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Study of Enrichment and Mechanical Activation Processes of Natural Clay Minerals

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ABSTRACT: The article presents the results of a study of the physicochemical characteristics of bentonite clays from the Krantau, Beshtyuben and Khodzhakul deposits, as well as the colloid-chemical properties of their aqueous suspensions. It has been established that enrichment and disintegrator grinding leads to an increase in the swelling of clays, which is associated with an increase in their dispersion, and which is reflected in the viscosity characteristics of their suspensions.

KEYWORDS: drilling fluid, bentonite, suspension, relative viscosity, swelling, fineness, fluid loss, static shear stress.

I.INTRODUCTION

Clays are the main structure-forming and crust-forming components of drilling fluids. The most important clay minerals of interest for drilling fluids are montmorillonite, kaolinite, hydromica, and palygorskite [1-3].

The most important indicators of clay solutions are the strength of the structure and the effective viscosity, because. these characteristics contribute to the solution of the problem of regulating the rheological properties of drilling fluids, which characterize the physicochemical state of the latter, the level of coagulation and stabilization, the colloidality of the solid phase, its concentration, which takes place in the fight against thickening caused by electrolyte or temperature aggression [4, 5].

The process of using natural clay materials is closely related to their processing, which is due to the presence in their composition of a large amount of impurities that adversely affect their physicochemical parameters and technological properties [6].

The quality of clay powders used in various industries, incl. as the basis of drilling fluids, is mainly formed from two factors: the quality of clay raw materials and the method of its grinding [7].

Depending on the purpose and objectives of obtaining the necessary technological parameters of clays, several methods are used to change the structure and physical and mechanical properties of their suspensions [8].

Enrichment is a set of operations for the primary processing of raw materials in order to remove impurities and waste rock, which contribute to the stabilization of the composition of the masses and improve the quality of the finished product [9-13].

During mechanical grinding in propeller-type mixers, disintegrators, vibrators, baking powder, the structure of minerals is “loosened” along the weakest points-defects, which is accompanied by brittle fracture of particle aggregates. When grinding large solid particles of clay, small aggregates are formed with the opening of basal surfaces and active centers of bentonites [14, 15].

The most effective method should be considered the method of fine grinding of clay materials when dispersed in apparatuses with a jet grinding method and in disintegrators. It is shown that grinding with the use of such mills makes it possible to improve the quality of bentonite powder by 30% compared to the original bentonite.

II. SIGNIFICANCE OF THE SYSTEM

The most important technological functions of drilling fluids are determined by their rheological properties - consistency, mobility, structural and mechanical parameters. Therefore, the purpose of the research was to establish the possibility of using some bentonite clays of Karakalpakstan as the basis of drilling fluids and to study the influence of clay preparation processes on changing the characteristics of their suspension. The study of methodology is explained in

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section III, section IV covers the experimental results of the study, and section V discusses the future study and conclusion. The study of methodology is explained in section III, section IV covers the experimental results of the study, and section V discusses the future study and conclusion.

III. METHODOLOGY

For these purposes, clay minerals from the Krantau, Beshtyuben, and Khodzhakul deposits were selected and studied [16–19].

An analysis of the physicochemical properties of clay minerals makes it possible to choose a rational method for obtaining clay powders from them, as well as drilling fluids based on them.

The density of suspensions was measured using hydrometers and a pycnometer. The nominal viscosity of the suspensions was determined using a VBR-2M funnel with a 5 mm tube. The static shear stress was determined using VSN-2 and SNS-2M instruments. The water loss of suspensions was measured with a VM-6 instrument designed to measure static filtration at temperatures from +10°C to 80°C and a pressure drop of 1 kgs/cm2.

The concentration of hydrogen ions was determined by applying both the calorimetric method using indicator paper and the potentiometric method using various pH meters (I-160MI brand ionomer).

Stability is the difference in density between the upper and lower halves of the suspensions. Daily sludge - the amount of clear water released from above the suspensions after holding for 24 hours, measured in%.

