STUDY OF INTERACTIONS IN SYSTEM “METAL - FILTER CAKE” IN APPLICATION TO WELL DRILLING

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In the given work the system “metal - filter cake” in application to well drilling is investigated on the basis of B.V.Derjaguin conception about the binomial law of friction. The appropriate method for study of antifriction properties of filter cake is offered. The influence of solid phase dispersion ability of a clay drilling fluid on its frictional properties is investigated.

INTRODUCTION

There are different perspectives on the nature of occurrence of resistance forces to movement of drill strings in wells caused by quality of a drilling fluid. However majority of the researchers mark presence always, alongside with frictional forces, molecular forces playing a significant role at the drags on and sticking of drill string [1,2,3].

With the purpose of studying of the mechanism of friction at phases contact interaction, eliciting some basic physico-chemical factors and definition their quantitative estimation, in the given work a new approach studying of this process is considered, which is based on B.V.Derjaguin, A.D.Zimon and E.I.Andrianov works[4,5].

As is known, one of the laws of friction is the Amonton law according to which the resistance to shear force of is directly proportional to normal loading on a friction pair and does not depend on the area of contact:

$$\tau=\mu N \qquad (1)$$

где τ – resistance to shear force, N – normal load to a shear plane, μ – proportionality factor named in friction factor.

According to the equation (1) the relationship between τ and N represents a straight line 1, which passes through the origin (fig. 1).

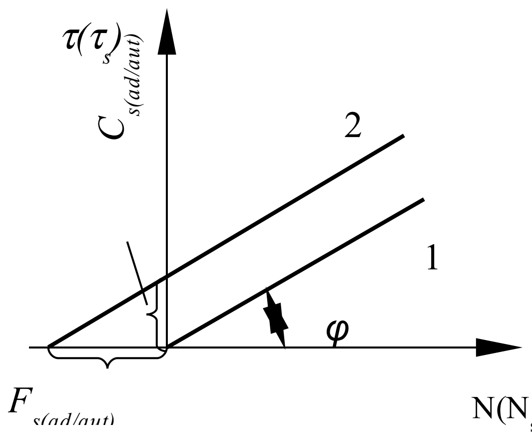

Figure 1. Graph of representing the relationship of resistance to shear force against load according to the Amonton law of friction (1) and B.V.Derjaguin binomial law of friction (2)

However Amonton law is truth for systems, in which both contacting phases are represented by homogeneous continuous mediums. A filter cake of a drilling fluid is a high-concentrated dispersing system with thixotropy properties, structurally non-uniform on thickness, the filter cake density increases from the top layers to bottom.

The numerous experimental researches at study of friction arising in pair "metal – filter cake" show, that the similar law is not observed. Actually the relationship of resistance to shear of force against normal load in the considered system essentially depends on the area of contact, therefore it is expedient to consider the relationship between specific forces τ_s and N_s (forces are referred to unit of the contact area). The relationship τ_s against N_s is not characterized by the straight line 1, and a straight line 2, which passes above the straight line 1 and is described by B.V.Derjaguin binomial law of friction [4]: $\tau_s=\mu(N_s+F_s)$.

In the given equation the value F_s is a resultant force of intermolecular interactions. In a case if the shear is directly on the contact boundary "metal – filter cake", the force F_s is a consequence of adhesion $F_{s(ad)}$, if there is the direct shear inside filter cake, F_s is a consequence of autohesion $F_{s(aut)}$.

The friction factor μ is equal to the tangent of an angle φ of an inclination of a straight line to the abscissa axis and characterizes the frictional force interfering movement of filter cake particles on a surface of metal (at adhesion) or relative movement of particles inside filter cake (at autohesion).

It is obvious, the direction of resistance forces in system "metal – filter cake" is possible by the variation of the adhesion, autohesion and friction factor values.

From a fig. 1 it is visible, that the straight line 2 cuts off some segments on coordinate axes. The segment on the abscissa axis $F_{s(ad/aut)}$ characterizes breaking strength of contact and the segment on the ordinate axis $C_{s(ad/aut)}$ - shear strength of contact. The values $F_{s/aut)}$ and $C_{s/aut)}$ are a consequence of autohesion, if the shear plane is in the filter cake, and $F_{s(ad)}$ and $C_{s(ad)}$ – a consequence of adhesion, if the shear is directly on the contact boundary "metal – filter cake".

