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In book of abstracts there are considered chemistry and physics problems of magnetic colloid nanosystems, physical properties and hydrodynamics, heat and mass transfer, application of magnetic fluids in medicine, biology and engineering. The reports on those researches are included in it which represent greatest scientific, educational and practically - methodical interest.

International Plyos Conference on Magnetic Fluids are carried out in Russia since a 1978. Now they are the largest and significant scientific measure for consolidation and association of scientific forces on a problem of magnetic fluids in Russia, countries of near foreign countries and for cooperation to scientific organizations and scientists of countries of distant foreign countries. The organization and realization of conference traditionally implements so that pursuant to trends of time in a high school science of Russia in a maximum degree to supply participation in activity of conference of the students, post-graduate students.

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PREPARATION OF MULTIFUNCTIONAL MAGNETIC CARRIERS FOR MEDICAL AND BIOLOGICAL INVESTIGATIONS

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Introduction

In present abstract the review of the literary data on ways preparation, properties and sphere of application multifunctional of magnetic carriers preparations on a basis ferrimagnetics, dextran and carboxymethyldextran, fluorocarbon, human albumin, polygluckine and ferrocarbone is submitted. The opportunity of use such ferrifluids in quality is shown: magnetic carriers of medicinal substances, antibodies and ferments, x-ray contrasting substances by physical and chemical immobilization by their particles of a viscous magnetic drop; means, transforming energy of radioindividual radiations in thermal - crates, raising temperature, and fabrics. Some technological aspects preparation of magnetic carriers liposomes, capable are considered to carry of anticarcinom preparations and contrast substances. Magnetic technology and perspective multifunctional magnetic carriers preparations are represented by new opportunities for treatment and diagnostics of tumours, to separation of crates of blood and marrow directed transport of medicines and immunodiagnostics means controlled x-ray and nuclear magnetic resonance contrasting. The results of work are used in experimental haematology, transfusiology, microbiology, immunology, oncology and other areas of science.

1. Preparation of ferrimagnetic fluids biocompatible

Way of preparation of ferrimagnetic fluid biocompatible and ferrimagnetic on a basis of dextranferrite [1, 2, 3], carboxymethyldextran and fluorocarbons [4-9] recently was developed. Ways of preparation of magnetic fluid the method precipitation of magnetite at presence of dextran [10] for a long time were known. However they were characterized by multigradualness, labour input, losses of substance at it aggregation and clearing. Ways of introduction in a molecule of dextran of active groups at the same time were found and on their basis derivative are synthesized, entering in various chemical reaction [4-9, 11-12].

One of such derivative is carboxymethyldextran (CMD), prepared by updating of preparations of dextran: polygluckin (PG) and rheopolygluckin (RhPG) by monochloracetic acid [11, 12]. The complex communication of oxide iron ions both carboxymethyldextran is rather strong and hydrolysis only at boiling in a solution of hydrochloric acid. CMD, as well as dextran, after of injection vein concentrates in bodies of retyculoendothelium system with the subsequent splitting by dextran-gluckozidase. Thus the speed of splitting depends on a degree of replacement - quantity of carboxymethyl groups on 100 rests of anhydrogluckose in a molecule of dextran.

For synthesis of medicinal preparations were to use carboxymethyl ethers of dextran with a degree of replacement about 60, as they were splitted by ferment systems easier of organism and were less toxically, than replacements, derivative with a high degree [11]. By result of the carried out investigations was the simplification of way preparation of magnetic hydrosole biocompatible, realization of process without heating and increase of final product output [5-9].

Reaction of synthesis of a preparation carried out at 20-25ºC. The salt mixed Fe^{2+} and Fe^{3+} taken in the ratio 1:2 accordingly, with a solution of sodium salt of carboxymethyldextran (CMD) with average molecular mass 40-60 kD and degree of replacement by carboxymethyl groups equal 70-80. Thus the strong complex of iron with polymer was formed, then a mix translate in a soluble condition by titration 30 % by a solution NaOH up to pH 10,8-11,0, which after complete dissolution of a deposit is established within the limits of 6,8-7,6. In result was formed biocompatible stable hydrosole of ferrimagnetic with the size of particles not exceeding 70-80 nm, with concentration of magnetic phase till 8-10 % (mass), adjustable dynamic viscosity 2,5 mPa · s and magnetic properties 1,0-1,5 kA/m. Thus were excluded: a stage of heating, multistages and labour input of process [5-9].

2. Preparation of ferrimagnetic particles on a basis of carboxymethylcellulose

By analogy with carboxymethyldextran for preparation of the magnetic carrier was used of sodium salt of carboxymethylcellulose (Na-CMC) of Russian manufacture with the following parameters: a degree polymerization 490-500, degree of replacement 76-81. The water solution Na-CMC, pH 7,0-7,3, relative viscosity about 30 was used 1 %. Because of high viscosity of solutions Na-CMC, initial concentration reagents, the replacements, participating in reaction, made 0,5%.

Earlier, ferrimagnetic particle for the medical purposes were prepared on the basis of starches and magnetite [13, 14]. For this technique were characteristic multigradualness, the presence of a stage of heating is higher 90ºC, use expensive organic solvents, and also loss of substance at wash of ferrimagnetic particles prepared in the organic solvents.

The simplification of way, reduction of realization process temperature and increase an output of final product was achieved by that the solutions of salts Fe^{2+} - and Fe^{3+}, taken in the ratio 1:2 accordingly, mixed with solution Na-CMC. A formed complex of polymer with iron subjected titration 30 % by solution NaOH (pH 10,5-11,0). The prepared particles «carboxymethylcellulose-magnetite» washed from impurity by distilled water (pH 6,5 - 7,2).

The particles «carboxymethylcellulose-magnetite» had a diameter 2-6 microns. Water suspension of particles contained 30 % - 50 % of ferrite with magnetic properties 1,5-2,1 kA/m [5-9].

Now become known of x-ray contrasting means or having magnetic properties, or suitable for double x-ray contrasting, however among them there is no such, which combined in itself and those, and other properties. One of them is oleoferrotrast, which contains as the carrier of vaseline oil [15]. However oleoferrotrast was intended for unary contrasting only on iron of magnetite, as into his structure do not enter the x-ray positive substances. Besides in view of the large viscosity of vaseline oil and his limited biological compatibility oleoferrotrast it is recommended only for diagnostics of hollow bodies, but not for lymphography.

It was offered x-ray contrasting means deprived of these lacks and suitable for lymphography. For this purpose in quality of dispersed medium were used perfluoric substances, described by biological inertness and raised ability to dissolve gases [5, 16].

Process of preparation carried out as follows: high dispersed magnetite carefully washed by distilled water up to pH 6,5-7,0 and dispergated it in ethyl alcohol. A suspension subjected to influence of ultrasound within 1 minute at frequency 20 kGz and capacity 50 W and flowed in capacity containing perfluoric substance (perfluordecaline, perfluortributhyl, perfluotripropylamine) and polyfluoricoxicarbonic acid as the stabilizer. Reaction carried out at a ratio of components: one volumetric part of a suspension of high dispersed magnetite in spirit two volumetric parts of perfluoriccarbonic substances. The concentration of magnetite was 2,8-3,0 % (mass), the concentration of the stabilizer was 1,8-2,0 % (mass). Peptisation of magnetite carried out at 78°C long as temperature of a mix did not exceed specified, then the prepared magnetic fluid concentrated by evaporation of alchohol till 18-20 % (mass) on a magnetic phase. Prepared by this way 20 % the magnetic fluid had magnetic properties 40 kA/m; gas capacity on oxygen 45-48 % (volumetric); a superficial tension 12-14 N/m; dynamic viscosity 8-10 mPa · s. It was not stratified in a magnetic field by an induction 0,15 Tesla within 1 hour and at centrifugation at 8000 rotations one minute within 1 hour [5-9].

4. Preparation of magnetic carriers albumin microspheres

The directed transport of medicines represents one of urgent tasks of modern pharmacology. It assumes creation in the certain part of organism of such concentration of a medicinal preparation, which is necessary for therapeutic effect at common bear doze. For this purpose the biocompatible containers - carriers containing of ferrimagnetic particles and the appropriate magnetic systems, capable were created to keep carriers with a medicine in the given site of vascular channel. Local concentrated of magnetic carriers with a medicinal preparation in sites of organism was described by many authors [5-9, 17-28].

The requirements showed to magnetic carriers were formulated. So, in order to prevent of risk embolisation of fine vessels and capillaries, the diameter of ferrite nucleuses of carrier should not exceed 1 micron, and for prevention them aggregation in a magnetic field - 11 nm. For increase of a share of useful loading of the carrier by a medicine the contents in it of ferrimagnetic should be minimal. On the other hand, the force caused by an enclosed external magnetic field, holding the carrier in vascular channel, is proportional to a diameter of particle of the carrier in the third degree and quantity of ferrimagnetiuc in it. Opposed the hydrodynamical force aspiring to carry away from a site - target stopped on internal wall of a vessel, a stopped on an internal to a wall, of particle only in the second degree. Hence, at reduction of nucleus diameter of carrier magnetic force decreases faster, than hydrodynamical, and consequently the diameter of particle - carrier and contents in it of ferrimagnetic material should be increased up to optimum size [17, 30]. Chemical structure and structure of the carrier should be such to exclude or even to reduce accumulation of ferrimagnetic in a liver [29-32].

The large distribution in medical-biological investigations was obtained by biostructural magnetic carriers. Them prepared, «loading» of magnetite of a cells (shadow eritrocytes, leucocytes) and liposomes or concluding clasters of magnetite in a spatial grid formed by macromolecules (albumine, dextran, polyethylenglyckole and others of minitoxical substances) [26, 27]. A various sort of difficulties connected to preparation and a storage of magnetic eritrocytes, leucocytes and lyposomes, have made microparticles prepared from ferrite and biopolymers, more perspective for the directed delivery of medicines. More often it of albumine microsphere [17-29] and dextranferrite [29, 30].

However described ways of their preparation by thermal or chemical denaturation of albumine lowered it affinity to ferments, antibodies and other biopolymers [21-23].

Were prepared magnetic carriers albumine microparticle with raised by sorption activity to fibers (antibody, ferments) at the expense of reduction of a denaturated influences and preservation of primary structure initial of albumine. For this purpose a mix of magnetite with human albumine subjected to periodic influence of ultrasound at cooling, temperature in an active zone does not exceed + 38ºC at a gradient of temperatures 2-4 grad./sm.

Process carried out as follows: water suspension of magnetite by concentration 20-28% (mass) subjected to influence of ultrasound by capacity 50 W within 18-20 minutes. After the control of concentration of a magnetite added a solution 20 % of human albumine in such quantity, that the ratio on dry substance «magnetite-albumine» made 1,5/1,0. A mix mixed and cooled up to 0ºC. Thus the geometrical forms and sizes of a vessel were important, that at ultrasonic processing temperature in an active zone above + 38ºC was maintained. In a chemical glass by a diameter of 50 mm of cooling of a mix and periodic influence of ultrasound 65 seconds reached by alternation ultrasound within 45 seconds and pause, during which a mix continuously mixed. After such 18-20 cycles with subsequent by clearing, freeze of sample and lyofilic drying in vacuum prepared of magnetic carriers microparticles by a diameter 0,8-1,2 microns and specific magnetic properties 60 $A \cdot m^2/kg$.

For the control of sorption properties of prepared magtnetic carriers microparticles to them suspension added a solution of sodium salt of a oleic acide and antibody to eritrocytes, three times processed by ultrasound. The prepared microparticles wash from untied antibodies, mixed with suspension appropriate of eritrocytes and placed in a non-uniform magnetic field by an induction 0,01 Tesla. At bringing of a constant magnet to subject glass with a drop of preparation suspension in microscope (4x10) observed movement of units and separate eritrocytes to a magnet. It meant, that antibodies adsorbed on albumine microparticles. The positive reaction of agglutination eritrocytes with formation of magnetic carriers aggregats consisting from eritrocytes and magnetic carriers albumine microparticles, confirmed preservation of primary properties of antibodies and eritrocytes [4-6]. At similar definition of sorptuion properties of magnetic carriers antibodies prepared by thermal processing [21-23], was established, that eritrocytic antibody practically not adsorbed of a particle owing to blocking of amine groupes of albumine. The reaction of agglutination thus occurs only between free antibodies and antigenes of eritrocytes, and the formed units were not controlled by magnetic field [7].

5. Preparation of magnetic carriers particles on a basis of polyglobine

For preparation of particles was used of medical polyglobine solution, which was prepared from erythrocytes of blood (donor and xenogenic), with use as the sewing agent of formaldehyde. The polyglobine had not reactogenic and anafilactogenic, at it were reduced of antigenic properties. The tolerance of polyglobine was proved on animals [5, 34]. The molecular-mass distribution of polyglobine had a polymodel kind with molecular mass equal 150 kD and molecular mass, equal 27 kD. The molecule of polyglobine had an average diameter 29,6 nm [34]. The solution of polyglobine by concentration 6 % in water had pH 6,95 and relative viscosity 1,17.

The magnetic carriers particles were prepared by way coprecipitation of magnetite from salts Fe^{2+} and Fe^{3+} solution NaOH in 0,5-1,0 % a solution of polyglobine at ratio «polyglobine - iron» 3/1, 4/1, 5/1. The there was less concentration of salts of iron in an initial solution, the there was less size of prepared particles. So, at a ratio polyglobine/iron 5/1 sizes of particles was 160 nm, and at a ratio 3/1 - 2230 nm. The particles washed by distilled water from untied initial substances and stored in lyofilic dried up condition. The contents of iron was investigated: total 20 %, Fe2 + 10 % [5-8].

Way of preparation of magnetic carriers conjugate of polyglobine used for division of crates or biopolymers, and also in the diagnostic purposes recently was offered. The suspension of magnetic particles of volume 0,5 ml three times wash out by phosphate buffer solution NaH_2PO_4 (pH 7,2) and dispergated in 6 ml that of buffer solution. The suspension mixed with solution containing 20 mg N - (γ-maleynimidebutiriloxi) - succinimide in 4 ml absolute of dimethylformamide, and a mix stirred up 1 hour at 20ºC. The suspension centifugated, wash out (3 times on 20 ml) by buffer solution, mixed with 6 ml that of buffer solution and combined with by monoclonalic antibodies [35].

6. Preparation of magnetic carriers liposomes

Last decade the interest to liposomes has increased which are widely used as model systems at study of principles of molecular organization, mechanisms of functioning of biological membranes, nuclear magnetic resonant contrasting and therapy [36-46]. They have appeared are suitable for study of passive transport of ions and small molecules through of lipidic double layer. Changing structure of lipids in liposomes, it is possible directing to change properties of membranes. By inclusion of mermbranic albumines in lipidic double layer prepared of protheoliposomes, which use for modeling various fermentating, transport and receptoring of functions of a cells membranes. The liposomes use also in immunological investigations, entering in them various antigenes or covalenting attaching to liposomes of an antibody. They represent convenient model for study of action on membranes of many medicinal means and biologically active substances. It is possible to include in internal water volume of liposomes of a medicines, peptides, albumines and nucleic acid, that creates an opportunity of practical application of liposomes as a means of delivery of various substances in the certain bodies and fabrics [36]. On this property of liposomes the experts in development of magnetic remote-controlled carriers biologically of active substances have concentrated the attention. In works devoted to the given problem [36, 38-43], consider various variants preparation of magnetic carriers liposomes, common in which the inclusion in their internal lipidic volume of microcrystals Fe_3O_4 or γ-Fe_3O_4 in a combination to medicinal preparations is.

The magnetic carriers liposomes were prepared on the following methods [43-46]. Initial substances and reagents are: high dispersed magnetite, prepared by coprecipitation of salts Fe^{2+} and Fe^{3+} iron in alkaline medium and washed up to pH 7,6-8,2, derivative of lecytine: L-a-phosphatdiclolyne (or ovotyne-200), prepared from egg yolk; D-a-tokoferol, chloroform, methyl alcohol, C - cholesterol [39-43]. A mix L-a- phosphatdiclolyne (20 micromoles) and D-a-tokoferol (0,5 micromoles) dissolve in 10 ml of chloroform and added to suspension of ferrite in methyl alcohol, there brought in C - cholesterol. The prepared mix processed by ultrasound up to complete dispersing of magnetite, then lyofilic dried up, that has allowed to generate on a surface of magnetite crystals a thin steady film of lipid - that is to prepared of lipid capsule with included inside of its ferrite nucleus. The lipid capsules with a ferrite nucleus were disperged in 1 ml of buffer solution containing H-inulyne. Process carried out at intensive shaking of capacity with contents on installation «Vortex» up to complete hydratation of capsules with formed liposomes. 1 ml prepared suspension of liposomes passed through gel-chromatographic column for branch generated of liposomes from free inulyne and aggregating ferrite. The ferrite lingered over in the beginning of gel-chromatographic column. Collected fractions on 2 ml eluate containing of lipid. In a standard preparation (during preparation of magnetic carriers liposomes used 1,9 mg of magnetite) common concentration of lipid and magnetite have made accordingly 8,6 mkg / ml and 133 mlg / ml. The liposomes had average diameter 1,54 microns.

The conclusion

From the given review of the domestic and foreign literature it is visible, that magnetic technology and perspective multifunctional magnetic carriers preparations are represented by new opportunities for treatment and diagnostics of tumours, to separation of crates of blood and marrow directed transport of medicines and immunodiagnostic means controlled x-ray contrasting. The results of work can be used in experimental haematology, transfusiology, microbiology, immunology, oncology and other areas of science.

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PREPARATION, STRUCTURE AND MAGNETIC PROPERTIES OF COBALT NANOCLUSTERS IN CARBON MATRIX

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Granular solids composed of magnetic nanoparticles dispersed into non-magnetic matrixes exhibit a wide variety of interesting magnetic and electronic properties that can be engineered by proper choice of the composition. Among these properties the following can be named: a size-dependent enhanced magnetic moment [1], giant magnetoresistance [2], and tunneling magnetoresistance [3]. These granular solids are usually fabricated by codeposition [4], sequential deposition of thin metallic layers and thicker insulating layers [5], sol-gel method [6], or by the combination of ion-beam metal cluster preparation with the inert-gas-matrix-isolation technique [7].

In order to obtain cobalt clusters imbedded in a carbon matrix the heat-treatment method of carboxylated cellulose fibers after the COOH-groups protons exchange by cobalt cations by means of ion exchange absorbtion has been employed. Homogeneous distribution of cations at an atomic scale into carboxylated fibers received by ion-exchange absorbtion gives an opportunity to obtain homogeneous distribution of cobalt clusters within carbon fibers after heat-treatment.

Three carboxylcellulose (TCC) was used as a carboxylated cellulose. It was obtained on a base of rayon fibers by means of introducing carboxyl groups as was described in [8].

Heat - treatment of the samples was conducted under vacuum at residual preasure 1,3 Pa. Temperature increase velocity was 3 ^oC per minute. When the final heat - treatment temperature was achieved (700 ^oC or 900 ^oC) the isotermal annealing of the samples during 30 min was employed in order to stabilize the thermochemical convertions in the samples. As a result of the heat-treatment the carbon fibers with cobalt clusters were obtained. The size and weight of the TCC fibers after heat treatment decreased: diameter of fiber was decreased from 3 to 0,5 mm, and the weight lose was about 70 % due to evaporation of flying lowmolecular components such as carbon mono- and dioxide and other compounds.

Auger spectroscopy shows that the investigated fibers includes carbon and cobalt, as the concentration of other elements is negligible. The cobalt content in the carbon fibers obtained from TCC with 2.5 and 3.1 mmol/g Co^{2+} at heat treatment temperature 700 ^oC was equal to 12.2 and 15.7 mol% respectively and these for 900 ^oC 14.6 and 18.5 mol%. The formation of cobalt clusters in carbon matrix for both temperatures of heat-treatment was estimated by means of transmition electron spectroscopy. The carbon fibers treated at 700 ^oC include cobalt clusters with diameter about 10 nm with small deviation from this value. Some clusters are not single-crystalline, but consist of a few particles with different crystal orientation.

When the heat-treatment temperature increases to 900 ^{o}C it leads to growth of clusters size. In this case the distribution of the clusters size is very inhomogeneous. The clusters size differs from very small (less than 30 nm) up to about 200 nm and more.

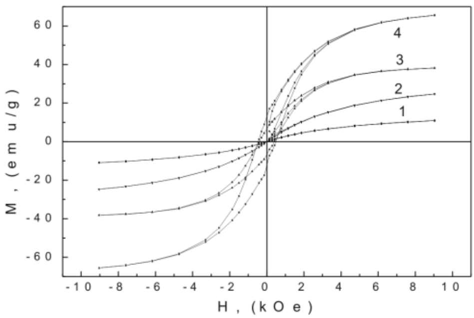

Fig. Room temperature hysteresis loops of carbon fiber matrix with different concentration of cobalt cations in precursor cellulose (mmol/g): 1-2,5; 2-3,1; 3 –2,5; 4-3,1 and different final heat-treatment temperature ^{o}C): 1,2 –700; 3,4 –900

Figure shows hysteresis loops at room temperatures for samples with different concentration of cobalt cations in the precursor TCC and different final heat-treatment temperature implyed during production of the carbon fibers. It can be seen that magnetisation increases when the cobalt concentration increases and the coercivity for the samples with final heat-treatment temperature 700^{o} C equals zero. It means that thermal energy is higher than the anisotropy barrier energy and a coherent rotation of the atomic moments of the clusters is allowed, i.e. room temperature is higher that blocking temperature for this size of cobalt clusters.

The magnitude of the blocking temperature is predicted by Neel's theory

$$25\ K_b\ T_b= K_{eff}.V. \qquad (1)$$

K_b and K_{eff} are the Boltzmann constant and effective magnetic anisotropy constant, respectively, and V is the average volume of the particles.

Using the equation (1) and the value of K_{eff} for cobalt nanoparticle from [9] one can calculate the blocking temperature for cobalt with average diameter 10 nm. The value of the blocking temperature less then 100 K and the particles are superparamagnetic.

When the heat-treatment temperature increases from 700^{o} C to 900 there large clusters start to appear. The carbon fibers with same value of cobalt concentration into precursor TCC, but annealed at 900^{o} C, show ferromagnetic behavior (curves 3,4) with coercivity for both samples 430 0e. Large size cobalt clusters are responsible for residual magnetization of the carbon fibers annealed at 900 C.

In summary, we used heat-treatment method of cellulose fibers with ion-absorbed cations of cobalt in order to synthesize cobalt clusters imbedded in a carbon matrix. When the final heat-treatment temperature was 700 ^{o}C nanoparticles of cobalt with average size of 10 nm were obtained. At 900 ^{o}C the distribution of cluster size was very inhomogeneus : from 30 nm up to 200 nm and more. The first carbon fibers at room temperatures show superparamagnetic properties, while the second – ferromagnetic ones with coercivity 430 0e.

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CHAIN AGGREGATES STRUCTURE IN POLYDISPERSE FERROFLUIDS

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Kantorovich Sofia S. is taking a master degree course. The sphere of scientific researches is chain aggregates mathematical modeling in ferrofluids. During three-year studying of the problem she has got 5 publications. This work is supported by RFBR grants for young scientists.

There is one thing that almost all known papers dealing with ferrofluid microstructure theoretical description have in common – it is monodispersity of a model magnetic fluid. It means an inherent feature of real ferrofluid such as the presence of different size particles is neglected. In the only work, where an attempt to take into account the polydispersity in the chain formation process was made [1], small particles did not play any role in aggregation and only remained as a part of a carrier liquid.

The present paper is devoted to the magnetic fluid polydispersity influence upon the structure of arising chain aggregates. As the three-fraction magnetic fluid proved to be the most suitable for chain aggregate structure studies, we focus our attention on the following approach. Continuous particle size distribution is obtained on the basis of an experimentally built magnetization curve. Parameters of such distribution could be found by means of magnetogranulometric analysis. Then, real polydisperse magnetic fluid is approximated by the three-fraction system, choosing the diameter of the first fraction as a maximum of continuous distribution. As far as the other parameters are concerned they are chosen from the experimental and model magnetization curves coinciding condition. Thus, for real ferrocolloids three-fractional models have the following parameters.

Table 1. Model bidisperse ferrofluid characteristics, obtained on the basis of real magnetic fluids. Fluid TTR630 (Romania); APG513 (Ferrofluidics Co., USA).

Name	x_1	x_2	x_3	υ_2	υ_3	φ_m	e_{23}	e_{33}
TTR630*	5.90	10.70	16.80	0.22	0.008	0.14	1.60	5.94
APG513*	5.56	11.02	18.90	0.22	0.003	0.073	1.30	6.98
FF**	6.05	11.53	19.08	0.22	0.009	0.023	1.24	6.11

It could be seen, model ferrocolloid is composed in general of small particles (fraction 1), with magnetic core diameter x_1=*5-7* nm and negligibly small interparticle dipole-dipole interaction energy e_{11}, so, this fraction is excluded from the further

* Curves were obtained by Dr. S. Odenbach (ZARM, Bremen, Germany)
** Curve, obtained be A. F. Pshenichnikov (Perm, Russia)

consideration. Middle particles (fraction 2), with x_2=*9-12* nm and large particles (fraction 3) x_3=*16-20* nm, with low mole portion ν_2 and especially low - ν_3, have the interaction energies e_{22}, e_{23}, e_{33} strong enough to form different chain aggregates.

Using Frenkel's theory [2] and the worked out mathematical algorithm, allowing to account for all chains having different topological structures [3], we obtain the following target setting for the three -fraction system.

$$F = kT \sum_{n+m\geq 1}^{\infty} \sum_{i=1}^{I(n,m)} K(i,n,m) g(i,n,m) \left(\ln\left(\frac{g(i,n,m)}{e} \right) - \left\langle \mathbf{E}, \mathbf{S}_i \right\rangle \right) \quad (1)$$

$$\frac{\rho_2}{\mathrm{v}_2} = \sum_{n+m\geq 1}^{\infty} \sum_{i=1}^{I(n,m)} K(i,n,m) g(i,n,m) n, \quad \frac{\rho_3}{\mathrm{v}_3} = \sum_{n+m\geq 1}^{\infty} \sum_{i=1}^{I(n,m)} K(i,n,m) g(i,n,m) m \quad (2)$$

Here **E** = (e_{22}, e_{23}, e_{33}) is an energy vector, *I(n,m)* is a finite number of energetically distinguishable chain structures. The set $\mathbf{S}_i = (a_i, b_i, c_i)$ is the set of structure vectors. Minimization of the functional (1) over *g(i,n,m)* – the concentration of *i*-th structure chains, consisting of *n* large and *m* middle particles, is carried out by means of the Lagrange method under the mass balance conditions (2). A factor *K(i,n,m)* has the value of topologically different chain structures relevant to the same energetic class number; ρ_2, ρ_3 are volume concentrations of middle and large particle fractions, respectively. Thus (3):

$$g(i,n,m) = \exp\left(\lambda_1 m + \lambda_2 n + \left\langle \mathbf{E}, \mathbf{S}_i \right\rangle \right) \quad (3)$$

here λ_1, λ_2 - are Lagrange multipliers that should be determined from the mass balance equations numerically. Since, the energy e_{22} is low in comparising with *kT*, the 22 bond cannot be treated as a stable one. So, it is reasonable to exclude from consideration all chain structures containing at least two middle particles connected with each other and chains, containing middle particle between two large ones, as the probability of such chains appearance turned out to be very small. Let us describe the main topological chain classes 1-3. Here are the concentrations (4):

$$g(I_1,n,0) = \exp(-e_{33}) p_2^n \qquad K(I_1,n,0) = 1 \qquad \text{OOO}\ldots\text{OOO}$$

$$g(I_2,n,1) = \exp(-e_{33}) p_1 p_2^n \qquad K(I_2,n,1) = 1 \qquad \text{OOO}\ldots\text{OOo} \quad (4)$$

$$g(I_3,n,2) = \exp(-e_{33}) p_1^2 p_2^n \qquad K(I_3,n,2) = 1 \qquad \text{oOO}\ldots\text{OOo}$$

$$\mathrm{p}_1 = \exp(\lambda_1 + e_{23}) \qquad p_2 = \exp(\lambda_2 + e_{33})$$

It is easy to find that parameter p_1, p_2 powers show the corresponding fraction particle number. The probabilities of three main class chain appearances are given by the following ratio:

$$g(I_1,n,m) : g(I_2,n-1,m) : g(I_3,n-2,m) = 1 : p_1/p_2 : (p_1/p_2)^2 \quad (5)$$

As the parameters p_1, p_2 stand for the 12 and 22 bonds establishing probabilities, respectively, this expression becomes clear. Naturally, $p_1 = p_2$ equality means that chains of these three classes are equiprobable. Consequently, the phase plane is divided by the curve $p_1 = p_2$ into two regions of chain structure predominance: above the curve there is an area of the 1st class chain structure dominating, and below - the most probable are the chains from the 3rd class (Fig. 1). The region of parameters for any industrial ferrofluid is situated below the corresponding phase curve. For example, points, corresponding to ferrofluids from Table 1 are encircled. Thus, in reality the most probable chain aggregates are those from the 3rd class, consisting of several large particles, at both edges of which there is one small particle.

Fig. 1. Phase diagram. Curve 1 is built for TTR630, curve 2 – for APG513 & curve 3 for FF see Table 1. Corresponding points show the alignment of real ferrocolloids.

In conclusion, the analysis presented shows that the polydispersity is a determinative factor that influence the chain aggregate structure in magnetic fluids. The built phase diagram allowed to find out that the most probable chain structure in a real ferrofluid is one, consisting of several large particles in the middle of the chain, at the both edges of which there is one middle particle.

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PRODUCTION OF MAGNETIC MICROSPHERES FOR IMMUNOMAGNETIC SEPARATION OF CELLS

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Magnetic separation is widely used in biology, drugs biotechnology, the scientific and applied clinical medicine and research work in the different branches of medicine. Microspheres are used for immunodeficiency state diagnosis, for blood cells and marrow isolation by the claster differentiation, for DNA, bacterium and antigen isolation. The possibility of carrying out immune reactions using immune active substances (antibodies, antigens) immobilized on magnetosensible microcarriers allows not only the separation of the required cell subpopulations without using complicated and expensive equipment but also makes it possible to develop express-methods for diagnostic of a number of diseases, providing the possibilities for immune reactions [1, 2].

