# Investigation of OIL wetting agent NG-1 influence on mechanical strength of polymineral sandstones

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**Abstract.** In the article problems of influence of saturation fluid type on mechanical strength of Priobskoe oil field natural rock samples are examined. Common characteristics of the deposit are given and reasons of wide application of fracturing treatment are explained. Some factors that influence on permeability and porosity of bottomhole formation zone are shown. In particular results of studying of rock pressure influence on permeability and porosity of Priobskoe oil field natural rock samples are given. Moreover in the article results of monoaxial compression experiments of core samples that were saturated with fresh and mineralized water, hydrocarbons and water solutions of oil wetting agent NG-1 are shown.

[Gladkov P., Rogatchev M.K., Maksyutin A.V. **Investigation of OIL wetting agent NG-1 influence on mechanical strength of polymineral sandstones.** *Life Sci J* 2014;11(11s):313-316] (ISSN:1097-8135). http://www.lifesciencesite.com. 71

**Keywords:** Polymineral sandstone, mechanical strength, surface effect, oil wetting agent, rock pressure, permeability, porosity

## Introduction

Main oil reserves of Tyumen region oil fields are confined to productive horizons of Jurassic, Achim and Neocomian complexes. The richest area is Sredneobskaya, multi-layer deposits of which have large oil productive areas and wide water-oil zones. In the given oil fields, reservoirs of the majority of pay horizons are composed of polymineral sandstones containing a significant amount of bound water, up to 30-60% [1].

In spite of the large amounts of hydrocarbon reserves, development of these deposits is complicated by the influence of adverse geological factors, among them the low permeability of reservoirs, increased clay content and the presence of zones of full lithological substitution.

In these conditions should be applied methods of stimulation, which could significantly improve well inflow conditions. For concerned region the most common method is the hydraulic fracturing, without which it is often impossible even the exploitation of oil wells. Specifically, on the south license area of the Priobskoe oil field, technological development plan provides fracturing in the construction cycle of production and injection wells.

Productivity of an individual well is determined by several factors, the key of which is the condition of bottomhole formation zone. Changing of condition of bottomhole formation zone begins with the phase of well construction, the cause of which is changing in the stress-strain state of the rock mass. During drilling the rock is replaced by drilling fluid, pressure of which is not equivalent to a pre-existing rock pressure and always is significantly below it. Existing violation of rock mechanical integrity leads to redistribution of stresses inside and on the surface of rock. Thermal stresses caused by rock temperature changing upon drilling fluid influence, as well as stresses due to osmotic redistribution of pressure in the pores are added. All these factors lead to alteration in capacity and filtration characteristics of reservoir in the bottomhole formation zone [2, 3].

## Materials and methods

In order to illustrate the impact of rock pressure change because of mass unloading when well drilling the researches of rock pressures impact on an absolute porosity and permeability were conducted. The researches were carried out in the Laboratory of Production Enhancement in Saint-Petersburg state mining university at automated permeameter-porosimeter AP-608 (Coretest Systems Corporation) using natural cores of $AS_{10}$ and $AS_{12}$ pay zones - basic exploitation targets of Priobskoe oil field.

Figure 1 shows the curves of relative changes in permeability and porosity of rock samples during changing of rock pressure. The initial values of permeability and porosity were considered at 3.4 MPa, and then current relative values for a given rock pressure were calculated.

As it seen from the curves shown in Figure 1, rock pressure has a significant influence on the permeability of the rock, while the porosity remains almost unchanged. For low permeability rocks, this phenomenon is determined by the fact that with a large number of pores in a matrix they have very small size, and therefore even a slight change in pore volume leads to collapse of previously permeable channels and deterioration of rock sample permeability.

Due to occurrence of these complications during drilling and development of low permeability reservoirs fracturing becomes the most effective method of stimulation. However, this method is one of the most expensive and complex among enhanced oil recovery methods, so optimizing labor costs during its implementation seems relevant and promising task. So in the paper appliance of the oil wetting agent NG-1 in the geological conditions in order to reduce treated interval rock strength is shown.

