A STUDY OF THE POWER CONTACTS IN MAGNETIC LIQUEFIED LAYER OF FERRO-IMPURITIES IN THE COOLANT IN THE WORKING VOLUME OF ELECTROMAGNETIC DENSITOMETERS (EPL)

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In article results of research of power contacts in magnetic liquefied layer of ferro-impurities in the coolant in the working volume of electromagnetic densitometers (EPL). Studies were conducted on the basis of the dipole model. Identified the main parameters that affect the magnitude of the force interaction between metal impurities in the lubricating-cooling liquids (coolant) under the action of a constant sign and is controlled by the magnitude of the electromagnetic field. A method for calculation of magnetic fields in the working volume of the EPL. To build the magnetic field of the coil with the current in the presence of the cylindrical rotor is used the method of integral equations. The method is based on the introduction of secondary sources and consists of reducing the problem to integral equations with their numerical solution.The conducted research allow for the design of high-speed instruments for the qualitative Express analysis of contamination of the coolant.

Keywords: electromagnetic densitometer, ferromagnetic impurities, rapid analysis

A lubricating and cooling technological environment is an essential element of technological process of material's treatment in repair shops in the agro-industrial complex (AIC). The processes of turning, milling, drilling, grinding etc. are characterized by high static and dynamic loads, high temperatures and mechanical effects of treated material on a cutting instrument.

The function of lubricating and cooling technological environment reducing the temperature, power treatment parameters and instrument wear. The development of environmentally friendly resource systems of using of lubricating and cooling technological environment in repair productions of AIC requires a solution of the questions connected with improving the system of cleaning of them and a development of science-based methods and devices diagnosing a quality of waste technological environment in repeated cycles of operation [9, 10]. A changing of dispersed state of lubricating and cooling technological environment in the process of exploitation leads deterioration of functional and performance properties of it. The exceeding a standardized concentration of trace metals that inevitably presents in lubricating and cooling technological environment after cleaning violates technological options and leads to premature wear of an equipment.

Meanwhile the existing practice of using of lubricating and cooling technological environment at the enterprises doesn`t imply an excessively attentive attitude to the diagnostics of quality on the secondary use. The known methods and devices determining trace metals in lubricating oils doesn`t provide an express and qualitative analysis in closed training systems of lubricating and cooling technological environment.

The objective of the work: investigation of the power contacts in magnetic liquefied layer of ferromagnetic impurities lubricating and cooling technological environment in the working volume of density electromagnetic (EPL).

The material and methods of the investigation: the subject of this study is power interactiom in the magnetic liquefied layer of ferromagnetic impurities determining the time of «ran out» in an instrument for conducting of express diagnostics of contamination of technological environment.

The results of the investigation and discussion about them

The operating principle of the electromagnetic densitometer [7, 12] is based method of forming a bonding force of ferromagnetic powder in magnetic liquefied layer under the influence of the electromagnetic field with a constant sign and a capacity to be adjusted largest [1, 4, 5, 6] and with relative displacement of surfaces of working volume of the instrument [2, 3, 11] (Fig. 1).

The concept design for the construction of the magnetic field of the diagnostic device shown in Fig. 2.

The integral equation for determining the unknown current sheet has the form [8]

$$\sigma(z) = \frac{1}{2\pi}\frac{\mu-\mu_0}{\mu+\mu_0}\left[B_Z^*(r_0,z)+B^{**}(r_0,z)\right], \quad (1)$$

where μ, μ_0 – respectively the magnetic permeability of ferromagnetic elements an working air gap; B_Z^*, B^{**} – the projection of the magnetic induction vector on the axis Z (axis aligned with the axis of the device) respectively the current layer and multi-layer coil with current.