The marrow and blood stem cells separation by means of composition magnetosensible materials is one of the important problems of modern medicine. Solution of this problem may have its application in modern oncology and hematology for stem cells transplantation. For medical purposes, immune magnetic cell separation began to be widely used in clinics for positive cells CD34+ separation. It was done for subsequent marrow repopulation in patients with different kinds of leukosis, breast cancer with metastases, localized stomach cancer, metastatic neuroblastoma, marrow aplasia and in the case of total irradiation [3, 4]. The source of stem cells is peripheral blood. There are a lot of advantages in stem cells separation: the process of separation does less invasive, it is not require anesthesia, in the case of leukosis the stem cells can be transplanted to absolutely not treated recipient with high probability of ghemopoese recovery. The use of the obtained from the peripheral blood stem cells for transplantation leads to faster приживляемости and reduce the terms of hospitalization in comparison with marrow autotransplantation.

But one of the main purposes of the current scientific direction is to develop the effective releasing agent for complex "microsphere – stem cell" separation, because microspheres with diameter 1-4 μ of in complex with stem cells may form thromboses when they are injected intravenously.

Microsphere is a ball-shaped disperses magnetic material protected by thin film that packs the magnetic material and provides a certain surface zone for absorption or molecules binding. The sphere size and form homogeneity provides constant physical and chemical characteristics. It leads to high-quality reproducible results. The particle cover can be either from natural biodegraded material (cellulose, agarose, albumin, gelatin, dextran) or synthetic one (polystyrene, copolymers of styrene and divynilbenzene, polyacroleine, polyacrylamide, polyvinyl alcohol, vinylpyridine).

Synthetic polymers have a number of advantages, such as the presence of different functional groups (OH, COOH, NH_2, CHO, SO_3H) in a polymer molecule. These groups promote formation of chemical and physical bonds with biosubstrata. Besides, ligands (streptovidine, oligo (dT), A and G protein monoclonal and polyclonal antibodies) can be drifted on the polymer matrix surface.

Microsphere synthesis is accomplished by the method of emulsion polymerization [5, 6]. The process of obtaining the stable emulsion is of a great importance in the emulsion polymerization. The emulsion stability is mainly influenced by monomer and emulsifier concentration. The magnetic material is entered in the system on the stage of getting microemulsion. For such purposes the magnetite (mixed iron oxides (II) and (III)) is frequently used because it can be easily obtained.

Magnetite is obtained by the following method: saturated solution of iron salts (II) и (III) (iron sulphate and iron chloride appropriately) is mixed up quickly with concentrated ammonia solution (25%) under room temperature. The given colloidal solution is cleansed by distilled water to neutral environment by method of magnetic decantation. After cleansing, the given magnetite suspension is treated by ultrasonic field during 2-3 minutes. The phase structure of given magnetite is analyzed by method of the X-ray diffraction analysis. According to the analysis results, the magnetic material is a mixture of magnetite and maghemite. Reflexes are expressed not very legibly. It allows assumption of the particles have small size.

The obtained magnetite colloidal water solution is entered in the reactional mixture of emulsion polymerization containing monomer and emulsifier. The water is a disperse medium. The obtained reactional mixture is mixed up during 30 minutes with the mixer speed of ~1500 revolution per minute. Then the initiator of radical polymerization (potassium persulfate, azo(bisiso)butironitrile, dicumilperoxide, hydrogen peroxide) is added. The reaction is carried out at the temperature of 70 ^oC during 24 hours. The mixer speed is ~1500 revolution per minute.

During radical polymerization the magnetite is oxidized and turns into maghemite as a result [7]. This process can be watched by reactional mixture which changes the color: from dark grey, right away after adding magnetite, to orange, in 3-4 hours after adding the initiator of radical polymerization. The next mechanism of magnetite oxidizing in the presence of peroxide compounds can be assumed:

$$K_2S_2O_8 \leftrightarrow 2K^+ + S_2O_8^{2-}$$

$$S_2O_8^{2-} + H_2O \rightarrow 2H^+ + 2SO_4^{2-} + O\cdot\ (1/2O_2)$$

$$2Fe_3O_4 + O\cdot \rightarrow 3Fe_2O_3$$

general equation of reaction:

$$K_2S_2O_8 + 2Fe_3O_4 + H_2O \rightarrow 2KHSO_4 + 3\ Fe_2O_3$$

The polymerization product is a colloidal orange-colored solution being stable for a long time. The dispersed phase is polymer balls with the magnetic material inclusion in volume. Microspheres are deposited well on the magnet and they are dispersed when shaking up with the magnetic field moved away. It is very convenient for medical use.

Received dispersion of microspheres are planned to be use for immunomagnetic cell separation aimed at their phenotyping, transplantology and study of cell and humoral immunity mechanisms.

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PHYSICAL PROPERTIES

THE MODULATION OF THE ULTRASOUND PULSE BY THE MAGNETIZED MAGNETIC FLUID

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The exploration of the features of the ultrasound waves propagation through the magnetized magnetic fluid is of great interest, as the acoustic investigations allow to receive the information about the structural changes in the magnetic colloid, provided that the optical transparence of the explored medium is required.

The amplitude and the form of the ultrasound pulse, passed through the acoustic cell, filled by the magnetic fluid under the lengthy influence of the magnetic field were investigated in this work.

The block diagram of the experimental unit is presented in the figure 1.

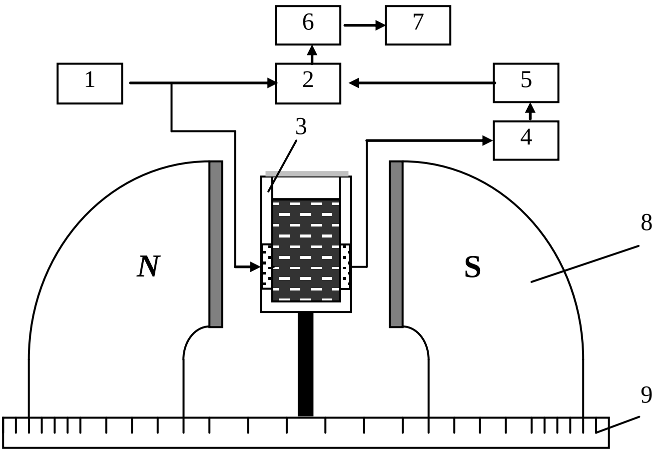

Fig. 1

The radiopulses on the frequency of 6 MHz from the generator 1 are applied on the radiating piesoelement. The ultrasound pulse, passed through the magnetic fluid, filling the acoustic cavity 3, is transformed by the radiopulse. Then the radiopulse through the attenuator 4 is applied at the receiver input of the superlocal oscillator 5 and is detected there. The resulted videopulses are applied on the oscillator input 2. The oscillograms are sensed by the digital videocamera 6 for the following processing on computer 7. The permanent magnet 8 is served as the origin of the magnetic field, which is installed on the rotating platform 9.

The investigated samples are the magnetic colloids, prepared on the base of kerosene. The dispersed phase in them is the magnetite Fe_3O_4, and the olein acid serves as a stabilizer. The main physical parameters of the magnetic fluid samples, used in the experiment, are presented in the table 1.

Table 1

Sample	ρ, kg/m^3	φ, %	M_s,kA/m
MF-1	1350	12,8	54±1
MF-2	1300	11,7	50±1

where: ρ- the density of the magnetic colloid, φ- the volume concentration of the solid phase, M_s- the magnetization of the saturation.

The experiment is performed at the temperature of 290±1 K.

The intensity of the magnetic field is 122 kA/m, and the origin angle between the vector of the magnetic field intensity $\vec{H}$ and the wave vector $\vec{k}$ is $\vartheta = 90°$.

During the experiment the considerable reduction of the ultrasound pulse amplitude was found.

Later t ≈ 50 hours (the magnetic fluid-1) and t ≈ 150 hours (the magnetic fluid-2) from the beginning of the experiment by the additional amplification of a signal in the receiver for the definite angles ϑ the change of the videopulse form is distinctly watched.

The oscillograms of the ultrasound pulse passed through the magnetic fluid -1, are presented in the figure 2 (value of a division on Y 0,5 V/div, on X – 5 mcs/div).

During the rotation of the magnetic field the form of the videopulse is changed, that is the managed modulation of the ultrasound pulse is taken place, at the angles of 130°-155° there is a pulse valley in the central part of the videopulse, which is watched at the angles of 200°- 230°. However in the first case the pulse valley is moved from right to left, and in the second case – vice versa.

In one of the first works on this theme [1] the effect of the “fast” pulse appearance in the magnetized magnetic fluid is marked. The origin of effect probably has the same physical nature.

CONCLUSION:

1. The ultrasound pulse modulation, passed through the magnetic fluid, taking place in the homogeneous magnetic field for a long time is obviously connected with the formation of the specific structure from the particles of the ferrophase.
2. This structure possesses the features of the filter with frequency character in depending on the angle between the direction of the wave vector and the magnetic field intensity.
3. The modulation of the passed pulse doesn’t allow to describe the received result on the basis of the standard methodology, used for the measurement of the coefficient for the ultrasound saturation.
4. The frequent rotation of the magnetic field around the tray with the magnetic fluid results obviously in the gradual destruction of the formed structure.
5. The restoration of the initial amplitude for the ultrasound pulse is performed during the careful mechanical mixing of this fluid.

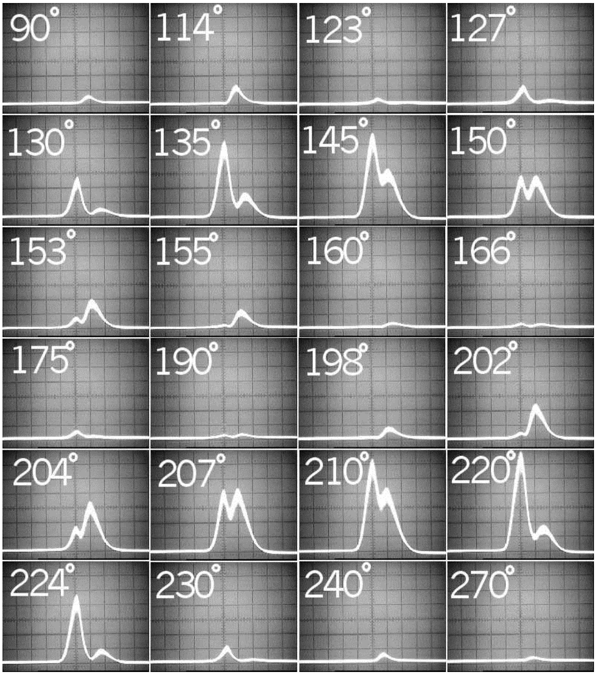

Fig. 2

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ENERGY DISSIPATION IN A MAGNETIC FLUID INERT ELEMENT

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Magnetic fluid (MF) in most of devices where it is an active element is partially or fully filling some cavity being in the magnetic field. And here not only strong magnetic properties of the MF but its high fluidity is used. Thus an MF drop can perform oscillation along the cylindrical channel axis or in the circular gap as, for example, in the magnetic fluid hermetics. That's why the problem of mechanical energy dissipational oscillating movement of magnetized MF is actual.

The experimental study of the oscillating system in which the magnetic field inert element spring-loaded by the gees cavity and the poudemotor type plasticity, were carried out on the plant schematically presented in Fig.1.

The MF 1 partially fills the glass tube 2 with the bottom end sealed (the tube diameter is 1.36 cm) and at the same time covering the gase space at the base of the tube. The tube is fixed in the holder 3, resting on the platform 5 with the help of the rubber shock absorbers 4. The impact mechanism 6 disturbs the MF column from

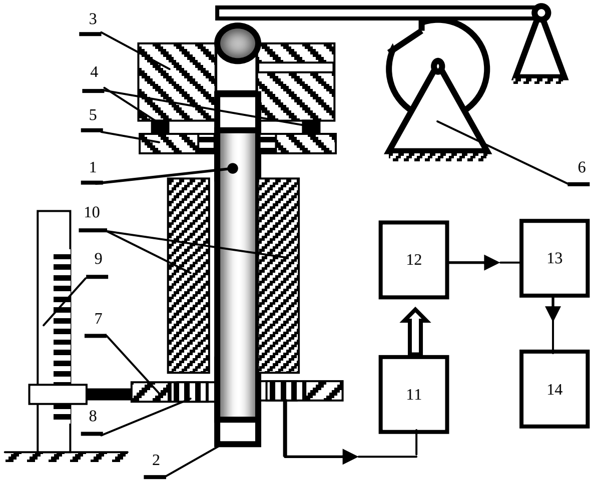

Fig.1

the state of equilibrium. The circular magnet 7 stabilized the lower surface of the fluid column. Inside the circular magnet the induction coil 8 to which the alternative E.M.F. is directed of MF oscillations is mounted. The magnet-induction coil system is rigidly attached to the cathetometer kinematic unit 9. To magnetize the fluid in the direction perpendicular to the tube axis there have been used magnetic plates 10. The plate length is 8.5 cm, the field magnetization in the gap is 52 kA/m. From the induction coil the electro-magnetic pulse comes to the oscillograph terminal 11. The oscillogram picture is shot by the video camera 12 and through the TV tuner enters the computer for further development and analysis.

In the experiment the MF prepared as per the standard technique based upon magnetite and kerosene was used. The physical parameters of the colloids examined are given in the table.

	ρ, kg/m^3	η, Pa·s
MF-1	1630	$11{,}6 \cdot 10^{-3}$
MF-2	1440	$8{,}3 \cdot 10^{-3}$

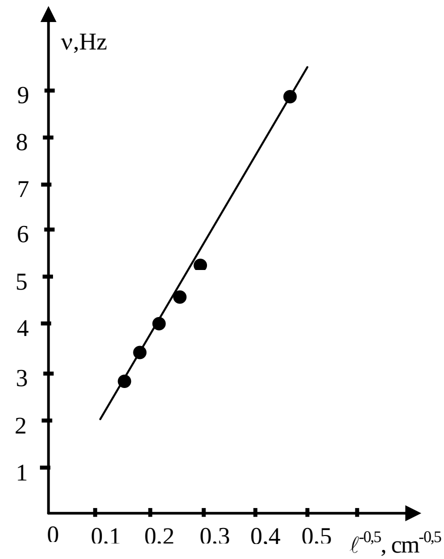

Fig.2

The damping oscillations oscillagram which with the help of the Corel DRAW programme determines the frequency ν and the oscillations amplitude A is brought to the computer monitor screen. The error of measurements ν and β by the above method is 3 and 10% correspondingly.

The dependence of ν upon the $1/\sqrt{\ell}$ obtained for MF-1 is shown in Fig. 2. The experimental points well enough lie upon the straight line which agrees with the oscillating system model the inert element of which is MF[1]. The reciprocating movement of a viscous drop inside the tube may be described by the two known models of Poiseuille and Helmholts. Poiseuille`s model can be used under the condition: $2\lambda' > \pi d$, where $\lambda' = 2\sqrt{\pi\eta/\nu\rho}$ is the length of a viscous wave.

While in our case we prefer Helmholts′s model because the demand of the viscous wave trifle length is met: $\pi d / 2\lambda' > 10$. In accordance with this model the damping factor is calculated by the formula:

$$\beta_T = \frac{2}{d}\sqrt{\frac{\pi\nu\eta}{\rho}}$$

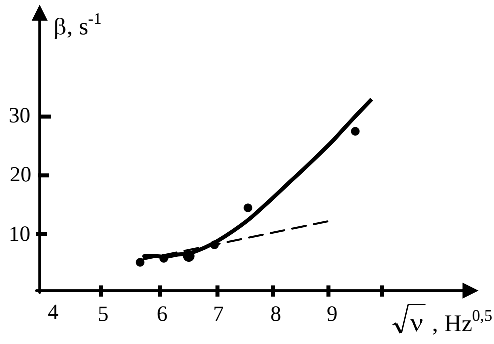

Fig. 3

In Fig. 3 the experimental dependence of B upon $\sqrt{\ell}$ for MF-2 which only in the lower portion of the frequencies range examined approximes by the straight line (dot line).

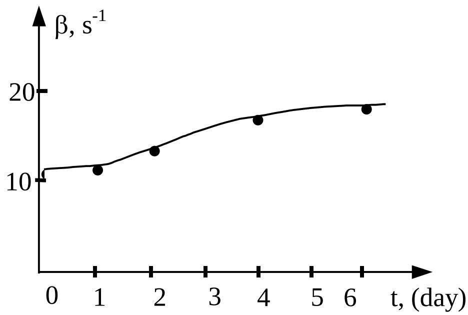

Fig. 4

All the above described experiments were carried out with absence of the magnetic field. In Fig. 4 the dependence of the damping coefficient β upon the time *t* of the fluid (MF-2) being in the magnetic colloids under the influence of the magnetic fields.

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MÖSSBAUER INVESTIGATION OF MAGNETIC FLUIDS PARTICLES

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In the present work the magnetic fluids on a water basis with various structure of dispersed particles and system of stabilization were prepared. Was carried out complex Mössbauer investigation given of dispersed systems. The influence of a nature of dispersed particles both layers of surfactants and a polymer on character of Mössbauer spectra was shown. By results of investigations were determined magnetic properties and size of particles in magnetic fluids.

Introduction.

Mossbauer investigation of magnetic fluids (MF) is a method of not destroying diagnostics and has a numbe of known advantages in comparison with other methods (x-ray difractometry, electronic microscopy). The application of Mossbauer spectroscopy (MS) for investigation of MF allows receiving the information on physical-chemical properties of particles. Carried out Mossbauer investigation of MF, containing magnetite (Fe_3O_4) and gamma - oxide of iron (γ-Fe_2O_3), have allowed to determine the average size of particles and to estimate a degree of influence of surfactants on a condition of a superficial layer of particles.

1. Preparation of dispersed systems

The magnetic fluids were prepared under the classical circuit: chemical condensation of salts Fe (III) and Fe (II) with formation of ferrite (magnetite and gamma - oxide of iron), stabilisation by superficial - active substances or polymers and peptization them in water medium [1 - 4]. The magnetic fluids on a base of magnetite (Fe_3O_4) and on a base of gamma - oxide of iron (γ-Fe_2O_3) were synthesised. Magnetite was prepared by coprecipitation of salts of iron Fe (III) and Fe (II) (10 % solutions) taken in the ratio 2:1 in a water solution of ammonia (25 %).

At synthesis of magnetic fluids on a basis magnetite as surfactant forming first chemical sorption the layer on a surface of particles, used oleic acid (1.7 g per 10 g prepared magnetite), and as surfactants (3.6 g per 10 g prepared magnetite), forming second, physically adsorpted layer, subsequently: sodium oleic, sulphonol (the salt of sodium of dodecilbenzensulphonic acid), cathamine AB (Dodecyldimethylbenzenammonium chloride).

At synthesis of a magnetic fluid on a basis gamma - oxide of iron was carried out operation of preliminary acidify of prepared magnetite with diluted hydrochloric acid (5 - 8 % HCl) until the formation of the activated form of ferrite with the subsequent reaction of connection of molecules polygluckine (20 g dextran per 10 g of the prepared ferrite) and preparation complex magnetically carriers of compound dextranferrite. Magnetic fluids were centrifuged at 6000 rotation per minute for separation of large particles. The prepared magnetic fluids had black or brown colouring and were steady in a gravitational field within five years.

2. Investigation of dispersed systems

Mossbauer spectra were measured on spectrometer with constant acceleration working in a mode of a bilateral saw with the subsequent convolution of the information for elimination of a geometrical background (a failure of a background at movement of a Mossbauer source from change of distance between the detector and a source of radiation). Was used Mossbauer source Co(Ro) with activity 20 mKu. Isomeric chemical shifts were given α-Fe. The measurements were carried out in a mode absorption scale - radiation at T ~ 298 K. Set of the information was carried out in 400 channels of the analyzer - store. Depending on size of effect (intensity of lines subspectra) the set of the information was carried out in a range from 2 up to 80 millions pulses on the channel (point) of a spectrum. The values of effect changed on samples in limits from 0,1 % up to 10%. Account of spectra at first carried out under the program Normos Dist, that is determined probability of distribution P(H) of superthin magnetic fields Heff (in kiloersted or Tesla). Then from this distribution the meanings Heff, bringing in greatest contributions were determined. These meanings Heff were given in the program Normos Site, on which were designed, in view of the physical and literary data, separate parameters of Mossbauer subspectra: number of phases - subspectra (synglets, doublets, sixtets), half-width of a line (width on half of height) "G/2", isomeric chemical shifts "δ", value of quadruple electrical interaction "Δ" (all in mm/s), superthin magnetic field Heff in kiloersted or Tesla, value of intensity of lines, ratio of intensity of lines I_{13}, I_{23}, (polarization of spectra), percentage of phases "S" in %, accuracy calculation of spectra "χ^2". Depending on the form of spectra, value of a set, intensity of a line, χ^2 changed in limits from 0,8 up to 10. G/2 was changed within the limits of 0,35-0,8 mm/s. Instead of theoretical meanings of the relations of intensity lines $A_{13} = 3$ and $A_{23} = 2$ values A_{13}, A_{23} were really changed in limits $A_{23} = 0{,}8\text{-}4$, $A_{13} = 1{,}5\text{-}2{,}81$. Values $\Delta = 0{,}01\text{-}0{,}035$ were changed insignificantly, therefore further them not is indicated.

Usually Mossbauer measurement of MF carried out with the help of temperature changes (down to 4,2 K). However at presence MF, the particles, in which were stabilized various surfactants or polymers, could take place magnetic phase transitions. Therefore we have chosen methods of lyofilic druing of a MF and filtration of MF through the filter and subsequent drying of samples in exicatore with addition of a shaving Zr within one month. After that the measurements carried out at T ~ 298K. For a way of druing in exicatore the spectra with very small value of effect ~ 0,1% were realized. They had wide lines of superthin splitting and failure at the centre from superparamagnetic particles. The data of spectra showed, that the particles were not in the aggregated condition, and were isolated by layers from surfactants (or polymer). Was noticed [4 - 8] same about the phenomenon at evaporation of particles of alloys earlier α-Fe, Fe-Ni, Fe-Mn. The increases of effect we achieved by mechanical-chemical influence - grinding of the dried up samples in agate mill.

3. Discussion of results

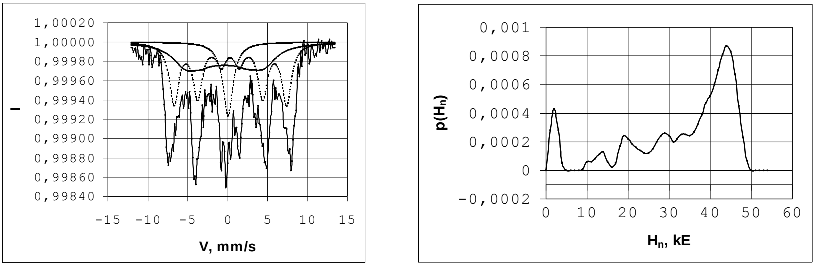
In the carried out work the features caused as by dimensions effects, and conditions of preparation of high dispersed powders were revealed. Applying a method of gas evaporation (fast tempering of aerosol particles arising at condensation pair of substance in an atmosphere of inert gas) has become possible to freeze and to investigate at T ~ 298 K high-temperature condition. Using this method, we managed directly to confirm a hypothesis Vass about existence of two spin condition for ferro- and antifderromagnetic structure both pure iron, and alloys Fe-Ni, Fe-Mn of different structure. In these works was marked, that the probability of Mossbauer effect (value of lines intensity) strongly grew after grinding powders in agate mill. Thus did not change (on the data x-ray) phase ratio and parameters of a lattice of powders.

After grinding dried up MF and magnetic separation we have fixed values of effects up to 4 % for MF on a basis Fe_3O_4 and up to 8 % for MF on a basis γ-Fe_2O_3, that is have fixed substantial growth of value of effect for ensemble already of cooperating among themselves particles.

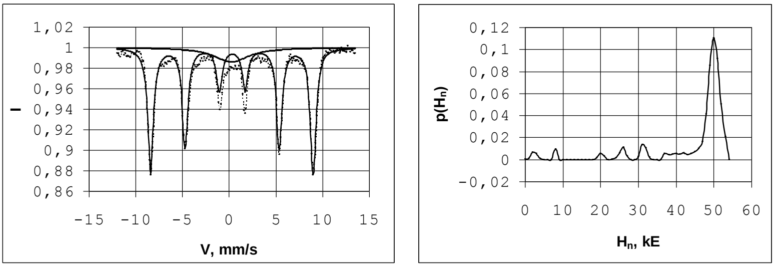
In work [9] the contribution in Mossbauer spectra ultra small was analysed γ-Fe_2O_3 of particles of superficial ions. The dependences Heff from the sizes of particles, temperature were investigated. Was established, what for particles it is less 70Å The time of relaxation of a ionic spins becomes less, the gradient of an electrical field on nucleuses is increased, the temperature dependence of light fraction sharply changes in comparison with more massive (500 Å) by substance. Moreover, the corner between an axis of a gradient of an electrical field and direction of easy magnetization becomes casual distributed for superficial atoms of these samples (<70 Å). Probably same about dependences are observed and for particles <70 Å Other materials (γ-Fe_2O_3, Fe_3O_4, of cobalt-ferrite $CoFe_2O_4$). Therefore in works [10, 11] on Mossbauer investigation by a diameter of particles 3,3 nm $CoFe_2O_4$ in MF was necessary to complicate experiment. The temperature measurements were carried out up to 4,2 K (or up to 10 K, but at external magnetic fields up to 6 Tesla).

In work was established, that at increase of temperature there is a transition from magnetic regulating of a condition to superparamagnetic at T ~ 80 K, that is at temperature is higher 80 K (especially at T ~ 298 K) Mossbauer spectra show superparamagnetic doublet without magnetic splitting. In researched samples at T ~ 298 K there is a polarization MF even at units Ersted of an external field (on an element of a Hall).

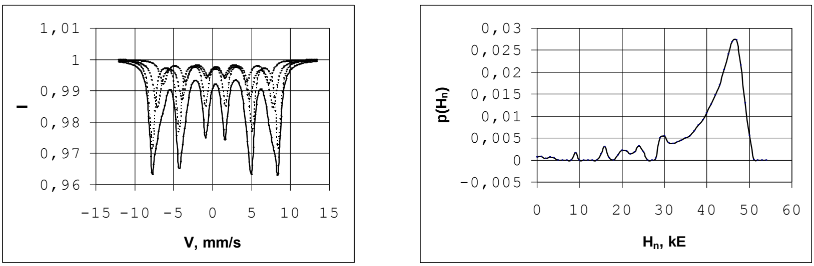
Figure 1. Mossbauer spectra of samples realized from magnetic fluids.



A) Powder from MF on a basis Fe_3O_4, missed through the paper filter, and dried up in excicatore within 1 month.

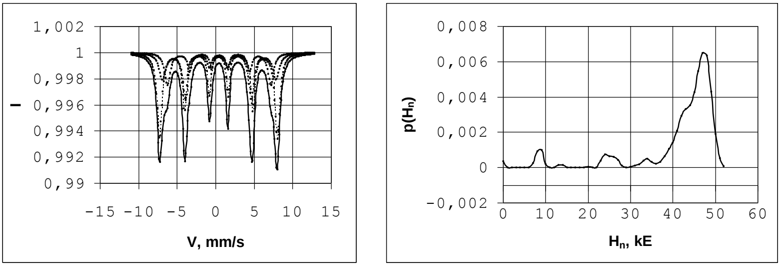


B) Powders from MF on a basis γ-Fe_2O_3, from excicatore with additional grinding in agate mill.

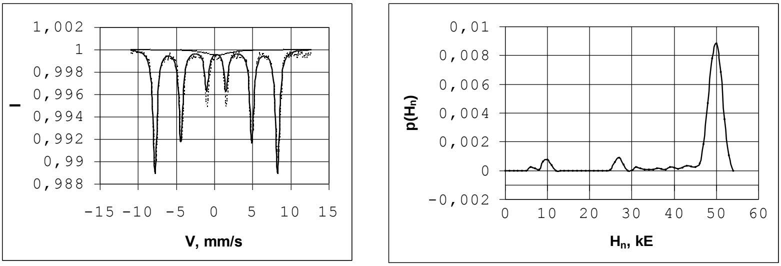


C) Powders from MF on a basis Fe_3O_4 from excicatore with grinding in agate mill.

Figure 2. Mossbauer spectra of samples MF, prepared by lyofilic drying method.



A) On a basis Fe_3O_4.



B) On a basis γ-Fe_2O_3.

Mossbauer spectra of samples (powders) prepared from a magnetic fluid, are submitted in figure 1. At the left spectra designed on the program Normos Site. On the right account of probability of distribution of superthin fields P(H), realized on the program Normos Dist. On figure 1A the spectrum of a powder from a fluid on a basis Fe_3O_4, missed through the paper filter and dried up in exicatore within one month is given. In figure 1B the spectrum of a powder from a fluid on a basis is given γ-Fe_2O_3, from exicatore with additional grinding in agate mill. In figure 1C the spectrum of a powder from a fluid on a basis Fe_3O_4, grinding in agate mill and past magnetic separation is given. In figure 2 are given Mossbauer spectra prepared by lyofilic druing method (2A from MF on the basis Fe_3O_4, 2B from MF on a basis γ-Fe_2O_3).

It is necessary to note, that the value of effect in spectra of a sample in figure 1A at the left, makes ~ 0,1 %, and after of grinding in agate mill of the same sample (on a basis Fe_3O_4) the value of effect grows up to ~ 3 - 4 %, that is is increased approximately in 40 times, thus the structure of a sample remains approximately identical. It is possible to explain it by change of root-mean-square displacement of fluctuation of nucleuses ^{57}Fe. If to assume, what the size of particles (magnetic domain structure of ultra small particles) does not vary (on the literary data [12 - 14] a diameter of particles 300-500 Å), the effect of precipitation particles in pores of the paper filter (effect ~ 0,1 % not aggregated condition which is not cooperating among themselves of a particle as one firm body) can be shown. The application of mechanical-chemical process translates particles in more condensation condition, the effect is increased. For samples after of lyofilic drying the intensity of peaks makes ~ 1 %, that is the conditions of drying (cooling - compression, heating - expansion) answer conditions of grinding, condensation, sintering of particles, removal of crystal water.