In the contact of two bodies distinguished by strength, the shear is not on their contact boundary, and inside a more plastic body. If the shear is directly inside a filter cake, in the absence of load ($N_s = 0$), the frictional factor is determined by shear specific strength to breaking specific strength ratio for a filter cake: $\mu = C_{s(aut)}/F_{s(aut)}$.

MATERIALS AND METHODS

The following model fluids were the objects of research:

№1 - 10% kuganaksk gel material + 0,5% carboxymethyl cellulose + вода;

№2 - 10% kuganaksk gel material + 0,5% carboxymethyl cellulose + вода + 0,125% Na_2CO_3;

№3 - 10% kuganaksk gel material + 0,5% carboxymethyl cellulose + вода + 0,25% Na_2CO_3

In the preparation of the fluids we used carboxymethyl cellulose with trade-mark "Tylose VHR". The addition Na_2CO_3in the fluids №2 and №3 was done with the purpose to change the dispersion ability degree of the solid phase particles, which was determined by Figurovsky method.

The researches of the filter cakes received on the fluid loss tester spent on the modified device KTK-2, in which the concave bed and the cylindrical puncheon were replaced, accordingly, with a rough place and metal load with the plane base. It provides preservation of the constant contact area in time between metal and filter cake.

Processing of experimental data made on a computer in the program Microsoft Excel: the graphs are plotted and for each period of time the equations in view $\tau_s = C_{s(aut)} + \mu N_s$ и $\tau_s = \mu\,(N_s + F_{s(aut)})$ are got.

RESULTS AND DISCUSSION

The results of research of the filter cakes frictional properties are submitted in a fig. 2a-4a and in the table 1.

The differential curves of the sedimentation analysis demonstrating particle-size distribution of the dispersed phase are submitted in a fig. 2b-4b.

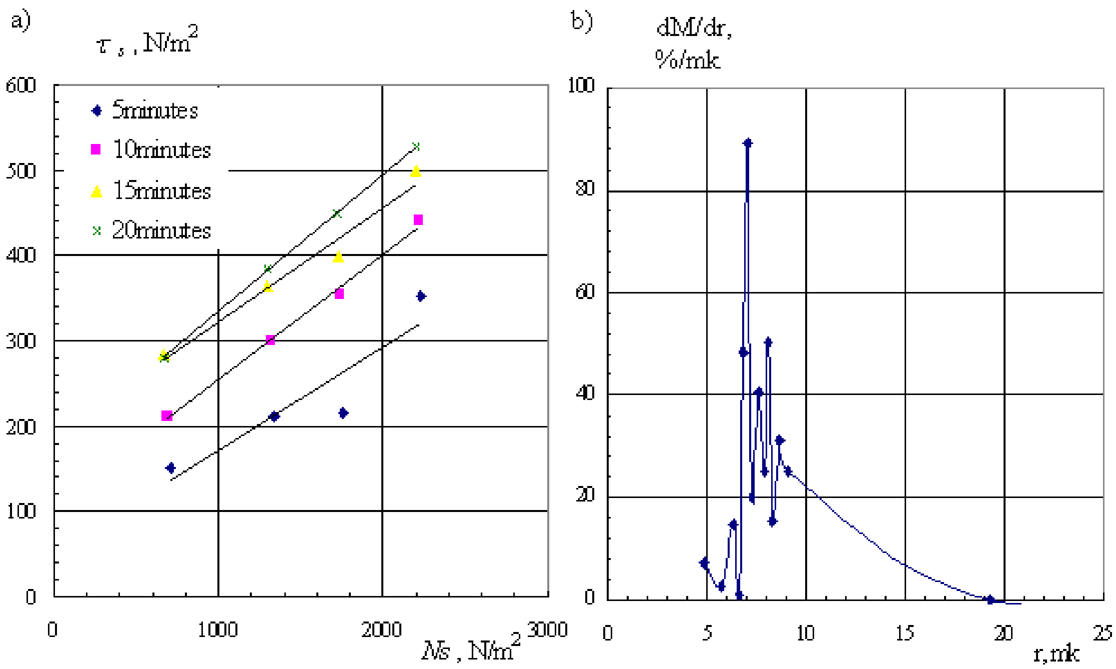

Figure 2. Relationship of resistance to shear specific force t_s against load N_s created on the filter cake in 5,10,15,20minutes contact (a) and differential curve of particles distribution on radiuses (b) for the fluid №1

On the data of tab. 1 the graphical relationship of the change of the contact shear strength and the contact breaking strength in a shear plane in the absence of load for each time period (fig. 5) are constructed.