On the basis of clays, clay powders were prepared from dried clay using the technology of grinding in a ball mill and technological studies were carried out in accordance with GOST 25796.83 “Clay raw materials in the production of clay powders for drilling fluids. Test methods” [20]. To prepare suspensions with different concentrations of the solid phase, boiled chilled household water was used.

In the work, a simple traditional method of clay enrichment was used - washing with water. Enrichment was carried out using special methods of crushing, washing and granulometric classification of raw materials. The grinding of enriched clay was carried out in a laboratory disintegrator with a variable number of rotor revolutions up to 12,000 rpm. The influence of the operating mode of the disintegrator and the degree of clay moisture on its grinding and the colloid-chemical properties of their suspensions were studied.

IV. EXPERIMENTAL RESULTS

The study of the main physicochemical characteristics brought the following results (Table 1).

Table 1.
Physical and technological properties of natural bentonite clays

Properties	Indicators					
	KR1	KR2	B1	B2	XD	NShB
Density, g/cm3	2,2	2,3	2,2	2,1	2,2	2,3
Natural humidity, %	3,2	5,4	4,6	3,4	3,5	5,3
Plasticity number	28,8	46,9	38,2	35,2	32,4	41,3
pH 10% suspensions	7,2	7,6	7,3	7,1	7,3	7,4

With a natural moisture content of clays of 3.24-5.50%, the density of bentonite clays is equal to 2.2 g/cm3 for KR1; for KP2 – 2.3 g/cm3; for B1 - 2.2 g/cm3; B2 - 2.1 g/cm3 and for Khodzhakulsky - 2.2 g/cm3. The maximum moisture capacity is 6.5-8.5%, and at higher humidity clays lose their friability.

In the diagram shown in fig. 1 shows changes in the relative viscosity from the content of the clay component of suspensions. As can be seen, to obtain clay suspensions with the same values of conventional viscosity, different amounts of clays are consumed. In table. Table 2 shows the colloid-chemical properties of 10% clay suspensions.

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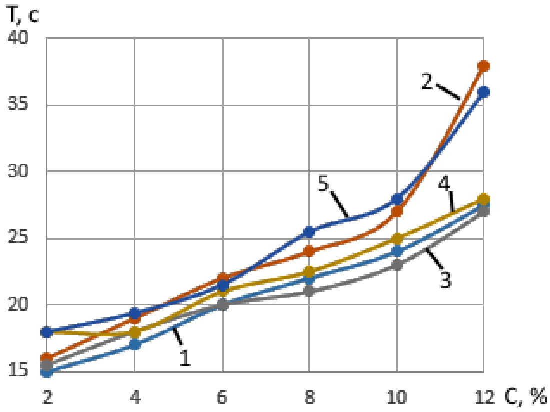

Fig. 1. Influence of changing the clay concentration on the conditional viscosity of suspensions: 1 - KR1; 2 - KR2; 3 - HD; 4 - B1; 5 - NSCHB.

Clays KR1, B2 and KhD are not suitable without modification for the preparation of low-clay drilling fluids. As can be seen from the data in Table. 2, their suspensions have high values of daily sludge and stability due to the kinetic and aggregative instability of the system. Analyzing the results of the research, we came to the conclusion that the B3 clay sample is not suitable for obtaining clay drilling fluids. Therefore, they were not further investigated.

Experiments have shown that as a result of primary enrichment, there are noticeable changes in the chemical composition of clays. The content of the finely dispersed fraction in the samples of clays KR1 and KR2 increases by 24-30%, and B1 and B2 by 14-18%. When enriching the samples of clays with HD, the fineness increased several times.

After enrichment, the degree of swelling of clays KR1, KR2, B1 and KhD increased from 0.91; 1.12; 0.88 and 0.92 cm3/g up to 1.26; 1.43; 1.37 and 1.24 cm3/g, respectively. The prepared suspension from clays, with a conditional viscosity of 25 s according to VBR-2, contains only 5-7% of the solid phase, which corresponds to a drilling fluid yield of at least 15 m3 from one ton of clay. An increase in the solid phase to 10% leads to a sharp increase in viscosity and the production of highly structured clay suspensions. The above data on the properties of suspensions prove the possibility of obtaining high quality clay powders based on KR2 and B1 without additional treatment with modifiers - sodium compounds.