By results of the analysis of the data, the basic fields Heff answered γ-Fe_2O_3 and Fe_3O_4. For γ-Fe_2O_3 had a set of fields Heff, depending on a way of preparation, in a range from 488 – 520 kE, that is intersection of fields Fe_3O_4, γ-Fe_2O_3, α-Fe_2O_3. For Fe_2O_3 the distributions of fields nor answer bee stechiometrical Fe_3O_4 and had meanings 304 - 488 kE. In all spectra from distribution P(H) the small quantity some more smaller meanings of fields adequate connections with surfactants or polymer was marked.

Conclusions

By results of investigations was shown, that Mossbauer spectroscopy allows to receive the information on physical-chemical structure of magnetic particles in MF. The influence of layers surfactants or polymers on character of Mossbauer spectra for various magnetic particles, and also preparation of a magnetic substance for similar of investigations was established. By results of the carried out investigations it is possible to calculate the magnetic characteristics of dispersed systems and to estimate the size of particles in MF.

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PHASE TRANSITIONS IN MAGNETORHEOLOGICAL SUSPENSIONS

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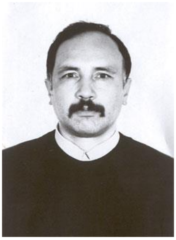

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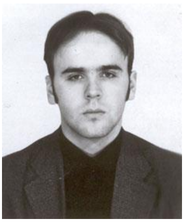

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Since the first experiments with magnetorheological suspensions (MRS) it is well known that under external magnetic field particles of these suspensions can unite into chain-like, drop-like, column and other heterogeneous aggregates. Appearance of these structures leads to dramatic, often several orders of magnitude, transformations of physical properties of the MRS. First models of the condensation phase transitions in ensemble of polarized particles of MRS [1,2] deal with the classical van-der-Waalse scenario of the “gas-liquid” phase transition, where single particles, under dipole-dipole forces, condense into homogeneous liquid-like phases. However, numerous laboratory and computer experiments show (see, for example, [3-5]) that real scenario of the phase transformations in MRS differs significantly from the classical picture. Namely, long linear chain-like clusters appear in thermodynamically equilibrium suspension before its spatial transformation into two massive phases. Occurrence of these chains changes, first, physical properties of MRS and, second, conditions and kinetics of phase transitions in the systems.

We present the results of theoretical study of the “gas-liquid” phase transition if MRS taking into account appearance of the chain-like clusters. The system of identical paramagnetic particles with volume v and magnetic permeability μ_p immersed into a carrier liquid with permeability μ_f is considered. Let g_n be the number of n-particle chains in a unit volume of the system. Free energy of the unite volume can be written as:

$$F = kT \sum_{n=1}^{\infty} g_n \left[\ln \frac{g_n v}{e} + u_{n,m1} + u_{n,m2}\left[g_k\right] + u_{n,st}\left[g_k\right] \right] \qquad (1)$$

The first term in square brackets presents the entropy of the gas of n-particle chains due to their translation motion, term $u_{n,m1}$ is the dimensionless energy of single n-particle chain in external magnetic field H, the third and forth terms are dimensionless energies of magnetic and steric interactions between chains. In equilibrium state the function g_n provides minimum of F under obvious condition of conservation of particles: $\sum_{n=1}^{\infty} n g_n = c = \varphi / v$, where c and φ are numerical and volume concentration of the particles. We found the distribution function g_n taking into account that interaction between chains is weaker than interaction between particles in the chains and, therefore, in the first approximation, the two last terms in brackets (1) can be neglected. Then, having g_n, and using (1), we calculated chemical potential ν(φ) and osmotic pressure p(φ) of particles in the suspension for a given dimensionless parameters $x=\mu_{.p} /\mu_f$ and $\alpha=\mu_f H^2 v/kT$. When $\alpha > \alpha_c$, van-der-Waalse loops appear on plots of functions p(φ) and ν(φ). This shows that equilibrium separation of MRS into dilute and dense phases can take place.

The results of calculations of binodals of the phase separation for two magnitudes of ratio of permeabilities x are shown in Fig.1 for the presented model of MRS with chains and under assumption that all particles are single (N=1). In the model with chains the phase transition takes place for magnetic fields smaller than those in model of the single particles. This means that, in accordance with all known experiments, the chains appear before the spatial phase separation of MRS into two massive phases.

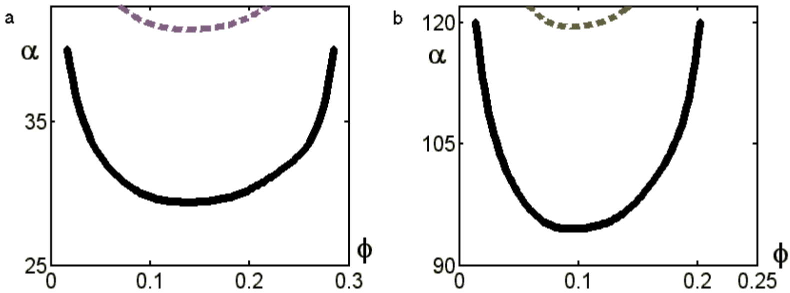

Fig1. Binodal of the phase separation of MRS for a) x = 5, b) x=3

Solid lines correspond to the model with chains, dashed ones – to the approximation of single particles.

In conclusion we would like to note that a new scenario of field induced phase transitions in MRS is suggested. Results of our analysis are in agreement with known experiments.

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DIELECTRIC PROPERTIES OF MAGNETIC FLUIDS

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1. Introduction

Physicochemical processes occurring in magnetic fluids are accompanied by various kinds of electric phenomena which may play the important part while forming one or another structural state in magnetic fluids (MF) [1,2]. One of the most important problems undecided till present time is an investigation of transport and redistribution processes of free and bound charges in magnetic fluids between dispersed phase (DP) and dispersive medium (DM). Side by side with this the change of capacitive and active components of impedance of a measuring cell filled with magnetic fluid while penetrating the alternating current of different frequency is conditioned by made a contribution of free and bound charges in the process of transport and redistribution them in magnetic fluid. In this connection the study of laws defining the change of electrophysical characteristics such as relative dielectric permeability, electric resistivity and tangent of dielectric loss angle depending on electric field frequency and concentration of dispersed phase for different types of magnetic fluids is very important task. From this point of view the application of developed procedure and of made automated impedancemetrical complex is of great value to estimate charges transport and redistribution processes in magnetic fluids on the basis of their electrophysical characteristics.

2. Procedure

To carry out investigations the unique device consisting of the highly sensitive primary transducers (sensors) and the second digital instruments (impedance meters) in which it is provided with the current measurement data output on the digital display of meter or on the monitor screen of computer has been developed. The investigated samples were placed into the homogeneous electric alternating field induced in a interelectrode space of a measuring cell with plane-parallel electrodes. The separate measurements of capacitive and active components of impedance is the basis of the developed procedure. The influence of parasitic phenomena on results of measured electric parameters such as electric capacitance (*C*) and conductance *(G)* of measuring cell filled with a magnetic fluid was eliminated by correction of the impedance components. The electrophysical characteristics such as ε, ρ and tgδ have been calculated using corrected values of *C* and *G.* The measurements of electrophysical parameters were carried out on the thermostating of a measuring cell. The accuracy of measurement of electric parameters is ±0,5 %.

3. Experimental results

In this work the results of investigations of relative dielectric permeability (ε), electric resistivity (ρ) and tangent of dielectric loss angle (tgδ) of magnetic fluids obtained on the basis of turbineoil[3], dekane[4], and water[5] with the use of oleic acid as a surface-active substance (SAS) depending on electric field frequency (10^2 – 10^7 Hz) under different concentrations of dispersed phase (DP) have been presented. The general tendency is the decrease of absolute values of ε, ρ and tgδ of MF based on turbine oil and dekane with increasing the electric field frequency (fig. l, 2, 3, 4).

At the same time, while changing the degree of polarity of dispersive medium (DM) such as turbine oil-water or dekane-water, a considerable difference in frequency dependencies profilesmentioned electrophysical characteristics of MF is being observed (fig. 5, 6).

If for MF based on turbine oil and dekane the variations of the value of electric resistivity are characterized by a steep decay in quite a limited section of frequencies, this value for MF based on water weakly depends on the frequency what is connected with the influence of the value of dielectric permeability of DM.

In doing so the absolute values of ε, ρ and tgδ of MF based on water undergo considerable variations in regard to MF based on turbine oil and dekane (4-7 orders of magnitude). The characteristic property for MF based on water in investigated frequency range is the insignificant decrease of value of ρ while increasing the concentration of DP and accordingly decrease of the water content as an electrolyte, that is conditioned by the influence of over-micellar structural formations forming in concentrated MF.

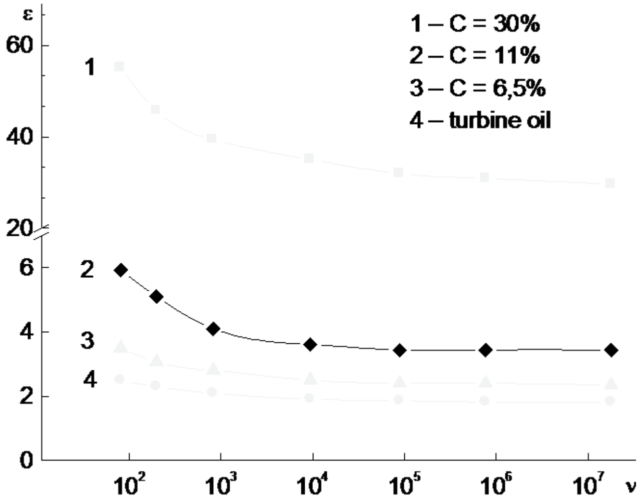

Fig. 1. Frequency dependence of ε value of MF based on turbine oil. T=293 K.

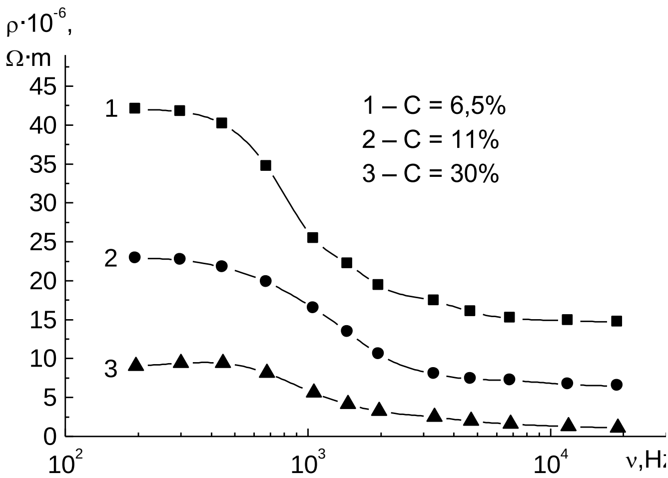

Fig. 2. Frequency dependence of ρ value of MF based on turbine oil. T=293 K.

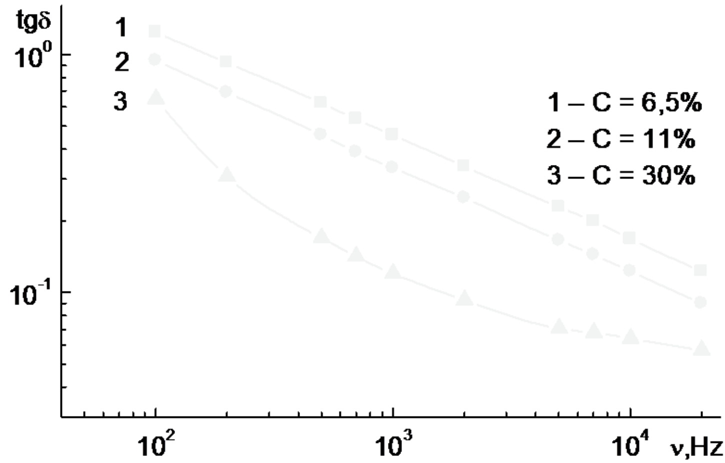

Fig. 3. Frequency dependence of tgδ value of MF based on turbine oil. T=293 K

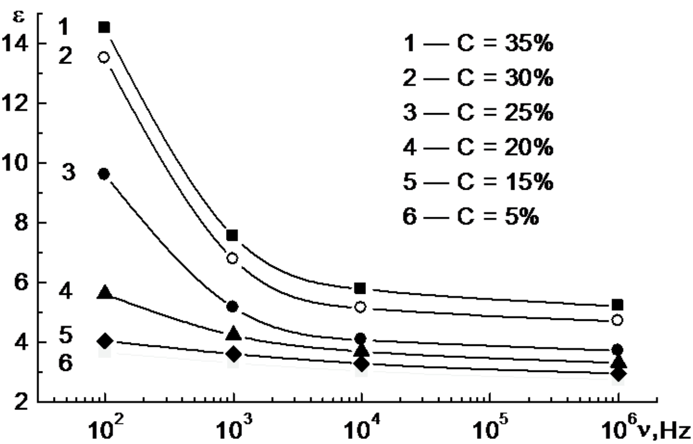

Fig. 4. Frequency dependence of ε value of MF based on dekane. T=293 K.

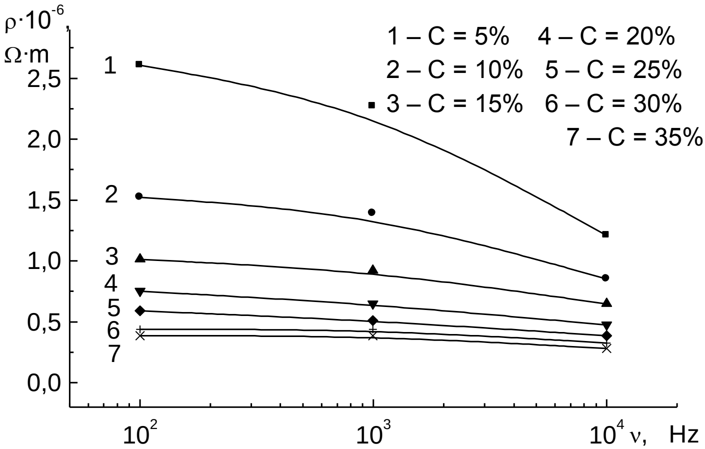

Fig. 5. Frequency dependence of ρ value of MF based on dekane. T=293 K.

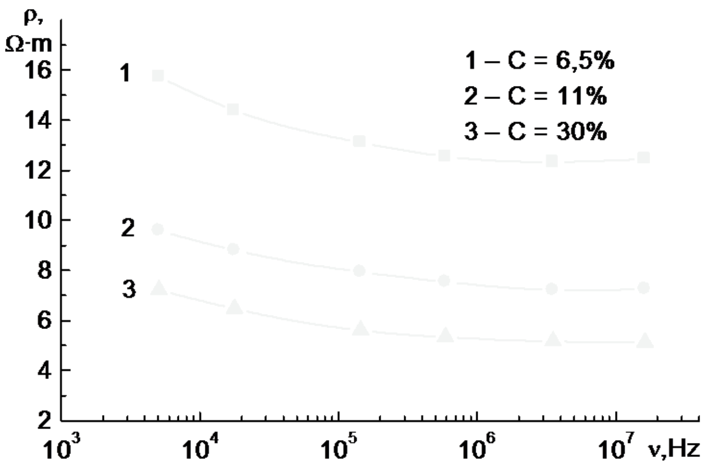

Fig. 6 Frequency dependence of ρ value of MF based on water. T=293 K.

The observed frequency dependencies of ε, ρ and tgδ of magnetic fluid are conditioned by a character of transmission of electric current of different frequency (10^2 - 10^7 Hz) through MF and they are bound up with a bulk charge accumulation on the interphase boundary (electrode-MF, DM-a protective layer of SAS, a protective layer of SAS-a particle of DP). And for MF obtained on the basis of polar DM and placed into alternating electric field the supplementary contribution to an aggregate process of system polarization is made at the expense of a relaxation of dipole molecules. Under low frequencies when relaxation time is too little in comparison with electric oscillation period, the charge has time to accumulate on the interphase boundary and the value of dielectric permeability attains relatively greater values. Under these favorable conditions the polydisperse particles of magnetite coated with the monomolecular protective layer of oleic acid possess sufficiently high electrical resistance. When increasing the frequency the relaxation time proves to be greater in comparison with electric oscillation period and electrical resistance of a protective layer of SAS decreases what creates real conditions for a transmission of the alternating current through particles of magnetite. As a result this leads to the increase of cross-section of conductive component and to the decrease of value of electric resistivity of MF accordingly.

The analysis of frequency dependencies under different concentrations of DP allows to reveal features of the change of electrophysical characteristics of MF, consisting of the following. The increase of concentration of DP in MF based on turbine oil and dekane leads to the increase of values of ε and tgδ whereas the value of ρ undergoes the decrease. One can see, that under relatively low concentration of DP the most pronounced variation of ρ takes place as the main contribution to the conduction of MF is made by free charges (fig. 2, 5). In contrast, the most pronounced variation under comparatively high concentrations of DP is experienced by the value of ε what, is bound up with a predominance of polarization phenomena (fig. 1, 4). The obtained results of researches of MF based on turbine oil and dekane are indicative of the presence of a critical concentration region which is characterized by the pronounced variation of MF conduction types. Side by side with this the pronounced variation is undergone by the value of charge relaxation time the extremal value of which is in the critical concentration region (fig.2). Independently of a correlation of one or another process occurring in MF, the bulk charge accumulation on the interphase boundary is a general physical mechanism. Taking into account the findings, tgδ ought to be regarded as the resultant index of correlation change of separate physical processes defining the redistribution of free and bound charges in MF. The confrontation of a relative course of frequency dependencies of values of ε, ρ and tgδ of MF is a confirmation of this (fig. 1,2, 3).

4. Conclusions

The developed procedure and made automated impedancemetrical complex have allowed to reveal the peculiarities of magnetic fluids behavior defining their electrophysical properties in the wide electric field frequency range under different concentrations of dispersed phase. On the basis of obtained experimental results the optimum working frequency range within which the electrophysical characteristics of magnetic fluids prove to be the informative to use them as criterion characterizing structure and properties of magnetic fluids has been determined. Side by side with this the fit analysis of magnetic fluids parameters is carried out on the basis of their electrophysical characteristics determining at a low-frequency region from 10^2 to 10^3 Hz which is the most sensitive to variation of DP concentration. The analysis of laws defining electrophysical properties for different types of magnetic fluids has allowed to reveal the tendencies electric charge transport in magnetic fluids depending on electric field frequency under different concentrations of dispersed phase and to define the requirements imposed on the experimental conditions and magnetic fluids parameters favoring the optimum display of the phenomena studied. The obtained results of investigations have been taken as a basis of rapid method development for controlling of electrophysical characteristics of magnetic fluids and have been used for optimization of technology to obtain present materials with the purpose of improving their operational properties.

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EFFECTIVE MAGNETIC PERMEABILITY OF AGGREGATED FERROFLUID: INFLUENCE OF FRACTAL CLUSTERS

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Elfimova Ekaterina Alexandrovna took a master degree in 2002 and at present is taking a post-graduate course. Scientific interests lie in the field of fractal aggregate evolution mathematical modeling in magnetic fluids.

As experiments show the presence of different structure aggregates influence greatly the properties of magnetic fluids. Usually chain and drop-like structures are considered. Quasispherical aggregates, known as "fractal clusters", could also appear in colloid systems (Fig 1). The main peculiarity of such structures is that the aggregated particle concentration decreases as a power function of the distance from the formal cluster center [1]. Same as the coagulation in colloids, molecular forces give rise for the fractal clusters in ferrofluids. As far as the physicochemical reasons are concerned there could be intensive van der Waals attraction, deformation or destruction of surface sterical layers, low values of interparticle repulsive electrostatic barrier in ionic ferrofluids. In all these cases van der Waals attraction drives to the uncorrelated particles adding to the aggregates skeleton. So, magnetic forces would not play a determinative role and ferroparticle size would not be a decisive factor in fractal cluster appearance. Some experimental data [2] evidence the existence of the latter structures in magnetic fluids and show their influence upon reological, diffusion and magnetic properties.

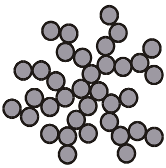

Fig.1
Fractal cluster

As the partial differential model developed for a single cluster shows, in an external field absence the fractal clusters have a quasispherical form with dense homogeneous core of the radius R_0, the random packing concentration of which is $\varphi = \varphi_m$, and friable surroundings, the concentration in which decreases over a power law $\varphi(r) \sim r^{d_f - 3}$ [3]. The cluster is bounded by the sphere with radius $\Sigma > R_0$. The main result obtained in [3] states that the exponent d_f (fractal cluster dimension) does not depend on the physicochemical conditions of the colloid system. Analytic value $d_f = 2.5$ corresponds well with three-dimension cluster computer simulation and experimental results.

It is absolutely evident, the fractal structures presence influences magnetic properties of ferrocolloid. Present article is aimed at studying the effective ferrofluid magnetic permeability and its dependence upon aggregates size and microstructure.

Following assumptions are made.

- Fractal cluster concentration is low enough for one cluster not to influence the neighboring clusters.
- Magnetic interparticle interaction between particles in the cluster is rather weak. Then $\chi = n(r)m^2 / 3kT$, where $n(r)$ - ferroparticle concentration in the unit volume, is an appropriate formula for magnetic susceptibility.
- External and internal magnetic field potentials satisfy Eq.(1)

$$div(\mu\vec{H}) = 0, \qquad H = \nabla\psi, \tag{1}$$

here ψ is magnetic field potential, $\mu = 1 + 4\pi\chi$ stands for magnetic permeability of the matter.

Thus, either inside the cluster core or outside the cluster the magnetic field potential could be found analytically [4]. In the region $R_0 < r < \Sigma$, where the aggregated particle concentration is a power function, the solution is found numerically. The magnetic potential dependence on the distance from the cluster center is shown in Fig. 2 Nevertheless, this dependence seems to be linear in the above-mentioned region, some loss of linearity could be noticed.

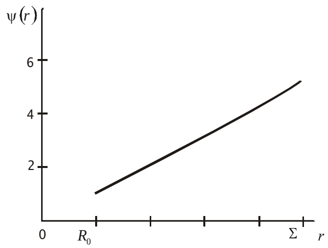

Fig. 2. Magnetic field potential against the distance from the cluster center, $R_0 < r < \Sigma$

Up to [4], if the considered matter is a fine-dispersed mixture, the field averaged over the volumes large in comparison with heterogeneity could be regarded. Mixture becomes a homogeneous medium for such mean field; so, it could be characterized by effective value of magnetic permeability. If there are homogenous impregnations in ferrocolloid, then mean magnetic permeability computes from [4]:

$\overline{\mu}_{R_0} = \mu_e + c_{R_0} \dfrac{3(\mu_i - \mu_e)}{2\mu_e + \mu_i}$ - for drop-like aggregate wit radius R_0,

$\overline{\mu}_{\Sigma} = \mu_e + c_{\Sigma} \dfrac{3(\mu_i - \mu_e)}{2\mu_e + \mu_i}$ - for drop-like aggregate with radius Σ, where c_{R_0} and c_{Σ} are homogenous impregnation concentration of radius R_0 and Σ respectively, in ferrofluid.

Mean magnetic permeability for magnetic fluid with fractal structure impregnations is composed from environment and fractal clusters mean permeability:

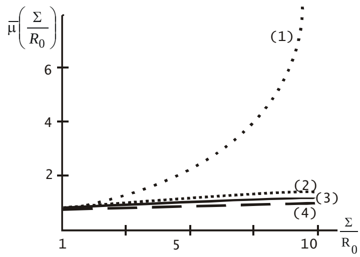

Fig. 3. Mean magnetic permeability against ferroparticle aggregates size for their constant concentration *c=0.01*.
Curve (1): for ferrofluid with drop-like aggregates of radius Σ,
Curve (2): for ferrofluid with fractal clusters $d_f = 2.5$
Curve (3): for ferrofluid with fractal clusters $d_f = 2.3$
Curve (4): for ferrofluid with drop-like aggregates of radius R_0

As it could be seen, $\overline{\mu}_\Sigma < \overline{\mu}_{d_f=2.5} < \overline{\mu}_{d_f=2.3} < \overline{\mu}_{R_0}$. Thus, the aggregates structure determines the mean magnetic permeability value of ferrofluid. It is worth mentioning that decrease of d_f drives to $\overline{\mu}$ decrease.

$$\overline{\mu} = \mu_e + \frac{c_\Sigma}{\frac{4}{3}\pi\Sigma^3}\left\{\frac{4}{3}\pi R_0^3(\mu_i - \mu_e)\frac{H_i}{H_0} + \int\limits_{V_{R_0 < r < \Sigma}} (\mu - \mu_e)\frac{H}{H_0}dV\right\}$$

In conclusion, it is worth saying that the problem of fractal aggregates influence on ferrofluid magnetic properties, in particular on effective permeability is regarded for the first time. As a result the mean magnetic permeability of the ferrofluid with fractal clusters turned out to be different from those in ferrofluid with homogeneous drop-like aggregates. It is necessary to note the value of mean magnetic permeability for the ferrocolloid with fractal aggregates lies between those for ferrofluid with drop-like aggregates of different size.

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ADCORBE WATER INFLUENCE OF ON MAGNETIC PERMITTIVITY OF MAGNETITE, γ - Fe_2O_3 AND MAGNETIC FLUID

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A hypothesis, that there are two water molecules modification: orto- (the spins of protons are parallel) and para- (spins of protons are anti parallel) was put forward for the first time in [1]. The molecules of orto-water have the magnetic moment, molecules of para-water - is not. As the size of the nuclear magnetic spin moments in 1840 times is less electronic, them usually do not take into account at theoretical accounts of molecular cohesion and properties of water systems.

The existence of orto- and para-water is confirmed experimentally in [2] and is discovered that the probability education process of molecule dimers and clusters are defined by their spin status. For example, dimers of water - carbonic gas mainly para molecule includes. In result have been possibilities for select of spin water molecule modification. An order water contains ¼ part para and ¾ orto-waters.

It is obviously, that under contact a surface of magnetic solid particles with water vapour will be predominantly adsorbed orto-water. There is a question, whether will affect of orto-water molecules adsorb on the magnetic characteristics of disperse magnetic materials. In this connection the dynamic magnetic permittivity μ of disperse powder samples magnetite, γ - Fe_2O_3 and magnetic fluid before and after adsorbed water vapour were investigated at frequency range 15kHz-10MHz. Researched powdery samples were fallen in glass test-tube with the vacuum crane and were pumped out within day by the fore pump. After measurement the value of μ vacuum samples, inside test tube with a magnetic powder samples was introduced the water vapours, in which the researched powder samples was maintained within day. Then the repeated measurements of μ were carried out. For increase of sensitivity of a method the large enough samples with volume about 100см^3 were used. The dynamic magnetic permittivity μ of researched samples was carried out by means measurement of solenoid coil inductance changes (L-cell) before and after introduction in coil the test tube with a sample by Q-method [3].

As a result of the carried out researches it was possible reliably, with accuracy on the order exceeding a mistake of experiment, to discover the effect of adsorb water influence on value of a dynamic magnetic susceptibility $\chi = \mu - 1$ powder samples magnetite and γ - Fe_2O_3 - fig. 1-2. The experimental data, represented in a fig. 1-2, were well reproduced at repeated cycles adsorb – desorb of water.

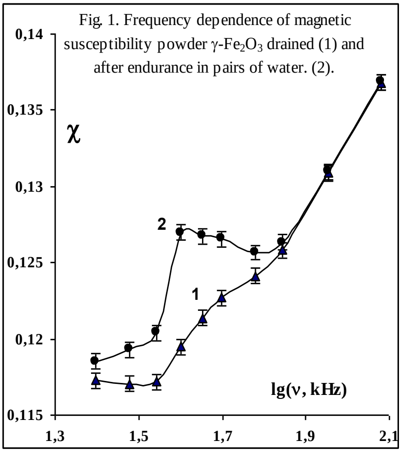


Fig. 1. Frequency dependence of magnetic susceptibility powder γ-Fe_2O_3 drained (1) and after endurance in pairs of water. (2).

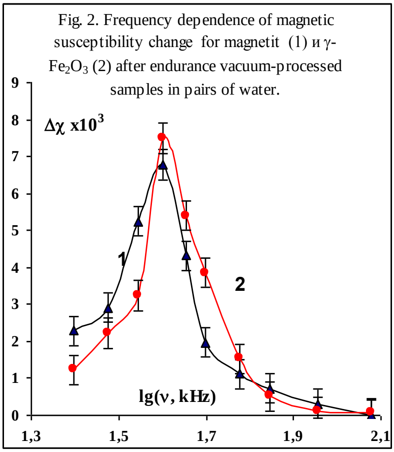


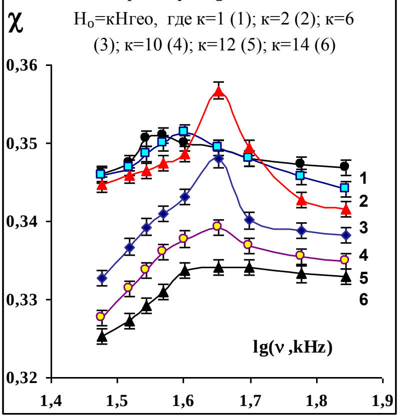
Fig. 2. Frequency dependence of magnetic susceptibility change for magnetit (1) и γ-Fe_2O_3 (2) after endurance vacuum-processed samples in pairs of water.

It was revealed that appreciable changes of a dynamic magnetic susceptibility for researched magnetic powdery samples after water vapour curing occur only at frequency range 20кГц - 70кГц. As it is visible in a fig. 1, on frequency magnetic susceptibility dependences of researched magnetic particles samples with wet surface on frequency equal 40кГц, there is a maximum, absent on dry samples. The changes of $\Delta\chi$ on both investigated samples after endurance them in water vapour are almost equal and occur on the same frequency 40кГц - fig. 2. The equality $\Delta\chi$ on two samples with various value size of χ shows, that presence of water at a surface of magnetic particles does not influence process of particles alternating magnetization in alternating magnetic field of a measuring L-cell, but gives a certain additional contribution in sample magnetization. Such additional contribution can be given only орто-water molecules.

