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Evaluation of Clay and Drilling Fluid Quality

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تقييم نوعية سائل وطينة الحفر

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تتناول هذه الدراسة تصميم نوموغرام يمكن إستخدامه في تقييم نوعية طينة الحفر الذي يعتمد بدورة على عامل الغرويّة ونسبة المواد الطينية النشطة كيميائياً ولزوجة سائل الحفر. كما يمكن إستخدام هذا النوموغرام في تقييم سوائل الحفر من حيث كمية المواد الصلبة المستعملة في تحضيره وتتبع عملية زيادة كثافة سائل الحفر للتأكد من أن كمية المواد الصلبة هي الكمية المثلى.

إستخدمت لغة البرمجة "C++" في تصميم النموغرام والحصول على النتائج الضرورية على هيئة رسوم توضيحية.

Abstract: *The present work is concerned with the construction of a nomogram, which can be used to evaluate the quality of clay materials. evaluation is carried out according to three parameters: Colloidity coefficient, fractional volume of active solid and mud viscosity. The constructed nomogram is also used to: Evaluate the quality of drilling fluid with respect to solid content, follow the process of increasing mud density to be sure the solid content is optimum. Design and drawing the proposed nomogram is carried out by using programming language "C ++".*

INTRODUCTION

It is well known that hydrophility of clay is the main physicochemical property that determines its suitability for drilling fluids preparation purposes. Basically, the hydrophility of clay depends upon: structure of clay minerals, specific surface area i.e. dispersion degree and Cation exchange capacity (CEC). The higher degree of dispersion, the higher CEC and the higher hydrophility, which leads to higher activity of clay particles. In order to evaluate the quality of clay and clay minerals, we should have quantitative parameter, which reflect their dispersion degree and chemical activity.

At the present time, the quality of clay is evaluated according to:

- Filtration and rheological properties of drilling fluids.
- Yield of clay.

In order to evaluate the dispersion degree of clay material quantitatively, the best method is adsorption of methylene blue (Mb). The methylene blue test measures the total exchange capacity of the clay system. CEC depends on the type and content of clay minerals present. The CEC is defined as cation-for-cation exchange between the clay building unit and a water solution, which contains the cation of greater attraction. CEC, which is reported in terms of milliequivalents (one meq = 120 ml.) of methylene blue per 100 grams of clay, is the relative ability of clays to carry exchangeable cations.

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The CEC is calculated, theoretically, as follows:

$$E = 10^5 \times \frac{S}{N \times \omega};$$

E - CEC of clay meq/100g;
S - specific surface area of clay m^2/g;
N - Avogadro's number = 6.02×10^{23}
ω - Surface area occupied by one cation of Mb = 95×10^{-20} , m^2

$$E = 0.175 * S$$

Inasmuch as specific surface area of pure montmorillonite is 800 m^2/g therefore;

$$E = 140 \text{ meq/100g}.$$

The following table shows typical CEC of different clays and drilled solids.

Table 1. CEC of various solids

Solids	Meq of Mb / 100g of solid
Montmorillonite	70 - 140*
Illite	10 - 40
Chlorite	10 - 40
Attapulgite (Sepiolite)	10 - 35
Koilinite	3 - 15
Gumbo shale	20 - 40
Sandstone	0 - 5
Shale	0 - 20

* Theoretically.

It is known from colloidal and drilling fluid chemistry that one gram of pure montmorillonite adsorbs ($59cm^3$) of methylene blue. This value ($59cm^3$), the author will consider as the standard to evaluate the relative activity of clay and drilled solids. Therefore, the quantitative parameter of clay quality will be represented by the colloidity coefficient "K". It describes the relative activity of clay and clay materials. "K" is defined as ratio of Mb adsorbed by one gram of a solid to ($59cm^3$) the amount of Mb adsorbed by one gram of pure montmorillonite;

$$K = V/59$$

K- Colloidity coefficient of tested clay.
V- Volume of Mb adsorbed by one gram of clay under consideration.

LABORATORY PROCEDURE OF Mb VOLUME DETERMINATION

In order to determine (V) the following procedure is used:

1. Prepare mud sample using clay of interest.

2. Add 1 ml of mud sample to 15 ml 3% of hydrogen peroxide and 0.5 ml of sulfuric acid. Boil gently for 3-4 minutes. After cooling dilute the mixture to 35 ml with distilled water.

3. Add Mb solution to flask. After each addition of 0.5 ml of dye, swirl the content of the flask for about 30 second and, while the solids are still suspended, remove one drop of fluid with the stirring rod and place the drop on the filter paper. The end point of the titration is reached when the dye spreads as a greenish-blue ring or tint around the spot of the dyed solids.

