PROJECT METHOD FOR WEIGHING ELECTRODYNAMIC CELLS

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Abstract: This article comprise in the authors research and realization same high performed devices for weighing, forces and mass, which may resolved more exacting applications of different domain: medical electronic- human dynamic equilibrium study and human gait human analysis, electronic devices for measure and control weighing, mass and force.

Keywords: *electrodynamics cells, medical electronic, measure weighing mass and force, measurement process, solenation elements, magnetic field, harmonic variation.*

I. INTRODUCTION

The project of an electrodynamic transducers have in view the dimensioning of the main active solenation elements, in direct current, respectively in alternative current, the dimensioning of magnetic circuits starting from the necessity to achive the imposed performances according to some conditions given by the loading cooling of the coil, as well as the execution technology, and the operation of electronynamic transducers [13]. The project is achieved in the following hypotheses – the modulation of the constant magnetic field in the working air gap by the magnetic field of the coil in AC is neglected the time variable quantities are considered with harmonic variation, - the project algorithm is draw up in hypothesis of using computer.

II. PROGRAMMING METHOD FOR WEIGHING ELECTRODYNAMICS CELLS

Programming elements of the electrodynamic vibrator are show in figure 1.

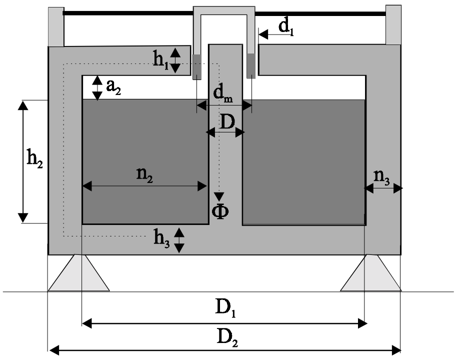

figure 1

The loading coefficient in current is $K_0=\theta_2/\theta_2$ where , are the solenation in DC current, respectively, alternative current, and it has an optimal value $K_0=6$ (it resulted from the projecting analyses done by other speciaised firms [4-13]). The force amplitude developed by the transducer is:

$$F_o = \sqrt{2}B_o I_S W_1 I_m = \sqrt{2}\pi B_0 D\theta_1 \quad \text{where:}$$

F_0 is the force that the amplitude developed in N, its value being given by the programming theme, B_0 represent the magnetic induction from the air gap in T, I_S is represent the effective value of the AC current in the mobile coil in A, W_1 is number of whirls of the coil of AC current, I_m represent the medium length of the whirl, $I_m=2\pi d_m$, in the calculation there will be taken, $I_m=\pi D$, in this way there results a higher solenation, therefore the calculation will be covering, D represent the diameter of central core, θ_1 the solenation of the coil AC current in Asp. From the condition of thermic stability, considering the coil of AC current bilaterally cooled by conversion, in result [1,2][12,13]:

$$\tau=\frac{\rho_1\theta_1^2}{2\alpha_1 f_1 n_1 h_1^2}\leq\tau_{1a} \text{ where:}$$

$\rho_1=\rho_0(1+\alpha\pi_{1a})$ represent the resitivity of the coil conductor in hot state, α the coefficient of the resitivity variation with the temperature *($\alpha=0.004^oC^{-1}$ for the copper conductor),* T_1 the supertemperature of the coil of Ac current in ^{o}C, π_{1a} the permitted supertemperature of the coil of AC current ($\pi_{1a}=100^o$C for a copper conductor CuEm type ET 155), α_1 the coefficient of the heat transmission at the mobile coil surface, for natural coding being determined by measurement, $\alpha_1=20$W/m^{2}K, $f_1=0,4;\ldots0,6$ with superior values for higher transducers (with higher developed force), n_1 the mobile coil thickness in m, h_1 the mobile coil leigh in m. The solenation in DC current is obtain by applying the magnetic circuit law for a contour made up by a field main line:

