voltage, developed force is proportional with square of current through mobile coil, and continuous component of this is compensated by elastic system or through magnetic systems.

For determination of current through mobile coil, we consider vibrator running with momentary movement of mobile furniture describable by function harmonic in time, from throb double by throb of power supply voltage u_a. Hypothesis [1], is in concordance with reality because the system electromagnetic vibrator - mechanic receiver, have for vibrocompacting a high mechanic rigidity factor and is involved selective by the harmonics of active force which actuate about mobile furniture. By approximating the movement with one sinusoidal is in connection with condition that oscillating system remains almost conserving [1].

Expression of electromagnetic vibrator mobile coil inductivity is:

$$L_a = \frac{N_a^2 \cdot \mu_0 \cdot A}{l_0} \cdot \frac{L_0}{1 - x/l_0} = \frac{L_0}{1 - x/l_0} = \frac{L_0}{1 - \varepsilon \cdot \sin(2 \cdot \omega \cdot t)}\,, \tag{2}$$

where: L_a is inductivity of mobile coil, μ_0 - blank permittivity, N_a – coiling number of mobile coil, A – magnetic pole area, l_0 – air gape length, x – mobile furniture displacement, ω – power supply voltage throb, ε – ratio of amplitude *x* of vibration and air gape spell length.

Experimental results show that in vibrocompacting process [2], grade of vibrocompacting increase together with frequency and for each frequency, correspond a optimal period of vibration, which up to 100 Hz is under 5 seconds, increasing up to 40 seconds at 800 Hz. High inductivity value, specific for reactive electromagnetic and high values of load currents, make possible in this situation, neglect alternative current coil resistance bearing with reactance. Starting by zero initial conditions, from balance equation of voltages, it is obtained extreme values i_0 and i_1 of load current in first alternation:

$$i_0 = \frac{U_0}{L_0} \cdot \frac{\pi}{\omega}, i_1 = 0, \tag{3}$$

And expression of load current is:

$$i_a(\omega \cdot t) = \frac{U_0}{L_0}\left(\frac{\omega \cdot t - (n-1) \cdot 2\pi}{\omega} + \varepsilon \cdot \frac{\cos 2 \cdot \omega t - 1}{2 \cdot \omega}\right),\ 2(n\text{-}1)\pi \le \omega t \le 2n\pi, \tag{4}$$

$$i_a(\omega \cdot t) = \frac{U_0}{L_0}\left(\frac{\omega \cdot t - n \cdot 2\pi}{\omega} + \varepsilon \cdot \frac{\cos 2 \cdot \omega t - 1}{2 \cdot \omega}\right),\ (2n\text{-}1)\pi \le \omega t \le 2n\pi, \tag{5}$$

For alternation *n* identically with he how from first alternation is showed in figure 1, for different values of the coefficient ε.

Current shape is quasi triangular, deviation from this shape it is determinate by work frequency and value of ratio *ε* between maxim amplitude of vibration and value of work air gape l_0 .

Function definite from relations (4) and (5), allow development in Fourier series with following coefficients:

$$A_0 = \frac{\pi}{2} \cdot \frac{U_0}{\omega \cdot L_0}\,, \tag{6}$$

$$\sqrt{2} \cdot B_k = \frac{1}{\pi} \frac{2 \cdot U_0 \cdot \varepsilon}{\omega \cdot L_0} \cdot \frac{k^2 + 2}{k(k^2 + 4)}(\cos k \cdot \pi - 1), \tag{7}$$

$$\sqrt{2} \cdot C_k = \frac{1}{\pi} \frac{2 \cdot U_0}{\omega \cdot L_0} \cdot \frac{1}{k^2}(\cos k \cdot \pi - 1), \tag{8}$$

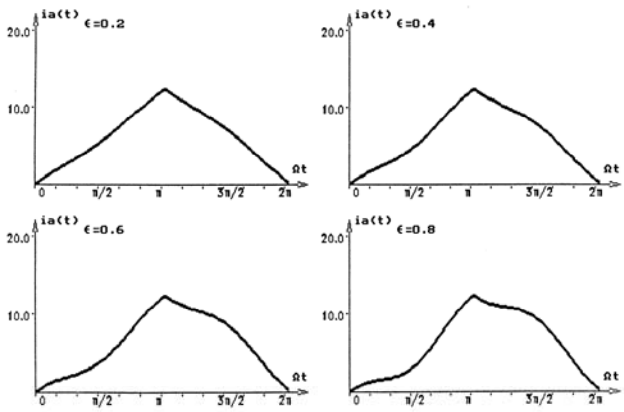

Figure 1. Shape of load current i_a for reactive vibrators.