4. When the blue ring or tint is detected around the spot, shake the flask for additional 2 minutes and place another drop on the filter paper. If the blue ring is again evident, the endpoint has been reached, whereas if the ring does not appear, continue the addition of 0.5 ml Mb until a drop taken after shaking for 2 minutes shows the blue tint.

5. Report the "V" as volume of Mb which has been required to reach endpoint of titration.

Table 2 shows typical "K" values for different clay materials used to prepare drilling fluids in USA and (former) USSR.

Table 2. Typical "K" values

Clay material	Adsorption Mb			K = V/59
	cu. cm/g	g/g	Meq/100g	
Montehill	50	0.225	69.6	0.84
Heko	51	0.229	61.3	0.86
Bentonite	45	0.202	54.1	0.76
Cherkaski	44	0.198	52.8	0.74
Saragooski	46	0.207	55.3	0.78

Optimum Limit for "K"

The optimum limit of "K" is the practical limit, which is in turn, depended on particular downhole conditions, lithology, technical requirements and others. However the optimum range must be established. Therefore, and according to the value of "K" presented in Table 2 for most clay materials used in the mud preparation, clay with colloidity coefficient ranged between (0.7 - 0.75) is considered as good clay. Drilling fluid prepared with clay having "K" of (0.7) and greater is good with respect to:

- Rheological and filtration properties,
- Mud stability,
- Density regulation.

Calculation of Active Portion of Clay:

The fractional volume of active solids can be estimated as;

$$V1 = V / 59$$

V1- Fractional volume of active solid.

V- Volume of Mb required to reach endpoint.

The (V1) is expressed as a ratio of volume of active portion of clay to the total volume of clay i.e.

$$V1 = Vactive / Vclay$$

$$Vactive / Vclay = V / 59$$

V / 59 = K -Colloidity coefficient (by definition)

$$Vactive = K * Vclay$$

NOMOGRAM FOR QUICK EVALUATION OF CLAY AND DRILLING FLUID QUALITY

Preface:

The essential parameters for construction of nomogram are densities of clay, barite and water. Use of nomogram requires the laboratory predetermination of mud viscosity, mud density and total volume of solid. This nomogram is intended for determination of:

- Solid density,
- Volume of clay,
- Volume of barite,
- Colloidity coefficient,
- Volume of active portion of clay,
- Yield of clay. In addition, the nomogram can be used to aid the selection of optimum amount of bentonite and barite, which are added to increase the mud density.

Nomogram Construction:

The nomogram (Fig. 1)consists of three charts A, B, and C.

Data required for nomogram construction are Water, Clay and Barite densities. These charts were constructed as follows:

1 - Chart (A)

Illustrates the relationship between the mud density (Dm) solid volume (Vs) and solid density (Ds).

Each line in chart (A) represents constant solid density as a function of fractional solid volume and mud density. Solid density (For case of Vs = 30%, Vm = 1 cc and Dm = 1.5 g/cc) is obtained from the following expression:

$$Ds = (Dm * Vm - Dw * Vw) / Vs,$$

$$Ds = (1.5 * 1 + 1.03 * (1 - 0.3)) / 0.3= 2.60 \text{ g/cc}$$

If the fractional volume of solid is decreased gradually from (0.30) until zero and (Ds) held constant the first (lower) line will be obtained. This line represents constant (Ds = 2.6 g /cc) as a function of different (Vs) and (Dm).

2 - Chart (B)

Chart (B) illustrates the relation between (Ds) and (Vc). In order to construct this chart, use a suitable scale to plot (Vc) on (x) axis as a function of (Ds). As solid density increased the (Vc) is decreased toward the upper left current, where the amount of clay is zero, whereas, the fractional volume of barite is 100%.

3 - Chart (C)

The relationship between mud viscosity, yield of clay and colloidity coefficient are shown in this chart. These relationships are obtained on the basis of laboratory experiments as a function of mud solid contents.

Examples

Ex. 1. ***Determination of clay and barite volumes***, colloidity coefficient , volume of active portion of solid, and yield of clay, assuming the following initial mud parameters:

- Mud density = 1.6 g/cc,
- Mud viscosity = 40 cp, and
- Total volume of solid = 20%.
- Volume of water is = 0.8 cc of water / 1 cc of mud. or 80%.

From point of intersection (of horizontal line of 1.6 g/cc and vertical line of Vs = 20%) draw line parallel to the nearest inclined line until intersecting with right (Y) axis of chart A. Read solid density (3.88 g/cc). From this point, draw a horizontal line into chart C until intersecting with inclined line of Vs%. From point of intersection, draw downward vertical until it intersects with the horizontal line representing mud viscosity of 40 cp. Read on the lower X axis of chart B clay volume (4.9% or 0.049 cc / 1 cc of mud). On the upper X axis of chart C read the yield of clay (60 bbl of mud of 40 cp per one ton of dry clay). Colloidity coefficient is 0.955. Thus, the amount of active solid is 0.049 * 0.955 = 0.0467 cc or 4.67%.