Practically at the same frequencies, at which it was revealed maximum χ of magnetite and γ - Fe_2O_3 -samples with wet surface was found out maximum χ and on a sample concentrated magnetic fluid (MF) - fig. 1,3. As it is visible in a fig.

3 the revealed maximum χ of magnetic fluid changes on amplitude and is displaced to the range of higher frequencies during increase of a constant magnetic field. But the frequency ν_{max}, on which the maximum χ is observed, is not linearly proportional H_0. For example, in a geomagnetic field $H_0 = H_{geo} \cong 50 A/m$, ν_{max} =35-37kHz, at H_0 =2 H_{geo} ν_{max} = 40kHz. The limiting value of ν_{max} = 45kHz is observed at H_0 =6 H_{geo} =300 A/m. In that field the maximum χ has the greatest value –fig..3.

Fig. 3. Frequency dependence of magnetic susceptibility magnetic fluid under H_0=кНгео, где к=1 (1); к=2 (2); к=6 (3); к=10 (4); к=12 (5); к=14 (6)



The further increase H_0 does not displace maximum χ on frequency, but reduces its amplitude, down to its complete disappearance. The disappearance maximum χ occurs at H_0=14 $H_{geo} \approx 350 A/m$ - fig. 3. Thus, maximum χ of magnetic fluid at frequencies 35kHz –45kHz is observed only in weak fields.

The concurrence of frequencies, on which are available maximum χ of magnetic oxides particles with wet surface and magnetic fluid, allows to assume, that the found out maximum χ on the investigated sample ФМЖ is caused by presence of water at a superficial layer of its particles. The presence of some of water in MF is caused by that the particles of a magnetic phase are synthesized in water and only then are transfer in a hydrocarbon phase. The complete replacement of water from a surface of magnetic particles thus does not occur. According to the given hypothesis, from fig. 3 follows, that the contribution from magnetic moments orientation of the orto-water molecule is maximal in a very weak magneticl field, about 100- 150 A/m, and in magnetic fields $H_0 > 14 H_{geo} \approx 350 A/m$ the influence of orto-water molecule magnetic moments disappears.

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ORIENTATIONAL ORDERING IN FERROFLUIDS: DENSITY FUNCTIONAL APPROACH AND MEAN FIELD THEORY

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Last decade the problem of long-range orientational ordering has been being one of the most exciting in the field of magnetic fluids. It was in the beginning of 80th when the spontaneous orientational order ("ferromagnetic state") was predicted by using the mean field method by Weiss [1]. In 90th, after publication of the computer modeling results [2], interest for the problem arose again. In these and later papers [3] the following fact was pointed out: while resting spatially disordered the polar fluid (and ferrofluid) undergoes the orientational phase transition. The subsequent theories [4] proved (!?) the existence of "liquid paramagnetic - liquid ferromagnetic" phase transition. Concerning the experimental results on spontaneous orientationally ordered state in ferrofluids, it should be noted that direct experimental evidences have never been found.

A modern approach to theoretical prediction of orientational ordering in dipole fluids is based on the density functional method: the free energy is expressed as a functional on the one-particle distribution function, which determines the probability for randomly chosen magnetic particle to be oriented along some direction. Minimization of the energy functional leads to an integral equation for one-particle distribution function, one of the solutions of which is anisotropic in the orientational space, even in the absence of an external field. Applying to ferrofluids the one-particle distribution function depends only on the angle ω_1 between the orientation of the magnetic moment of randomly chosen ferroparticle 1 and an external field direction. To study the properties of orientational distribution we use the BBGKI formalism, which leads to the differential equation [5], connecting the one-particle distribution function with the pair correlation function of ferroparticle system. The main idea of the density functional approach is the following: the pair correlation function is self-consistently expressed in terms of the one-particle distribution functions of two interacting ferroparticle magnetic moments. It is worth noting that such replacement is only an approximation that cannot be treated as an exact statistical result. With the help of this self-consistent expression we get the integral-differential self-consistent equation for the one-particle distribution function, which is dependent on interparticle correlations. Solution of this self-consistent equation presents the one-particle distribution function in an exponential form according to ideal paramagnetic gas. Only difference is that the exponential factor contains the sum of an external field and the function of interparticle dipole-dipole correlations. The last one should be expressed in terms of ferrofluid magnetization *M*. This sum should be considered as effective magnetic field acting on a single particle. The approximation of the 1st order perturbation method over dipole-dipole interaction in the pair correlation function results in the Weiss mean field model. This solution coincides with expression for an ideal paramagnetic gas, in which an external field strength *H* is replaced by effective field $H_e = H + 4\,\pi\,M\,/\,3$. Thus, the self-consistent density functional approach is equivalent to the mean field theory resulting in well known "paramagnetic – ferromagnetic" phase transition. In the framework of 1^{st} order perturbation theory the self-consistent expression leads to the prediction of spontaneous orientational ordering in magnetic fluids. Apparently, this is caused by the fact that in exact virial expansion of the pair correlation function all the influence of dipole-dipole interaction is determined only by the multiparticle correlations. The approximate self-consistent expression imposes an additional influence by way of the one-particle distribution functions, which also take into account the dipole-dipole interaction. Thus, an influence of the last one turns out to be overestimated. Therefore, it is not a surprise that such an excess account for the dipole-dipole interaction leads to the prediction of "ferromagnetic state" in dipole fluids.

Much more strange behavior appears when this effective field is calculated on the basis of the 2nd order perturbation method [5], in the framework of which the pair correlation function is determined under the condition when all the corrections linear in dipole-dipole interaction energy U_d is taken into account. The result for one-particle distribution function is as follows: the exponential factor represents the expansion over zero, 1^{st} and 2^{nd} order Lagrange polynomials. The coefficients of this expansion have to be determined numerically. In the case of an external magnetic field absence two kinds of the solution exist. The first one is trivial, when the expansion coefficients equal to zero. It means that the orientational distribution of ferroparticle magnetic moments is homogeneous according to no magnetized liquid state of ferrofluid. Besides that, when the interparticle dipole-dipole interaction is rather intensive, the bifurcation of a solution occurs resulting in appearance of the inhomogeneous orientational distribution. In this case, the inhomogeneous distribution is characterized by the presence of two maximums describing the probabilities for the randomly chosen magnetic moment to be parallel ($\omega_1 = 0$) or antiparallel ($\omega_1 = \pi$) to an external field direction. This behavior of the one-particle distribution function seems to be physically meaningless because it looks like the liquid "ferrimagnetic state" instead of the liquid "ferromagnetic state", predicted by the theoretical models [4]. The physical reason is connected with the fact that, unlike the 1^{st} order perturbation method, the approximation of 2^{nd} perturbation order over the dipole-dipole energy takes into account the interaction in all pairs and triplets of ferroparticles. Namely, the account of dipole-dipole interaction in ferroparticle triplets results in disordering of magnetic moments. Thus, the physically meaningful is only the homogeneous orientational distribution of particle magnetic moments in the absence of an external field. The point is that the 2-nd order perturbation theory does not predict the spontaneous orientational ordering. So, the principal physical conclusion on the possibility of "ferromagnetic state" in ferrofluids, arising from the mean field theories and the density functional models, is not verified by the experimental studies and cannot be treated as an exact theoretical result. This conclusion seems to be an artificial consequence from the self-consistent approximation, and the phenomenon of spontaneous orientational ordering in ferrofluids induced by the dipole-dipole interaction has to be considered as extremely questionable.

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МАГНИТОЖИДКОСТНЫЕ ЗВУКОПРОВОДЫ ДЛЯ ВОЗБУЖДЕНИЯ РЭЛЕЕВСКИХ И ПОДПОВЕРХНОСТНЫХ ВОЛН В ТВЕРДЫХ ТЕЛАХ

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Применение магнитных жидкостей в качестве управляемого внешним полем нового акустического материала - магнитожидкостного звукопровода (МЖЗ) - перспективно для создания акустического контакта при контроле объектов со сложным рельефом поверхности, расположенных в труднодоступных местах, в зоне радиации и в невесомости, при автоматизации акустических измерений [1]. В вышеуказанных случаях МЖЗ выполняет функцию акустической контактной среды в системе преобразователь УЗК -объект - преобразователь. Анализ данных по акустическим [2] и другим свойствам МЖ [3] показал перспективность их использования и в качестве наклонной призмы –

удерживаемого магнитным полем магнитожидкостного звукопровода, через который передаются упругие волны в исследуемые материалы под углом

$$\alpha_p = arcsin[n^{-1} sin\beta] = 0 \div \pi/2 \qquad (1)$$

где $n=C_{2p}/C_1$ - коэффициент преломления звука на границе раздела сред МЖЗ-объект; индекс $p=\{l, t, s\}$ соответствует возбуждению в объекте продольной ($p=l$), поперечной (t), Рэлеевской (s) мод, β - угол падения волнового фронта на объект в МЖ. Выпускаемые серийно ультразвуковые наклонные преобразователи предназначены, как правило, для контроля стальных объектов, в которых C_{2l} 5,9×10^3 м/с и C_{2t} =3,2 ×10^{3}м/с. Как непосредственно следует из экспериментальных данных [1], и предположения об аддитивности и неизменности сжимаемостей и плотностей веществ, вводимых в коллоид, зависимость коэффициента преломления упругих волн n от концентрации магнетика q в растворе является монотонно возрастающей функцией, и может быть представлена в виде

$$n=C_{2p}/C_1 = n_0 (1+Aq)(1+Bq) \qquad (2)$$

где $n_0 = C_{2p}/C_d$, $C_d=C_{1\ q=0}$, A и B – постоянные, характеризующие плотность и адиабатную сжимаемость дисперсной фазы соответственно. Как следует из (2) , $\Delta n = n_{q=q*} - n_{q=0} = (25 \div 30)\ \%$, но $\Delta n = n_{q=10\%} - n_{q>10} \le 7\ \%.$ Поскольку скорость УЗК в используемых на практике дисперсионных и неагрессивных средах может быть ~ (1200 ÷1300) м/с, то C_1 ~ (900÷1000) м/с согласно (2). А это позволяет (при критическим углах $\beta_p^* \approx arcsin[n^{-1}]$) возбуждать в пластмассах, чугунах, меди и других материалах “низкоскоростные” моды волн: рэлеевские (ПАВ); подповерхностные - продольные (ППВ) и сдвиговые (ПСВ), распространяющиеся тангенциально контактной поверхности объекта [3]. Необходимо отметить, что несмотря на высокую эффективность и перспективы применения, особенности распространения упомянутых выше мод в твердых телах изучены недостаточно. Так, для случая возбуждения в объекте подповерхностных волн отсутствует теория, описывающая акустический тракт измерительной системы, и в частности , функцию прохождения зондирующего сигнала при различных граничных условиях

$$N \sim K_p\ \Phi(\varphi,\gamma) = K_1 D_{21}\ \Phi(\varphi,\gamma) \qquad (3)$$

где, K_1 – коэффициент преобразования электрического напряжения на пьезопластине в механические колебания и обратно; D_{21} - коэффициент прозрачности по потоку акустической энергии на границе МЖ-твердое тело;.$\Phi(\varphi,\gamma)$- диаграмма направленности источника УЗК. Поэтому при изучении проблемы экспериментальный метод исследований является предпочтительным. Ниже представлены результаты исследования влияния акустических свойств МЖ не только на возбуждение подповерхностных, но и поверхностных волн.

Для экспериментальных исследований были приготовлены высокоустойчивые образцы МЖ на углеводородной основе с q от нуля до 27%. Экспериментальные методики поясняются на рис. 1 – 4. В качестве материала твердотельных образцов использованы плексиглас, сталь и алюминий. Определение амплитудных характеристик акустического тракта измерительной системы производится согласно методикам [3].

Как показывают исследования, увеличение концентрации магнетика в растворе сопровождается монотонным снижением критических углов падения продольной волны β^*, при которых в объектах возбуждаются подповерхностные и рэлеевские волны. При этом рассчитанные по формулам (1) и (2) зависимости $\beta^*(q)$ находятся в хорошем согласии с данными эксперимента в пределах погрешности измерений. Установлено, что диаграммы направленности наклонного преобразователя с локальной иммерсионной ванной, предназначенного для возбуждения волн типа ППВ, и ПСВ имеют максимум для углов преломленной волны в окрестности $\alpha \approx 75 - 76^o$ (рис.1), что неплохо согласуется с данными работы [2], выполненной для случая ввода УЗК в сталь через плексигласовую призму. Обнаружено, что с ростом q в растворе происходит лишь расширение основного лепестка раскрытия диаграммы направленности, что, по-видимому, связано с уменьшением “мнимой апертуры» источника колебаний. Последнее, в свою очередь, вызвано снижением критического угла падения волны β^* из-за уменьшения скорости УЗК в коллоиде согласно формуле (2). Как видно из рис.2, экспериментальная зависимость амплитуды сигнала $P_A(\beta)$, полученная для случая работы пары преобразователей ППВ или ПСВ в теневом режиме, имеет неплохое количественное соответствие с расчетными данными. Это позволяет оценить девиацию $P_A(\beta)$ при качании угла наклона преобразователя и изменении свойств МЖ. Нормализованная зависимость $P_A(\beta^0)$, где $\beta^0 = \beta^* - \beta$, по сути дела, представляет собой диаграмму направленности прямого преобразователя $\Phi(\beta^0)$, погруженного в МЖ. Отличие данных эксперимента и теории, по-видимому, обусловлены особенностями интерференции непрерывных колебаний (теория) и импульсных, имеющих огибающую “колоколообразной” формы.

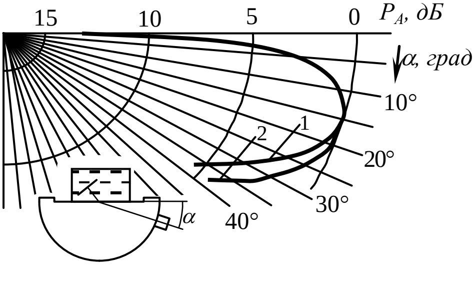
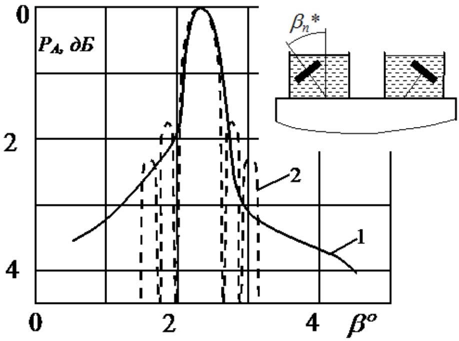


Рис.1. Поле излучения ППВ в стали. Концентрация магнитной фазы в МЖ на керосине: 1 – 0% ; 2 – 8%.

Влияние концентрации q в коллоиде на амплитуду зондирующего сигнала в тракте измерительной системы (рис.3) характеризуется функцией $K^*_p = (K_1 D_{21})_q / (K_1 D_{21})_{q=0}$. Как видно, $K_p \sim q$, а $d K_p/dq > 0$ для случая возбуждения в металле и плексигласе указанных на рис.3 волновых мод. Необходимо отметить, что варьирование концентрации магнетика в МЖ от нуля до предельной сопровождается ростом K^*_p на 13÷14 дБ, если акустическое сопротивление демпфера пьезопластин достаточно большое. Нанесение МЖ на контактную поверхность объекта приводит к существенному ослаблению амплитуды основной Рэлеевской моды, так что $P_A \sim exp(-\delta x)$, где $\delta = \delta_\lambda \lambda$. Как установлено и показано на рис. 4, в интервале $\varepsilon_R = 0{,}05 \div 0{,}2$ зависимость $\delta_\lambda \sim \varepsilon_R=(\rho C)(\rho C)_S^{-1}=R/R_S \sim q$, где R и R_S удельные акустические сопротивления МЖ и объекта соответственно. При этом δ_λ



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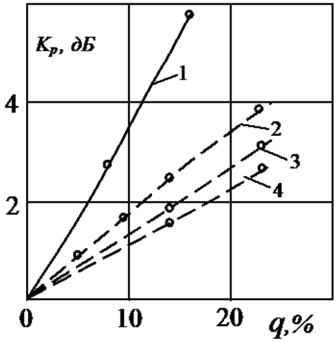
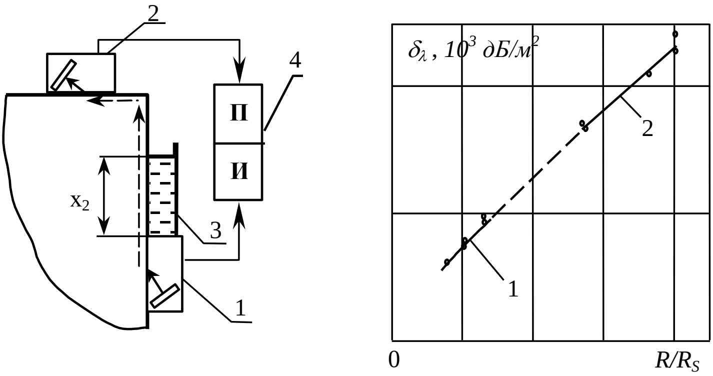


3.

Рис.2. Зависимость $P_A(\beta)$: а) мода ППВ; зависимость 1 – эксперимент, 2 – расчет.
Рис. 3. Влияние концентрации магнетика в МЖ на K_p : объект: сталь (1); плексиглас (2÷4); мода: ППВ - 1,2; ПСВ – 4; ПАВ – 2.

возрастает в 3 раза. Изменяя с помощью магнитного поля длину контакта МЖ с объектом L, вдоль которой распространяются ПАВ, представляется возможным управлять ее амплитудой. Однако, при этом необходимо учесть, что спектральные составляющие немонохроматического сигнала будут ослабляться по-разному, что может быть положено в основу работы частотного фильтра. С другой стороны, если сигнал монохроматический, то на основании упомянутого эффекта можно предложить достаточно простой аттенюатор мегагерцового диапазона, точностные характеристики которого определяются преимущественно относительной погрешностью установки длины жидкого контакта $\Delta L/L$, которая может составлять ~$(10^{-2}\div10^{-3})$. Учитывая зависимость коэффициента ослабления δ от длины волны ПАВ λ , может быть предложен более простой принцип измерения скорости ПАВ. Для этого определяют амплитуду зондирующего сигнала при двух значениях длины МЖ-пятна контакта x_1 и x_2 и находят скорость ПАВ - $C_S = [ln(A_1/A_2)][(x_2 - x_1)\ \nu]^{-1}$. При этом, погрешность измерения C_S может быть доведена до нескольких десятых процента.

На рис. 4 показана принципиальная возможность управления диаграммой направленности источников поверхностных волн. путем изменения радиуса кривизны фронта мениска R_m внешним полем. При этом затухание для лучей волнового фронта ПАВ направлении перпендикулярном волновому вектору $\vec{k}$ разное, что достигается путем деформации формы контактного пятна объема МЖ, расположенного на пути распространения ПАВ. Как показывают предварительные исследования, существуют оптимальные соотношения между частотой волны ν, излучаемой преобразователем, концентрацией частиц магнетика в растворе, шириной волнового фронта $2a$ и кривизной мениска R_m, когда наиболее существенно проявляется эффект изменения диаграммы направленности.



а) б)

Рис.3. Схема эксперимента (а) и зависимость коэффициента затухания ПАВ на границе МЖ-металл от $R'=R/R_S$ (б): а) 1,2 – излучатель и приемник ПАВ; 3 – МЖ; 4 – источник и приемник УЗК; б) металл: 1 – сталь; 2 – алюминий

С ростом частоты волны и q коэффициент δ возрастает, и при этом эффективность управления параметрами акустического поля повышается. Необходимо отметить, что, как впервые обнаружено, наличие МЖ на поверхности объекта (схема как рис.3, где приемный преобразователь установлен на вертикальной поверхности)) вызывает не ослабление, как считалось [2,3], а “усиление” амплитуды подповерхностных волн до 3 - 4 дБ. При этом установлено, что коэффициент $\delta<0$, изменяется нелинейно в зависимости от длины зоны МЖ-пятна контакта x_2 и является симметричной функцией относительно $x_2= x_0/2$, где x_0 – расстояние между преобразователями.

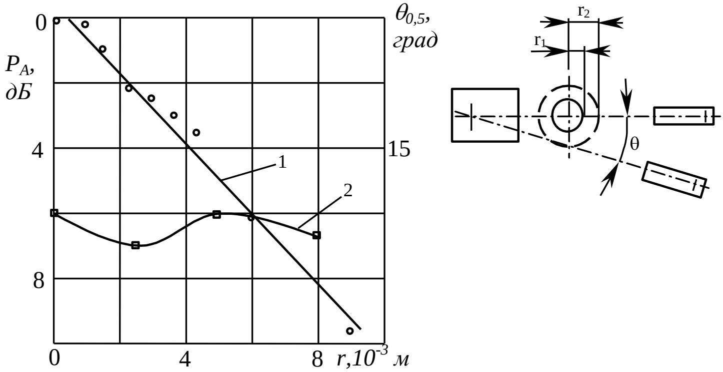


Рис.4.. Зависимости амплитуды ПАВ (1) и угла раскрытия основного лепестка диаграммы направленности на уровне 0,5. (2) от радиуса кривизны мениска МЖ.

Таким образом, в результате проведенных исследований выявлены основные закономерности изменения акустического тракта измерительной системы при использовании МЖЗ для возбуждения подповерхностных волн и ПАВ. Разработанные конструкции преобразователей имеют высокостабильный и локализованный акустический контакт их применение позволяет в ряде случаев повысить на порядок и более производительность дефектоскопии.

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HYDRODYNAMICS

MODEL POSSIBILITIES OF MAGNETIC FLUIDS STRUCURING

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Classification of possible forms of energy of anisotropic models of magnetic fluids is considered. The author's full description of continuous subgroups of unimodular group of linear transformations of Lagrangian variables is assumed as a basis. If we do not consider the liquid-crystal and solid states, then we have only three magnetic fluid anisotropic structures which correspond to the formation of flat or elongated structure elements and their combination. The investigation of surface energy symmetry also gives only one anisotropic magnetic form.

1. Affine Symmetries of Magnetic Media Energy

In case of the structuring of magnetic fluid, in simplest case, there arise media with specific internal energy of the form $U(S, \mathbf{g}, \mathbf{B}, R_k)$, where S is the specific entropy, $\mathbf{B}$ is the magnetic field induction, $\mathbf{g}$ is the metric tensor, R_k is scalar order parameters describing phase transitions.

One can classify all the possible continuous media models according to symmetries groups of the function U using groups of volume-preserving linear transformations of Lagrangian coordinates, i.e. subgroups of the group SL_3. Full classification of continuous subgroups of the group GL_3 has been given previously [1]. Degenerative cases may be chosen with the help of subgroups of the general linear group SL_3.

The energy of unstructured fluid is invariant under the group SL_3 and has the form $U(S, \rho, |\mathbf{B}|)$, where $\rho = \rho_0/\sqrt{g}$ is the density of the medium. Structuring diminishes symmetry group.

In case of restriction on symmetry, there arise two possibilities connected with the invariance under two 6-parametric groups which have the following sets of metric invariants

$$G_{6.1} - \rho, \quad |\mathbf{B}|, \quad \frac{\mathbf{B}\cdot\mathbf{q}}{|\mathbf{q}|}, \qquad G_{6.2} - \rho, \quad |\mathbf{B}|, \quad \frac{\mathbf{B}\cdot\mathbf{Q}}{|\mathbf{Q}|},$$

where $\mathbf{q}$ and $\mathbf{Q}$ are, respectively, covector and vector with constant Lagrangian coordinates.

For 5-parametric symmetry groups we have the following invariants

$$\begin{array}{lllll} G_{5.1}- & \rho, & |\mathbf{B}|, & \mathbf{B}\cdot\mathbf{q}/|\mathbf{q}|, & \mathbf{B}\cdot\mathbf{Q}/|\mathbf{Q}|, \\ G_{5.2}- & \rho, & |\mathbf{B}|, & \mathbf{B}\cdot\mathbf{q}, & |\mathbf{q}|, \\ G_{5.3}- & \rho, & |\mathbf{B}|, & \mathbf{B}\cdot\mathbf{Q}, & |\mathbf{Q}|, \end{array}$$

in this case $\mathbf{q}\cdot\mathbf{Q} = 0$.

In case of 4-parametric symmetry groups, even in the absence of magnetic field, the majority of the groups lead to unstable media which may be left out. There remains two cases with invariants

$$\begin{array}{llllll} G_{4.1}- & \rho, & |\mathbf{B}|, & \mathbf{B}\cdot\mathbf{q}, & |\mathbf{q}|, & \mathbf{B}\cdot\mathbf{Q}/|\mathbf{Q}|, \\ G_{4.2}- & \rho, & |\mathbf{B}|, & \mathbf{B}\cdot\mathbf{Q}, & |\mathbf{Q}|, & \mathbf{B}\cdot\mathbf{q}/|\mathbf{q}|. \end{array}$$

where $\mathbf{q}\cdot\mathbf{Q} = 0$ also.

Similarly, one can write the invariants in cases of lower symmetry too, but such media relate rather to solids than liquids.

This chain of symmetries ends with 3-parametric symmetry group having the invariants

$$\rho, \quad |\mathbf{B}|, \quad \mathbf{B}\cdot\mathbf{q}, \quad \mathbf{B}\cdot\mathbf{Q}, \quad |\mathbf{q}|, \quad |\mathbf{Q}|,$$

though here also might be other sequences of symmetries.

Strictly speaking, the last two invariants are no longer connected with magnetic field. Their presence allows to place these media among liquid crystals. In this sense, it is sufficient to consider only two chains of symmetries for classifying anisotropic magnetizable fluids:

$$SL_3 \supset G_{6.1} \supset G_{5.1}, \quad SL_3 \supset G_{6.2} \supset G_{5.1}, \tag{1}$$

which correspond to the appearance of flat or elongated structure elements.

2. Symmetries of Surface Energy

It makes sense to take into account the dependence of surface energy upon magnetic field [2]. Per unit area, $U_\Sigma(S, \mathbf{a}, B_{n\Sigma}, \mathbf{m}, R_k)$, where $B_{n\Sigma}$ is the normal component of surface magnetic induction, $\mathbf{m}$ tangential component of surface magnetization, $\mathbf{a}$ is surface metric tensor.

Here the following symmetries are possible

$$SL_2 - \rho_\Sigma, \quad |\mathbf{m}|, \qquad G_2 - \rho_\Sigma, \quad |\mathbf{m}|, \quad \frac{\mathbf{m}\cdot\mathbf{q}}{|\mathbf{q}|}, \tag{2}$$

where $\rho_\Sigma = \rho_{0\Sigma}(\det(a_{\sigma\tau}))^{-1/2}$ is the surface mass density, $\mathbf{q}$ tangential frozen-in covector.

Next, it is possible a transition to liquid-crystal film or immediately to isotropic solid state of surface

$$G_{1.1}- \quad \rho_\Sigma, \quad |\mathbf{m}|, \quad \mathbf{m}\cdot\mathbf{q}, \quad |\mathbf{q}|,$$
$$G_{1.2}- \quad \rho_\Sigma, \quad |\mathbf{m}|, \quad (\mathbf{m}\cdot\mathbf{q}_1)^2 + (\mathbf{m}\cdot\mathbf{q}_2)^2, \quad |\mathbf{q}_1|^2 + |\mathbf{q}_2|^2,$$

where $\mathbf{q}_1$, $\mathbf{q}_2$ are two tangential frozen-in covectors. Here we omitted one unstable case of 1-parametric group like Lorentz group.

Thus, we have two sequences of symmetries

$$SL_2 \subset G_2 \supset G_{1.1}, \qquad SL_2 \supset G_{1.2}.$$

In case of fully anisotropic surface tension surface energy depends upon all indicated arguments.

So, to sum up, the main results of our investigation can be represented by the formulae (1), (2).

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WAVE MOTION IN STRATIFIED MAGNETIC LIQUIDS ABOVE THE POROUS BEDDING

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Introduction. In this work built full process model of spreading the shallow waves in two-layer magnetic liquids, which inheres on porous not deformable base. Considered private event, when not indignant magnetic field parallel speedup vector of free falling and porous ambience is replaced by a layer a magnetic liquid with constant magnetic permeability. Received and analysed dispersion equation for shallow waves in stratified magnetic liquids on the hard day. Found expression for the wave fluctuation frequency and explored its dependency from the wave number and other parameters, characterizing magnetic liquid.

1. Statement of a task. The distribution of gravitational superficial waves in not electroconductiv magnetic of a two-layer liquid which is taking place on the not deformable porous bedding. The bottom magnetic liquid will penetrate into the porous bedding, and from below porous environment is limited to a firm impenetrable wall.

The equations of movement of a liquid in porous environment look like [1,3,4]:

$$\frac{\rho_2}{\varepsilon}\cdot\frac{\partial\overrightarrow{u_1}}{\partial t}=-\nabla\rho_1+\rho_2\vec{g}+\frac{\eta}{K}\cdot\overrightarrow{u}_1,\qquad \text{div}\ \overrightarrow{u_1}=0. \tag{1}$$

In the field of 2,3 initial equations of movement of a magnetic liquid with constant magnetic permeability look like [2]:

$$\rho_i\frac{\partial\overrightarrow{u_i}}{\partial t}=-\nabla\rho_i+\rho_i\cdot\vec{g},\quad \text{div}\ \overrightarrow{u_i}=0\quad (i=2,3) \tag{2}$$

In the bottom and top layers of a magnetic liquid potentials of speeds φ_i ($\overrightarrow{u_1}=\nabla\varphi_i(x,y,z,t)$ (i=2,3)) Satisfy to the equation of Laplass [2]: $\Delta\varphi_i=0$ (i=2,3) .The scalar potentials of a magnetic field are from the equations: $\Delta\psi_j=0$ (j=1,2,3,4) .