In all the investigated fluids the increase of frictional factor in time is observed mainly. Perhaps, it is connected with a displacement of the shear planes in more dense bottom layers of the filter cakes or a compaction of the filter cake. The displacement of the shear plane is a result of joint action adhesion and autohesion forces, the compaction of the filter cake - continuous action of normal making load.

The data of the sedimentation analysis show, that the dispersed phase of the fluid №1 (fig. 2b) more polydispersed, than in the fluid №2 (fig. 3b) and №3 (fig.4b), that causes higher values of its frictional factor.

The displacement in time of the straight lines is relative to each other (fig. 2a-4a), apparently, is connected to action of the split pressure (B.V.Derjaguin), that essentially depends on the distance between particles and their charging condition.

The differential curve of the fluid №1 shows, that the given fluid contains particles of smaller radius, than the fluids №2 and №3. On the one hand, it can promote the increase of number of contacts between particles on unit of an area, that promotes the increase of the forces of the intermolecular interaction. On the other hand, polydispersion ability can be the reason of occurrence of the large clearances between particles, that considerably slackens forces of intermolecular interaction.

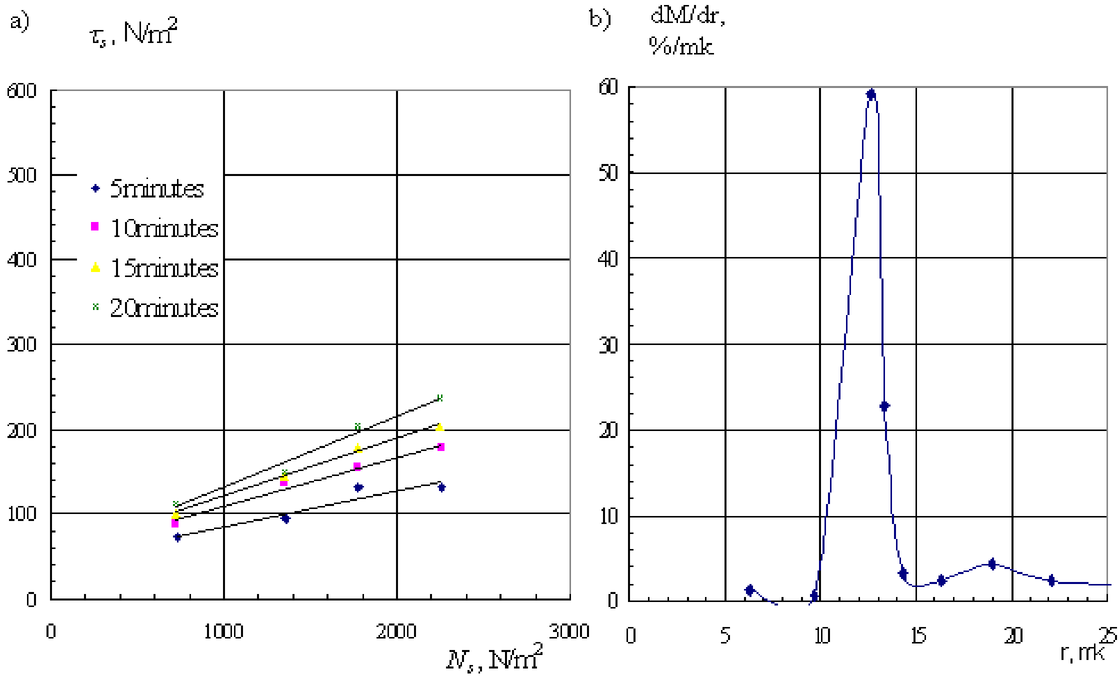

Figure 3. Relationship of resistance to shear specific force t_s against load N_s created on the filter cake in 5,10,15,20minutes contact (a) and differential curve of particles distribution on radiuses (b) for the fluid №2

The analysis of the plots $F_{s(aut)} = f(t)$ (fig. 5) shows, that in first 15minutes the autohesion force is increased, that can be explained by the filter cake compaction under action of load in time and the prevailing in the system of some intermolecular attractive forces. In subsequent 5minutes the autohesion reduction is observed, that can be connected with prevailing intermolecular repulsive forces.

In the fluid №1 in 15minutes contact forces of intermolecular interaction, apparently, have the higher values in comparison with the fluids №2 and №3 in all the period of time that is connected to presence of higher number of contacts on unit of an area.

