ELEKTROMAGNETICAL FILTRATION IN HIGH –GRADIENT MAGNETICAL FIELD ANALYSIS

R.A.Muradova, R.M.Mirzoev, S.B.Yusifova

Azerbaijan State Oil Academy , Baku, Azerbaijan

ABSTRACT

The generalized method of magnetic admixtures separation by means of high-gradient magnetic field influence which allows to take into liquids properties and to broaden the limits of electromagnetic filtration theory application is proposed on the base of theoretical and experimental investigations original electromagnetic separators and filters were developed and applied into industry. These devices intended to oil products and technologic liquids refining have shown good capacity for work and high efficiency.

Keywords: generalized method, electromagnetic, separation, filtration, capacity.

I. INTRODUCTION

Generally applicated methods of liquid separation don't provide high quality of products refining from micron ferriferous admixtures. The great majority of last one is characterized by magnetic susceptible properties and as a consequence, may be extracted by means of magnetic sedimentation. That's why the magnetic filters (sedimentors) application is advisable to do [1,2].

On fig.1 magnetic and hydromechanics forces curves depending on the canal width between two points of ferriferous balls are drawn. The points of these curves intersection correspond to magnetic seizure zone radius.

Within that radius magnetic force value is exceed resistance force value in a number of times. That kind of force correlation provides the admixtures seizure and sedimentation in contact zone of high-gradient magnetized balls. The seizure radius is growing to reduce based on non-Newton properties of technical liquid. The profile of speeds distribution for non-Newton liquid flowing around the only cylindrical pivot with round section can be tubing on the base of its flowing through the elementary cell:

$$V_Z = V_0 f(n,\delta_1)\left[\frac{3n-1}{\delta_1^2}\ln r_a - r_a^{\,3-\frac{1}{n}} + 1\right]$$

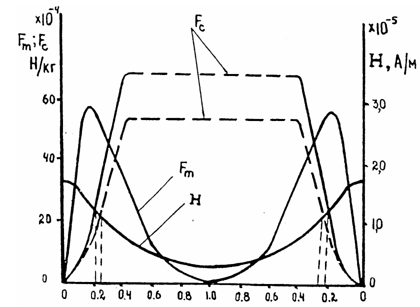
$$f(n,\delta_1) = \left[\frac{3n-1}{\delta_1^2}\ln\frac{1}{\delta} - \delta_1^{\,\frac{1}{n}-3} + 1\right];\ \delta = \frac{a}{R}$$

where a - pivot radius; R -cell radius; V_0 -liquid speed.

The profile of speeds distribution for non-Newton liquid flowing around the great number of parallel pivots with round section can be found on the base of Happel –Cuvabara cell mode [3,4]:

$$V_Z = V_0 f(n,\delta_1)\left[\frac{3n-1}{2\gamma}\ln r_a - r_a^{\,3-\frac{1}{n}} + 1\right]$$

$$f(n,\delta_1) = \left[\frac{3n-1}{2\gamma}\ln\frac{1}{\gamma} - \gamma_1^{\,\frac{1-3n}{2n}+1}\right]$$



where γ - pivots packing density.

Fig.1. The curves of forces within the canal of high-gradient magnetized balls for $H_0 = 150 kA/m$, $\mu = 10.6$ for $n = 1,\ k = 0.001$ — for $n = 0.952, k = 0.004$

where k is the consistence coefficient.

Liquids reologic properties have a deep influence on particles sedimentation kinetics. Fig. 3 illustrates the kinetics of particles sedimentation on magnetized pivot surface. As it seen, insignificant increasing of non- Newton properties lead to great reduction of particles sedimentation speed under other equal conditions.

High – disperse ferriferous particles sedimentation is going on within the contact zone of magnetized balls. The relief of magnetic seizure zone with taking into considering the liquids reologic characteristics is found such as given below:

$$\frac{X}{a} = \frac{1}{e}\left(\frac{Y}{a}\right)^2 - \frac{\left[\frac{0.65n}{n+0.4}\right](P_a^*)^{2n+1}}{\frac{Y}{a}}$$

where X and Y -coordinates of seizure zone relief. Relative equivalent radius of magnetic seizure zone are determined as:

$$P^* = \left[\frac{a_\rho \chi \delta^{n+1} H^{0.75}}{\eta_e X_n f_2(n) V_\phi 2^{n-1} a^n}\right]$$

where $f_2(n)$ - function of n ; a_ρ - calculating η_e -coefficient of magnetic; seizure zone radius; coefficient (imaginary viscosity; χ - particle's magnetic susceptibility).