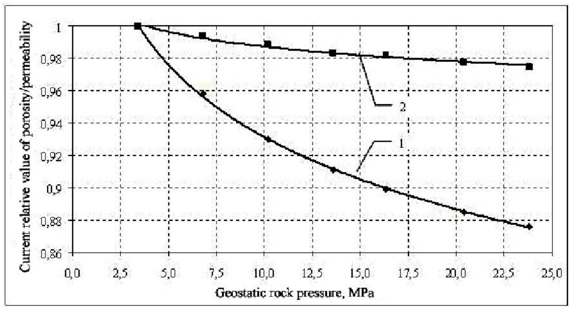


**Figure 1. Curves of relative change of permeability (curve 1) and porosity (curve 2) at different rock pressure values**

Oil wetting agent NG-1 is a mixture of triethanolamine reaction product with tall oil fatty acids or with high boiling fractions of synthetic fatty acids with solvents and additives.

As the process fluid being used before fracturing it is proposed to use aqueous solutions of oil wetting agent NG-1 with reactant mass concentration of 0.15% to 1%. This composition is easy to prepare, thermally stable, contributes to keep initial reservoir oil permeability and also acts as a corrosion inhibitor.

From literature sources it is known that various surfactants are usually added to drilling fluids during drilling to reduce rock strength and to facilitate its breaking. In the paper [4] P.A. Rebinder surface effect is indicated, which consists in strength reduction of inorganic dielectric (rock) in the presence of a fluid in consequence of relaxation of electric charges through the liquid, which penetrates into a cavity of opening mode crack.

To identify the effect of strength reducing of Priobskoe oil field rock samples saturated with solutions of water-repellent NG-1 in different concentrations, a set of researches consisted in determining core strength at uniaxial compression was carried out.

Before starting the experiment, the samples were drilled from natural cores, then they were trimmed and polished. Further the cores were prepared to research - extracted with alcohol-benzene mixture and dried at temperature of 105 ºC. Geometric parameters of cores were measured with a caliper, gas porosity value were determined on an automated porosimeter permeameter-AP-608 (Coretest Systems Corporation). Further core saturation with liquid took place (vacuumizing method). As the dispersion medium for surfactants a fresh water was used.

Determination of Priobskoe oil field reservoir samples strength was performed by uniaxial compression with flat plates in accordance to GOST 21153.2-84 "Rocks. Methods for determination of ultimate strength under uniaxial compression" [5]. The essence of the method consists in measuring the maximum destructive pressure applied to flat ends of regular cylindrical sample via flat steel plates.

Number and distribution of interstices in sample matrix has the greatest influence on core strength [6]. However, to obtain reliable and reproducible results, a certain number of samples with the same geometry and filtration-capacity parameters should be chosen. Make that is rather difficult, so experimentally obtained approximation dependence of strength of rock saturated with a model of reservoir water, on the porosity was used when interpreting the results of studies. This dependence is shown in Figure 2 as a graph, where each point corresponds to one experiment.

Strength values of rock samples saturated with other fluids were obtained based on studies of 30 cores - 3 samples for each saturating fluid.

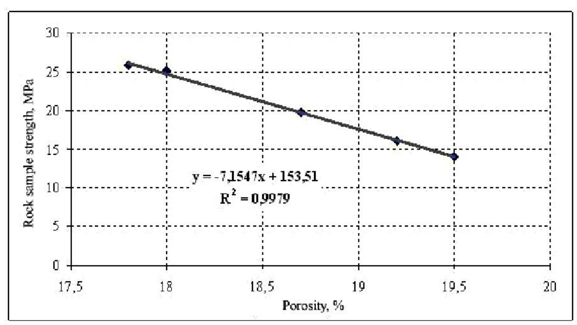


**Figure 2. Dependence of strength of rock sample saturated with the model of reservoir water on absolute porosity**

As a result of conducted experiments absolute values of uniaxial compression strength for each sample were obtained, but comparing of strength of cores saturated with liquid (oil wetting agent NG-1 aqueous solution, oil, diesel, fresh water) with strength of the same samples saturated with model of reservoir water is of more interest. This parameter allows to make an assessment of changes in the sample strength during replacing the mineralized water by another saturation liquid. The experiment results are shown in tabular style in Table 1 and in graphic style in Figure 3.