Table 2.
Colloidal-chemical properties of 10% suspensions of the studied clay samples

Clay	ρ, g/cm3	PV, MPa•s	T, c	CHC1/ CHC10, dPa	CO, %	C, g/cm3	pH
KR1	1,063	14,4	23	34/41	8	0,03	7,3
KR2	1,061	15,8	27	36/43	3	0,01	7,5
B1	1,061	14,2	24	30/34	4	0,02	7,5
B2	1,060	11,1	18	22/25	44	>1	7,1
B3	1,060	7,6	16	15/16	68	>1	7,0
XD	1,059	13,9	24	24/26	9	0,05	7,5
NShB	1,062	16,1	28	35/44	2	0,01	7,5

The swelling capacity of B2 and B3 without enrichment is only 0.127 and 0.098 cm3/g, respectively. As a result of enrichment, their swelling capacity increases several times. However, these enriched forms of clays are not able to form kinetically and aggregatively stable suspensions. The suspension prepared from enriched form B2 contains at least 15% of the solid phase, which corresponds to a drilling fluid output of 6 m3 from one ton of clay. In this case, the daily settling of the suspension, i.e., the amount of free water is 25-30%. Even more unsatisfactory technological properties are exhibited by the drilling fluid prepared on the basis of B3, while the yield of the fluid is only 3-3.5 m3.

Information on the grinding of clays with different moisture content is given in table. 3 and 4.

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Table 3

Influence of Clay Moisture and Disintegrator Processing Mode on Its Particle Size Composition

N	Clay	Humidity, %	Particle sizes, mm				
			1,0 – 0,063	0,063 – 0,01	0,01 – 0,005	0,005 – 0,001	Less 0,001
5000	KR2	5%	3,1	17,8	19,8	28,6	30,7
		10%	2,4	12,4	10,2	26,3	48,7
		15%	6,1	29,2	10,2	15,7	38,8
	B1	5%	5,6	21,6	10,7	33,4	28,7
		10%	2,1	8,4	18,2	30,2	41,1
		15%	7,1	31,6	13,6	10,9	36,8
	XD	5%	3,4	2,9	18,9	15,6	59,2
		10%	0,2	3,5	2,3	25,6	68,4
		15%	3,6	16,5	4,5	46,5	28,9
10000	KR2	5%	1,2	11,2	18,4	29,5	39,7
		10%	0,9	9,4	8,7	22,4	58,6
		15%	0,4	7,2	15,2	27,4	49,8
	B1	5%	5,6	21,6	10,7	33,4	42,4
		10%	2,1	8,4	18,2	30,2	56,7
		15%	7,1	31,6	13,6	10,9	57,8
	XD	5%	2,8	8,8	9,6	18,4	60,4
		10%	0,1	2,5	1,6	26,6	69,2
		15%	0,1	2,3	2,3	16,8	78,5

As can be seen from these tables, with an increase in rotor speed, the specific surface area of clays increases. At the same time, with a clay moisture content of 15% or more, their specific surface decreases to a large extent. However, there is evidence that an increase in the moisture content of clays improves the technological properties of finished clay powders. This character of the dependence is explained by a doubling of the content of amorphous silica in the clay powder, which forms polysilicic acid upon dissolution. Due to this, the structural-mechanical and filtration properties of drilling fluids prepared on their basis are improved.

From the point of view of drilling technology, the mud has the best thixotropic properties, the strength of which increases faster, and the CHC10/CHC1 ratio decreases.

As shown, the results of the study of disintegrator grinding of clays and its moisture into SNS-suspensions based on them, with a rotation of the rotors of the disintegrator of 10,000 rpm and a clay moisture content of 10%, the best structure-forming ability for the clays of the Krantau deposit is achieved. To achieve relatively better values of this indicator for the clay of the Beshtyubenskoye deposit, the rotation of the rotors is 12,000 rpm and the moisture content of the clays is 8%. Apparently, the differences in the optimal modes of mechanical grinding are primarily due to the difference in the mineralogical compositions of clays.