Having got the seizure radius value, on can determine filter efficiency to the seizure radius value, one can determine filter efficiency from the obvious physical particularities. For axial type of magnetic filter it found as:

$$\psi = 1 - o(L_a, \gamma, n)\exp\left[-\frac{4}{\pi}\left(\frac{L_a}{X_n}\right)^{0.5}\gamma\right]$$

$$o(L_a,\gamma,n) = \frac{1}{\gamma} - \Big/ 2f(n,\gamma)\left\{\frac{3n-1}{4\gamma}\left[\left(\ln\frac{1}{\gamma}-1\right)\frac{1}{\gamma}+1\right] - \right.$$
$$\left. -\frac{n}{5n-1}\left[\left(\frac{1}{\gamma}\right)^{\frac{5n-1}{2n}} - 1\right] + 0.5\left[\frac{1}{\gamma}-1\right]\right\}$$

where $L_a = \left(\frac{V_m}{V_0}\right)\left(\frac{L}{a}\right)$ -undimensional coefficient of filter length.

For filter consisted of great number of magnetized balls magnetic sedimentation equation in stationary form can be defined from filter's efficiency modified equation obtained on the base of A.V.Sandulyak formula:

$$\psi = \lambda\left\{1 - \exp\left[-1.66\left(\frac{0.65n}{(n+4)f_2(n)}\right)^n\right]\frac{a_\rho \chi H^{0.75}\delta^{n+1} L}{2^{n-1}\eta_3 a^{n+1} V_\phi}\right\}$$

where λ -share of ferromagnetic admixtures; $f_2(n)$ -function of n ; L -filter length.

Experimental investigation concern magnetic field intensity H influence on ψ have demonstrated (Fig.4) noticeable increase of P for the case $H = 40 - 100KA/m$. As speed of non-Newton liquid filtration is growing high (Fig.5). The value is intensively increasing, especially, when $V > 100rn/h$ $\psi = f(L)$ dependence curve is shown on Fig.6. As it seen, the most high quality of non-Newton liquid refining $(\varphi \geq 0.6)$ can be obtained for the case $L = 0.8m$

Differential equations depicted the ways of particles movement in high –gradient magnetic field of the only ferromagnetic cylindrical pivot with round section for the case of viscous liquid laminar flowing around is calculated with PC. But taking into consideration the technologic liquids particulates this problem can be applicable for practical calculations. Assuming that $n-1 << 1$ and Reynolds number $\mathrm{Re} < 1$ the equation of particle full sedimentation from the viscous non –Newton liquids laminar flow without taking into consideration the liquid profile is found as:

$$Z' = \frac{r_{a^0}^{\;4}}{2\sin^2 2\theta} X_n\left[\cos 2\theta - \cos 2\theta_0\right]$$

$$r_a = \frac{r}{a}$$

where $X_n = X(n)$; $X(1) = 1$; γ_0, θ_0 - particle initial coordinates in high – gradient magnetic fields;

$Z' = \left(\frac{V_m}{V_0}\right)\left(\frac{L}{a}\right)$; L -pivot length; V_0 -particle speed; V_m - so called "magnetic speed ": depending on the magnetic, reologic and geometrical parameters of system.

Profile of viscous non –Newton liquid speed distribution have a great influence on sedimentation process. Taking into consideration above mentioned assumption one can solve differential equation depicted the particle way in high–gradient magnetic fields of magnetized ferromagnetic pivot analytically too. Comparative diagram illustrating the typical ways of particle sedimentation in the of magnetized pivot from non –Newton liquid laminar flow with and without taking into consideration the liquid profile is shown on Fig.2.