$$A_k = \frac{1}{\pi} \frac{\sqrt{2} \cdot U_0}{\omega \cdot L_0} \cdot \frac{\cos k\pi - 1}{k} \cdot \sqrt{\varepsilon^2 \cdot \frac{k^2 + 2}{k^2 + 4} + \frac{1}{k^2}}\ , \tag{9}$$

The expression of load current is:

$$i_a(\omega t) = \frac{\pi}{2} \cdot \frac{U_0}{\omega \cdot L_0} - \frac{1}{\pi} \cdot \frac{4 \cdot U_0}{\omega \cdot L_0} \sum_{k=1}^{\infty} \left(\frac{1}{k}\sqrt{\varepsilon^2 \cdot \frac{k^2 + 2}{k^2 + 4} + \frac{1}{k^2}}\ \sin(k \cdot \omega t + \gamma_k)\right), \tag{10}$$

Include continuous component and odd harmonics, and initial phase of *k* harmonic is:

$$\gamma_k = arctg \frac{k^2 + 4}{\varepsilon \cdot k(k^2 + 2)} \cdot, \tag{11}$$

Effect to modulate inductivity L_0 demonstrate through existing component B_k for odd harmonics, and sub-unit values of ε coefficient permit simplify of the relation (10):

$$i_a(\omega t) = \frac{\pi}{2} \cdot \frac{U_0}{\omega \cdot L_0} - \frac{1}{\pi} \cdot \frac{4 \cdot U_0}{\omega \cdot L_0} \left(\sqrt{\frac{3}{5}\varepsilon^2 + 1}\ \sin(\omega t + \gamma_1) + \sum_{k=2}^{\infty} \frac{1}{k^2} \cdot \cos k\omega t\right), \tag{12}$$

For $k \geq 2$, initial phase γ_k is approximated with $\gamma/2$.

3. ENERGETIC EXPRESSIONS

RMS Value of voltage u_a, is giving by relation [3]:

$$U_{aef} = U_0 \cdot \sqrt{1 - \frac{\alpha}{\pi}}\ , \tag{13}$$

where modulation angle ά is zero in case of vibrocompacting. RMS value of load current is obtained by relations (4) and (5):

$$i_{aef} = \frac{U_0}{\omega \cdot L} \cdot \sqrt{\frac{\pi^2}{3} + \frac{\varepsilon^2}{4}}\ , \tag{14}$$

Active power is calculated with known relation [4]:

$$P = U_0 \cdot I_0 + \sum_{k=1}^{\infty} U_k \cdot I_k \cdot \cos \gamma_k\ , \tag{15}$$

After successive conversions result is:

$$P = \frac{1}{\pi^2} \cdot \frac{8 \cdot U_0^2}{\omega \cdot L_0} \cdot \sum_{k=1}^{\infty} \frac{1}{k^2} \cdot \sqrt{\varepsilon^2 \cdot \frac{k^2+2}{k^2+4} + \frac{1}{k^2}} \cdot \cos\varphi_k , \tag{16}$$

Or with approximation from relation (12):

$$P = \frac{1}{\pi^2} \cdot \frac{8 \cdot U_0^2}{\omega \cdot L_0} \sqrt{\frac{3}{5}\varepsilon \quad +1}. \tag{17}$$

Total power, from relation (13) and (14), is:

$$S = \frac{U_0^2}{\omega \cdot L_0} \sqrt{\frac{\pi^2}{3} + \frac{\varepsilon^2}{4}}, \tag{18}$$

Expression of power factor is:

$$\cos\varphi = \frac{16}{\pi^2} \cdot \sqrt{\frac{3}{5}} \cdot \sqrt{\frac{3 \cdot \varepsilon^2 + 5}{3 \cdot \varepsilon^2 + 4 \cdot \pi^2}} . \tag{19}$$

Variation of power factor cosφ, varying with modulating grade of inductivity is showed in figure 2.

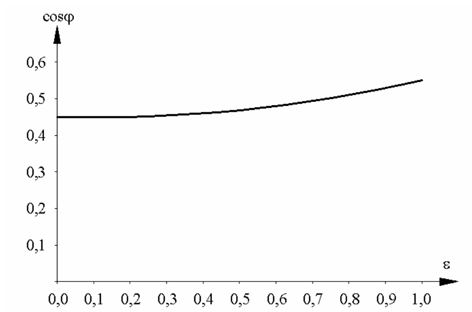

Figure 2. Power factor variation of reactive electromagnetic vibrators power supplied by inverter.

4. CONCLUSIONS

Power supplying of electromagnetic vibrators fated vibrocompacting with adjustable frequency and voltage, is made efficient with inverter who work without modulation, this because mechanical characteristics of load.

From energetic point of view, is remarked low value of power factor, which from blocked armature (ε=0) are value 0,45; and for maxim value of modulating factor (ε=1), value 0,55.

In perspective, must be find solutions for power supply which increasing value of power factor, especially in applications in that power necessary doing element is high.

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