The boundary conditions on surfaces of the unit look like. At the bottom (z= -h_1): $u_{1z}=0$; ψ_1 =0. On a surface undressed the bottom layer of the stratified magnetic liquid – porous environment (z=0):$u_{1z}=u_{2z}$; $\psi_1=\psi_2$;

$$\mu_1\vec{n}\cdot\nabla\psi_1=\mu_2\vec{n}\cdot\nabla\psi_2;\qquad p_1-\mu_1\frac{H_{1n}^2}{4\pi}+\frac{1}{4\pi}\int_0^{H_1}\mu_1 HdH=p_2-\mu_2\frac{H_{2n}^2}{4\pi}+\frac{1}{4\pi}\int_0^{H_2}\mu_2 HdH.$$

On a surface of the unit of two layers of a two-layer magnetic liquid (z=$h_2+\xi_1$ (x,y,t)):

$u_{2z}=\dfrac{\partial \xi_1}{\partial t}$, where $\xi_1=\xi_1$ (x,y,t) – deviation of the indignant surface of the bottom layer of a magnetic liquid from a plane; $u_{2z}=u_{3z}$; $\psi_2=\psi_3$;

$$\mu_2 \vec{n}\cdot\nabla\psi_2=\mu_3\vec{n}\cdot\nabla\psi_3;$$

$$p_2-\frac{\mu_2}{4\pi}H_{2n}^2+\frac{1}{4\pi}\int_0^{H_2}\mu_2 HdH=p_3-\frac{\mu_3}{4\pi}H_{3n}^2+\frac{1}{4\pi}\int_0^{H_3}\mu_3 HdH-\alpha_1\Delta\xi_1(x,y,t),$$

where α_1 - factor of a superficial tension of a surface of the unit $z=h_2+\xi_1$ (x,y,t). On a free surface of the stratified liquid ($z=h_2+h_3+\xi_2$ (x,y,t)):

$$u_{3z}=\frac{\partial \xi_2}{\partial t}\ \mu_3\vec{n}\cdot\nabla\psi_3=\mu_4\vec{n}\cdot\nabla\psi_4,$$

$$p_3-\frac{\mu_3}{4\pi}H_{3n}^2+\frac{1}{4\pi}\int_0^{H_3}\mu_3 HdH=p_4-\frac{\mu_4}{4\pi}H_{4n}^2+\frac{1}{4\pi}\int_0^{H_4}\mu_4 HdH-\alpha_2\Delta\xi_2(x,y,t)$$

. In an atmosphere ($z\to+\infty$): ψ_4 =0. (3)

2. Decision. For the decision of the initial equations (1) - (2) with boundary conditions (3) we search as fading running waves:

$$u_{1z}(x, y, z, t)=v(z)\exp[-\gamma\cdot t+i(k_1x+k_2y)];$$

$$\varphi_i(x,y,z,t)=\Phi_i(z)\exp[-\gamma\cdot t+i(k_1x+k_2y)] \quad (i=1,2); \qquad (4)$$

$$\psi'_j(x,y,z,t)=\Psi_j(z)\exp[-\gamma\cdot t+i(k_1x+k_2y)] \quad (j=1,2,3,4),$$

where k_1, k_2 - material wave numbers describing periodicity of the wave decisions on directions x, y accordingly, γ =Re(γ)+iIm(γ) , β = Re(γ) – decrement of attenuation of fluctuations of a wave, ω =Im(γ)- frequency of fluctuations of a wave.

We shall be limited further to case $H_{0jx}=H_{0jy}=0$ (j=1,2,3,4), i.e. not indignant magnetic field in parallel to vector $\vec{g}$, and case, when $\varepsilon\to 1$, $\eta/K\to 0$ ($K\to\infty$), which corresponds to replacement of porous environment by a layer of a magnetic liquid with constant magnetic permeability μ_2. Received dispersion equation for the given private event.

At absence of a magnetic field ($\overrightarrow{H_{0i}}=0$ (i=1,2,3,4), $\alpha_1=\alpha_2$ =0, $\mu_1=\mu_2$ =1), when $\rho_1=\rho_2=\rho$ it turns out known the dispercion equation for superficial waves in a layer of a liquid on firm bottom [4]: $\omega^2 = gk \cdot th(k(h_1 + h_2))$.

3. Basic results. The results of accounts are given as the diagram of dependences of frequency of fluctuations of a wave from initial parameters in a fig. 1.

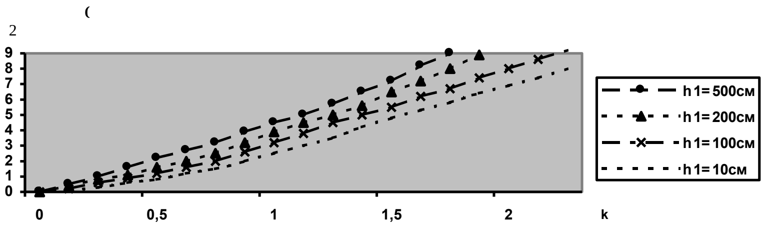

Fig. 1 Dependence of frequency of fluctuations of a wave on wave number k (k= $2\pi / \lambda$, where λ -Length of a wave) at various values of thickness of the bottom layer of the stratified magnetic liquid.

From the diagrams it is visible, that at increase of wave number and fixed value of thickness of the bottom layer of a magnetic liquid, the frequency of fluctuations of a wave is increased, as well as at the fixed value of wave number and increase of thickness of the bottom layer of the stratified magnetic liquid.

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INFLUENCE OF A MAGNETIC FIELD ON MOTION OF PARTICLES IN A FLOW WITH A PARABOLIC VELOCITY PROFILE

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In [1], [2] an analytical method of solving the problem of hydrodynamic interaction between particles in a flow with the velocity represented by a polynomial of arbitrary integer order was suggested. In [3] the problem of particle interaction in a flow with a parabolic velocity profile was solved and obtained the particle behaviour in flows with parabolic velocity profile quite differs substantially from that in flow with linear velocity profile. Thus, in a parabolic flow the two particles tend to take up positions at equal distances from the flow symmetry axis. It was assumed that no external forces or torques are exerted on the particles. Dependence of the behaviour of the particles on the non-hydrodynamic forces exerted on the ones in a flow with a parabolic profile is interesting problem.

1. Formulation of the problem. We will consider the hydrodynamic interaction of two rigid spherical particles *A* and *B* of the same radius *a* immersed in an unbounded magnetic incompressible fluid with the viscosity η and permeability μ =const.. It is assumed that there is external magnetic field $\vec{H}_0$ and the particle size is small enough, for the Reynolds number to be small (Re < 1). The flow velocity at infinity $\vec{U}$ is a quadratic function of the co-ordinates:

$$U_i = C_{ijk} x_j x_k , \qquad C_{iik} = C_{iki} = 0 .$$

The location of the centres of the spheres *A* and *B* relative to the flow is denoted by $\vec{r}_a$ and $\vec{r}_b$, respectively. The equations for the flow velocity $\vec{u}(\vec{x})$ and the pressure $p(\vec{x})$ are written in the Stokes approximation:

$$\operatorname{div}\vec{u} = 0, \qquad -\nabla p + \eta\Delta\vec{u} = 0 . \qquad (1)$$

On the particle surface, the no-slip condition is valid:

$$u_i + U_i(A) + EE_{ij}(A)x_{aj} + W_{ij}(A)x_{aj} + C_{ijk}\, x_{aj} x_{ak} = V_i^a + \Gamma_{ij}^{\ a} x_{aj} , \ \left|\vec{x}_a\right| = a,$$

$$u_i + U_i(B) + EE_{ij}(B)x_{bj} + W_{ij}(B)x_{bj} + C_{ijk}\, x_{bj} x_{bk} = V_i^b + \Gamma_{ij}^{\ b} x_{bj} ,, \ \left|\vec{x}_b\right| = a.$$

At infinity, we have: $u_i \to 0$, $p \to 0$, $\left|\vec{x}\right| \to \infty$

Here, we have introduced the following notation: the vectors $\vec{U}^a$, $\vec{U}^b$, $\vec{\Gamma}^a$, $\vec{\Gamma}^b$ are the absolute linear and angular velocities of the spheres *A* and *B.* The vectors $\vec{U}(A)$ and $\vec{U}(B)$ are the flow velocities at points coinciding with the centres of the spheres A and B respectively. The linear and angular velocities of the spheres are unknown functions of the vector $\vec{r} = \vec{x}_a - \vec{x}_b$ and the parameter $\varepsilon = a/r$.

Within the inertialess approximation, sum of the forces and torques are exerted on the particles by the fluid and magnetic field should be zero.

$$\vec{F}_a{}^h + \vec{F}_a{}^m = 0, \qquad \vec{F}_b{}^h + \vec{F}_b{}^m = 0, \qquad (2)$$
$$\vec{T}_a{}^h + \vec{T}_a{}^m = 0, \qquad \vec{T}_b{}^h + \vec{T}_b{}^m = 0.$$

Here, $\vec{F}_a{}^h$, $\vec{F}_b{}^h$ - hydrodynamic forces, $\vec{F}_a{}^m$, $\vec{F}_b{}^m$ - magnetic forces, $\vec{T}_a{}^h$, $\vec{T}_b{}^h$ - hydrodynamic torques , $\vec{T}_a{}^m$, $\vec{T}_b{}^m$ - magnetic torques are exerted on spheres A and B respectively.

2. The solution. As in the case considered in [1, 2] we can represent the solution of the hydrodynamic equations (1) with the boundary conditions as a sum of solutions of several problems. The solution of those problems is obtained in [3]. Using the conditions (2), we can find the relative linear and angular velocities of the particles. For two interacting spheres in a flow with a quadratic velocity profile, the calculations give the following expressions for the relative linear velocity:

$$V_i = U_i^b - U_i^a = \Omega_{ij} r_j + E_{ij} r_j (1 - B) + E_{jl} \frac{r_j r_l r_i}{r^2} (B - A) + [2C_{ijk} r_j^a r_k + C_{ijk} r_j r_k]$$
$$+ [EE_{ij} + \frac{1}{2} \Delta EE_{ij}] r_j (1 - B) + [EE_{jk} + \frac{1}{2} \Delta EE_{jk}] \frac{r_j r_k r_i}{r^2} (B - A) + F_{bi}{}^m - F_{ai}{}^m$$

Here, the coefficients A and B are equal: $A = 5\varepsilon^5 - 8\varepsilon^5 + 25\varepsilon^6$, $B = \frac{16}{3}\varepsilon$.

Relative linear velocity are the same as in [3] when the magnetic forces exerted on particles are equal $F_{bi}{}^m - F_{ai}{}^m = 0$. It is possible, for example, when nonmagnetic particles are immersed in strong non-uniform magnetic field. The magnetic forces are following in this case

$$\vec{F}_a{}^m = k_\mu \nabla H_0^2 + \vec{F}_{ab}, \quad \vec{F}_b{}^m = k_\mu \nabla H_0^2 + \vec{F}_{ba}.$$

Here, the coefficient k_μ is including difference of permeabilities of fluid and particles; $\vec{F}_{ab}, \vec{F}_{ba}$ - forces in results of magnetic interaction of particles. If the ∇H_0^2 is the constant vector we can write $\vec{F}_a{}^m = \vec{F}_b{}^m$. In this case particles behaviour in the parabolic flow is the same as in case when magnetic field is absent. In other words particles tend to take up positions at equal distances from the flow symmetry axis.

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UNITS FOR WATER NON – CONTACT SATURATION IN THE FLOW

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When saturated water is used for medical and food industry it is necessary to preserve its quality, for example, its chemical composition has to be the same as after treating without electrolytic dissociation [1]. It is desirable to carry out water saturation in the flowing and nonflowing units using noncontact method. Nonflowing units being used glass and non-metallic containers meet this requirement [2].

It is desirable for saturated water used for dough to eliminate contacts with metal poles in the flowing units. Pipe and disk units allow to control running clearance and time action of magnetic fields upon this flow [3].Both units are used to regulate liquid layer thickness in the flow without interference into it.

Regulation method is to provide division of water - line into ring spaces differed by volume and layer thickness. One pole is movable in every pair of alternated poles. Layer thickness is determined by replacing movable poles and fixing their positions over given spaces.

Such unit provides easy assembly and disassemly, washing and replacement. Pipe flowing unit includes a non-magnetic pipe –line, a magnetizing coil, a pipe-type core, a cylinder magnetic circuit connected with face covers [Fig. 1]. The core is bulged out of the limits of the magnetic circuit and is produced with ledges of one direction at both ends. Face covers of the magnetic circuit may be connected by tie rod and have the possibility to remove when rotating. The core is connected with the pipe –line as in interference fit. It is installed in such manner that core ledges form ring running clearance with suface face covers. The distance between alternative poles is constant when setting any of provided sizes of clearance.

To provide non-contact water saturation the unit construction has liquid isolation from poles by fluoroplastic pipe –line. Isolation of another pole is done by coating it with polymer materials such as polytetrafloure thylene[4.5]. Core steel and magnetic circuit are connected electrically and earthed.

Unlike other units water heating is not an important factor in the pipe-flowing units because of its insignificance. Power active losses are decreased under given number of ampere – turns. This unit allows to compare it with a flowing unit.

A pipe-flowing unit saturates water by alternating electromagnetic fields of commercial frequency at one or two pairs of poles. It allows to treat water by electromagnetic field of direct current, to change relation between water for saturation using plugs with calibrated orifices to close a path of a water core and the flow without being subjected by treatment. The unit may treat seeds and bulk materials, for this purpose the core is removed from the coil.

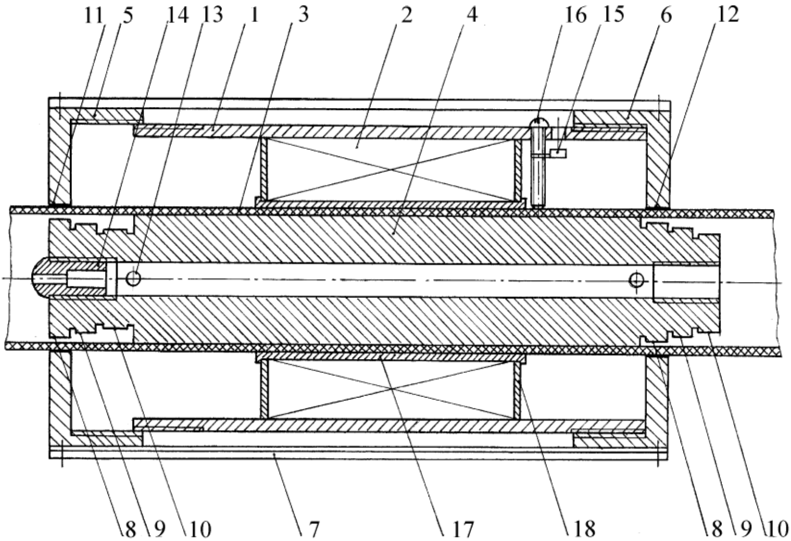

Fig. 1.A cylinder magnetic circuit connected with face covers, 1 – cylinder magnetic circuit , 2 – magnetizing coil, 3 – non-magnetic pipe-line , 4 – water core, 5,6 – face covers, 7 – tie – rod, 8,9,10 – core steps, 11,12 – through holes surface of face covers, 13 – axis holes, 14 – plug, 15 – plug joint, 16 – retainer screw, 17 – coil sleeve, 18 – check – piece.

There is no returning to earth in this figure.

Liquid treated in the magnetic field by a pipe –flowing unit flows perpendicular to the force lines of the magnetic field.

This unit takes precedence over known units, they are:

- there are three control ranges to set in various thickness of water layer in the flow,
- it works at direct and alternating current,
- it works at any space orientation,
- it lets the liquid pass from an inlet pipe to outlet pipe without being treated and vice versa. The outlet and inlet are interchangeable,
- it has small power consumtion,
- it lets to saturate water by both pairs of alternative poles,
- it saturates a part of liquid passing through this unit when it is necessary.

The unit may be used to change time amount of the action of electromagnetic fields upon the flow owing to the increasing of the treatment extent zone as much as twice or three times as compared to the initial one. It allows to expand the range of used treatment condition in conjunction with the possibility to control the flow speed.

The field zone expansion upon any running clearance takes place on account of ferromagnetic concentrates of the field like rings fitted on the core steps and water-line. Ferromagnetic concentrates being brought into the coil circuit of this unit they are confined on the core steps and magnetic circuit by magnetic flux, they do not need to be fixed.

Fig. 2. is a graph of induction against voltage for three quantities of annular gaps. When thickness of the liquid layer is 1_{mm} a total gap between poles in the magnetic system is 5_{mm} (The total gap is shown in a legend). The first and second gaps provide necessary operating conditions at 220V, the third gap requires to apply a voltage governor. Having alternating voltage of winding power at 220V in obtained heat conditions, the temperature excess of winding over the environment is 20^0C, the core – 33.2^0C, the magnetic circuit surface – 13.5^0C. By water supplying these increments are much lower.

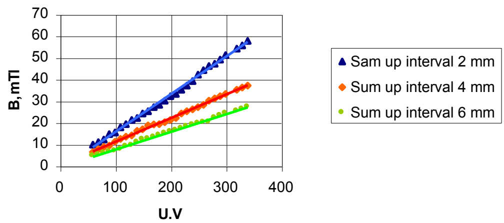

Fig.2.Dependence B from U

This construction is assembled from several identical modules which windings are connected with each other if alternated pairs of poles are taken into account. Every module consists of two disks inserted into each other by the sides forming the core. The required number of pole pairs is set by placing disk on a fluoroplastic water line, its inner surface is in contact with treated liquid.

Water is supplied via the annular gap formed by the water line and fluoroplastic core containing thin ferromagnetic torn rings. Operating magnetic flux is closed between module poles and ferromagnetic rings via the liquid, layer using for saturation.

Conclusions:

Suggested construction permits to conduct the non-contact magnetie treatment of water used for baking industry both at d.c. and a.c., practically unstricted flow speed in water lines of production areas and housing.

Liquid saturation takes place with changes of layer thickness without interference into the total flow and its noticable warming up and the changes of chemical composition.

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HEAT AND MASS TRANSFER

THE TEMPERATURE DEPENDENCE OF DEFORMATION OF AGGLOMERATE MAGNETIC DROPS IN MAGNETIC FIELD

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We have studied the temperature dependences of an elongation of agglomerate magnetic drops and the temperature dependences of the interfacial tension at the phase boundary between microdrop and its surroundings.

At research of thermal properties of magnetic fluids containing agglomerate magnetic drops, it was founded that the warming could accelerate the process of a mass transfer between microdrop and its surroundings that produce partial or complete dissolution of agglomerate magnetic drops in surrounding fluid. Therefore disperse composition of heated samples of magnetic fluids with agglomerate magnetic drops depends on temperature, speeds and duration of warming [1].

For obtaining temperature dependences of an elongation of agglomerate magnetic drops the samples are selected, which disperse composition at warming varies insignificantly.

At change of temperature from 20°C up to 50°C the stability of a disperse composition of magnetic fluids containing agglomerate magnetic drops, is possible to receive at dilution of the concentrated magnetic fluids of magnetite in kerosene up to concentrations of magnetite less than 2%.

The temperature dependences of an elongation, interfacial tension σ and anisotropic light scattering are obtained for a sample of magnetic fluid (magnetite in kerosene) containing agglomerate magnetic drops outside of a field. The experimental sample was obtained by dilution of the initial concentrated fluid with oleic acid in kerosene solution. The agglomerate magnetic permeability $\mu \approx 35$ was calculated from measured values of H_1 and H_2. H_1 is the threshold field in which the agglomerate magnetic drops become strongly elongated and H_2 is the threshold field in which drops return to slight elongated form ($H_1 > H_2$)[2]. In diluted sample the volume fraction of magnetite was 1,8%.

At measurements of an elongation for elimination of evaporation and interaction with an environment, the magnetic fluid was in a hermetic capillary. The capillary container located in immersion oil, eliminating distortions at measurement of linear dimensions, was posed inside cell supplied with a heater, thermoelectric couple and Helmholtz coils. The cell with a sample was installed on a subject plate of an optical microscope. The field dependences of an elongations obtained at temperature 20, 30 and 50°C represented in a figure 1. Initial radius of agglomerate magnetic drop was R=9μm both before and after heating. The curves 1-5 represent the data that are obtained at the different temperatures: t=30°C (curves 1,5); 40°C (2 and 4); 50°C (3). The curves 4-5 are obtained after the many times repeated cyclic heating**.** The field changes from 0 to H_o and then from H_o to 0. The value of applied field $H_o \geq H_1$ was selected to ensure that the disperse composition of magnetic fluid remains unchanged. When $H_o >> H_1$ strongly elongated agglomerates are joined into larger ones

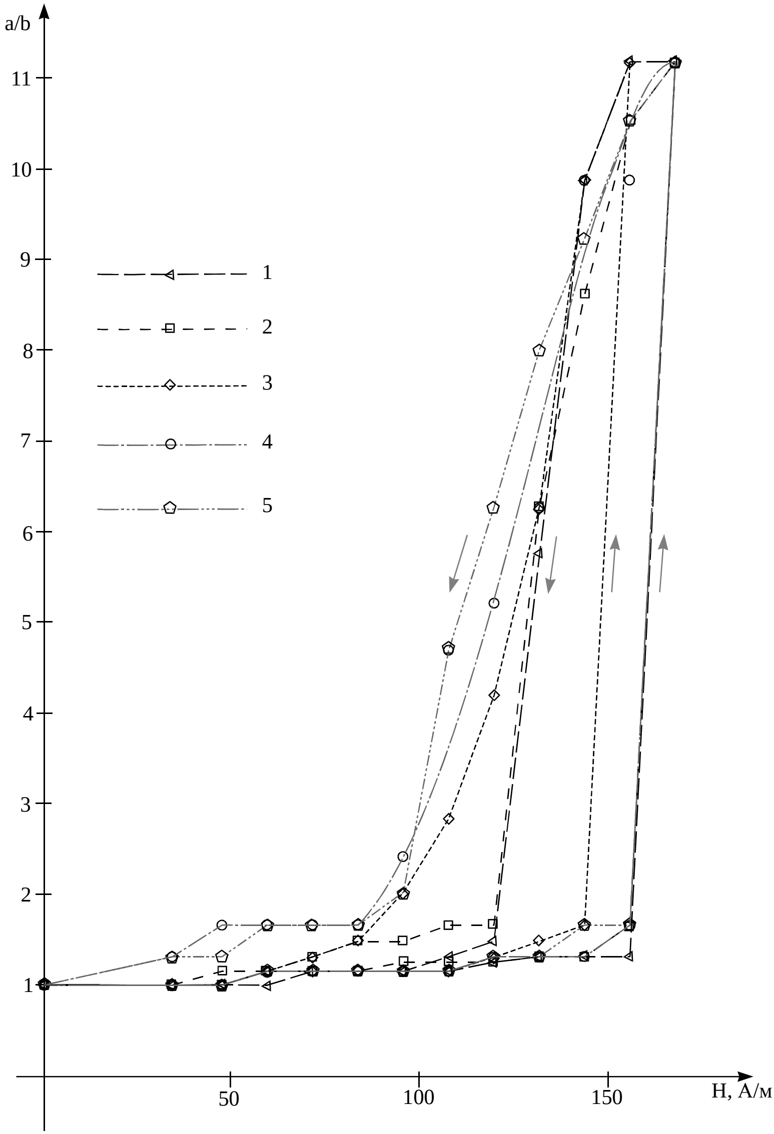

Figure 1

and the fluid changes **its** disperse composition. The hysteresis of deformation of agglomerate magnetic drops is obtained in all a temperature range. The threshold values of a field H_1, obtained at temperatures 30°C and 40°C, coincide. At temperature 50°C the value H_1 decreased only slightly.

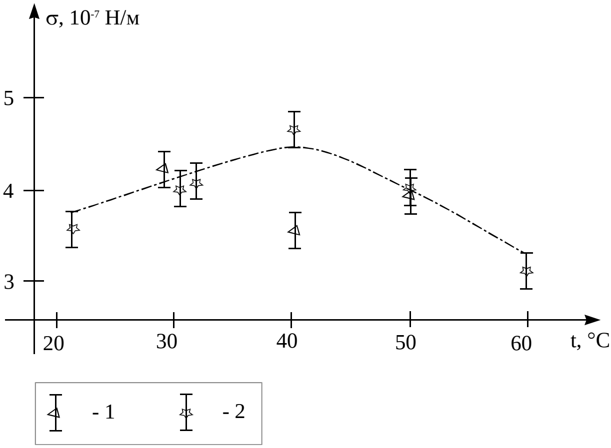

Figure 2

The σ values calculated with help of measured linear dimensions of weakly deformed microdrops having the shape of ellipsoids of revolution, represented in a figure 2. The curve represents the data that are obtained after the many times repeated cyclic heating (points 2)**.** Points 1 are obtained for fresh samples.

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MAGNETO-GRANULOMETRIC ANALYSIS OF CONCENTRATED FERROFLUIDS

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When dealing with magnetic fluid studies it is extremely important to know so called granulometry, it means in peculiar to know the ferrofliud disperse composition. Magneto-granulometric analysis proved to be the most effective tool of solving this problem, because this method, based on magnetization curve analysis, allows to obtain not only magnetic particle sizes, but the matter magnetic properties. Example of magneto-granulometric analysis application could be found in [1-4].

It is worth mentioning, magneto-granulometric analysis is suitable only for spatially homogeneous distribution of ferroparticles, thus all further computations do not take into account the different aggregates appearance in a ferrofluid. In the paper [4] the detailed magneto-granulometric analysis was carried out on the basis of different theoretical models The results of it are given in tables 1 and 2, the last rows of which contains data obtained with the help of described bellow method.

The following models proved to be the most suitable for diluted and moderately concentrated magnetic properties description: mean spherical model (MSF) [5], thermodynamic perturbation theory (TPT) [6] and modified mean field theory (MMFT) [4]. However they do not meet an experimental data for more concentrated magnetic fluids [3,7]. In papers [8,9] original method of concentrated ferrofluid magnetic properties calculation, based on correlation function approach, is presented. The expression (1) successfully describes the experimental data for ferrocolloids with extremely high concentration.

$$M(H) = M_L(H_e) = n\int_0^\infty m(y)\, f(y) L\left(\frac{m(y)H_e}{kT}\right) dy,$$

$$H_e = H + \frac{4\pi}{3} M_L(H) + \frac{(4\pi)^2}{144} M_L(H) \frac{dM_L(H)}{dH}, \qquad (1)$$

Here n is ferroparticle numerical concentration; $m(y)$ reflects particle magnetic moment dependence on this particle magnetic core diameter y; M_L stands for Langevin magnetization; $f(y)$ – particle magnetic core diameter distribution function; and H_e has the meaning of effective field, acting on a single particle. Formula (1) has simple asymptotics in weak and strong external field (2,3).

$$M(H) = \chi H, \quad \chi = \chi_L \left[1 + \frac{4\pi\chi_L}{3} + \frac{(4\pi\chi_L)^2}{144} \right], \quad H \to 0 \qquad (2)$$

$$M(H) = \left(M_\infty - \frac{nkT}{H} \right) \left(1 + \frac{4\pi}{3} \frac{nkT}{H^2} \right), \quad H \to \infty \qquad (3)$$

Where M_∞ is saturation magnetization, χ_L – Langevin initial susceptibility. The following algorithm is placed in a base of magneto-granulometric method used bellow. First step is to find ferrofluid concentration and saturation magnetization from (3), thus, the mean magnetic moment, consequently $\langle y^3 \rangle$. The second step consists of finding χ_L from (2), it means mean squared magnetic moment and, so, $\langle y^6 \rangle$. After making a model distribution choice (eg, Γ-distribution (4) seems to suit [7]), the last step could be easily defined, because it is enough to know $\langle y^3 \rangle$ and $\langle y^6 \rangle$ to restore *f(y)* – particle magnetic core diameter distribution function.

$$f(y) = \frac{1}{y_0} \left(\frac{y}{y_0} \right)^a \frac{\exp(-y/y_0)}{\Gamma(a+1)} \qquad (4)$$

Finally, it is possible to check whether an obtained curve coincides with the experimental data.

In paper [4] the concentrated ferrofluid with saturation magnetization M_0=57 kA/m and magnetite magnetization M_s=480 kA/m was regarded. By diluting 6 additional ferrocolloids were obtained. Their properties are given in tables 1,2 (φ - the degree of diluting).

Table 1. Magnetic core diameter distribution function width.

Model	φ						
	0.088	0.137	0.197	0.296	0.444	0.664	1
Langevin	0.44	0.45	0.47	0.54	0.57	0.6	0.64
Weiss	0.41	0.40	0.39	0.40	0.36	0.31	0.25
MSM	0.41	0.41	0.44	0.44	0.44	0.45	0.45
TPT	0.41	0.41	0.42	0.46	0.47	0.48	0.55
MMFT	0.41	0.41	0.42	0.45	0.45	0.44	0.46
	0.410	0.410	0.409	0.409	0.410	0.410	0.410

The main idea was the following: magneto-granulometric analysis for any φ had to give the same *f(y)*.

Table 2. Magnetic core mean diameter (nm)

Model	0.088	0.137	0.197	0.296	0.444	0.664	1
Langevin	7.1	7.2	7.0	6.4	6.3	6.3	6.0
Weiss	7.3	7.6	7.7	7.6	8.0	8.5	8.9
MSM	7.3	7.5	7.5	7.1	7.2	7.2	6.9
TPT	7.3	7.4	7.4	6.9	6.7	6.5	5.6
MMFT	7.3	7.5	7.5	7.1	7.1	7.1	6.8
	7.299	7.319	7.316	7.311	7.299	7.299	7.293

However, as results in first four rows evidence above mentioned functions obtained by different models are close only for highly diluted magnetic fluids. As with concentration growth the difference between parameters also grows, it is the consequence of models observed in [4] precision of interparticle dipole-dipole interaction taking into account being not enough. Usage of the model (1-3) seemed to be worth applying for magneto-granulometric analysis, because it (1-3) allowed describing extremely high concentrated ferrofluids. The following results were obtained for model (1-3) $<y>$ = 7.3 nm, y_0=1.2 nm и α=4.9. When diluting the magnetic fluid, only concentration and saturation magnetization are to change, as for the distribution parameters they should be constant. The analysis of built magnetization curves showed almost total coincidences with experimental data in low and high concentration. A loss of coincidences could be observed for moderate concentrations (φ=0.137, φ=0.197). On the one hand, this loss lies within the accuracy, on the other; it might be the consequence of different aggregate appearance.

To summarize, theoretical model choice exerts a decisive influence upon ferrofluid magneto-granulometric analysis results. It turned out that the most stable for diluting are results given by the model [8-9].