**Table 1. Relative strength of cores saturated with various fluids (to mineralized water)**

| Saturating fluid | Fresh water | Diesel | Priobskoe oil field degassed oil |
|---|---|---|---|
| Relative strength index | 1,21 | 1,29 | 1,42 |

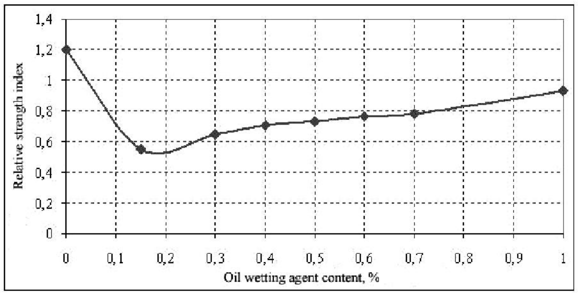


**Figure 3. Dependence of relative strength indexes of rock samples on oil wetting agent NG-1 content**

**Results and discussion**

As it seen from the presented data (Table 1), the maximum rock strength is achieved when it is saturated with oil, in this case the strength of the test samples is 1.42 times higher than strength of the sample saturated with mineralized water. Saturation with oil wetting agent aqueous solutions conversely leads to a significant decrease in strength of the samples, the average decrease is 30-40% (Figure 3).

The main causes of the obtained regularities consist in the mechanism of deformation release and in the decrease in rock strength. According to the paper [7, 8, 9] the essence of this mechanism is the formation of the double layer of molecules (adsorption and diffusion) on the surface of pores and microcracks in the presence of an electrolyte (oil wetting agent solutions, water, oil, etc.).

In the paper [10] it is indicated that the saturation of Priobskoe oil field cores with fresh water is accompanied by an increase in the size of the diffusion layer, spreading it in volume and involving large number of water molecules in it. Consequence of this process is an increase in electrokinetic potential and intermolecular forces within a microcrack and bond of it. The results of the studies confirm this position because the cores saturated with fresh water possess greater strength than the cores saturated with mineralized water.

The cause of high strength of rocks saturated with hydrocarbon phase is probably a greater thickness of a diffusion layer which is formed by molecules of the oil or diesel.

Considering the influence of oil wetting agent NG-1 on core strength it should be noted that this surfactant can significantly alter the molecular bond of solid body surface with the surrounding fluid due to particular orientation of their molecules in the adsorption layer. As a result a very thin shell of a diffusion layer on the rock surface is formed, which leads to a reduction in electrokinetic potential - the rock strength is reduced (with a typical concentration of oil wetting agent NG-1 of 0.15% by mass). Further increase of the surfactant concentration over 0.15% leads to a thickening of the diffusion layer because of own oil wetting agent`s molecules and as a consequence to an increase in the rock strength.

In general, the mechanism of rock strength reduction when rock is exposed to a surfactant results in three basic provisions [7]:

1. Screening of the adhesion forces acting between the opposed surfaces of primordial microcracks due to intermediate layers formed by adsorption layers.

2. Active spreading action of adsorption intermediate layers in all those areas of most narrow veed cracks where these layers can penetrate.

3. Impediment or retardation of closing of primordial microcracks zones under the influence of adsorption layers and solvation liquid films after relieving of external forces. In this case, the surfactant molecules act as a sort of "proppant" restraining natural microcrack rebonding.

In summary, the presence of P.A.Rebinder skin effect in cores saturated with solution of water-repellent NG-1 is experimentally confirmed. Using of the identified property in hydraulic fracturing in the field with polymineral low permeability reservoirs is associated with reduction of required fracturing pressure, which at the moment of fracture initiation is particularly high. According to paper [11,12] fracturing pressure of reservoir is determined by geological parameters, but the possibility of its creation depends on technical parameters of the well - casing durability and state of a wellhead. Reducing of rock strength will result in decreasing of generated wellhead pressure, enhancement of hydraulic fracturing technological efficiency and in overall reduction of consumed energy.

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7/4/2014