BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LXI No. 4/2009	39 - 47	Seria Tehnică

Corrosion of Drill Pipes in Contact with Drilling Mud

Mihaela Manea, Maria Georgeta Popescu, Floarea Manea

Universitatea Petrol – Gaze din Ploieşti, Bd. Bucureşti nr. 39, Ploieşti
e-mail: mmanea@upg-ploiesti.ro

Abstract

The paper presents aspects regarding the corrosive action of salty drilling fluids in contact with the metallic surfaces of the drilling equipment.
Drilling fluids are characterized from the rheological point of view. In addition, other standard properties are determined, such as density, filtrate volume and cake thickness. All these properties help to establish the stability degree of the dispersed system water – clay.
In static regime, the corrosive processes are evaluated using the gravimetric method, at temperatures of 25°C and 80°C and NaCl concentrations of 15% and 30% respectively.
Based on the experimental results, the intensity of the corrosive process, due to temperature and salt content from the drilling mud, is correlated with the main characteristics of these fluids.

Key words: *corrosion, drilling mud, NaCl contamination, temperature.*

Introduction

The activity in the drilling – exploitation industry leads, worldwide, to a great consumption of tubing material due to the aggression of the working environment.

It is estimated that, after almost 16 operative weeks in the field of oil reservoirs exploitation, the thickness of the metallic equipment decreases by 1/8 from the initial one [1].

The different composition of the fluids that come in contact with the tubing, as well as the chemical composition of the metallic compounds, determines different enhancements of the corrosive process [2].

Reservoir waters, injection waters and drilling fluids are electrolytic media rich in oxidants which, under reservoir conditions, cause serious damage to the metallic equipment [3].

Steel corrosion in contact with the reservoir waters that accompany the crude oil is a complex process, depending on various factors: the nature of the aggressive medium, the type of metal, temperature, etc. [4]. The salts dissolved in the reservoir waters, especially NaCl, intensify the corrosion processes [5].

The diversity of the drilling fluids of the last generation [6] imposes the study of aspects concerning the corrosive action of the compounds and, in addition, concerning the anticorrosive protection given by certain additives [7].

Thus, it is necessary to establish the conditions in which the destruction of the tubing material takes place, especially under the action of drilling fluids.

Experimental Data

The corrosive processes in drilling fluids were studied by gravimetric tests in static regime at 25°C and 80°C, determining mass losses of metallic samples at different immersion times.

The metallic samples were made of steel used at manufacturing the tubing material. The chemical composition of these samples was determined by the spectral method. Samples were derusted, degreased, washed with deionized water and dried with acetone.

The drilling muds were prepared [8] by dispersing, under continuous agitation, of a non-treated bentonite clay, previously pre-hydrated for 24 hours. The clay content was the one necessary to obtain a density of 1050kg/m^3 for the drilling fluid, as the clay efficaciousness is of 12 m^3, being a metha-bentonite clay.

Ulterior, equal volumes from the initially prepared drilling fluid were contaminated with NaCl in concentrations of 15%, 30% respectively. The measurements were performed on both contaminated samples and on a witness probe of natural mud.

Using the Baroid filter-press, the cumulative volume of filtrate was determined, followed by the thickness of the filter cake.

Other measurements regarding the drilling fluid properties dealt with the rheological behavior [6]. Using a PVS Brookfield rheometer connected to a software, PVS Rheovision, the experimental rheological curves were drawn and analyzed by establishing the confidence degree with the theoretical models such as the Bingham model and the Herschel Bulkley model. The rheological parameters for each model were determined. The constitutive equations for these two models are given below:

$$\tau = \tau_0 + \eta_{pl} \frac{dv}{dx} \tag{1}$$

where τ_0 – yield stress;
η_{pl} – plastic viscosity.

$$\tau = \tau_0 + k\left(\frac{dv}{dx}\right)^n \tag{2}$$

where k – consistence coefficient;
n – behavior index.