Barite volume is; 0.2 - 0.049 = 0.151 cc of barite / 1 cc of mud.

Weight of clay is 0.049 * 2.6 = 0.1247 gm.

Weight of barite is 0.151 * 4.3 = 0.6493 gm.

Total weight of solid is 0.1274 + 0.6493 = 0.7767 gm.

Density of solid is 0.7767 / 0.2 = 3.883 g /cc., which is very close to density obtained from nomogram (3.88 g / cc), error is 1%.

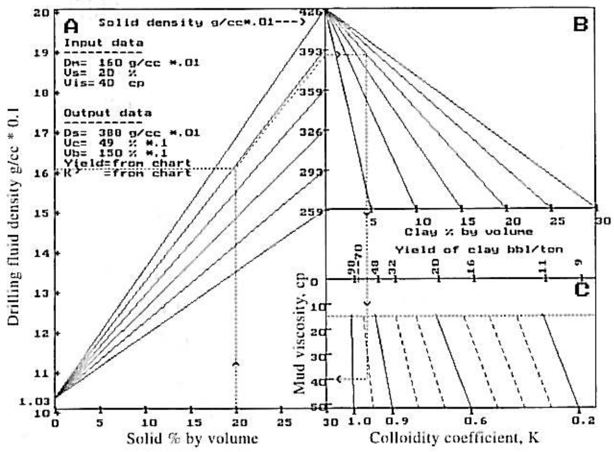

Fig. 1. Nomogram for evaluation of clay and drilling fluid quality.

Ex. 2. ***Follow the process of increasing mud density*** to be sure the solid content is optimal.

Situation:- The drilling below the intermediate casing requires an increase in the drilling fluid density from 1.6 to 1.8 g/cc. Show the optimum amount of solids required to increase the drilling fluid density.

Increase mud density usually is achieved by adding barite, but too much weighting material can cause the loss of the suspension system stability due to barite sedimentation. The final decision is dependent on field experience. However it is decided to use only barite for increasing the mud density. Let us refer to Figure 2. From this figure the following is obtained: Amount of barite is

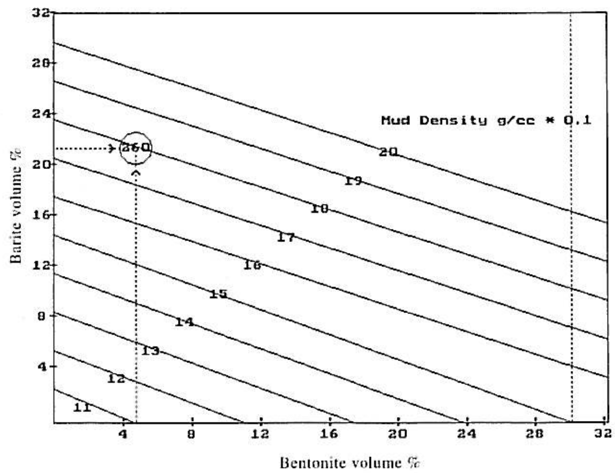

Fig. 2. Mud density as function of barite and bentonite volumes.

21.4% and amount of bentonite is still as previous i.e. 4.9%. from nomogram, the solid density is 3.963 g/cc. After viscosity measurement, the colloidity coefficient can be easily determined. Initial and final solid content are summarized in the Table 3.

Table 3. Optimum concentration of solid content

Initial mud density = 1.6 g/cc	Final mud density = 1.8 g/cc
Vsolid = 20%	Vsolid = 26.2%
Vclay = 4.9%	Vclay = 4.9%
Vbarite = 15.1%	Vbarite = 21.1%
K = 0.95	K = 0.955

CONCLUSIONS

1- A nomogram for quick evaluation of clay and drilling fluid quality has been successfully constructed.

2- Bentonite or any type of clay material having colloidity coefficient greater than 0.7 is recognized as good clay for drilling preparation purposes.

3- Drilling fluid contains any clay materials, having colloidal coefficient greater than (0.7), in range of (3.5 - 13%) is good mud with respect to the system stability and chemical additives consumption.

4- Content of clay materials greater than (13%) in the mud is not recommended because of low responsibility to chemical treatment and high consumption of dispersant. In contrary, a fractional volume of clay less than (3.5%) requires a greater quantity of filtration reducer and may result in the loss of system stability due to weighting materials sedimentation.

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