Taking into consideration the liquid of speed distribution one can obtain equation depicted particles ways in high–gradient magnetic field of magnetized ferromagnetic pivot with round section:

$$Z' = X_n f(n,\delta_1)\frac{r_{a^0}^{\ 4}}{\sin^2 2\theta}\left\{\frac{3n-1}{2\gamma}\ln\frac{tg\theta_0}{tg\theta}+\right.$$

$$+(\cos 2\theta+\cos 2\theta_0)\ \Big\}\cdot\left[\frac{3n-1}{2\gamma}\ln\frac{r_{a^0}^{\ 4}}{\sin^2 2\theta}+1-\right.$$

$$-\frac{3n-1}{2\gamma}\ \Big]+\frac{3n-1}{2\gamma}\Big[\cos 2\theta \ln\sin 2\theta -$$

$$-\cos 2\theta_0 \ln\sin 2\theta_0\ \Big]+\left(\frac{r_{a^0}^{\ 2}}{\sin 2\theta_0}\right)^{\frac{3n-1}{2n}} 2\theta\frac{\theta-\theta_0}{180}\pi -$$

$$-0.25(\sin 4\theta-\sin 4\theta_0)\ \Big]\ \Big\}$$

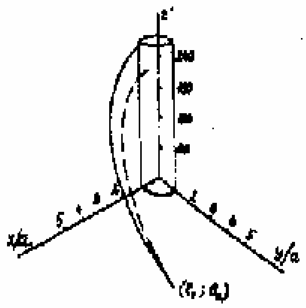
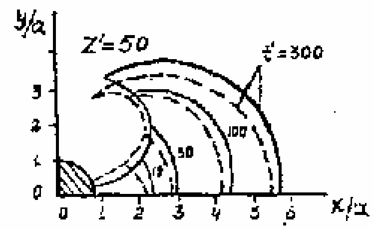


Fig.2



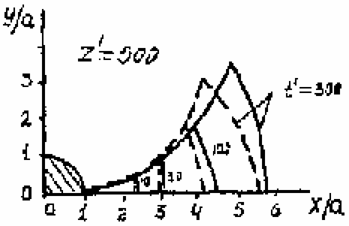


Fig.3

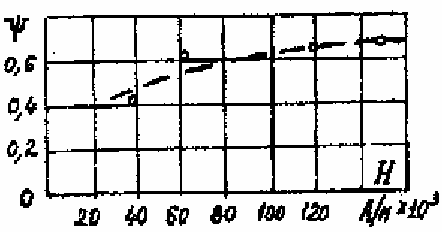


Fig.4

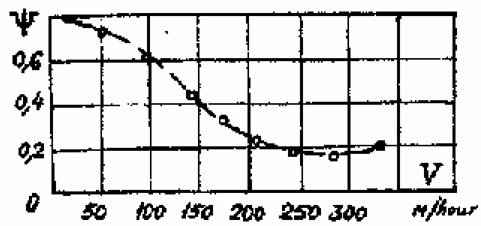


Fig.5

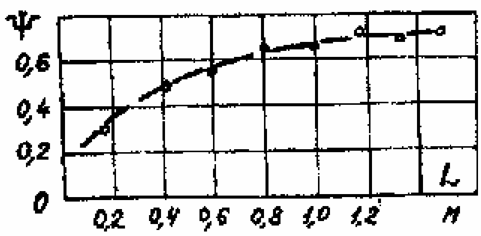


Fig.6

The possibility of sedimentation from-viscous non-Newton liquids under magnetic centrifugal and hydrodynamic forces influence was investigated. For this purpose one can develop centrifugal device with cylindrical body and tangential piper for clean and sewage liquids removal. Time required for liquid phases full separation is

$$t = \frac{18X_n(2a)^{n-1}}{4(P_m - P)\omega^2\delta^{n+1}} \ln \frac{\chi\mu_0 H^2 a^2 - f\omega^2 r_2^4}{\chi\mu_0 H^2 a^2 - f\omega^2 r_3^4}$$

$$f = \frac{P_m - P}{P_n - P}$$

where

P_m , P_n and P - magnetic, nonmagnetic particles and liquids densities, respectively;

r_1 and r_S -inner and surface cylindrical body;

r_2 - separating fence radius.

Thus, model developed let us to take into consideration liquid's reologic properties. Theoretical results obtained are in good correspondence with experimental data.

The basic advantage of above mentioned developed and patented devices application is sedimentation efficiency rice and great improvement of apparatus construction [3,4].

II. CONCLUSIONS

1.The generalized calculation method of magnetic admixtures sedimentation by means of high –gradient magnetic field influence which allows to take into consideration the liquid properties is developed.

2.With the aim to find out the character of liquids flow in magnetic filter pores curves of viscous non-Newton liquids speed distribution were determined.

3.On the base of reologic liquid degree model analytical expressions depicted magnetic sedimentation in high-gradient magnetic field of only magnetized ferromagnetic pivot were obtained.

4.Formulas got may be used for not only Newton but non- Newton liquids main technological and regime parameters calculation.

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