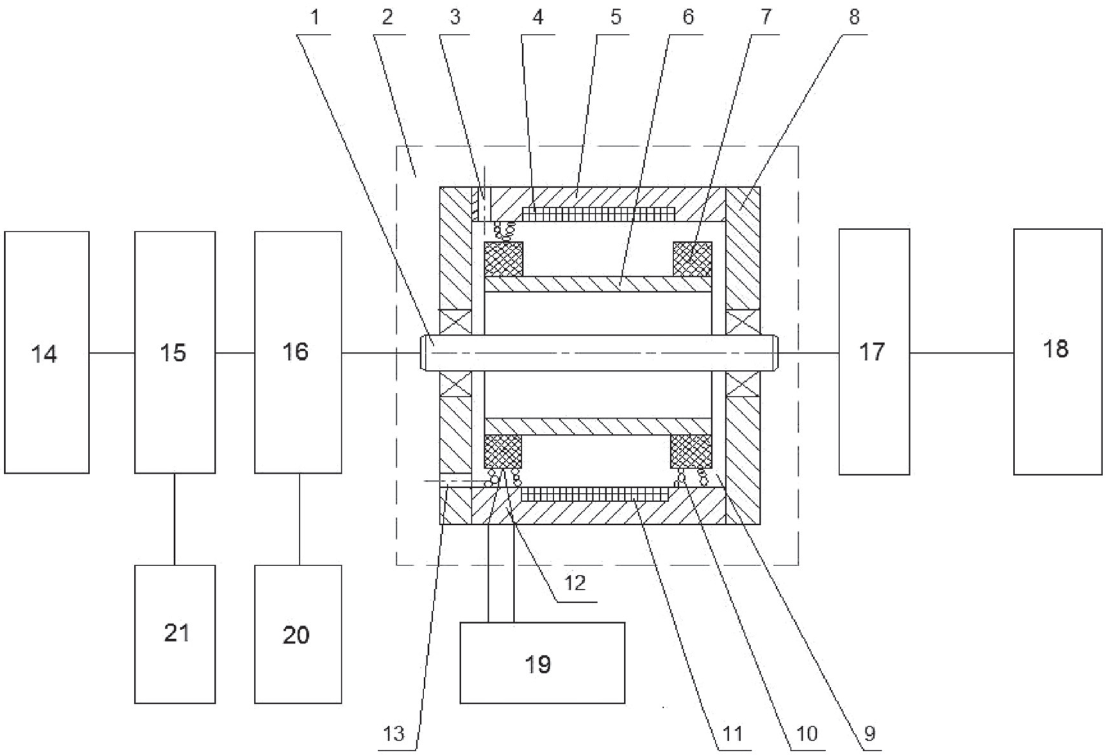

Fig. 1. The concept design of the diagnostic device:
1 – shaft; 2 – sensor; 3 – hole; 4 – control winding; 5 – fixed outer cylinder;
6 – movable outer cylinder; 7 – fins of cylinder; 8 – end shields; 9 – working volume;
10 – ferromagnetic impurities; 11 – annular groove; 12 – temperature sensor; 13 – drain hole;
14 – gear; 16 – connecting device; 17 – disk; 18 – flywheel; 19 – inductor; 20 – stopwatch fixing gear time from tripping until the complete cessation of rotation ; 21 – indicator

The component B_Z^* of the magnetic field in the gap defined by the formula

$$B_Z^*(r_0,z)=\mu_0 r_0\int_{-\alpha}^{\alpha}\int_{0}^{2\pi}\sigma(z_Q)\cos\varphi\left\{\frac{1}{r_0\sqrt{2r_0^2(1-\cos\varphi)+(z-z_Q)^2}}-\right.$$
$$\left.-\frac{r_0(1-\cos\varphi)}{\left[2r_0^2(1-\cos\varphi)+(z-z_Q)^2\right]^{3/2}}\right\}d\varphi\, dz_Q. \quad (2)$$