$$\Phi\overline{H}\,\overline{dl}=H_0\delta+H_{fe}I_{fe}=\theta_2=K_{fe}H_0\delta$$

where: δ in the length of the air gap in m, H_{fe}, H_0- the magnetic field intensity in iron, respectively, in the air gap $K_{Fe}=(\theta_0+\theta_{Fe})/\theta_0$ – the coefficient of the calculation for the magnetic voltage drop on the iron section, θ_0,θ_{Fe} the corresponding solenation for the magnetization of the air gap, respectively of the iron from the magnetic circuits, $K_{fe}=1,1\ldots1,4$ (in the primary programming phase, $H_{Fe}I_{Fe}$ are not know, which is taken into consideration through K_{Fe}..

In order to obtain an induction in drawn up by programming that in the neighborhood of the air gap should exist a very high induction (close the saturation induction of material in the rest of the magnetic circuit, a low induction, in order to reduce the magnetic voltage drop in iron). For this reason, the minimal section of a iron portion is taken in the imminent neighborhood of the air gap, on the inferior magnetic flux transmission to the polar part and to the air gap. The section of the inferior magnetic yoke plate S_3, in order to reduce the magnetic voltage drop in iron, is taken: $S_0=S_{fe}=Dh_1$, $S_{fe}=K_1S_0=S_{fe}$, $S_3=K_1S_0$, $K_1\pi Dh_1=\pi Dh_3$, $h_3=K_1h_1$ where: h_3 represent the high of the growth coefficient of the section in iron, determined by the optimization calculations $K_1=1,1\ldots1,4$. Analogously with relation:

$$\tau=\frac{\rho_1\theta_1^2}{2\alpha_1 f_1 n_1 h_1^2}\leq\tau_{1a}$$

it is obtain for the coil DC current (which we consider as having an iron care):

$$\tau_2=\frac{\rho_2\theta_2^2}{2\alpha_2 f_2 n_2 h_2^2}\leq\tau_{2a}$$

where: $\alpha_1=10$W/m^{2}K the heat transmission coefficient to surface of the DC current coil, f_2 the filling coefficient of the coil of the DC current, $f_2=0,4\ldots0,6$, the high values are taken for big coils and those having no insulation between their layers, n_2 the thickness of the DC current coil in m, h_2 the leight of DC current coil. The inferior diameter of the magnetic lateral yoke plare $D_1=D+2n_2$. From the law of magnetic flux relation results:

$$\frac{\pi D_2}{4}=\frac{\pi(D_2^2-D_1^2)}{4}$$

$$K_1(\pi Dh_1)=\frac{\pi D^2}{4}$$

In the programming of the electrodynamic transducer we have also in view the coefficients of a geometric shape K, Kn and the coefficients of a security K_2, $K_{f1}=h_1/n_1$ the shape coefficient of the coil of alternative current, $K_{f1}=5\ldots7$, $K_2=a_2/h_1$ the coefficient of security in order to avoid the hitting of the mobile coil against that of DC current $K_2=0,4\ldots.0,6$. By Rotterrs' relation, we calculate the different portions permeances of the air gap , the permeance corresponding to the flux aroud the air gap. If the magnetic voltage drop an the air gap is written down in two different ways (referring to the total flux, respectively to the useful flux) there will be obtain:

$$\Delta_u=\frac{2\pi\mu_0 h_1}{\ln\left(1+\frac{2\delta}{D}\right)}$$

$$\Delta_S=\mu_0 D\left[3+2\ln\left(\frac{a_2}{2\delta}+\frac{1}{2}\right)+\ln\left(1+\frac{D}{\delta}\right)\right]$$

$$\frac{\Phi}{\Delta_0}=\frac{\Phi_U}{\Delta_U}$$

where: Φ represent the total flux, Φ_1 is useful flux in the air gap, Λ_0 is the total permeance of the air and U represent the air gap permeance. The coefficient of magnetic circuit dispersion K_0 is:

$$K_\theta=\frac{\Phi}{\Phi_U}=\frac{\Delta_0}{\Delta_U}=1+\frac{\Delta_S}{\Delta_U}$$

$$K_\theta=1+\frac{D\ln\left(1+\frac{2\delta}{D}\right)}{2\pi h_1}\cdot\left[3+2\ln\left(\frac{a_2}{\delta}\right)+\ln\left(1+\frac{D}{\delta}\right)\right]$$

from the magnetic flux retention low results:

$$\Phi=K_\theta\,\Phi_U$$

$$B_{Fe}S_{Fe}=K_\theta B_0S_0$$

$$B_{Fe}S_0K_1=K_\theta B_0S_0$$

$$B_{Fe} = \frac{K_\theta B_0}{K_1}$$

The B_0 induction in the air gap is imposed by the researching theme. The magnetic field intensity in iron $H_{fe}=H_{fe}(B_{fe})$ is obtain from the magnetization characteristics for the calculated value of the induction by the relation. For the result geometric configuration is calculated coefficient K:

$$K'_{Fe} = 1 + \frac{\mu_0 H_{Fe} l_{Fe}}{B_0 S}$$

$$l_{Fe} = 2\left(n_2 + \frac{n_3}{2} + \frac{D}{6} + h_2 + a_2 + \frac{h_1}{2} + \frac{h_3}{2} \right) - \delta$$

The K_{fe} value is compared to that initially imposed K_{fe}, where is determined the calculation error in its estimation. If imposed:

$$\varepsilon_{KFe} = \left| \frac{K'_{Fe} - K_{Fe}}{K'_{Fe}} \right| = \left| 1 - \frac{K_{Fe}}{K'_{Fe}} \right| \le \varepsilon_{Ke}$$

The preliminary calculation is framed into the initially imposed data, if imposed $\varepsilon_{Kfe} \le \varepsilon_{Ke}$the calculations with the new value K_2 are resumed:
The iron mass m_{fe}:

$$m_{Fe} = \rho_{Fe} \left[2\pi D_2 H + \frac{\pi (D_1^2 - D^2}{4} (h_3 + h_1) \right]$$

$$H = h_1 + h_2 + h_3 + a_2$$

The copper m_{Cu}:

$$m_{Cu} \approx \rho_{Cu} f_2 \frac{\pi (D_1^2 - D^2) h_2}{4}$$

The auxiliary elements mass $m_{aux}=K_3(m_{fe}+m_{Cu})$ with $K_3=0{,}05\ldots0{,}2$. The total mass of the transducer:

$$m_T = m_{aux} + m_{Cu} + m_{Fe}.$$

III. THE EQUATIONS WHICH DESCRIBLE THE OPERATION OF AN ELECTRODYNAMIC TRANSDUCER [13].

If we write down the equilibrium equqtion at the terminal jack of the mobile coil in voltage:

$$u = Ri + Li + Bl\left(\frac{dx_m}{dt} + \frac{dx_S}{dt}\right) \text{ where:}$$

R – resistance, L-inductance of the mobile coil, B- the magnetic induction in the air gap, l- the length of the coil conductor, dx_m/dt – the liniar speed of the mobile equipment , dx_S - the speed of stator and the supply voltage of the mobile coil The equation of a mechanical equilibrium is:

$$M\left(\frac{d^2xm}{dt^2} - \frac{d^2x_S}{dt^2}\right) + C\left(\frac{dx_m}{dt} - \frac{dx_S}{dt}\right) + K_e(x_m - x_S) = F$$

where: M – the total mass in displacement, C- the coefficient of the dynamic viscosity, Ke- the equivalent coefficient of elasticity an F – force developed by the transducer:

$$F = B\,L\,i = \Gamma\,i$$

If voltage has harmonic variation the current and its displacement has also some harmonic variations. Writing down in a simplified complex the relations of stationary condition, we have:

$$\begin{aligned}
&\underline{U} = \underline{Ze} \cdot \underline{I} + \Gamma(V_m - V_M) \\
&\underline{Z}_M \underline{V}_M + \underline{Z}_e (V_m - V_M) = \underline{F} \\
&\underline{Z}_m \underline{V}_m + \underline{Z}_e (V_m - V_M) = -\underline{F} \\
&\underline{F} = \Gamma \underline{I}
\end{aligned}$$

where: $Z_M=j\omega M_M$ represent the mechanical impedance of the elastic element, the previous system and $Z_m=j\omega m$ represent the mechanical impedance of the mobil element. If we note: $Z_e=C_e+k_e/j\omega$ the mechanical impedance of the elastic element the previous system becomes:

$$\begin{aligned}
&\underline{U} = R \cdot \underline{I} + L \cdot \underline{I} + \Gamma \dot{I} \\
&M \cdot \ddot{x} + C \cdot \dot{x} + K_e x - \Gamma \cdot I = 0
\end{aligned}$$

In the harmonic stationary condition we can write down in a simplified complex:

$$\begin{aligned}
&\underline{x} = X e^{j\omega t} \\
&\underline{U} = U e^{j\omega t} \\
&\underline{i} = I e^{j\omega t}
\end{aligned}$$

By replacing into the relation that characterize the system we obtain:

$$\begin{aligned}
&(R + j\omega L) I + j\omega \Gamma x = U \\
&-(K_e - M\omega^2 + j\omega C) X = 0 \\
&\underline{I} = \frac{\underline{U} - j\omega \Gamma \underline{X}}{R + j\omega L} \\
&\Gamma \frac{\underline{U} - j\omega \Gamma \underline{X}}{R + j\omega L} - (K_e - M\omega^2 + j\omega C) X = 0
\end{aligned}$$

or:

$$\begin{aligned}
&\underline{X} = \frac{\Gamma \underline{U}}{(K_e - M\omega^2 + j\omega C)(R + j\omega L) + j\omega \Gamma^2} \\
&\underline{I} = \frac{\underline{U}}{R + j\omega L + j\omega \dfrac{\Gamma}{K_e - M\omega^2 + j\omega C}}
\end{aligned}$$

The force developed by the transducer will be defined by relation:

$$\underline{F} = \Gamma \underline{I} = \frac{\Gamma \underline{U}}{R + j\omega L + j\omega \dfrac{\Gamma^2}{K_e - M\omega^2 + j\omega C}}$$

$$\Gamma = B \cdot L$$

If voltage source has a constant amplitude, the force produced by the transducer is function of the frequency, the relation being of reverse proportionality, with a considerable diminution of the force in the area the resonance frequency of the excited system. During the rest, the impedance of coil $Z_L=R+j\omega L$, is powerfully resistive (L=0) an the last relation above becomes:

$$\underline{F} = \Gamma \underline{I} = \frac{\Gamma \underline{U}}{R + j\omega \dfrac{\Gamma^2}{K_e - M\omega^2 + j\omega C}}$$

IV.CONCLUSIONS

1)In order that the force produced by the transducer should take minimal values st the resistance, the ratio R/Γ must be as high as possible (R-high, Γ- low).

2)It is necessary the introduction of some compensatory circuits of the coil inductivity through series compensation with capacitors and the avoidance of the operation at resonance through the practicing of a short circuit whirl in the working air gap. Recommended for the achievement of the whirl compensation in the short circuit is the one of a closed magnetic screen type which encloses the mobile coil, and on the main pole we place a cooper ring with a thickness of 1…2mm and the high of the working air gap.

3)The achievement of the mobile coil from two section, with the same number of whirls winded in opposite ways and connected in series, in this case, the coil equal as value and it superposes as direction, but the proper magnetic flux of the concatenation of the each section is opposite, canceling each other, fact that leads to the diminution of the mobile coil reactance.

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