The metallic samples were immersed into the three types of drilling fluids: the witness sample, the sample with 15% salt and the sample with 30% salt, during 48 hours, 672 hours and 816 hours, respectively, at 25°C.

To evaluate the corrosive process at 80°C, the samples were immersed in the drying oven for 3 hours, 5 hours and 8 hours.

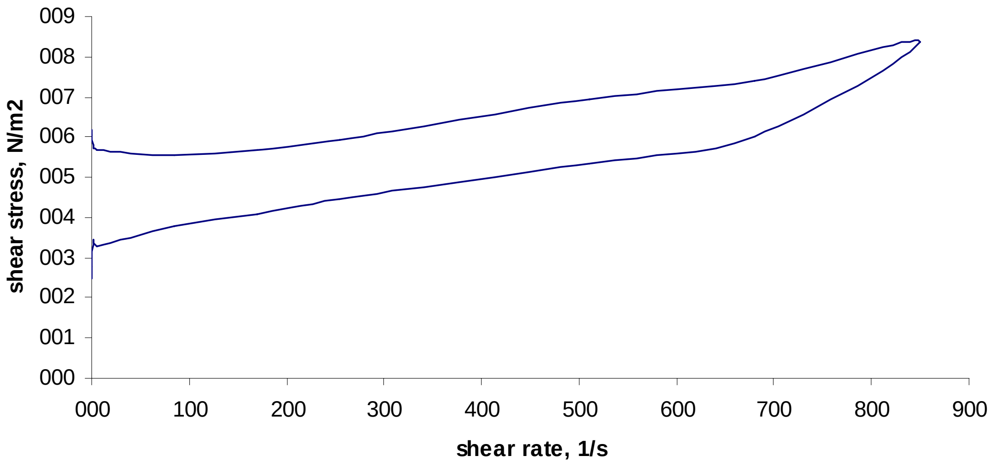
After each period of time, the metallic samples were pulled aut form the fluid medium, observed and weighted with an analytical balance type Partner WPS/C/2.

The weighting the metallic samples was done immediately after pulling out of the corrosive fluid, drying and removing the settled down layer. Thus, the amount of deposits on the metallic surface could be evaluated, as well as the weight loss due to the corrosion process.

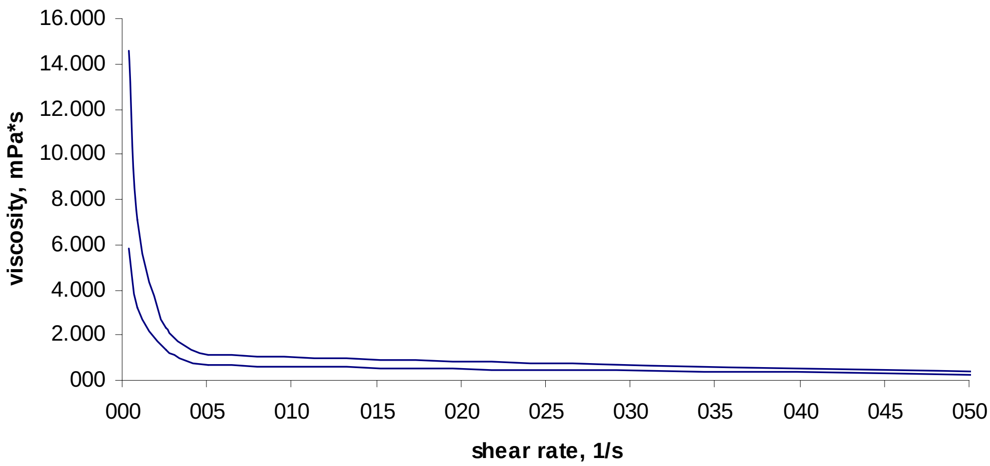
Results and Discussions

The corrosive processes occurring in drilling mud, with or without salt contaminants, are dynamic processes, being necessary a preliminary study on the rheology of the corrosive medium. This study was completed by measurements on the filtration – cake formation phenomena, giving extra information on the stability of these water – clay dispersed systems.