Designating the distance to any point of the working gap through Q_1^* и Q_2^*,

$$Q_1^*=\sqrt{r_0^2-2r_0r_1\cos\varphi+r_1^2+(z-z_Q)^2}; \quad (3)$$

$$Q_2^*=\sqrt{2r_0^2(1-\cos\varphi)+(z-z_Q)^2}, \quad (4)$$

the formula for determining the induction B^{**} takes the form

$$B^{**}(r_0, z)=\frac{\mu_0 IW}{2b(r_0-r_1)}\int_{-b}^{b}\int_{0}^{2\pi}\left\{(1+\cos 2\varphi)\ln\frac{Q_2^*+r_0(1-\cos\varphi)}{Q_1^*+r_1-r_0\cos\varphi}+\frac{Q_2^*-Q_1^*}{r_0}\cos\varphi-\right.$$
$$-\left\{r_0^2\left(r_0Q_1^*-r_1Q_2^*\right)\cos 4\varphi-r_0\left(Q_1^*-Q_2^*\right)\left[r_0^2+\left(z-z_Q\right)\right]\cos 3\varphi-2\left(z-z_Q\right)^2\times\right.$$
$$\times\left(r_0Q_1^*-r_1Q_2^*\right)\cos 2\varphi+r_0\left[r_0^2+\left(z-z_Q\right)^2\right]\left(Q_1^*-Q_2^*\right)\cos\varphi- \tag{5}$$
$$\left.\left.-\left[r_0^2+2\left(z-z_Q\right)^2\right]\left(r_0Q_1^*-r_1Q_2^*\right)\right\}\frac{1}{2Q_1^*Q_2^*\left[r_0^2(\cos 2\varphi-1)+2\left(z-z_Q\right)^2\right]}\right\}d\varphi dz_Q.$$

The magnetic field at any point in the working volume is calculated by formulas

$$B_r(r,z)=-\mu_0 r_0\int_{-\alpha}^{\alpha}\int_{0}^{2\pi}\frac{\sigma(z_Q)(z-z_Q)\cos\varphi}{\left[r^2-2rr_0\cos\varphi+r_0^2+\left(z-z_Q\right)^2\right]^{3/2}}+\frac{\mu_0 IW}{2b(r_0-r_1)}\times$$
$$\times\int_{-b}^{b}\int_{0}^{2\pi}\left\{\frac{(z-z_Q)}{r^2\sin^2\varphi+\left(z-z_Q\right)^2}\left[\frac{1}{Q_1^*}\left(-rr_1\cos\varphi+r^2+\left(z-z_Q\right)^2\right)-\right.\right. \tag{6}$$
$$\left.\left.-\frac{1}{Q_2^*}\left(-rr_0\cos\varphi+r^2+\left(z-z_Q\right)^2\right)\right]\right\}\cos\varphi d\varphi dz_Q;$$

$$B_Z(r_1, z)=\frac{\mu_0 IW}{2b(r_0-r_1)}\int_{-b}^{b}\int_{0}^{2\pi}\left\{(1+\cos 2\varphi)\ln\frac{Q_2^*+r_0-r\cos\varphi}{Q_1^*+r_1-r\cos\varphi}+\frac{Q_2^*-Q_1^*}{r}\cos\varphi-\right.$$
$$-\left\{r^2\left(r_0Q_1^*-r_1Q_2^*\right)\cos 4\varphi-r\left(Q_1^*-Q_2^*\right)\left[r^2+\left(z-z_Q\right)\right]\cos 3\varphi-2\left(z-z_Q\right)^2\times\right.$$
$$\times\left(r_0Q_1^*-r_1Q_2^*\right)\cos 2\varphi+r\left[r^2+\left(z-z_Q\right)^2\right]\left(Q_1^*-Q_2^*\right)\cos\varphi- \tag{7}$$
$$\left.\left.-\left[r^2+\left(z-z_Q\right)^2\right]\left(r_0Q_1^*-r_1Q_2^*\right)\right\}\frac{1}{2Q_1^*Q_2^*\left[r^2(\cos 2\varphi-1)+2\left(z-z_Q\right)^2\right]}\right\}d\varphi dz_Q;$$