Table 4

Influence of Clay Moisture and Processing Mode on Properties

10% suspensions

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№	Clay moisture, %	PV, mPa•c	T, c	V, cm3/min	TK, mm	CHC1/CHC10 dPa	CO, %
Krantau clay (KR2)							
4000	5	16,8	31	16	1	34/38	1
	10	18,7	32	14	0,5	37/41	0
	15	17,8	32	14	0,5	37/44	0
8000	5	19,1	34	13	0,5	39/47	0
	10	25,5	43	10	0,5	54/87	0
	15	22,1	38	12	0,5	48/61	0
12000	5	22,3	39	11	0,5	41/49	0
	10	27,2	45	10	0,3	56/84	0
	15	27,5	49	9	0,3	59/74	0
Beshtyubenskoyr clay (B1)							
4000	5	13,2	26	18	1	31/35	3
	10	16,7	28	16	0,5	33/40	2,5
	15	15,2	27	16	0,5	34/41	2,5
8000	5	18,1	29	17	0,5	33/39	2
	10	22,3	33	14	0,5	40/46	2
	15	20,1	31	14	0,5	38/48	2,5
12000	5	22,3	31	15	0,5	38/42	1
	10	24,2	36	13	0,3	46/64	1
	15	25,4	39	11	0,3	49/65	1
Khodjakul clay							
4000	5	13,1	24	17	1,5	24/28	2
	10	16,2	27	15	1,5	27/34	2
	15	15,3	26	16	1,5	28/35	2
8000	5	15,6	27	16	1	29/37	2
	10	19,1	35	14	1	44/57	1,5
	15	18,2	34	15	0,5	46/61	1,5
12000	5	20,8	31	12	0,5	38/49	1
	10	25,9	39	11	0,5	48/74	1
	15	29,2	42	10	0,5	49/76	1

As a result of the chemical analysis of clays, a noticeable decrease in the total SiO_2 content was found compared to the original enriched clay. A further decrease increased with an increase in the specific surface area of clays. This is probably due to the aggregative stability of the suspensions prepared on their basis, due to which the chemical analysis

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is complicated by the difficult coagulation of the sparingly soluble $H_2SiO_3•H_2O$ in the form of which silica is determined in clays. Also, it was found that after disintegrator grinding, SiO_2 losses are up to 3%, which leads to an overestimated content of R_2O_3 oxides, and a change in the quantitative content of clay minerals, as evidenced by a change in the intensity of X-ray diffraction patterns. The study of the effect of disintegrator grinding of clays on the relative viscosity of their suspensions showed that the increase in viscosity occurs only up to a certain number of revolutions, and then there is a slight decrease in the index, i.e. an increase in the number of revolutions above 8000-10000 per minute negatively affected the conditional viscosity of the suspensions. This effect is explained by the partial hydrophobization of clay particles due to air adsorption on them. As the results of the conducted studies have shown, high-temperature flashes are possible during disintegration treatment, which contribute to hydrophobization due to high-temperature loads on the newly formed surface areas. Therefore, an increase in clay moisture contributes to an increase in the optimal number of revolutions, because. for the evaporation of water during processing, a significant proportion of heat is expended and the total mass of clay is cooled.

V. CONCLUSION AND FUTURE WORK

Thus, the study of the physicochemical characteristics of clay minerals from the Krantau, Beshtyuben, and Khodzhakul deposits revealed a difference in the colloid-chemical and rheological characteristics of their suspensions. Experiments have shown that as a result of primary enrichment, there are noticeable changes in the chemical composition of clays. The content of the finely dispersed fraction in the samples of clays KR1 and KR2 increases by 24-30%, and B1 and B2 by 14-18%. When enriching the samples of clays with XD, the fineness increased several times.

After enrichment, the degree of swelling of clays KR1, KR2, B1 and XD increased from 0.91; 1.12; 0.88 and 0.92 cm^3/g up to 1.26; 1.43; 1.37 and 1.24 cm^3/g, respectively.

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