For the non-contaminated natural mud, the rheological curves are presented in figure 1:



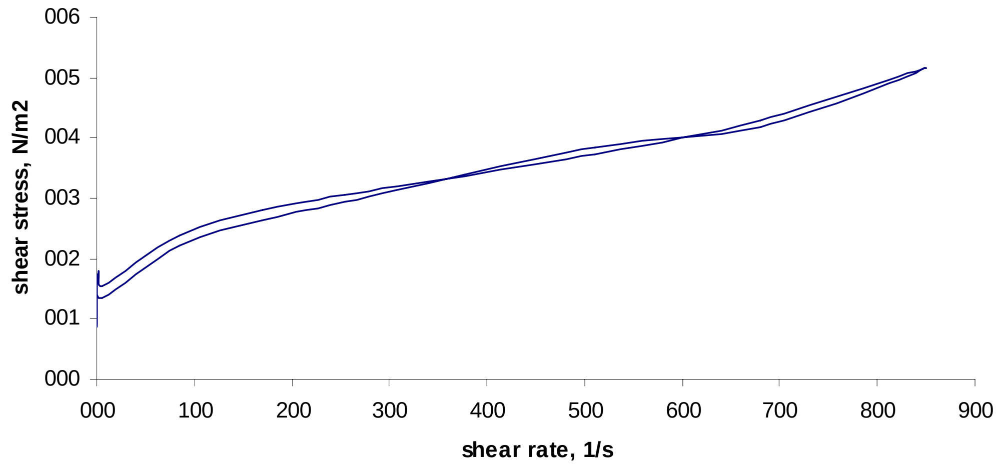
a)



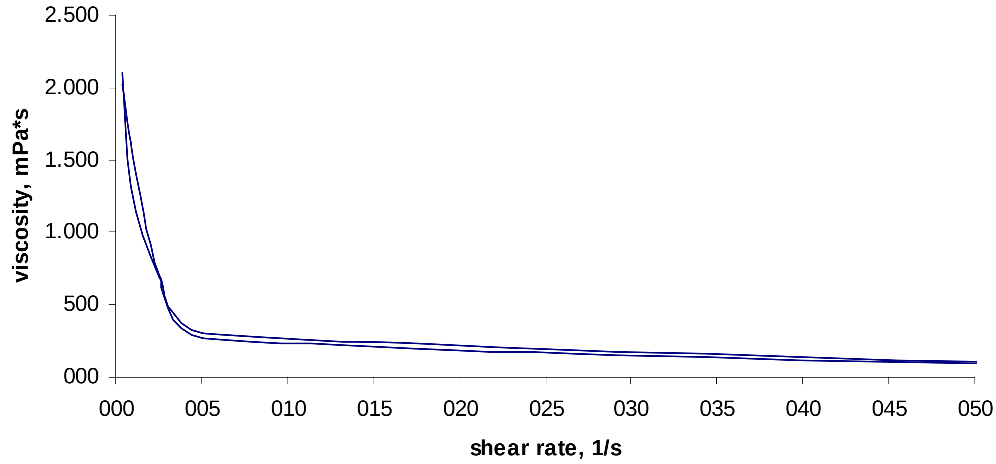
b)

Fig. 1. The rheological curves of the natural mud

The curves in figure 1 can be compared with the curves for the mud contaminated with 15% NaCl, figure 2, and with 30% NaCl, respectively, in figure 3.