$$B(r,z)=B_r^2(r,z)+B_Z^2(r,z). \tag{8}$$

The magnetic field strength is determined from the expression

$$H(r,z)=\frac{1}{\mu_0}B(r,z). \tag{9}$$

According to the research the force interaction between particles Metal impurities in the lubricating and cooling technological environment in a homogeneous magnetic field is

$$Fr=\frac{1}{2}\frac{\mu-1}{\mu+2}R_0^3\left.\frac{\partial H^2}{\partial r}\right|_{r=2R_0};$$

$$Fr=-\frac{3}{256}H_0^2R_0^2\frac{(\mu-1)^2}{(\mu+2)^3}\left[(13\mu+11)+9(3\mu+5)\cos 2\nu\right]. \tag{10}$$

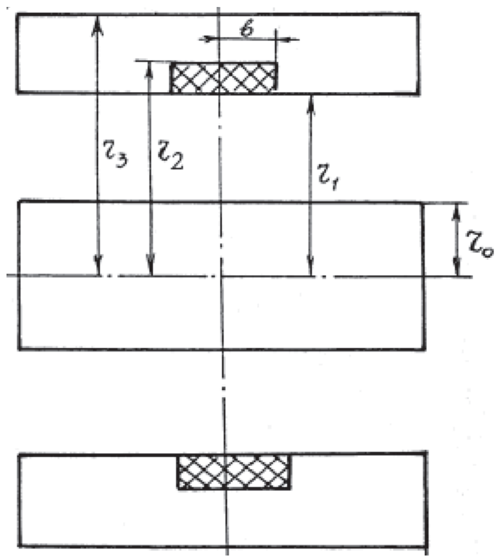

Fig. 2. Scheme to construct the magnetic field in the working volume of the diagnostic device:
r_0 – rotor radius of diagnostic devices;
r_1 – the radius of the working volume;
r_2 – the radius of the control winding;
r_3 – the radius of the body;
$2b$ – the width of the groove under the control winding

The moment of force field interaction with the system is defined by two elements

$$M_U = \frac{1}{2}\frac{\mu - 1}{\mu + 2} R_0^3 \frac{\partial H^2}{\partial U}\bigg|_{r = 2R_0};$$

$$M_U = -\frac{3}{128} H_0^2 R_0^2 \frac{(\mu - 1)^2}{(\mu + 2)^3} (17\mu + 31)\sin 2\nu. \quad (11)$$

Analysis formula shows that this force is proportional to the square of the unperturbed magnetic field and the square of the radius of the elements. The angle is the angle of the structure group of ferromagnetic elements impurities strain and the value of it determining the power of interaction between this elements describes the process of organizing and fracture of structural combinations. At $\nu = 0$

$$Fr(0) = -\frac{3}{32} H_0^2 R_0^2 \frac{(\mu - 1)^2}{(\mu + 2)^3} (5\mu + 7). \quad (12)$$

The minus sign before the formula indicates that between the ferromagnetic elements of impurities occurs attraction. In this case organized stable combination of these structural elements is carried out and their interaction force between themselves and surfaces limiting the working gap with maximum intensity.

By moving the surfaces relative to each other there is a structural deformity group and the angle ν is growing that causes a decrease in the force of attraction between the balls. Upon reaching the critical ν_{KP} deformation angle of the interaction force vanishes.

The angle ν_{KP} satisfies the following equation

$$(13\mu + 11) + 9(3\mu + 5)\cos 2\nu_{KP} = 0. \quad (13)$$

Thence the critical angle at which the attraction of ferromagnetic elements replaced by their repulsion is

$$\nu_{KP} = \pm\frac{1}{2}\left(\pi - \arccos\frac{13\mu + 11}{9(3\mu + 5)}\right). \quad (14)$$

During the deformation of the structure group, when the critical ν_{KP} angle is reached the chain of ferromagnetic bodies collapses.