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EFFECT OF A LONGITUDINAL MAGNETIC FIELD ON THE CAPILLARY BREAK-UP OF A FERROFLUID THREAD AT LARGE OHNESORGE NUMBERS

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We consider a stationary cylindrical thread of a Newtonian ferrofluid of magnetic permeability μ_1 immersed in an infinite mass of immiscible fluid of permeability $\mu_2 \neq \mu_1$ and the same density ρ and viscosity η. Both contiguous liquids are subjected to uniform axial magnetic field $\mathbf{H}$. On the basis of magnetostatics equations, hydrodynamic continuity and linearized momentum balance equations and the appropriate boundary conditions at the interface of two liquids we examine an influence of magnetic force on the capillary instability and break-up of a ferrofluid thread at rest, surrounded by a nonmagnetic liquid (a system I). The behaviour of an inverse liquid configuration under the magnetic field where inside a ferrofluid body there is a nonmagnetic liquid thread of the same diameter a (a system II) is studied as well. In both corresponding to each other configurations we consider the same pairs of magnetic and nonmagnetic liquids. To simplify mathematical manipulations, the capillary force is incorporated directly in the momentum balance equation [1].

We study the temporal evolution of periodic disturbances proportional to $\exp(\sigma t + ikz)$, $i = \sqrt{-1}$ and derive a relation between the growth rate σ, the wave number k and the geometry and physical properties of the fluid configurations (the dispersion equation). We focus our attention on the case of large Ohnesorge numbers $Oh = \eta / \sqrt{\rho \alpha a}$ where the dynamics of fluids is controlled by capillary, viscous and magnetic forces whereas the inertial force is negligible [2]. It is shown that at $Oh \gg 1$ the root of the dispersion equation is written as

$$\sigma = \frac{\alpha}{\eta a}\left[1 - x^2 - x\varphi(x, \mu_{r1}, \mu_{r2}) Fi\right]\left\{\frac{x}{2}\left[I_1(x)K_0(x) - I_0(x)K_1(x)\right] + I_1(x)K_1(x)\right\}$$

$$\varphi(x, \mu_{r1}, \mu_{r2}) = \frac{(\mu_{r1} - \mu_{r2})^2 I_0(x)K_0(x)}{\mu_{r1} I_1(x)K_0(x) + \mu_{r2} I_0(x)K_1(x)} \qquad (1)$$

$$x = ka\,,\ Fi = \frac{\mu_0 a}{\alpha}\mathrm{H}^2\,,\ \mu_{r1} = \mu_1/\mu_0\,,\ \mu_{r2} = \mu_2/\mu_0\,,\ \mu_0 = 4\pi \cdot 10^{-7}\ H/m$$

where α is the surface tension coefficient and $I_l(x)$, $K_l(x)$ are modified Bessel functions.

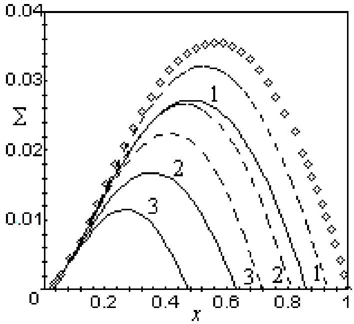

Fig.1. The growth rate versus the wave number for different field numbers

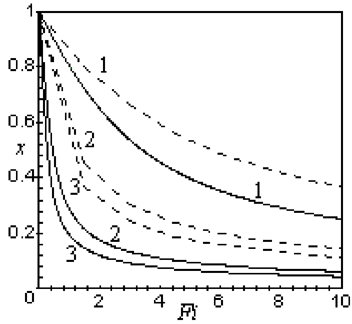

Fig.2. Curves of neutral stability

Numerical calculations based on (1) provide insights into the effect of magnetic force on the capillary break-up of threads. Figure 1 shows the typical dependence of dimensionless growth rate $\Sigma = \sigma\eta a/\alpha$ on dimensionless wave number x for different magnetic field numbers Fi. Diamond line corresponds to $Fi = 0$. Solid lines correspond to systems I with $\mu_{r1} = 4$, $\mu_{r2} = 1$ whereas the dashed ones correspond to systems II with $\mu_{r1} = 1$, $\mu_{r2} = 4$. Curves 1-3 correspond to $Fi = 0.1;0.3;0.5$, respectively.

In the (x, Σ)-coordinate plane for given $Fi \neq 0$, μ_{r1}, μ_{r2} and all $x > 0$ lying to the left of the point of intersection $[x_c(Fi, \mu_{r1}, \mu_{r2}), 0]$ of the corresponding curve with the abscissa axis, the condition $\sigma > 0$ is fulfilled whereas $\sigma < 0$ at $x > x_c(Fi, \mu_{r1}, \mu_{r2})$. Thus the modes with $0 < x < x_c(Fi, \mu_{r1}, \mu_{r2})$ are unstable while the modes with $x > x_c(Fi, \mu_{r1}, \mu_{r2})$ are stable.

In the absence either of a magnetic field or of a permeability jump when passing the liquid-liquid interface (the diamond curve in Fig.1), we arrive at the classical result for the cut-off wave number $x_c = 1$. As may be seen from the Fig.1 a tangential magnetic field stabilizes a certain range of modes $x_c(Fi, \mu_{r1}, \mu_{r2}) < x < 1$ (with wavelengths $\lambda > 2\pi a$) that are unstable when there is no field.

In Fig. 2,3 solid lines 1, 2, 3 correspond to systems I with $\mu_{r1} = 2; 4; 5$, respectively, while dashed lines 1, 2, 3 correspond to systems II with $\mu_{r2} = 2; 4; 5$.

Figure 2 presents the neutral stability curves along which in the (Fi, x)-coordinate plane the condition $\sigma = 0$ is fulfilled. For given μ_{r1}, μ_{r2} these curves divide the first quadrant into stability regions (above the curves with considered μ_{r1}, μ_{r2}) and instability ones (below the same curves). Figure 2 indicates that in both systems I and II the width of instability regions (i.e., the cut-off wave number $x_c(Fi, \mu_{r1}, \mu_{r2})$) decreases when increasing the magnetic field number or the relative permeability jump $|\mu_{r1} - \mu_{r2}|$. For the same values of Fi and $|\mu_{r1} - \mu_{r2}|$, the cut-off wave numbers in systems II are greater than in systems I.

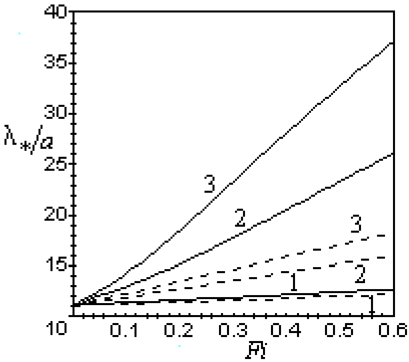

Fig.3. The wave length of the fastest-growing mode versus the magnetic field number

Figure 3 illustrates the effect of the magnetic field number on the dimensionless wave lengths λ_* / a of the most rapidly growing modes in systems I and II. It follows from the graphs that at fixed values of a relative permeability jump an increase in the magnetic field number produces larger λ_* / a, i.e., coarser droplets. In the case of the fixed Fi the same occurs when increasing the permeability jump. Finally, as a result of the capillary break-up of threads, at the same conditions coarser droplets are formed in systems I as compared with systems II.

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MEDICAL AND BIOLOGICAL APPLICATIONS

BIOLOGICAL EFFECTS OF ULTRADISPERSED FERROUS POWDER

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Magnetic liquids have got a widespread use in biology and medicine lately. Experiments concerning with tumor treatment by ultra-high frequency radiation upon ferromagnetic liquid being injected, roentgenoscopy and controlled with external magnetic field drug transport were carried out. But biological effects associated with nanoparticles themselves, synergism or antagonism with medicinals and postponed effects of ferromagnetic liquid injection are unsufficiently studied. Evolutionally formed homeostatic mechanisms including trace elements’ level control support normal metabolism in the living organisms, additional supply of any metal into metabolic pathways affecting not only trace element homeostasis but other regulating systems too. That phenomenon manifests in the total biological response of the organism. Metals being administered in the ionic form are readily bonded and then eliminated from the organism due to high effectiveness of regulating systems. However, metals in the form of ultradispersed powders (UDP) provide a gradual dissolution and utilisation of a specimen, manifesting a prolonged effect on trace element homeostasis system together with other conjugated regulating systems .This phenomenon can initiate a biological response differing from the one in case of metal administration in the ionic form. So the investigation of trace element and other conjugated homeostatic regulating systems responses to the UDP administration appeared to be an important problem in the study of possibility of metal suspensions use in medicine.

We had undertook a research concerning with growth stimulation and toxic effects of UDP Fe powder (particle size 50 – 100 nm) on purpose to clear some peculiarities of UDP's biological action. On that groundwork some characteristics of biological action zones (BAZ) were established. A single subcutaneous injection of Fe UDP in doses 1 – 100 mg/kg was found to increase a growth rate of immature mice upto 10-15% ($p \leq 0,05$) in comparison with control. Ferrous sulphate administration induced growth retardation in the same dose interval.

Table 1.Comparative toxicological parameters of UD ferrous powder and ferrous sulphate.

Dose, mg/kg	Fe^0	$FeSO_4$*
MTD	1100	20
LD_{50}	2200	60
LD_{100}	3200	90

MTD – maximum tolerance dose – the largest dose which does not induce animals' death; LD_{50} – dose value inducing death of a 50% animals in the test group; LD_{100} -dose value inducing total animal's death in the group.

* - doses were recounted as metal ion content – Fe^{++}(mg)/animal weight(kg) .

Characteristic curves "Dose-Response" have been got on the base of these data, and biological action zones were estimated. Fe UDP has a biotic stimulation zone (StZ) in the interval 1 – 10 mg/kg, safety zone (SZ) is upto 1100 mg/kg, farmaco-toxic zone (FTZ) started from doses higher than 1100 mg/kg.

ESP studies demonstrated an active distribution of metal particles injected in various organs and tissues. ESP spectra not only typical for normal tissues but also for ferromagnetic particles were registered in test organs (liver, spleen, kidneys, lungs and heart) after a single injection of 2 mg/kg Fe UDP, maximum sygnal being observed 1 week after metal administration. ESP sygnal with g-factor 2,1 appeares 2 weeks after powder injection indicating that metal particles being found in organs and tissues gradually transform in a structure with a modified type of exchange interaction. Metal ions generated in dissolution processes remain within a cell in the form of simple complexes or react with transport proteins. ESP sygnal of paramagnetic complexes of ferric ions and Fe^{3+}- transferrin amplitude fluctuations were observed in blood after UDP injection; the phenomenon coinsided with maximum increase in blood metal content. Metal powder administration changes the type and amplitude of natural Fe and Zn fluctuations in tissues upto 50 - 70% with regard to control values. Therefore trace element regulating system operating in the organism copes with the increased load after Fe UDP administration. The nature of metal assignes the UDP particles dissolution rate and characteristic features of dissolution products biological action. Thus, the widening of the area of Fe(III) stability in bioligands' occurrence in comparison with aqueous medium partially accounts for lower toxicity of Fe UDP compared to ferrous sulphate. Realization of Fe UDP biological effects is associated with its influence on various biosystems: trace elements regulating system, natural antioxidants, lipid peroxidation system (LPS), etc.

Our investigations enabled to disclosure growth stimulation with Fe UDP. To study the mechanisms of such growth stimulation, we selected a model of partial hepatoectomy on account of the model of liver regeneration enables to study processes and control scemes of differentiation, proliferation and growth.

A decrease in regenerating liver weight was found both in the case of intraperitoneal and subcutaneous injection of 10 mg/kg Fe UDP preliminary administration (just before the hepatoectomy operation) in comparison with untreated operated mice (control group) during 6 days after operation : after intraperitoneal injection upto 8 – 10%, and after subcutaneous – 5 – 7%. Thus, regeneration delay due to 10 mg/kg Fe UDP injection was less pronounced in the case of subcutaneous injection.

Mortality data for mice exposed to partial hepatoectomy and preliminary Fe UDP administration are presented in Table 2.

Table 2. Mice mortality 3 days after partial hepatoectomy and Fe UDP injection.

Fe UDP administration mode	Dose of metal, mg/kg	Mortality, %
Control group	0	15
Intraperitoneal, immediately before the operation	10	30
Intraperitoneal, immediately before the operation	100	100
Subcutaneous, immediately before the operation	10	30
Subcutaneous, immediately before the operation	100	50
Subcutaneous, 3 days before the operation	10	7
Subcutaneous, 3 days before the operation	100	22

Fe UDP intraperitoneal injection immediately before the operation in dose 100 mg/kg nduced death of experimental animals. So from here on UDP's were administered only subcutaneously. A preliminary 10 mg/kg Fe UDP injection induced a decrease in liver regeneration percentage upto 1.2 times versus control group data during first 3 days after operation. An acceleration of weight rehabilitation of regenerating liver upto 12% versus control has occured later on and lasted until regeneration processes were finished (Table 3).

Table 3. Mice regenerating liver weight changes (%) after partial hepatoectomy and Fe UDP injection.

Mode of administration	Dose of Fe UDP	Regeneration time (days):							
		0	1	2	3	4	5	6	7
Control	0	33,3 ± 0,2	42,7 ± 0,8	54,5 ± 0,8	67,5 ± 1,2	78,1 ± 1,9	87,2 ± 2,6	100,4 ± 3,6	-
Immediately before the operation	10	33,3 ± 0,2	45,0 ± 2,1	51,4 ± 1,6	60,1 ± 2,6	76,9 ± 3,2	-	93,1 ± 2,1	104,2 ± 3,5
3 days before the operation	10	33,3 ± 0,2	35,1 ± 1,3	51,8 ± 0,9	71,6 ± 2,4	86,2 ± 2,8	99,8 ± 3,4	-	-
3 days before the operation	100	33,3 ± 0,2	41,0 ± 2,3	50,3 ± 1,4	64,9 ± 2,5	72,5 ± 3,7	81,6 ± 3,6	-	97,7 ± 3,5

The time of UDP administration changes the mode of liver regeneration after partial hepatoectomy. A subcutaneous injection of 10 mg/kg Fe UDP immediately before the operation inhibited liver regeneration during the whole rehabilitation period and a preliminary (3 days before) administration led to a stimulation of liver regeneration. Besides that, a preliminary Fe UDP injection (3 days before operation) led to a 2-fold decrease in animal mortality at post-operation period versus control.

A preliminary (3 days before operation) 100 mg/kg subcutaneous Fe UDP injection led to a liver weight regeneration delay upto 8 – 10% versus control operated animals.

Therefore, Fe UDP administration in 10 and 100 mg/kg doses affects on liver weight regeneration process. Both intraperitoneal and subcutaneous administration of 10 mg/kg of Fe UDP immediately before the operation and a ubcutaneous injection of 100 mg/kg of Fe UDP 3 days before led to a delay in liver regeneration. An acceleration of liver weight rehabilitation in comparison with control was observed after preliminary (3 days before operation) subcutaneous Fe UDP injection in a dose 10 mg/kg, animal survival in the post-operation period being 2 times higher than in the control group. The data obtained enable to drive a conclusion that Fe UDP administration stimulates regeneration processes in mice liver. A possible scemes of stimulation of regeneration processes with Fe UDP will be discussed in the report.

USE OF MAGNETIC OINTMENTS FOR TREATMENT OF PURULENT WOUNDS IN EXPERIMENT

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Despite of achievements of modern medical science, the struggle with a purulent surgical infection is still one of the urgent problems.The most advanced methods of surgical treatment of purulent wounds can not completely prevent the development of wound infections and the steadybuild-up of the microflora that is non-susceptible to antibiotics. Therefore the experiments with new medicinal means such as magnetic ointments (MO) represent a great interest. The MO havevaseline-lanolin, collagenous and natrium -carboxilmetilcellulose* (CMC)bases. Fine dispersive magnetite (Fe_3O_4), powder of stainless still and barium ferrite are used as the magnetic filling.The experiments in vivo were carried out on white mongrel ratshaving the mass 180 to 230 grams. By in the caerses of direct action on wound, there is creation of diversified small focuses of maximal geterogeneosus magnetic fields with exposition about 1-3 min.It was found, that after a single application and evacuation of the wound's contents by the external magnetic field, the bacterial population decreases 1000 times (from 10^4-10^5 to 10^1-10^2). Cytological study of the wound's surface prints showed the presence of a great number of formed elements of blood (leucocytes) and staphylococci. After processing the wound, there were only isolated colonies and leucocytes. The healing occurred 1,5 times faster, than at control animals.Thus, MM could be used for clearing purulent wounds from the content, the magnetic field promoting the regeneration and epithelisation of wounds.

EXPERIMENTAL MYRINGOPLASTY WITH FERROMAGNETICAL MATERIAL

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The most common cause of plastic graft rejection the with exception of tissue incopatibility are the disadvantages of plastic graft fixation along the borders of deepitelized tympanic membrane. These disadvantages result from blood clots residues, airial streaks, incomplete graft attachment, graft shifting in involuntary sneezing, coughing and abrupt head movements. Thus the insufficient quality of plastic graft fixation during the final stage of myringoplasty lead to ineffective surgery.

To fix plastic grafts the acoustic meatus can be filled with cotton tampons saturated in antiseptic ointments. But even attachment and fixation of the graft reqiure virtous manipulations and sufficient experience on the part of the surgeon. Besides external acoustic meatus is kept closed for 7-21 days and makes it impossible to control regeneration course or perform antiseptic redressings on the operation site.

Our approach is based on the idea to use soft magnetic forms (SMF) to fis plastic graft in the course of myringoplasty.So far there has not been found any reference to SMF myringoplasty in the available literaure.

The essence of the new method is in the following.m On deepitelization of perforated borders and hemostasis , the internal surface of tympanic membrane is covered by a layer of ferromagnetic ointment containing aniseptics and regeneration simulating agents (orotic acid) and plastic graft is then applied.It is fixed by a teflon ring with samariy-cobalt magnet elements being placed in the zone of magnetic ointment projection. Mathematical calculations of the required slides and magnetide magnetization being done.

The suggested technique of myringoplasty graft fixation provides a steady and reliable graft attachment excluding any blood/air contact and filling the external acoustic meatus with a tampon .Having the acoustic meatus open makes it possible to examine the graft immediately after operatin, correcting its position and to activate the operation zone regeneration by physiotherapeutic and laser stimuli.

There were performed 53 experiments on animals (18 guinea pigs and 9 rabits) with the following results:

1. SMF is maintained in tympanic cavity by a magnetand is easily released through acoustic tube on its removal;
2. Some temporary tympanic response changes were observed on SMF being introduced into tympanic cavity;
3. SMF being applied on inflamed mucous produced a certain antibacterial effect. Control examinations revealed a lessening ear discharge with relieving inflammatory events;
4. On removing the magnet pieces or slide SMF automatically releases through acoustic tube during 7-14 days;
5. On follow up period (30-45 days) no inflammatory signs were observed either in middle ear or external acoustic meatus.

The received findings provide a sufficient reason to bring the method into successful clinical practice.

THE CREATION OF STANDARTIZING METHODS FOR MAGNETIC DRUG FORMS

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Magnetic drug forms (MDF) such as magnetic rectal suppositories (MRS) and magnetic ointments (MO) were created. MRS include barium hexaferrite and MO include magnetite as magnetic fillers. These MDF were clinically tested on volunteers and showed good clinical results. We present the criteria for MDF which are necessary for creation Pharmacopoeia articles. Pharmacopoeia articles are necessary for wide use of MDF in medicine.

THE FERRIFLUIDS AC MAGNETIC FIELD EXCITATION - THE PRINCIPLE OF MAGNETO-THERMODYNAMICS THERAPY

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INTRODUCTION: We have developed magnetic dextran-ferrite (DF) nanoparticles [1] and photogem (PG) [2-6] for the tumor cells induction DF AC magnetic field hyperthermia (ACH) [7] and PG magneto- [8] and thermosensitization [9] in the dark (MTS). DF ferrifluids (DFFs), that had been prepared from DF, may be ideal magnetic carriers [1,7,10]. DF dissipates of AC magnetic field energy and therefore causes hyperthermia in the area of their confinement [7].

Hematoporphyrin (HP) derivatives potentiate the radiosensitizing effects of 2-deoxy-D-glucose in cancer cells, possibly by further reducing the energy supply leading to an irreversible inhibition of DNA repair, and the increasing cytogenetic damage and cell death [11-13].

Histidine (His) is a known scavenger of singlet oxygen [8]. The thermal of glioma cells damage enhancement by HP was suppressed by addition of β-carotene, a singlet oxygen scavenger or a superoxide-anion radical ($O_2^{-\cdot}$) scavenger bat not by the addition mannitol, which is a scavenger only of hydroxyl radicals. Thus it is possible to assume the next mechanism of PG-cytotoxic influence on tumor cells. PG, as the other lipophylic HP-derivatives intercalates between membrane lipid molecules and induces the membrane-related damages: morphological changes of cell membranes on light activation. Changes in the ratio of saturated/unsaturated fatty acid content of membrane lipids or other chemical events such as cross-linking of membrane components during the photosensitization process can also account for observed effects [12]. At the magneto- and thermosensitization possible enhances an ability of the incorporated PG molecules to produce free radicals, such as at photosensitization. The cell damage is probably mediated by singlet oxygen (O) generated via superoxide-anion radical ($O_2^{-\cdot}$). PG on the analogy to HP [8] may generate superoxide radical and singlet oxygen that cause destroying of a tumor cells. The analysis of publications on PG (Russia) and photofrin II (PF) Canada, USA, showed, that they are very close analogous by their structure, physical and chemical characteristics and therapeutic features [6, 14]. Seven patients with endometrial carcinomas stage FIGO 1a (restricted to the endometrium) and also 4 patients with recurrences of vaginal and vault cervix carcinoma, carcinoma of the corpus uteri and the vulva were treated primarily. Residual tumors after conventional therapy of cervix and vulvas carcinoma were treated in 2 patients. Tumor illumination was performed by an Argon dye laser during 24-72 h following the intravenous administration of HP derivatives (Photosan III, 2 mg/kg^{-1} body weight). The intracavitary tumor irradiation by means of a glass fiber was controlled by ultrasound. Superficial and small lesions of vaginal and vulvas carcinomas were subjected to superficial light irradiations whereas tumors exceeding 1 cm in depth were treated interstitially. Tumor response was estimated 1 month after therapy. Complete remission was achieved in 8 patients, partial remission in 2, and no remission in 3 cases. Subsequent radiotherapy was performed in 3 patients with bleeding endometrial cancer with consecutive complete response [14]. In case of PF clinical use complete and partial regression of tumor was registered in 98% [6], in case of PG the same is 94% [15].

The inevitable technical problem of photodynamic therapy is the initiation of the absorbency of visible light by a tumor that has been injected with photosensitizing agent, because an incident light at wavelengths between 600 and 1000 nm reacts with the photosensitizing agent only at short deeps (0.1-1.0 cm) of tissue body.

The purposes of this work were: to evaluate of PG containing dextran-ferrite ferrifluids for the combination of an ACH with MTS; to analyze the influence of AC magnetic field and hyperthermia on the cells death and lysis in the presence of PG, to obtain further insights into the mechanisms of these processes.

METHODS AND MATERIALS: We have tested the five of water-based dextran-ferrite (DF) ferrifluids (DFFs): 12.0; 0.6; 0.2; 0.02 and 0.002%, that were prepared by the procedure modified from [10]. The survival of CaOv and P388 cells, as the result of the exposure temperature and concentration of DF alone, PG alone, histidine (His) alone, DF in combination with PG (DF+PG), PG in combination with His (PG+His) during magneto- and thermosensitization of tumor cells by PG in the dark and heating DFFs achieved simultaneously by AC magnetic field or by a flow thermostat was investigated. For the survival of CaOv and P388 cells study, previously used experimental setup [7] was modified. AC magnetic field 0.88 MHz, 9.3 kA/m, 0,15 kW was achieved inside a water-cooled copper induction coil of 4.5 cm radius (20 turns with turn-to-turn distance 0.9 cm). The tumor cells (concentration 10^6 cells/ml) alone and with reagents: DF, PG, His, PG+DF, PG+His were placed in the center of the coil and exposed 30 min to the AC magnetic field in the dark. To 6 isolated test tubes (TTs) containing by 2 ml of fresh peritoneal ascitic limpholeukosis P388 or CaOv cells ($2X10^6$/ml) were added: in first TT 2 ml 12 % (w/v) DFF (net γ-Fe_2O_3 weight: 60 mg); in second ones - 2 ml 0.6 % DFF; in third ones - 2 ml 0.2 % DFF; in fourth ones - 2 ml 0.02 % DFF; in fifth ones - 2 ml 0.002 % DFF; in sixth (control TT) 2 ml 0.9 % saline was added. Then TTs were exposed to AC magnetic field as described above, and the selected temperature in the range of +37 – +44°C was maintained for 30 minutes (Table 1). The cells temperature measuring at the same time with AC magnetic field treatment was done by alcohol thermometer. Alternatively, cells were exposed to AC magnetic field in the dark in the presence of PG alone, His alone, PG+DF, and PG+His; in the control TTs the cells were incubated at +37°C in the laboratory thermostat. To 6 isolated TTs, containing by 0.1 ml of fresh P388 or CaOv cells ($2X10^6$/ml) by 0.1 ml, enumerate above reagents, were added; in control TT 0.1 ml 0.9 % saline was added. A volume of reaction mixture in TTs, containing a tumor cells and reagents, was 4 ml (Table 1) and 0.2 ml (Table 2,3), the concentration in the all TTs was 10^6 cells/ml. The temperature of the reaction mixtures from +37 to +41°C was achieved by a flow thermostat; from +37 to +44°C (Table 1) and from +37 to +41°C was achieved by AC magnetic field. The survival of P388 and CaOv cells as the result of the exposure concentration of DF, PG, His, PG+DF and PG+His at +37 and +41°C during tumor cells PG magneto- and thermosensitization (MTS) achieved by AC magnetic field in the dark was fixed. After CaOv or P388 cells exposure to AC magnetic field, DFFs, PG, PG+DF, PG+His at various conditions the survival of the cells was analyzed by a hemocytometer counting and by intraperitoneal injection of 0.1 ml analyzed compositions of P388 cells to DBA_2 mice. The interaction of DF with cells was investigated taking into account the recommendations in [16]. The results represent the mean ±SD from the four independent experiments.

RESULTS AND DISCUSSION: DF appeared as dark-brown leaflets and contained about 27 % of γ-Fe_2O_3, 71 % dextran and 2% H_2O; the value of σ was 18 $A \cdot m^2$/kg, LD_{50} 5 g/kg. 12% DFF appeared as dark-brown sol, pH 7, ζ 15 mW, M_s 1.5 kA/m, SAR 240 W/g Fe. TEM data allowed to evaluate of DF particles size: the maximum of microcristalls and of microspheres diameter was 12 and 240 nm, respectively, it was in a good accordance with the results of the analytical fractionation and dynamic light scattering analysis of the DF particles samples and Gaussian/Nicomp and Volume-weighted Gaussian distribution analysis of the particles diameter in the diluted DFFs that was 2 peaks: at 205 and 220 nm.

PG sols particle diameter distribution that was in 3 peaks: peak 1, at 5 to 7 nm; peak 2, at 50 to 70 nm and peak 3, at 300 to 400 nm, that was in a good accordance with PG gel-chromatography results. The obtained DFFs were resistant to gravitational forces, magnetic fields and liophylising. Determinations showed direct proportion decreasing of M_s and the heat production to DF concentration decreasing. Under the chosen conditions the heating of a 0.9% NaCl solution was always bellow the detection limit. DFFs showed satisfactory heating to 2°C/mg Fe min. The experimental results are presented in Tables 1, 2. No long-term toxicity or acute cells death was detected when cells were exposed to DFFs (up to 60 mg DF/ml) alone, or to AC magnetic field alone for the periods of time to 6 hours at +37°C. However, when P388 or CaOv cells were exposed to ACH at +41 to +44°C for 30 minutes in the presence of DFFs, the high hyperthermia effect was observed (Table 1).

Table 1. Influence of DF on CaOv cells during 30 min of AC magnetic field exposure.

Test tubes	Survival. cells (%)	Dead cells (%)	DF (mg/ml)	Temperature (°C)
1	0.0	100±6	60.0	43-44
2	4±0.8	96±5.8	6.0	42-43
3	48±3.4	52±3.6	1.00	41-42
4	91±5.5	9±1.4	0.10	39-40
5	95±5.8	5±1.0	0.01	37-38
6	96±5.8	4±0.8	0.00	37

Table 1 shows the temperatures in TTs 1-6 were proportional to DF concentration. The cells death fractions were proportional to DF concentration: the cells survival fractions at 37 to 41°C were high, at 42 to 43°C were insignificant, and at 43-44°C were absent. No fractions of lising cells were discovered at the highest concentration of DF 60 mg/ml.

So, we investigated the role of: DF, PG, His, PG+DF, PG+His alone; hyperthermia, AC magnetic field, induction DF AC magnetic field hyperthermia (ACH) alone; PG magneto- and thermosensitization in the dark (MTS) to increase the destroying of a tumor cells. Two types of the tumor cells: adherent human carcinoma ovarii (CaOv) and murine ascitic limpholeukosis P388 cells in the presence or absence of the enumerate reagents and physical factors were incubated. They were successively heated at +41 to +44^{o}C and by AC magnetic field treated with 0.88 MHz, 9.3 kA/m, 0,15 kW in induction coil. The combined effects of ACH and MTS were then examined and tested statistically for significance.

These data confirm the feasibility of using induction DF AC magnetic field hyperthermia in combination with tumor cells PG magneto- and thermosensitization. The advantage of this method is the much deeper penetration of magnetic field in body tissues with comparing to light. The further in vitro and in vivo investigations allow to choose of PG+DF optimal doses and AC magnetic field range intensity and continuity.

Table 2. Influence of DF and PG on CaOv cells during 30 min of AC magnetic field exposure at +41 to +43°C (TTs 1-3) and at +37°C (TTs 4-6).