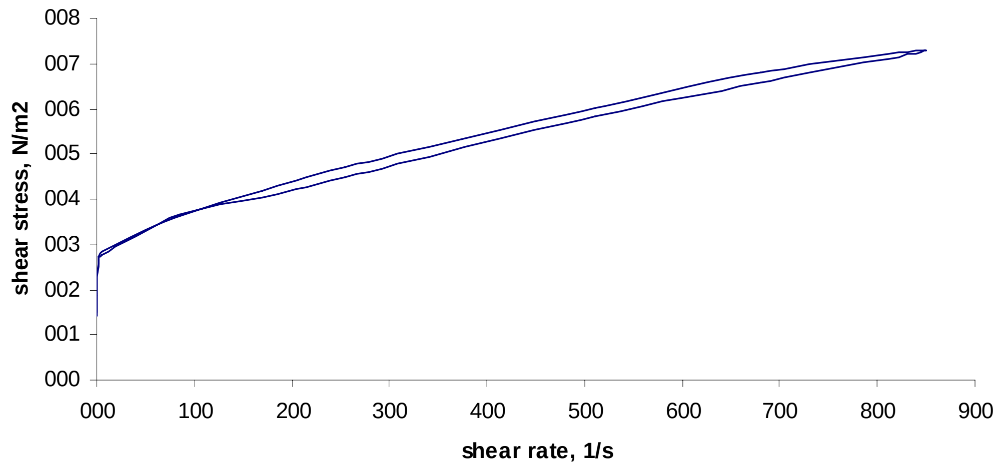


a)

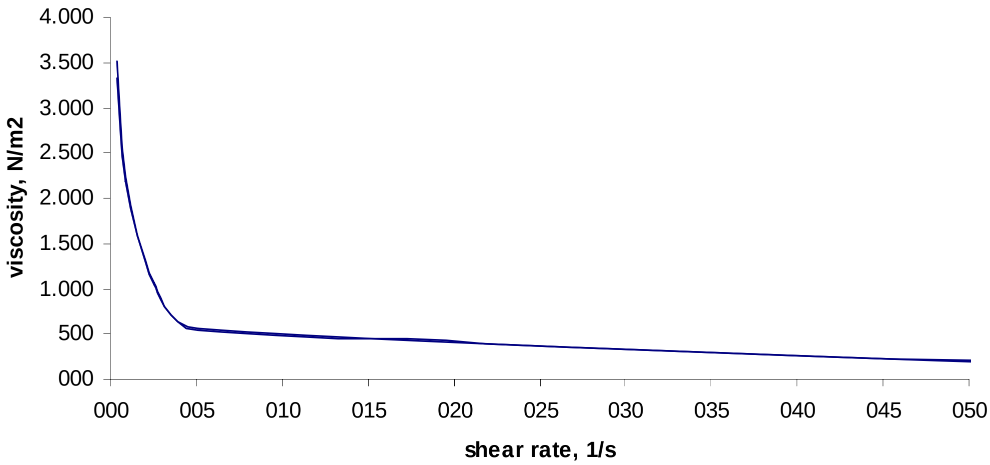


b)

Fig. 2. The rheological curves of the salty mud containing 15% NaCl



a)



b)

Fig.3. The rheological curves of the salty mud containing 30% NaCl

By adding NaCl, the thyrotrophic properties of the mud are visibly affected. The diminishing of gel formation is due exclusively to the flocculants action of the salt on the clay micelles. At saturation concentrations of salt, 30%, the flocculation process continues by further aggregation of clays colloids, thus by the volume increment of micelles and their decrease in number. The effect is an enhanced loss of gel strength and a slight increase of the viscosity, compared to the mud contaminated with 15% NaCl. The latter is due to the fact that large dispersed particles move more difficult in the continuous phase.

The rheological behavior determined experimentally is compared with theoretical rheological models: the Bingham model (eq. 1) and the Herschel-Bulkley model (eq. 2). In table 1 it is shown that the fluids contain salt have different characteristics from the drilling mud with only water and clay, the natural mud.