It is interesting the comparison of similar relationships for the fluids №2 and №3 with each other having approximately the identical dispersion ability degree of the solid phase. In 5 and 10minutes contact the value of intermolecular forces working between particles in the fluid №2 is less, than in the fluid №3 (fig. 5, tab. 1). At the same time, the values of frictional factors in the fluid №2 are higher, than in the fluid №3.

In 15 and 20minutes the values of forces of intermolecular interaction are more in the fluids №2, but the friction factors have smaller values, than in the fluids №3.

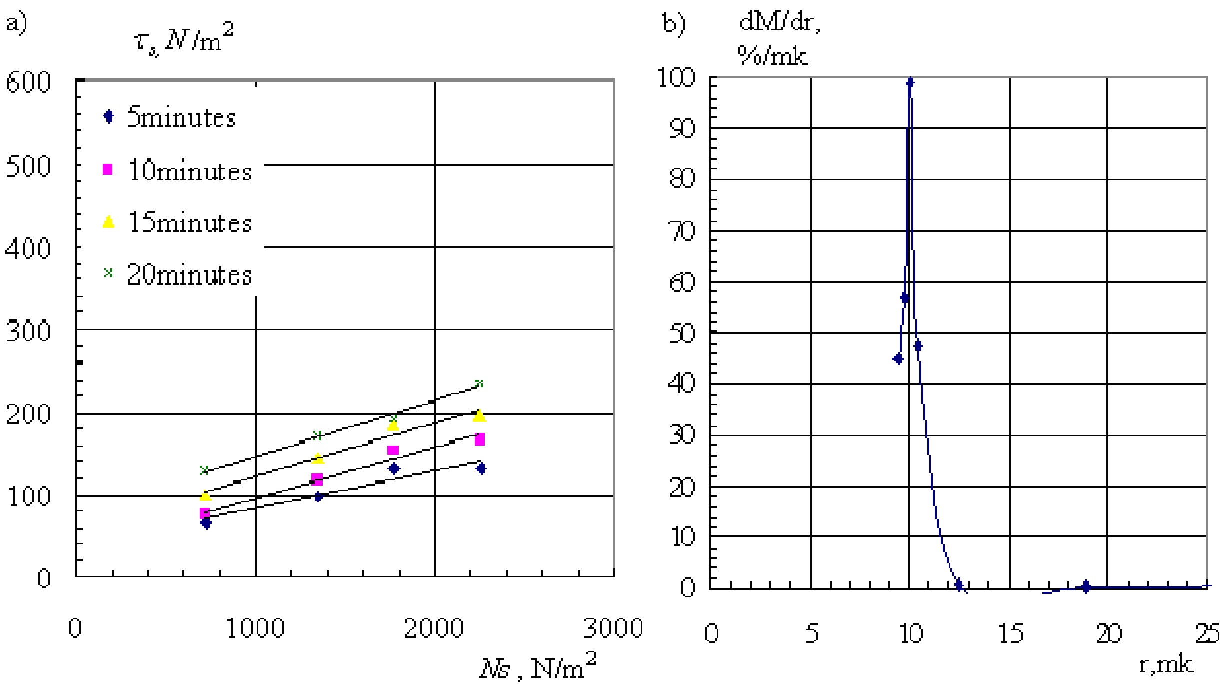

Figure 4. Relationship of resistance to shear specific force t_s against load N_s created on the filter cake in 5,10,15,20minutes contact (a) and differential curve of particles distribution on radiuses (b) for the fluid №3

It is necessary to note, that in the fluids №3 the filter cake breaking specific strength constantly decrease in time that specifies prevalence of the repulsive forces. The alternate prevalence of the repulsive and attraction forces in time is marked in the fluid №2. At the same time, observable increase frictional factor in time in the fluid №2 is less intensive, than in the fluid №3.

Table1

Equations $\tau_s = C_{s(aut)} + \mu N_s$ and $\tau_s = \mu (N_s + F_{s(aut)})$ for each time period of contact of metal with filter cake for fluids №1, №2 and №3

Время, мин	$\tau_s = C_{s(aut)} + \mu N_s$			$\tau_s = \mu (N_s + F_{s(aut)})$		
	№1	№2	№3	№1	№2	№3
5	τ=50+0,121N	τ=43+0,042N	τ=37+0,046N	τ=0,121(N+413)	τ=0,042(N+1022)	τ=0,046(N+815)
10	τ=106+0,148N	τ=51+0,058N	τ=34+0,062N	τ=0,148(N+717)	τ=0,058(N+894)	τ=0,062(N+547)
15	τ=187+0,135N	τ=53+0,068N	τ=57+0,066N	τ=0,135(N+1392)	τ=0,068(N+775)	τ=0,066(N+876)
20	*τ=174+0,161N*	*τ=49+0,083N*	*τ=79+0,068N*	*τ=0,161(N+1077)*	*τ=0,083(N+589)*	*τ=0,068(N+1152)*