T. T.	Surv. cells (%)	Dead cells (%)	Cells lysis (%)	DF, mg/ml	PG, μg/ml
1	0	91±5.5	9±1.4	9.0	0.80
2	0	88±5.4	12±1.6	6.0	1.60
3	3±1	52±3.6	45±3.3	3.0	32.50
4	20±2	45±3.3	35±2.8	0.10	3.25
5	10±1	50±3.5	40±3.0	0.01	32.50
6	0.0	0.00	100±6	0.001	325.0

Table 2 shows PG+DF cytotoxicity that were obtained at +41 to+43°C and at +37°C for 30 minutes period; the cells lysis and death fractions were proportional to the concentrations of PG and DF. As the result of combination ACH with MTS at the moderate concentrations of PG (0.8-32.5 μg/ml) and the high concentrations of DF (3-9 mg/ml) the cells survival fraction was absent; at the moderate PG concentrations (3.25-32.5 μg/ml) and the low DF concentrations (0.001-0.1 mg/ml) the cells survival fractions were average; at the high PG concentration (325 μg/ml) and the low DF concentration the cells survival fraction was absent.

Table 3. Influence of PG and His on P388 cells during 30 min of AC magnetic field exposure at +37°c (test tubes 1-3) and at +41°C (tubes 4-6).

T. T.	Surv. Cells (%)	Dead cells (%)	Cells lysis (%)	PG, μg/ml	His, mg/ml
1	94±5.7	6±1.2	0.00	0.00	1.6
2	9±1.4	51±3.5	40±3.0	32.5	0.00
3	77±4.9	12±1.6	11±1.5	32.5	1.60
4	84±5.2	16±1.8	0.00	0.00	1.6
5	3±0.6	51±3.5	46±3.3	32.5	0.00
6	63±4.2	20±2	17±1.8	32.5	1.6

Table 3 shows substantial inhibition of cell lysis and death by PG in the presence of 1.6 mg/ml His was observed. AC magnetic field cell damage enhancement by PG at +37°C (TT 2) and simultaneous thermal- and AC magnetic field cell damages enhancements by PG at +41°C (TT 5) was effectively suppressed by the addition of singlet oxygen scavenger, His (TTs 3,6).

Significant differences between cytotoxic effects produced by PG at +37°C and +41°C at the same concentrations of PG were found. Therefore the cytotoxicity of ACH should be attributed to the effects of heat itself. Combination of PG with DF have potential as a magneto- and thermosensitizes because of the following advantages: their dose-dependent enhancement of magneto- and thermal cell damage; lack of toxicity at physiological parameters AC magnetic field (frequency, induction, strength, power and temperature) and at the non-toxic doses of PG+DF required for tumor cells PG+DF magneto- and thermosensitization. Combination of ACH with MTS is summary method.

CONCLUSIONS: Dissolution of dextran-ferrite in water results in formation of dextran-ferrite ferrifluids useful for the tumor cells magnetically controlled combination of AC magnetic field induction hiperthermia with photogem magneto- and thermosensitization. A new mode of tumors treatment, magneto-thermodynamic therapy in the dark, based on the magneto- and thermosensitization of tumor tissues promoted by accumulated porphyrins is offered. The mechanism of ferrimagnetic heating most likely involves the magnetization relacsation loss process and of tumor cells photogem magneto-thermosensitization most likely involves free-radical processes with a key role of superoxide radical.

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WATER PARAMAGNETISM IN ANIMALS SUBSTANCE

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The reason of high sensitivity of animals to influence of very weak magnetic fields till now is not established. Last years many authors assume that the reason of observable effects is the change condition of water, which is included in substance of all bioobjects on the Earth. However given hypothesis contradict with very small magnetic susceptibility of water. Let's to show, that in very weak fields, order geomagnetic field $H_{geo} \cong 0{,}5Э$, water in animals is paramagnetic, and this fact is a necessary condition of mammal's existence.

This hypothesis is based on experimental data received by inductive dielectric method (L- method), in which the researched object is located inside solenoid coil (L-cell) [1-3]. A water condition in researched object by the given method is characterized by frequency value ν_{max} , on which the maximum for angle tangent of dielectric losses ($tg\delta$) at a frequency range 10kHz – 40MHz is observed. As has appeared [1-2], the dependence of frequency ν_{max} on temperature and concentration water solutions is not monotone, but has jaggies- fig.1-2. The jump of frequency ν_{max} is the indicator of sharp change of a water condition. In a frequencies range 10кГц - 40МГц on dependence $\nu_{max}(\sigma)$ of water solutions is present jaggies on frequencies: (20-25) kHz; (45-50) kHz; 200kHz; (20-25) MHz. Consequently 4 water conditions are possible. The two first "water - I" and "water - II" conditions are similar ice structure, since on frequencies $\nu_{max}(I)$=(20-25) kHz and

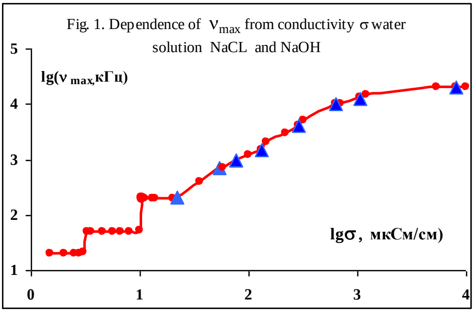

Fig. 1. Dependence of ν_{max} from conductivity σ water solution NaCL and NaOH

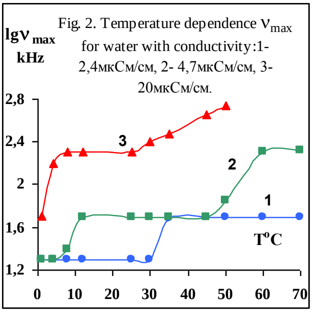

Fig. 2. Temperature dependence ν_{max} for water with conductivity:1- 2,4мкСм/см, 2- 4,7мкСм/см, 3- 20мкСм/см.

ν_{max} ***(II)*** =(45-50) kHz the maximum not only at water, but also ice (first - from pure water, second - from water with impurity) is observed. The third status, "water - III", - is a conditions of "boiling" water, because the water with the small impurity concentration is in it only at temperature about 100°C. The fourth water conditions, "water - IV", is similar to salts solutions with conductivity above $10^{-3}\,Om^{-1}sm^{-1}$ (1mS/sm). In this conditions there is water in physiological solutions.

According to experimental data of many authors animals blood and cell water have conductivity above, than 1mS/sm. As in salts solutions with such conductivity the $tg\delta$ maximum is observed at frequency 20MHz, therefore, it would seem, what exactly on this frequency should be observed a $tg\delta$ maximum in substance of plants and animals. And it is really the $tg\delta$ maximum for all investigated vegetative objects and also for earth warms is observed on frequency of "water - IV". Therefore, the water conditions in substance of this bioobjects similarly to a water condition in salt solutions. However, a fish substance has already $tg\delta$ value at frequency 20MHz more less, than at frequency 20-50 kHz. The water in substance of the mammals class representatives (mouse, hamster) in a normal status exist mainly in a conditions of "water - II" - fig. 3. The analysis of the received data results in a conclusion, that during evolutionary development of an animal the distinction between water conditions in his substance and conditions of a water salt solution is increased. The degree of distinction between these water conditions can be characterized by value of parameter "K", equal the ratio of animal substance $tg\delta$ values at frequency 50kHz and 20MHz. The

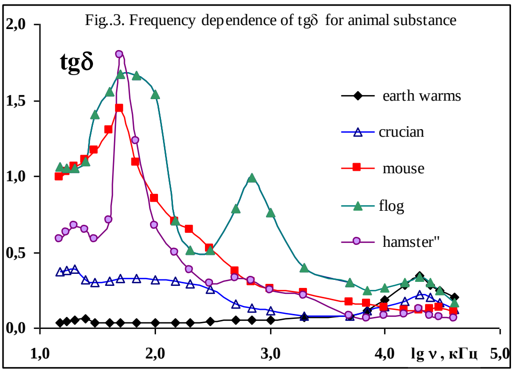

Fig..3. Frequency dependence of tgδ for animal substance diagram represented in a fig. 4, shows, that the fauna evolution is accompanied by increase of parameter "K", and, hence, and increase of a water structurization degree in animal substance.

The diagram given in a fig. 5 on an example of the mouse shows high sensitivity of "K" value to a status of a mammal health. As we see on fig. 4, during the normal vital functions of a mouse water in his substance is mainly in a "water - II" conditions, and in this case is observed a maximum "K" - fig. 5. As a result of inten-

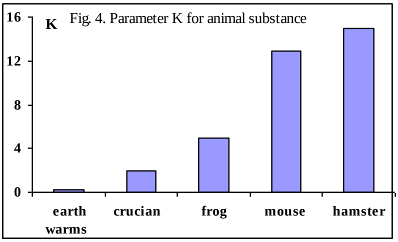

Fig. 4. Parameter K for animal substance

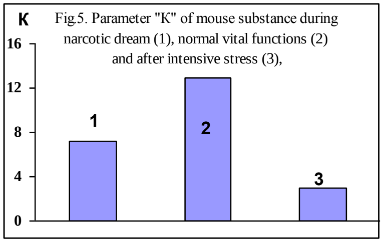

Fig.5. Parameter "K" of mouse substance during narcotic dream (1), normal vital functions (2) and after intensive stress (3),

sive stress the part of water in the mouse substance transform to a "water - III" conditions similar to water at 100°C ("blood has begun to boil"), besides is increased and part of "water - IV" conditions, equivalent to water salt solutions. If the mouse is in narcotic dream under influence chloroform, water in her substance transform to the "water - I" conditions, similar to that in ice structure. That the sharp reduction of vital functions processes of bioobject is accompanied by transition of water in its substance in the most structured conditions of "water - I", was noticed not only at an animal, but also on seeds and leafs of plants. [4]. Than more the $tg\delta$ value of seeds and plants leafs at frequency 20kHz, appropriate to "water - I" conditions, the below the seeds germination, growth rate and plants productivity.

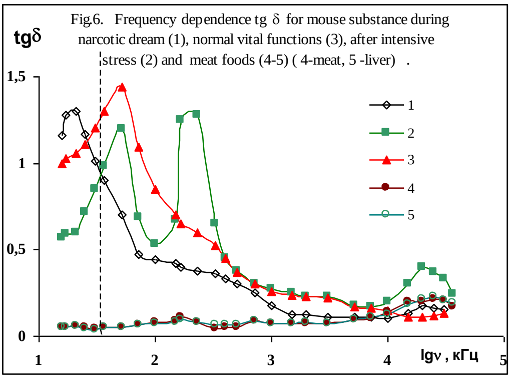

Fig.6. Frequency dependence tg δ for mouse substance during narcotic dream (1), normal vital functions (3), after intensive stress (2) and meat foods (4-5) (4-meat, 5 -liver) .

Structured conditions of "water - I" and "waters - II" are peculiar only to living mammals. After death of animal water in his substance gradually passes in a "waters - IV" conditions. The water in substance of beef meat foods (meat, liver, easy) does not differ from "water - IV" in day - fig. 6. In bone substance this process goes more slowly.

So, the received data show that water in the strictly certain status is necessary for normal vital functions of an animal. The evolution of fauna from the elementary forms to a mammal was accompanied by increase of a water structurization in their substance. The given effect availability in the evolutionary doctrine of fauna was not taken into account earlier.

Practically exact coincidence of frequencies ν_{max} , on which the $tg\delta$ maximum in usual pure water and animal substance are observed, results also in a hypothesis about existence of some external factor, which promotes synchronization of a proton exchange in water objects. Let's show that such factor is the geomagnetic field.

The influence of very weak fields, about a geomagnetic field $H_{geo} \cong 0{,}5Э$, on objects, containing water it is possible to explain with the help of effect Hanle.[5], which is observed in weak fields and consists in strong dependence of scattered light polarization on magnetizing force.

The effect is caused that by light pumping of resonant frequency advance atom in the exited condition with lifetime τ . At presence of an external magnetic field H_o the magnetic moments (spin) of the exited atom precess with frequency $\Omega = \gamma H_o$ around of a H_o direction. In a strong field, when $\Omega\tau >> 1$, the spin in time τ make many revolutions, and their distribution becomes isotropic. The maximal effect Hanle is observed provided that $\Omega\tau \cong 1$, hence

$$g_p \tau e \mu_o H_o / m \cong 1 \qquad (1)$$

At performance of the given condition the spin precess in a field H_o give the maximal contribution in atom magnetization on a direction H_o .

Accepting in the relate (1), that $H_o = H_{geo}$, and g_p, e, m - are the g-factor, charge and mass of a proton, we shall find life time of the proton in exited condition, at which projection its spin onto H_{geo} direction is maximal

$$\tau = \tau_{geo} = 3 \cdot 10^{-5} \text{ sek}, \quad f_{geo} = 1/\tau_{geo} = 33\text{kHz} \qquad (2)$$

The frequency f_{geo} is marked by a dotted line in a fig. 4. As we see, the values of f_{geo} and ν_{max} for "water - I" and "water - II" are close agreement. The difference τ from $\tau_{H_2O} = 1/\nu_{max}$ for these water conditions does not exceed 40%. While for "water - III" - τ / τ_{H_2O} =6. Consequently, the "water - I-II" conditions has not zero value projection of proton spins onto a geomagnetic field direction. In "water - III" conditions this phenomenon does not occur any more.

Let's estimate, in what degree proton spins direct toward H_{geo} can affect magnetic properties of water. With this purpose we shall define diamagnetic and paramagnetic magnetization 1 mol of waters in a geomagnetic field as

$$I_{dia} = \chi H_{geo}; \qquad I_{para} = 2 K N_a g_p \beta_n S / V_M \qquad (3)$$

where $\chi = -9{,}066\cdot 10^{-6}$ - molar magnetic susceptibility of water at 20°C, $V_м$ - molar volume of water, - N_a, β_n Avogadro number and nuclear Bohr magneton, - $S = 1/2$ - spin, g_p - g-factor of proton, ***K***- a share direct toward H_{geo} protons. From (3) is received, that $I_{dia} = I_{para}$ at К=$10^{-6,3}$, what equal the number of dissocated protons in water with pH=6,3. As on proton paramagnetism can be imposed and water para-molecules magnetic moment with parallel orientation of proton spins, we come to a conclusion, that water in living animals is not diamagnetic, but paramagnetic.

As the "water - II" condition, similar to that in ice structure with direct toward H_{geo} proton spins is peculiar only to substance of living animals and transform in a " waters IV " condition after their death, animals during evolution have developed the mechanism due to action H_{geo} on proton spins is arise. As follows from the modern theory of Hanle effect, the influence of a weak magnetic field on atom spin can be arise by a weak alternating magnetic field, in which amplitude ***H*** and frequency ***f*** satisfy to a condition of a parametrical resonance ***H / f=const.*** At animals, apparently, such action is carried out by them biofield. And between focused backs of protons and biofield of an animal, most likely, there is also feedback: the biofield promotes additional orientation of protons, and the electromagnetic field of focused protons strengthens and supports at the necessary level a biofield.

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ENGINEERING APPLICATIONS

ABOUT OSCILLATION FREQUENCES OF THE MAGNETIC FLUIDS SEALANTS

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The experimental examination of elastic properties is performed on the model in which sealing of the tube (with the R radius, *S* cross section area) cross-section connected to the vessel (with the V_0 volume) by MF drop is effected thanks to the circular magnet embracing the tube. We'll suppose that both the free surfaces of the fluid are flat and are located from one another at the distance b. The oscillations of the gas density are of an equilibrium character. The measurements results are represents in Fig.1 as the dots.

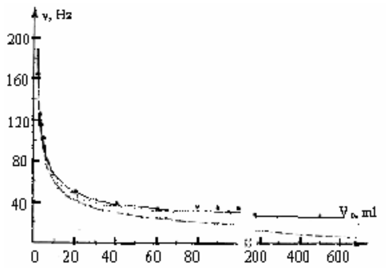

Fig 1. The dependence of oscillation frequency
upon the air space volume V_0

The experimental examination results analysis is given on the basis of the oscillation system with the concentrated parameters. The elasticity coefficient of the k system is determined by the sum of gas and pondemotor elasticity: $k = k_g + k_p$. Expression k_g is known [1], $k_g = \rho_g c^2 S^2 / V_0$, where ρ_g is air density, c is sound velocity in air. To obtain k_p we'll suppose MFS performing small oscillations along the *Z* axis near to the equilibrium position which given by

$$\frac{\mu_0}{2}\left(M_z^2(z_2) - M_z^2(z_1)\right) + \mu_0 \int_{z_1}^{z_2} M_z(H_z)\frac{\partial H_z}{\partial z} dz = \rho g b$$

Taking into account $\Delta z << b$ we obtain:

$$k_p = 2\mu_0 S\left[M\left(\frac{dH_z}{dz} + \frac{dM_z}{dz}\right)\Bigg|_{z_1} - M\left(\frac{dH_z}{dz} + \frac{dM_z}{dz}\right)\Bigg|_{z_2}\right] \qquad (1)$$

Because of the magnetic field symmetry relative to $z = 0$ and of small weight of MF drop we suppose z_1 = $-z_2$ = b/2. The frequency dependence $\nu = \sqrt{k/\rho b S}/2\pi$ is represented graphically in Fig.1 by a thick continuous line. Here the experimental datas are M= 25 kA/m, dH/dz = $4{,}6 \cdot 10^6$ A/m^2, S= $2 \cdot 10^{-4}$ m^2, MF volume – 3 cm^3, the known numerical values ρ_g, c and the condition $\Delta M_z = \chi \Delta H_z$ with $\chi = 0{,}1$ (M_s=60±1 kA/m). The dottier line in fig.3 shows the dependence curve $\nu(V_0)$ without pomdemotor elasticity.

In mechanical engineering there have been used the hermetic sealings with the symmetrical location of the packing elements [2]. The simplest MFS design of this type is schematically presented in Fig. 2. The pole pieces 2 embracing the shaft 3 made of magnetic material is attached to the circular magnet 1. MFH is imput into the gaps between the pole pieces at the shaft. The resulting closed space 5 is filled with air. This space serves as an elastic linking element between the two identical MF jumpers.

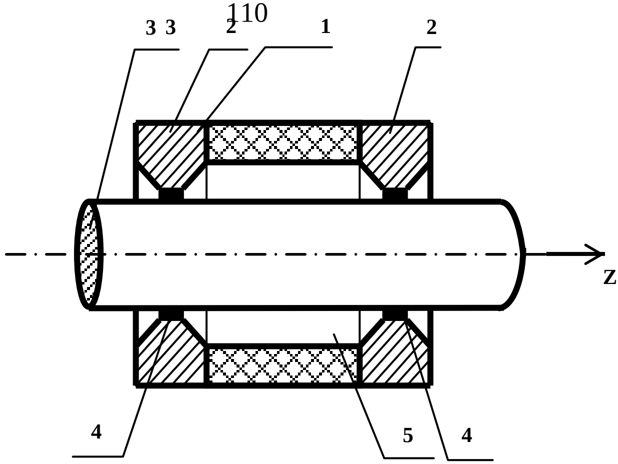

Fig. 2 Magnetic fluids sealant

Applying the Newton's second law to each of the MF jumpers we obtain the set of two equations:

$$\rho \cdot S_{cg} \cdot b \, \frac{d^2 Z_{1,2}}{dt^2} = -k_g \cdot (Z_{1,2} - Z_{2,1}) - k_p \cdot Z_{1,2}\,, \qquad (2)$$

where S_{cg} is the area of the circular gap, Z_1 and Z_2 are the shifting of the left and right jumpers from the state of balance. The set of equations (2) is actually nothing but the known set of two linked oscillations [2].

Such oscillating set has two normal frequencies:

$$\omega_1 = \sqrt{\frac{k_p}{\rho \cdot S_{cg.} \cdot b}} \quad \text{and} \quad \omega_2 = \sqrt{\frac{k_{p.} + 2k_g}{\rho \cdot S_{cg} \cdot b}}$$

The $2k/k_p << 1$ inequality determines the weak bond condition. Taking into account this condition and and initial conditions $Z_1 = Z_2 = 0$, $\dot{Z} = v_0$ the solution of the set of equations (2) is [3]:

$$Z_1 \approx \frac{v_0}{\omega_1} \cdot \cos\Omega t \cdot \sin\omega_1 t\,,\ Z_2 \approx -\frac{v_0}{\omega_1} \cdot \sin\Omega t \cdot \cos\omega_1 t,$$

where $\Omega = k_g \left(2\rho S_{cg} b \omega_1\right)$.

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EMULSIFICATION EFFECT OF MAGNETIC LIQUID INTO LIQUID NON-MAGNETIC MEDIUM ON THE OPERATION RESOURCES OF FS

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If ferrofluid seals (FS) be used, emulsification of magnetic liquid (ML) takes place from a seal into liquid medim in contact with liquid non-magnetic medea. The task for determining the work activity of FS in the conditions of seal emulsification was under the study [1,2,6] but it has not been completed because the effect of characteristics of non-magnetic medium and seal parameters has not been allowed for in details.

A maximum speed of relative motion is known to be when emulsification starts according to the emulsification theory of two insoluble liquid medea [3]. To simplify this task, consider the case when a shaft of FS is immovable and non-magnetic liquid is revolving around.

Critical pressure is defined as

$$P_{cr} = U_{M1\max} - U_{M2} \tag{1}$$

where U_{M1max}, U_{M2} are the magnetic field energy of a volume unit on the boundary of free surfaces occupied by magnetic-liquid working medium.

Hence, U_{M1max}=const, but dring the emulsification process a boundary position of working medium changes and the magnitude of magnetic field energy (U_{M2}) increases (See Fig). Consider the transformation character of special magnetic field energy along an axle of a shaft of FS as a relationship:

$$U_{M2} = \frac{U_{M1\max}}{ab^x + 1} \tag{2}$$

where b is the length of magnetic-liquid working medium along an axle of the seal shaft, x is the unknown quality.

Obtain from the equality [1] and taking into account [1]:

$$P_{cr} = U_{M2} ab^x \tag{3}$$

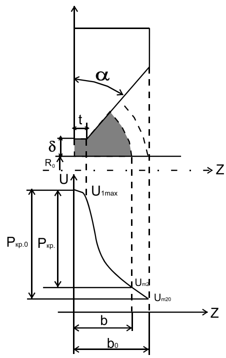

Fig. Distribution of special magnetic field energy on the boundaries occupied by ML during the transformation process of the volume of magnetic-liquid working medium under emulsification.

Using boundary condition where $b=b_0$, $P_{cr}=P_{cr0}$, $U_{M2}=U_{M20}$, $b=t\approx 0{,}03$, $\frac{d^2U_{M2}}{db^2}=0$ and taking into account that $b\approx\sqrt{\frac{V}{\pi R_0}}$, we find from (3)

$$P_{cr}=\frac{AP_{cr0}\left(\frac{V}{V_0}\right)^{0{,}56}}{1+(A-1)\left(\frac{V}{V_0}\right)^{0{,}56}}$$

(4),where : $A=\frac{U_{1\max}}{U_{M20}}$ A=3-5 (when $a=45^0$)

Relation obtained from (4) is used to determine critical pressure of ML in a static condition of its operation. ($\omega_0=0$) is easy to obtain for a dynamic condition of operation if the action of interval forces to be considered [4]

$$P_{cr.p}=P_{cr}-\rho_{ML}\omega_0^2R_0\delta_m \quad (5)$$

Where P_{ML} is the density of ML δ_{cr} is the mean value of the layer height of ferrofluid working medium in a seal clearance, ω_0 is the angular velocity of rotation of a seal shaft.

It is necessary to determine the dependence upon time volume of ferrofluid working medium under emulsification.

Let us consider the emulsification process of time-averaged continous function if density of ML is supposed to be constant

$$V_0-V=\int_0^t q\,dt \quad (6)$$

Where V_0 is the initial volume of working medium of the seal-ML; q is the volume flow rate of ML from a seal clearance during the mass-transfer process into non-magnetic medium; V is the running volume of working medium of the seal.

Suppose the volume flow rate is proportional to the running volume of ML

$$q=C\omega_0(V-V_L) \quad (7)$$

where V_L is the timing value of the ML volume when emulsification completes under the given rotational speed of the shaft ω_0; c is a nondimensional factor of proportionality depending on the flow condition of non-magnetic medium defined by Reynolds centrifugal number $Re_c = \frac{\rho\omega_0 R_0^2}{\mu}$, where ρ, μ are the density and the dynamic viscosity of non-magnetic medium respectively. We obtain from the equality (7), taking into account of (6)

$$V = V_L + (V_0 – V_L) \exp [-C \omega_0 t] \quad (8)$$

The coefficient C and the value V_L are determined experimentally for the exact type of the seal.

If the energy balance equation be used, one may estimate the order of the magnitude of C for the given standard sized series of seals:

$$C \sim \frac{\eta\delta}{\delta_g^* \eta_{ML}}$$ (9), where η, η_{ML} is the dynamic viscosity of non-magnetic medim and ML respectively; δ_g^* is the thickness of a boundary layer of non-magnetic liquid on the boundary of division – ML – medium.

For the discussed problem of medium rotation over the immovable foundation (FS) [5] is $\delta_g^* = 8\sqrt{\frac{\nu}{\omega_0}}$ (where ν - kenimatic viscosity of medium), hence, eqatation [9] will be as the criterion [10]

$C \sim \mathbf{Re}^{1/2} \Gamma$ (10) where $\Gamma = \eta / \eta_{ML}$ is the criterion-simplex; Re is Reynolds number for the medium flow in the interface of division.

If obtained expressions [4], [5], [8], [10] be used, one may define or evaluate the order of magnitude of time rate of ML as the time t_p when critical pressure of the seal decreases to surplus pressure of the medium P in consequnce of emulsification of the seal working medium.

The obtained expressions are true to a non-turbulent condition of the flow of non-magnetic medium. They allow to correct engineering methods of resource calculations of FS and to work out the recommendations for its increasing, to improve test methods of seals to reliability.

THE REGULATION OF THE PARAMETRES OF THE MAGNETIC FLUID SEALS

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The conception [1] of the creation of the open-frame magnetic fluid seals (MFS-OF) and the magnetic fluid seals with the buried pole piece (MFS-BPP) are well defined in the designing of the modeling line MFS for the damp-proof and dust-proof electric motors of BACO, BACB, 2 ACBO 710 types [2]. Basic constructions of the MFS-OF [3] and MFS-BPP [4] total only 4 simple details (without consideration of the fast and permanent magnets), and the application of the color metals is reduced to a minimum. Vacuum [5] and aerospace engineering is a perspective direction of the practical application of the MFS-OF and MFS-BPP. It is possible to obtain the decreasing mass of the MFS with the application of the honeycomb elements [6, 7] in 2 - 3 times. It is very important to use this construction in aerospace technique.

Further development of the MFS-OF and MFS-BPP conception is connected to creation on the basis of controllable MFS, in which there is a regulation of the primary performance parameters. Primary performance parameters are, first of all, the induction of the magnetic fluid in the running clearance and second, temperature of the magnetic fluid (MF) in the running clearance.

The shunting of the main flux with the magnetoconductive mobile element, which includes a magnetic system, adjusts to the regulation of the induction of the magnetic field. The construction of the MFS shown on Fig. 1 [5] provides an opportunity for the fluent regulation of the magnetic induction in the running clearance and gives the opportunity to use the drive of the forced rotary for the displacement of the shunting element and change the magnetic induction in the relation with the adjustment rule. For example, in the dependence of the pressure difference, the frequency of the shaft rotation, and the temperature of the MF, etc.

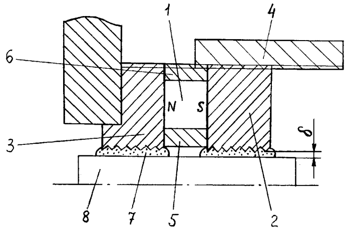

Fig. 1. MFS-OF including the shunting element: δ - running clearance; 1 - permanent magnet, 2 and 3 - pole-pieces, 4 - mobile shunting element, 5 - inner non-magnetic ring, 6 - outer non-magnetic ring, 7 - MF, 8 - shaft.

The analysis of the controllable MFS gives us the basis to consider controllable MFS like the totality of functional modules, which is characterized by the quantity, inter-osculation, and mobility of the one module relative to another [8]. MFS on Fig. 1 consists of two, located in order, on the radius modules: magnetic module and the magnetodriving module. The magnetic module is the aggregate of the permanent magnets and magnetoconductive elements, which are motionless relatively to permanent magnets, and the magnetodriving module is totally of the mobile magnetoconductive (in this case - shunting) elements, which regulate the magnetic flux in the magnet system.

The magnetic module in the construction of Fig. 2 [9] consists of two modules, which are located one after another: the magnet module is mobile relative to the drive frame, and the motionless pole is aggregate of the magnetoconductive elements, which organize topography of the magnetic field in the running clearance of the MFS directly.

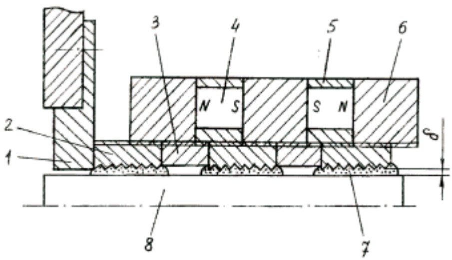

Fig. 2. MFS with the mobile magnetic system: δ - running clearance; 1 - conjunctive flange, 2 - pole-piece of the pole module (motionless), 3 - non-magnetic hub, 4 - permanent magnet, 5 - non-magnetic yoke, 6 - pole-piece of the magnetic module (mobile), 7 - MF, 8 - shaft.

It is rational to use a sealing type-setting radially magnetized magnetic system in which a magnetodriving module consists of the separate magnetoconductive plates, which are mobile in the axe direction [10] or removable [11], for the bid diameter shafts.

Regulating the MF temperature in the running clearance is necessary for the high speed MFS and for MFS which are in high temperature conditions.

Regulating the MF temperature is efficiently carried out with help of the autonomous module of the temperature control.

The module of the top-up of the MFS is one of the most important modules of the MFS. The placing of the non-magnetic honeycomb element, which is saturated with MF, to the inter-pole space of the MFS [12] opens additional opportunities to increase reliability and the recourse of the MFS working properly. Because there are no conditions for stagnant zones to appear in the honeycomb capillary structures as distinct from the porous materials, the top-up of the MF can be realized in the lesser values of the magnetic field tensity gradients.