Table 1. The properties of the drilling muds

Fluid	Bingham Model			Herschel Bulkley Model				V_f, mL	t, mm
	Confidence Fit, %	η_{pl}	τ_0	Confidence Fit, %	k	n	τ_0		
Natural	75.6	0.38	0.44	75.4	0.01	1.54	0.45	25	3.1
15% NaCl	81.6	0.43	0.15	89.2	9.96	0.53	0.12	71	12.6
30% NaCl	82.2	0.63	0.25	89.6	18.5	0.50	0.19	70	11.1

The natural mud equally fits both theoretical models considered; while the salt contaminated mud behaves rheological, closer to the Herschel Bulkley model. The fact that, adding salt, the clay dispersive state is affected is noticed from the low values of the yield point, τ_0. In addition, the significant increase of the cumulative volume of filtrate, V_f, together with the cake thickness, *t,* indicates the coagulation the of the clay colloids.

Concerning the corrosive processes in drilling mud, a low dispersion of the clay diminishes its capacity to form protective barriers at the surface of metallic surfaces, thus favoring the corrosion.

Using spectral analysis, the percent chemical composition of the metallic samples was determined. The elements Sn, As, Zr, Ca, Se, La şi Nb are present in percentage of below 0.0003%. The results obtained show that the metallic material is, according to SRN 1084, a special non-allied steel C 10E, used at manufacturing the tubing for the oil industry.

Observations were made concerning the aspect of the metallic surface after corrosion occurred (figure 4).

a)

b)

c)

Fig. 4. The aspect of the post-corrosion metallic samples. a) corrosion in the natural mud; b) corrosion in the mud with 15% NaCl; c) corrosion in the mud with 30% NaCl.

On the surface of the metallic sample kept in the natural mud there is a consistent deposit of clay particles from the fluid, besides metallic oxidation (figure 4.a). This deposit was evaluated by weighting (tables 2, 3), and, after its removal, a uniform corrosive process was observed. On the metallic surfaces kept in fluids with addition of 15%, respectively of 30% NaCl, the corrosive process occurred in shape of plague (figure 4.b; 4.c), without the adherence of clay particles. The intensity of the corrosive processes was evaluated by the gravimetric index, K_g, and by the penetration index, P.

Table2. Corrosion kinetic parameters for C 10E steel in drilling fluids at 25˚C

Characteristics	Time, days	Fluid		
		natural	with 15% NaCl	with 30% NaCl
Deposits, g	2	0.0254	0.0220	0.0201
	28	0.0401	0.0308	0.0215
	34	0.0610	0.0411	0.0223
K_g, $g \cdot m^{-2} \cdot h^{-1}$	2	0.0740	0.0921	0.0982
	28	0.0195	0.0855	0.0881
	34	0.0145	0.0634	0.0879
P, $mm \cdot year^{-1}$	2	0.0825	0.1026	0.1094
	28	0.0217	0.0953	0.0982
	34	0.0162	0.0707	0.0979

Table3. Corrosion kinetic parameters for C 10E steel in drilling fluids at 80˚C

Characteristics	Time, days	Fluid		
		natural	with 15% NaCl	with 30% NaCl
Deposits, g	2	0.0102	0.0095	0.0091
	28	0.0159	0.0105	0.0096
	34	0.0205	0.0156	0.0120
K_g, $g \cdot m^{-2} \cdot h^{-1}$	2	0.0955	0.0999	0.1088
	28	0.0881	0.0899	0.1035
	34	0.0753	0.0889	0.0995
P, $mm \cdot year^{-1}$	2	0.1064	0.1113	0.1212
	28	0.0982	0.1002	0.1154
	34	0.0839	0.0991	0.1109

The increase of temperature determines the intensification of the corrosive process.

A very important aspect when following the corrosive process refers to the stability of the dispersed systems containing clay minerals [9]. Thus, it is confirmed that the stability of drilling fluids influence on the destructive processes on metallic surfaces.

The corrosion rate decreases in time, in all studied cases (figures 5, 6).