At $\nu = \pm\pi/2$ th power of the interaction is determined by the expression

$$Fr\left(\pm\frac{\pi}{2}\right) = \frac{3}{128} H_0^2 R_0^2 \frac{(\mu - 1)^2}{(\mu + 2)^3} (7\mu + 17). \quad (15)$$

Ferromagnetic elements pushing each other organize “sliding layer”.

Conclusion

On the basis of the research identified key parameters affecting on the amount of force interaction between metal impurities coolants under the forces of the electromagnetic field with a constant sign and a capacity to be adjusted largest. The technique of building a magnetic field in the working volume of the EPL provided followed by determination of the value of the contacts in magnetic liqufied layer of ferromagnetic impurities. The studies allow to design high-speed devices for rapid analysis of qualitative coolant contamination.

References

1. Bezzubtseva M.M., Volkov V.S., Gubarev V.N. A method for diagnosing pollution technological environments ferroprimesyami // International Journal of Applied and Basic Research. – 2014. – № 1. – P. 60–62.

2. Bezzubtseva M.M., Volkov V.S., Zagajewski N.N. Investigation of electromagnetic mechanical activation (EMMA) mortars. In: Scientific support agribusiness development in the context of reforming the Proceedings of the conference faculty. Editorial board: NB ALT, A.I. Anisimov, M.A. Arefiev, S.M. Bychkova, F.F. Ganusevich, G.A. Efimova, V.N. Karpov, A.P. Kartoshkin, M.V. Moskalev, M.A. Novikov, G.S. Osipova, N.V. Pristach, D.A. SHishov; Chief editor: V.A. Efimov, deputy editor: V.A. Smelik. 2015. – P. 435–438.

3. Bezzubtseva M.M., Volkov V.S., Obukhov K.N., Kotov A.V. Determination of forces and moments acting on the grinding system of ferromagnetic elements in a cylindrical shape magnitoozhizhennom layer of the working volume of the electromagnetic mehanoaktivatorov // Basic Research. – 2014. – № 11–3. – P. 504–508.

4. Bezzubtseva M.M., Ravens M.S. K subject study of contact interactions in devices with a layer magnitoozhizhennym // International Journal of Experimental Education. – 2015. – № 9. – P. 83–85.

5. Bezzubtseva M.M., Mazin D.A., Zubkov V. Study volume filling factor of the ferromagnetic component in devices with magnitoozhizhennym layer // Bulletin of St. Petersburg State Agrarian University. – 2011. – № 23. – P. 371–376.

6. Bezzubtseva M.M., Nazarov I.N. A study of the electromagnetic method for evaluating the degree of contamination of process fluids impurities // Bulletin of St. Petersburg State Agrarian University. – 2009. – № 17. – P. 240–246.

7. Bezzubtseva M.M., Obukhov K.N. On the question of the study of physical and mechanical processes in magnitoozhizhennom layer ferrotel // International Journal of Applied and Basic Research. – 2015. – № 7–2. – P. 191–195.

8. Bezzubtseva M.M., Ruzhev V.A., Volkov V.S. Theoretical studies of the deformed magnetic field in the working of the volumes with electromagnetic mehanoaktivatorov magnitoozhizhennym layer grinding elements cylindrical form // Basic Research. – 2014. – № 6–4. – P. 689–693.

9. Bezzubtseva M.M., Smelik V.A., Volkov V.S. Issledovanie patterns of wear layer ferroelementov magnitoozhizhennogo electromagnetic mehanoaktivatorov // Basic Research. – 2015. – № 2–20. – P. 4398–4402.

10. Bezzubtseva M.M. On the issue of research into the effect of size reduction equipment with magnitoozhizhennym layer ferrotel // International journal of experimental education. – 2014. – № 8–3. – P. 96.

11. Pugovkin P.R., Bezzubtseva M.M. Model education efforts in bonding EPM // Proceedings of the higher educational institutions. Electromechanics. – 1987. – № 10. – P. 91.

12. Sokolov A.V., Bezzubtseva M.M. The device for assessing the degree of contamination of liquids with impurities. – Utility model number 11343 (G01N11 / 10).