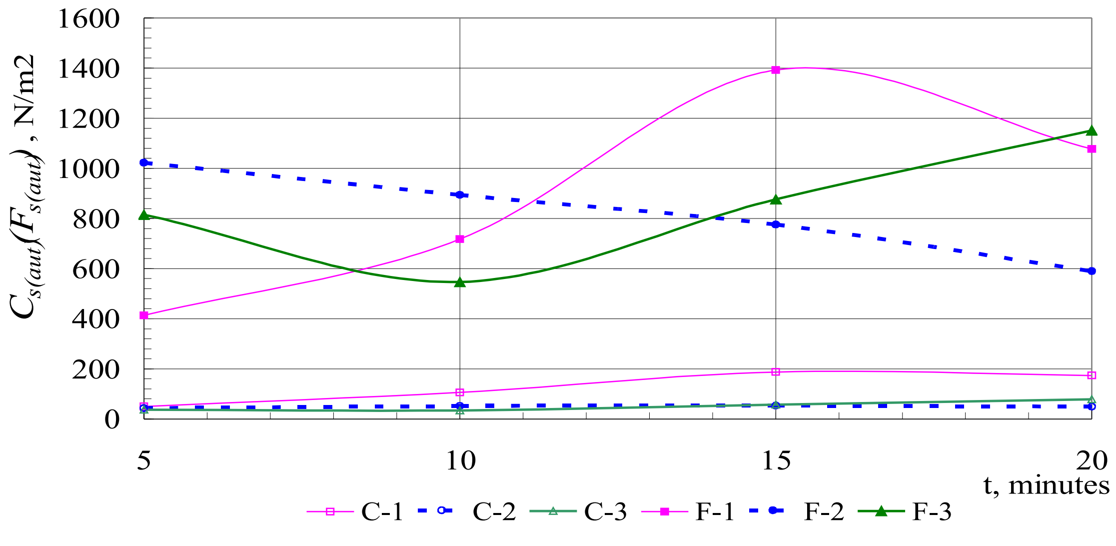

Figure 5. Kinetic curves of the shear specific strength (C-1, C-2, C-3) and the breaking specific strength (F-1, F-2, F-3) in the absence of load for pair “metal - filter cake” (1, 2, 3 - № fluid)

CONCLUSION

The executed researches have allowed to appraisal influence of the dispersion ability degree of the solid phase of the clay drilling fluids on frictional properties of the filter cakes. It is established, that the best antifrictional properties have the monodispersed filter cake. Hence, the perspective methods are some methods of homogenization of the dispersed phases of well drilling fluids, alongside with some hardening cakes methods and improvement their properties in a direction of decrease of resistance to shear forces. Realized with our participation a hardening filter cakes method by some chrome content substances for drilling deep wells in Turkmenistan has given positive results for the prevention of sticking.

LIST OF SYMBOLS

τ - resistance to shear force, N; τ_s - specific resistance to shear force, N/m^2

μ - frictional factor; N – normal load to a shear plane, N

N_s – normal load to a shear plane, N/m^2

$C_{s(ad/aut)}$ – specific shear strength of contact in a shear plane in the absence of load at the adhesion (autohesion), N/m^2

$F_{s(ad/aut)}$ – specific breaking strength of contact in a shear plane in the absence of load at the adhesion (autohesion), N/m^2

t – time, minutes

REFERENCES

1. Sherstnev N.M., Rasizade Y.M., Shirinzade S.A.: "Prevention and liquidation of complications in drilling." – M., 1979. – 304p.

2. Kister E.G., Miheyev V.L.: "Mehanical properties of clay filter cakes // Chemical treatment of drilling and cement fluids." – M., 1971. – p.82-94.

3. Gray G. R., Darley H.C.H.: "Composition and properties of oil well drilling fluids." - M., 1985. – 509p.

4. Deryagin B.V.: "What is friction?." – M., 1963. – 230p.

5. Zimon A.D., Andrianov Y.I.: "Autohesion of loose materials." - M., 1978.-288p.