Module construction of the controllable MFS allows changes in the wide range composition and configuration of the MFS modules in relation with concrete service conditions and the purpose of the seal systems, and to optimize their positional relationship and interaction. The construction of each module is adequately autonomous and has its own independent logic of the construction and development. It provides an opportunity for the prediction of the tendencies of their future perfection.

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THE PECULIARITIES OF THE OPERATION OF A HIGH-SPEED MAGNETIC FLUID SEAL

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To seal shaft outputs from separate plain bearings in large electric motors driving compressors, labyrinth seals are most frequently used [3]. However they do not always prevent oil fog and oil droplet ejection from bearings and their ingress onto current-conducting devices and electric motor windings.

It is practically impossible to use contact seals in the similar situations because of high speed shafts and, correspondingly, considerable heat emission.

Therefore application of magnetic fluid seals seems rather promising: firstly, due to the fact that they provide for the complete sealing of the unit; secondly, due to insignificant heat emission in fluid friction in the gap between a shaft and a seal.

It is very important to take into account the interdependence of magnetic and centrifugal forces for this type of seals, especially when shaft speeds increase. Froude's magnetic number should be used in this case [1].

Taking into consideration the fact that the pressure drop for the task is not significant, we may assume that magnetic fluid occupies the area which is bounded by a shaft and an outer case in the radial direction and by free surfaces in the axial direction. To estimate the dependence of centrifugal forces, it is possible, in the first approximation, to consider the task for viscous fluid separately. This area is a ring-like gap of finite width. When a shaft rotates, centrifugal forces throw the fluid off a shaft to an outer case and increase the pressure when a shaft is moving in the radial direction. It leads to the distortion of the initial area occupied by magnetic fluid and may significantly influence magnetic fluid pressure keeping. The area geometry presents the greatest difficulty for the task solution.

However, assuming that field concentration takes place in the seal central zone where the boundary influence is not significant, we may consider the flat task of viscous fluid movement between two coaxial cylinders to estimate the influence of centrifugal forces — the inner rotating cylinder modelling a shaft, and the outer rotating cylinder modelling the pole surface. It is also assumed that a shaft rotates at constant speed, i.e. this is a stationary task. Besides, for a flat task the axial component of V_2 speed, and z derivative from all given functions are equal to zero, i.e.

$$V_z \equiv 0, \qquad \frac{\partial}{\partial z}(\cdot) \equiv 0.$$

In this case the task is related to Navier-Stocks equation integration in the cylindrical system of coordinates (r, θ, z), involving the equation of impulse preservation.

$$V_r \frac{\partial V_r}{\partial_r} + \frac{V_\theta}{r}\frac{\partial V_r}{\partial \theta} - \frac{V_\theta^2}{r} = -\frac{1}{\rho}\frac{\partial P}{\partial r} + \tag{1}$$
$$+\nu\left[\frac{1}{r}\frac{\partial}{\partial_r}\left(r\frac{\partial V_r}{\partial_r}\right) + \frac{1}{r^2}\frac{\partial^2 V_r}{\partial \theta^2} - \frac{V_r}{r^2} - \frac{2}{r^2}\frac{\partial V_\theta}{\partial \theta}\right],$$

$$V_r \frac{\partial V_\theta}{r} + \frac{V_\theta}{r}\frac{\partial V_\theta}{\partial \theta} + \frac{V_r V_\theta}{r} = -\frac{1}{r\rho}\frac{\partial p}{\partial \theta} + \tag{2}$$
$$+\nu\left[\frac{1}{r}\frac{\partial}{\partial_r}\left(r\frac{\partial V_\theta}{\partial_r}\right) + \frac{1}{r^2}\frac{\partial^2 V_\theta}{\partial \theta^2} - \frac{V_\theta}{r^2} + \frac{2}{r^2}\frac{\partial V_r}{\partial \theta}\right],$$

and the storage equation

$$\frac{1}{r}\frac{\partial}{\partial_r}(rV_r) + \frac{1}{r}\frac{\partial V_\theta}{\partial \theta} = 0 \tag{3}$$

The boundary conditions should be fulfilled on cylindrical surfaces

$V_r(r,\theta)\big|_{r=re}=0,$ $\qquad$ $V_r(r,\theta)\big|_{r=rs}=0,$ (4)

$V_\theta(r,\theta)\big|_{r=re}=0,$ $\qquad$ $V_\theta(r,\theta)\big|_{r=rs}=V_{0\theta}^s(\theta$ (5)

$p_r(r,\theta)\big|_{r=rs}=p_0^s(\theta).$ (6)

Where V_r and V_θ — radial and tangential components of velocity vector; p and ρ — fluid pressure and density; ν — viscosity coefficient; r_s — shaft radius; r_e — outer cylinder radius; $V_{0\theta}^s$ — specified speed of shaft surface; $p_0^s(\theta)$ — environmental pressures.

If there is no shaft deviation in a gap, the task may be considered axis-symmetrical, and the derivatives of the given functions according to the arc coordinate are equal to 0.

$$\frac{\partial}{\partial\theta}(\cdot)\equiv 0.$$

Besides, let's present V speed field and p pressure in the following view:

$$V_r=V_{0r}(r),\ \ V_\theta=V_{0\theta}(r),\ \ p=p_{0r}(r).$$

and get the expression for pressure

$$p_{0r}=\frac{p_0^s}{\rho\left(V_{0\theta}^s\right)^2}-\frac{1-r_e^4}{2\left(1-r_e^2\right)^2}+\frac{1}{\left(r_e^2-1\right)^2}\left[\frac{r^2}{2}-2r_e^2\ln r-\frac{r_e^4}{2r^2}\right]. \qquad (7)$$

The increase in shaft rotation speed considerably influence both the seal-retained pressure drop and magnetic fluid seal resource. It is connected with the fact that pressure distribution is influenced by centrifugal forces besides magnetic forces, and to pressure axial gradient caused by the magnetic volume force, $\sim V^2/r_s$, pressure radial gradient induced by fluid movement is added.

The pressure radial gradient influences both the form of magnetic fluid boundary and the current in the gap [1].

The pressure of centrifugal forces is determined as:

$$p_ц=p_0^s+\rho V_{0\theta}^s\int_0^\varepsilon v^2(\varepsilon)d\varepsilon \qquad (8)$$

Finally, when the fluid speed from a moving shaft to a stationary pole is reduced linearly, the pressure drop retained by a seal, is determined according to the following formula:

$$\nabla p=\nabla p_{ct}-\rho\left(V_{0\theta}^s\right)^2h/\left(2r_s\right). \qquad (9)$$

Then the pressure drop retained by a seal is determined according to the following formula:

$$\Delta p = \Delta p_{ct} + \frac{2\rho\left(V_{0\theta}^{s}\right)^2 r_s^2}{\left((h+r_s)^2 - r_s^2\right)^2}\left(\frac{r_s^4 - (h+r_s)^4}{2r_s^2} + 2(h+r_s)^3\left(\frac{4}{3} - \ln(h+r_s)\right) - \right.$$

$$\left. - 2(r_s + h)^2 r_s(\ln r_s - 1) + \frac{r_s^3}{6h} + \frac{(h+r_s)^4}{2hr_s}\right).$$

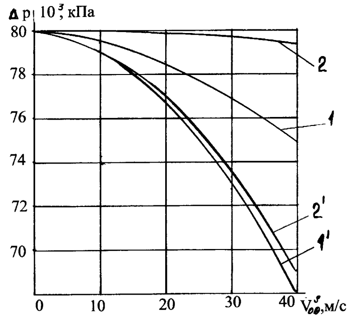

Fig. 1

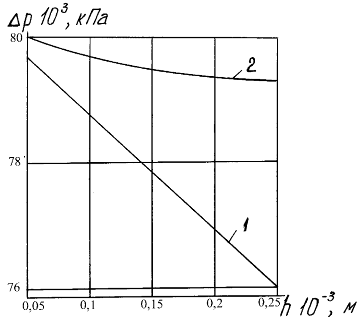

Fig. 2

Fig.1 The dependence of the seal — retained pressure drop on the shaft speed.
1 – linear; 2 – non-linear at radial gap h = 0,2 mm; 1'-2' – the same at radial gap h = 0,5 mm.
Fig.2 The dependence of the seal-retained pressure drop in radial gap at $V_{0\theta}$ = 1 m/sec

In Fig.1 and 2 the curves for the linear law of speed change (curve 1) and non-linear law (curve 2) are analysed. It is necessary to note the following: insignificant change of the retained pressure drop for the non-linear law of the change of speed in comparison with the linear one for the gap h = 0,2 mm, and also for the non-linear law of the speed change, the gap may be increased to 0,3-0,35 mm.

This fact is important for practical purposes. The maintenance staff is interested in the greater gap for magnetic fluid seals in comparison with labyrinth ones.

Naturally, a designer is also interested in it. In this case we practically do not depend on shaft beats in bearings. Besides, the greater gap results in smaller heat of fluid in the gap.

It is possible to increase the non-linearity of speed distribution by the non-uniformity of its longitudinal cross-section. Besides, magnetic fluid seal operation is organized by hydrodynamical oil flow throw-off along the shaft and oil grooves in the direct proximity from a magnetic fluid seal.

Similar design solutions are applied for a magnetic fluid seal of bearing units of a number of electric engines. They are successfully used for the following electric engines: СДН type of ЦНД network pump drives ("Azot" Production Association in Cherkassy); 2500 kWt GEK-42585 engine of carbon oxide turbocompressor drive ("Azot" Association in Severodonetsk); compressor bearings ("Sera" Enterprise, "Stirol" Concern in Gorlovka, "Jenakievka Metallurgical Plant" Joint-stock Company) and others.

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THE DEVELOPMENT OF MAGNETIC FLUID SEALS OF BEARING UNITS OF OPERATING COMPONENTS OF MINING CLEANING MACHINES

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At "Ferrohydrodynamica" R&D Enterprise we are developing seals for fine disperse media. The experience of developing magnetic fluid bearing units for sulphur grinding mills and carrying out other research and development enabled to develop the magnetic fluid seal for the bearing unit of the operating components of a mining cleaning machine at Gorlovka Machine-building Plant Joint-Stock Company.

The specific operation of the given seal lies in the fact that the operation takes place under the conditions of fine disperse abrasive particles and there is also the necessity of high strength of the device. It was decided to place a magnetic fluid seal inside the components of a standard seal of a bearing unit. The seal of a bearing (for 1ГШ68У combine) consists of a cover for a bearing unit of 360 mm diametre and 80 mm height with two ГОСТ 8752-79 packing seal and a spline bushing on a shaft executed together with a seal cover of 25 mm thickness. The ring flanges on the lower surface of a bushing cover are inserted into the ring grooves of the bearing cover and form the preliminary seal stage.

Two magnetic fluid seals for 1ГШ68У and Р96М mining machines have been developed for Joint-Stock “Gorlovka Machine-building Plant”.

For a magnetic scheme, we used the scheme for magnetic fluid seals of electric motors for chemical granulating tower ventilators [1] which are applied at “Azot” Association (Severodonetsk) and “Stirol” Concern (Gorlovka).

At the beginning of 2001 a number of R&D works were carried out by Gorlovka Machine-building Plant and “Ferrohydrodynamica” to increase the reliability and resource of output shaft seals. Ferrohydrodynamica experts designed magnetic fluid seals to protect the outer shafts of Р96М and 1ГШ68У mining machines. They also designed the compatibility of seal units to the existing designs, and all necessary components were produced. Ferrohydrodynamica representatives and plant specialists assembled magnetic fluid seals and installed them to the standard place. They were installed into newly-produced mining machines.

Half-year application of seals under mining conditions proved the high efficiency of magnetic fluid seals in comparison with conventional ones. Therefore “Ferrohydrodynamica” designed magnetic fluid seals for outer shafts of 1К101У mining machines.

At present the cooperation with Gorlovka Machine-building Plant continues: joint patent work is carried out, magnetic fluid seals are installed into other combines. At the same time the magnetic fluid seals are produced at Gorlovka Machine-building Plant (usually “Ferrohydrodynamica” supplies its own magnetic fluid seals to contractors).

The design solutions which are applied for new samples of magnetic fluid seals for mining machines take the experience of cooperation with machine-builders and miners into account.

Magnetic fluid allows for specific features of the whole component in operation and this is very important. Therefore “Ferrohydrodynamica” continues selecting magnetic fluids for sealing fine disperse granular media. Magnetic fluids and various bases for their compositions were tested. For example, there were produced the types of fluid in which its dispersion was not conducted in carbon-base fluid (e.g. vacuum oil) after peptization of ferromagnetic phase with the surface-active substance but in the fluid heated to 90˚С to lower the viscosity of plastic lubricants. The compositions obtained did not have the stage of centrifuging to be released from large ferromagnetic particles due to high viscosity different from conventional magnetic fluid. Saturation magnitization of these compositions was 60 kA/m and more. Their application for magnetic fluid seals at 3-5 m/sec linear velocities in a gap did not cause the temperature increase in the component, and their mixing with the sealed medium was minimal.

The following stage is the testing of the selected compositions under mining conditions.

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THE IMPACT OF MAGNETIC FIELD CONCENTRATORS ON THE TEMPERATURE DISTRIBUTION IN THE CLEARANCE OF A MAGNETIC FLUID SEAL

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The operating clearance occupies the area bounded in the radial direction by a shaft and an outer case of magnetic, fluid seal, and in the axial direction — by free surfaces. During magnetic fluid seal operation heat emission takes place in the working zone. Viscous friction causes heating the magnetic fluid and it impacts the seal resource because, firstly, fluid heating causes the increased evaporation, and, secondly, it may cause disorption of surface-active substance (SAS) molecules from particles surface. The both factors put the magnetic fluid out of operation in the seal gap, i.e. a magnetic fluid seal itself.

Heat emission in the fluid is determined by viscous friction, and its power is determined by the expression [1]

$$N = \frac{1}{2}\int_{\Omega} \eta \cdot \left(\frac{dV}{dr}\right)^2 d\Omega,$$

where Ω – the area occupied by fluid; η – the coefficient of dynamic viscosity, Pa·s; V – velocity, m/sec; r – radius, m.

The dependence of the coefficient of magnetic fluid viscosity on the basis of vacuum oil is described by the equation [1]

$$\eta = 7{,}356 \cdot 10^{-6} \cdot \exp\left(\frac{3836{,}8}{T}\right),$$

where T – the absolute temperature of magnetic fluid, K.

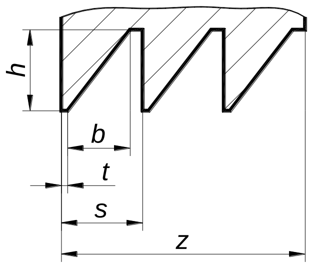

Fig.1 The dimensions of magnetic field concentrators

The solution of the task of the temperature distribution in the running clearance is of some difficulty which is, in the first turn, caused by the area geometry.

To solve the task, the following mathematical model was used.

The velocity of magnetic fluid in a magnetic fluid seal V_θ is the function of r radius and z axial coordinate and is described by the equation:

$$\frac{1}{r} \cdot \frac{\partial}{\partial r}\left(r \cdot \frac{\partial V_\theta}{\partial r}\right) - \frac{V_\theta}{r^2} + \frac{\partial^2 V_\theta}{\partial z^2} = 0$$

The boundary conditions for the velocity are the following:

on the shaft surface $V_\theta \big|_{r=R} = V_\theta^0$,

were R – shaft radius, m; V_θ^0 – linear velocity on the shaft surface, m/sec

on the surface of ψ pole piece

$$V_\theta \big|_\psi = 0,$$

on magnetic fluid side surfaces

$$\frac{\partial V_\theta}{\partial z} = 0.$$

The temperature distribution inside magnetic fluid is described by the differential equation of heat-conductivity

$$\Delta T + \frac{q}{\lambda} = 0,$$

were q – heat-emission density, W/m^3; λ – magnetic fluid heat-conductivity coefficient, W/(m·k).

The boundary problem is formulated in the following way.

The conditions on the shaft surface

$$\left.\frac{\partial T}{\partial r}\right|_{r=R} = 0.$$

The conditions on the surface of ψ magnetic field concentrators:

$$T\big|_{\psi} = T_{k,}$$

were T_k – the case temperature.

The given condition is quite accessible because heat-conductivity coefficient of carbon steel 50 W/(m·K), and magnetic fluid on the basis of transformer oil – 0,111 W/(m·K) [2].

The task was solved by the method of finite differences concerning a magnetic fluid seal for a shaft of d = 0.15 m. The geometry of a concentrator of magnetic flow is shown in Fig.1. The following geometric dimensions appeared the most acceptable from the point of view of technological and magnetic characteristics: h = 2.5; b = 2; t = 0.2; s = 2.5; z = 7.5. The temperature of a housing of a magnetic fluid seal is equal to 323.0 K, and it corresponds to the temperature level of a bearing unit of an electric motor.

The dependence of the temperature of magnetic fluid on the shaft surface upon its rotation frequency for 0.2 mm running clearance is typical for real designs (Fig.2). Here there are the results of calculations which do not take concentrators forms into account. As we can see, concentrators of magnetic flow are related to lower values of magnetic fluid temperatures. It is especially noticeable at high speeds of shaft rotation. It is explained by the fact that in this case the surface of between of magnetic fluid and end pole piece considerably increases.

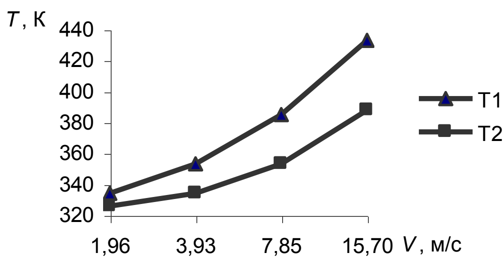

Fig.2 The dependence of the temperature of magnetic fluid on the shaft surface on the linear velocity; T1 – without taking the influence of magnetic field concentrators into account; T2 – taking the influence of magnetic field concentrators into account.

The distribution of temperature between the flanges of magnetic flow concentrators along the distance which is equal to the value of the working gap at 15.7 m/sec speed of the shaft surface (Fig.3). The numeric value of the speed was chosen to be not less than 20% higher than the maximum speed for contact seals.

The above allows to make the conclusion that at high linear speeds of the shaft surface it is necessary to consider the forms of magnetic flow concentrators to determine the temperature field.

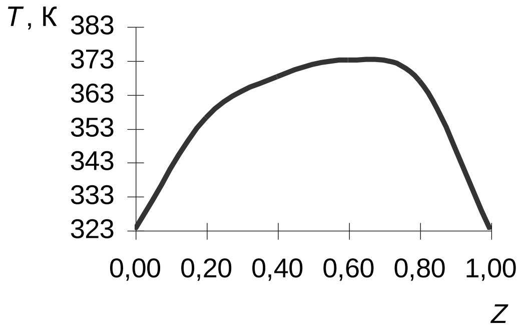

Fig.3 The distribution of temperature between magnetic field concentrators at V = 15.7 m/sec linear speed of shaft.

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THE ESTIMATION OF THE EFFECT OF ALTERNATING ELECTROMAGNETIC FIELD ON THE BAKING QUALITY OF YEASTLESS DOUGH

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Starodubzeva Y.P. graduated from the SSPI, the faculty of Physics and Mathematics in 1968. Since 1975 she has been working at the SSAU, the Department of Physics. In 1988 she was awarded her candidate's degree. The theme was "The effect of presowing treatment of seeds in electrical fields on sowing qualities and sunflower productivity". In 1989 an assistant professor was conferred on her at the Department of Physics. Since 1993 she is a head of the Department In 1998 she was awarded her doctor's degree. The theme was "Higher productivity of sowing and yield qualities of seeds and adoptive properties of farm crops". She is a professor, has 136 publications including 131 learned articles and three textbooks, two patents of RF, two articles published in the foreign learned journals. Now she is a head of the Department of Physics (SSAU) and a leader of the Educational Research Laboratory, has several diplomas of Ministry of Agriculture and regional government.

Kovaleva G.E. graduated from the SPI in 1989. She has been working at the SSAU since 1995. Now she is a competitor of the SSAU and a senior lecturer of the Department of Physics.

The effect of electromagnetic field upon the processes in dough fermenation was carried out by water. Potable water is one of the main bread components. It affects the rate of microbiological enzyme processes, thus the consumption properties of bread. But water from surface sources seldom meets sanitary requirement. At present various physical and chemical methods are used to add biological activity to water, this quality being necessary when bread is baked. The investigation task was to study how activated water affected physical and chemical properties of yeastless dough including its formation and property changes under conditions of mechanical treatment.

The experiments were carried out in the research laboratory with the valorigraph QA-205 produced in Hungary. The device records dough formation and property changes in conditions of permanent mechanical load as a continuous curve on a chart paper. Parameter estimation of dough quality was made. Dough was made with water and flour, with salt and flour, water. Test results are represented as a continuous curve on a chart paper (Fig.1). The device was turned off in 12 minutes after the beginning off curve dropping, the valorigram was interpreted (Fig.1b). The following indicators were recorded by a strip – chart recorder:

- hygroscopic capacity of flour (Va),i.e. water amount in percentages added to the flour weight in term of 14% humidity. The indicator value is 50.4-75.6%, the upper limit is typical for strong wheat.

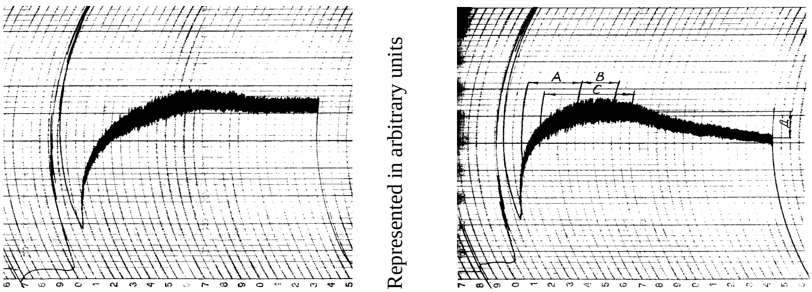

Fig.1. Valorigram of dough made from strong wheat flour and tap water: a – saturated (Va – 62.8%), b – balanced.

- time formation of dough in minutes (A) recorded from the beginning of the records to the maximum point corresponding to the moment of full dough formation.
- dough stability to kneading (stability, B, min) – a time interval between the beginning of dough formation and the beginning of the curve dropping, i.e. the beginning of dough dilution.
- drough resistance to kneading, time minute between the beginning of the dough formation and the beginning of dilution (C) min.

- the degree of dough dilution (P) is represented in arbitrary units. It is determined by dropping the curve center in 12 minutes from the beginning of dilution as compared to the curve center of the stable part. This value ranges from 0 – 250(unit) to 0-50 unit if good and top grades are used.

To make dough the flour of the top, first and second grades was used with indicators of quality IPK 31.4, 43.7, 40.9 units respectively. To estimate the effect of table salt on baking value of dough it was added into tap water before saturating in the amount of 2%. Dough value turned out to be practically the same when water with salt addition befor and after treating being used [2]. Investigation results are represented in the table 1. Tests are shown that the application of the tap water treated by alternating electromagnetic field does not change practically the value of the hygroscopic property of flour both the first and top grade. More appreciable changes of the delution degree can be noticed with the top grade flour. It has been decreased with a test sample at 40 valorigraphic units as compared to the control. The result has been improved by 60 units adding two per – cents of table salt.

The effect of saturated water on the dough dilution is reduced, when flour grade is decreased.

Water being treated by alternating electromagnetic field, such indicators as formation, hygroscopic capacity, stability, resistance of dough are also changed. For example, the stability of a test sample of the dough kneaded by the top grade flour has increased to one minute as compared to the control; to two minutes if the first grade flour was used (adding two per cents of table salt), to 0.5 minute if the second grade flour was used (adding two per cents of table salt).

Results.

Investigations carried out confirm the considerable changes in the structural – mechanical value of dough by using the water treated by alternating electromagnetic field. It affects not only the salt dissolved in water but water itselt.

Furthermore it is necessary to study the effect of the saturated water on flour samples produced on various climatic zones of the Stavropol Territory.

Table 1. Comparative estimation of the indicators of made dough when tap water and the water treated by alternating electromagnetic field are used.

№n/n	Flour grade	Hygroscopic capacity	Time formation of dough	Dough stability	Dough resistance	Degree of dough dilution
		%	min	min	min	
1	flour					
	test	62	4.5	3.0	5.5	60
	control	62	3.5	2.0	3.5	100
2	flour + 2% NaCl					
	test	62	5.0	5.0	8.0	0
	control	58	2.5	5.0	5.5	80
3	flour					
	test	62	6.5	3.0	7.5	0
	control	62	5.0	3.5	6.5	60
4	flour + 2% NaCl					
	test	60	4.5	3.5	6.0	0
	control	59	3.5	1.5	3.0	20
5	flour					
	test	62	5.0	4.0	7.0	80
	control	62	4.5	4.0	7.5	80
6	flour + 2% NaCl					
	test	56	4.0	2.0	4.0	60
	control	55	3.5	1.5	3.0	50

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THE PROGRAM FOR DISPERSION ANALYSIS OF MAGNETIC COLLOIDS

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The aim of this work is to introduce automation into the labor-consuming process of the analysis of the photographs obtained by different methods for construction of particle size distribution for magnetic colloids.

The similar task was considered in paper [1]. There as the substance to be analyzed the magnetic fluid with powdered particles of manganese-zinc ferrite 2000 HM was used. The given magnetic fluid contains in a researched sample about 300 particles. The computer program carried out a two-stage analysis of a sample and built a distribution curve.

The algorithm of dispersion analysis of magnetic colloids, its program realization and test have been devised in the given work. As a sample for test the magnetic fluid C1-20 was used.

The magnetic fluid C1-20, used in seals at encapsulation of the liquid and gaseous environments, contains large particles and aggregates.

Analysis of the size and the amount of particles united in aggregates is possible to make conclusion about a status of magnetic fluid, and accordingly, make the resource prediction of the operation of the seal.

For dispersion analysis of microphotographs, the software MJ_FOTOSCAN is designed. The operation of the program consists of two main stages: digitization and analysis. After digitization of microphotographs the stage of their identification and analysis of size distribution follows.

The designed program yields the following operations: converses a photo in a grey range of colors to the monochrome pattern. The obtained monochrome pattern is exposed to the subsequent recognition and analysis. After that the program creates the diagram of size distribution of aggregates.

The technique of the analysis of the discrete black-and-white pattern is based on selection of separate groups of black points, which immediately paired with each other that is are adjacent on a horizontal and vertical. The designed algorithm for selection of integral continuous objects is grounded on graph theory, namely on an undular principle of finding of path with a minimum quantity of vertexes.

The way, used in the given algorithm, of the preset of the graph is prescribing of a matrix of connectivity S of a size n*n, where n is an amount of vertexes of the graph, that is power of set V. Thus a unit $s_{i\,j}$=1, if there is an edge from vertex number i to vertex number j and s_{ij}=0, if such edge is not present. It is an easy matter to see, that the matrix S is symmetric, if the graph is undirected, and can be asymmetrical otherwise. Thus we suppose, that s_{ii}=0, i.e. in the graph there are no closed loops. Such way of prescribing of the graph is used in undular algorithm. The given algorithm discovers one of minimum paths, that is one of paths passing through a minimum quantity of vertexes in the graph G = (V, E), given of matrix of connectivity S. Here V - set of vertexes, and E - set of edges of a graph. The path is searched from vertex number u_1 to vertex number u_2.

It must be emphasized that the undular algorithm in the pure state for preset task of selection of objects on the pattern would not do, as it solves the task of finding of path in the given graph. In the given work the task of creation of the graph on a given set of conditions is set. The inverse problem to undular algorithm is solved.

The set of criteria for creation of the list of vertexes of the graph consists in the following:

- the path should transit through all vertexes of the graph, and the repetition of sites of path is admitted;
- the graph should be unweighted, the amount and the character of edges are of no importance, they are to be determined at the moment of creation of the graph.

The designed algorithm consists of two main stages: search of a primary starting point of the analysis and search of points, adjacent with primary. At the first stage, the function ScanCanvas scans by horizontal lines from left to right area of the pattern, and after identification of the first black point it returns its coordinates, and the auxiliary variable tochka accepts value 1. If that point is not retrieved, the function will return as coordinates a pair (-1, -1), and the auxiliary variable tochka will accept value -1. If the point is retrieved, the function AnalizeObject that determines all points, adjacent with given and deletes the selected object from a figure is called. Then the function ScanCanvas is called again and the following point is searched. This process is prolonged so long as all objects will not be selected and are remote and the function ScanCanvas will not return (-1, -1). Except for selection of objects, the function AnalizeObject realizes count of square of objects in standard units of square.

The function ScanCanvas fulfils the following operations:

- sorts out all points of the row of the pattern one by one;
- determines color of a point (black or white);
- if color is black, the function returns coordinates of the retrieved point;
- if black points is not retrieved, the function will return a pair of coordinates (-1, -1), that speaks that the pattern any more does not contain objects for the analysis.

After selection and count of all aggregates the program creates the histogram of size distribution.

Generally at calculations of sizes of aggregates the program uses conventional units of a size. It enables to analyze photos made at different increase. To receive an actual size it is possible as follows: on digital pattern of an optical micrometer we define distance between adjacent divisions in pixels. It can be made in any raster editor, for example Paint. Actual distance D between adjacent divisions of an optical micrometer we divide on obtained distance in pixels D_n and obtain the corrective coefficient K. Further, accepting a size of an aggregate in conventional units of square for S_c, we shall receive its actual size S under the formula:

$$S = S_c * K, \text{ where } K = D / D_n.$$

Figure 1 shows the size distribution, which was obtained for the sample of magnetic fluid C1-20.

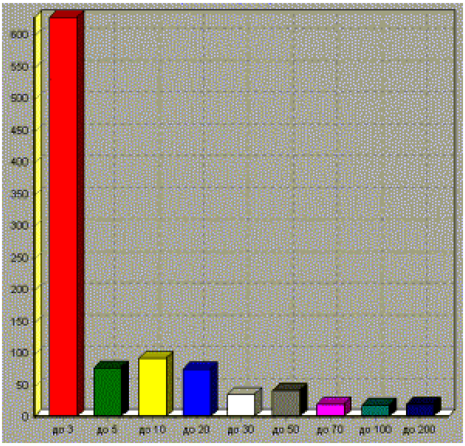

Figure 1

REFERENCES

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AUTHOR INDEX