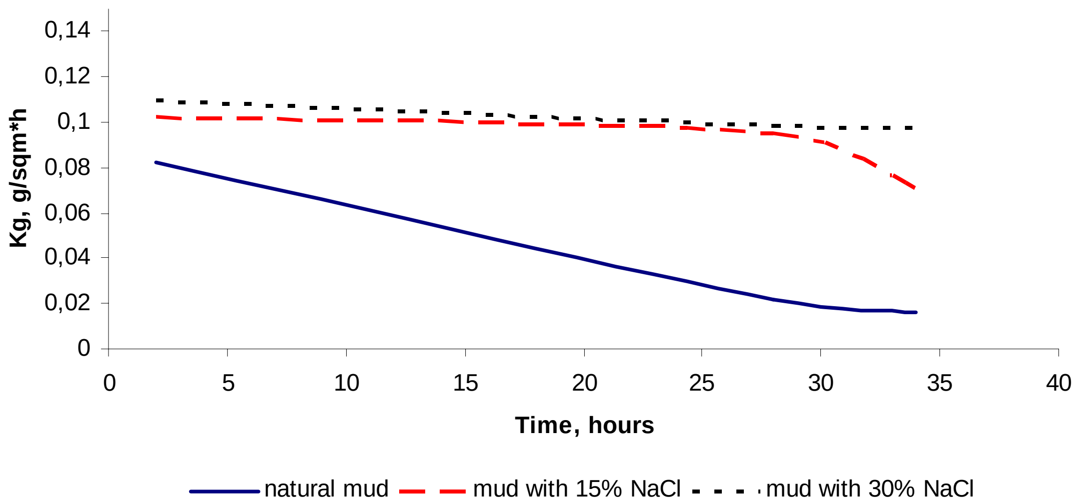


Fig.5. Corrosion rate variation for C 10E steel in drilling fluids at 25ºC

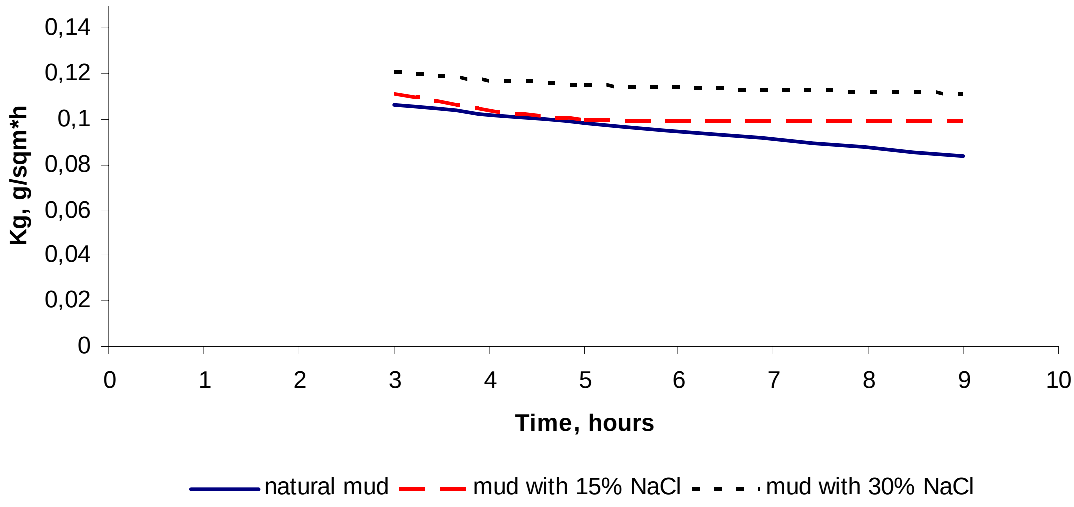


Fig.6. Corrosion rate variation for C 10E steel in drilling fluids at 80ºC

The absolute values of the corrosion rate are higher at high temperatures, 80ºC, where, in addition, the evolution profiles are uniform. The natural mud at 25ºC has the strongest tendency to brake the corrosive process in time, in the lack of salty medium and of high temperature.

Conclusions

1. The salt contamination of natural mud, water – clay dispersion, produces its loss of stability, a phenomenon manifested by change of the rheological behavior and of the filtration capacity.
2. The corrosive processes in non - salty drilling fluids containing clay minerals are slower. The adherent coating formed on the metallic surface, made up by clay particles, acts as a protective mechanical barrier against the aggressive components of the continuous medium.
3. The salty drilling fluids act aggressively on the metal surfaces that contact, directly proportional to the amount of NaCl.
4. Increasing the salt concentration in drilling fluids impedes the adsorption of clay mineral particles onto the metallic surface, favoring the corrosive process.
5. The aspect of corrosion on the metallic samples differs in the case of salty continuous medium from the natural mud medium.
6. In time, the decrease of corrosion rate is more pronounced for the natural mud because it grows the thickness of the compact film formed by the adherence of clay minerals.
7. The increase of temperature in salty drilling fluids determines an increase of the corrosion rate more enhanced than in natural mud.
8. The contamination with salt of water – clay based drilling mud determines, together with the loss of dispersion stability, an intensification of the corrosive process onto metallic surfaces.

References

1. Fontana M.G., Greene N.D. - *Corrosion Engineering,* McGraw-Hill International Book Co., 1983.
2. Manea F., Trâmbițașu E., Manea M. - Aspecte privind acțiunea corosivă a apelor de injecție asupra materialului feros folosit în industria extractivă a petrolului*, Bul. Ştiinţific, Seria C*, Vol XVIII, Baia Mare, 2003, pp. 177-182.
3. Manea F., Tudor I., Râpeanu R.G. - Acțiunea corosivă a apelor de zăcământ asupra componentelor pompelor de extracție*, Rev. de Chimie*, 56 (1), 2005, p. 103.
4. Oniciu L., Constantinescu E. - *Electrochimie şi coroziune,* Editura Didactică şi Pedagogică, Bucureşti, 1982.
5. Gasanov Y.G., Habibov I.A. - Investigation of the Mechanism of the Corrosion in the Pressure Natural Gas Condensate Wells*, Bul. U.P.G. Ploieşti*, Vol LIII, nr. 1-2, 2001.
6. Manea M. - *Contribuții privind prepararea şi utilizarea fluidelor de foraj nepoluante în industria de foraj-extracție,* Teză de doctorat, Ploieşti, 2008.
7. Cameniță I. - *Procese caracteristice de coroziune şi protecție anticorosivă în industria petrolieră,* Teză de doctorat, Bucureşti, 2008.
8. Popescu M.G. - *Fluide de foraj şi cimenturi de sondă,* Editura Universității din Ploieşti, 2004.
9. Manea F., Bădulescu R.E. - Stability *of the Dispersal Systems Based on the Clay Minerals Used in the Technology of Oil Extraction, 3rd International Conference of the Chemical Societies of the South-Eastern European Countries on „Chemistry in the New Millenium an Endless Frontier"*, 22-25 Sept. 2002, Vol II, Bucharest, Romania, p. 261.

Coroziunea prăjinilor de foraj în contact cu fluidele de foraj naturale

Rezumat

În lucrare sunt prezentate aspecte privind acțiunea corosivă a unor fluide de foraj sărate, care vin în contact cu suprafețele metalice ale echipamentelor de foraj.
Fluidele de foraj sunt caracterizate din punct de vedere al comportării reologice. Se determină, de asemenea, şi alte proprietăți standard precum densitatea, volumul cumulativ de filtrat şi grosimea turtei de colmatare. Cu ajutorul acestor proprietăți se caracterizează stabilitatea sistemului dispers apă – argilă.
Evaluarea proceselor corosive, în regim static, se face prin metoda gravimetrică, la temperaturi de 25°C şi 80°C şi la concentrații de NaCl de 15% şi 30%.
Pe baza rezultatelor obținute se corelează intensitatea procesului coroziv datorat temperaturii conținutului de sare din fluidele de foraj cu principalele caracteristici ale acestora.