Improvement of Hydraulic Facing Technology by Modeling Permeability Formed Cracks for Specific Mining and Geologica

A S Arutyunyan¹, E O Petrushin², L G Kusova³
¹Associate professor of applied mathematicians department
Kuban state technological university,
Moskovskaja street, 2, Krasnodar, 350072, Russia
²Deputy head of oil and gas trade JSC «Pechoraneft»
Mira street, 6, Usinsk, Komi Republic, 169711, Russia
³Student
St Petersburg Mining University
2, 21st Line, St Petersburg, 199106, Russia

E-mail: mereniya@mail.ru

Abstract. The article describes the improvement of hydraulic fracturing technology by modeling the permeability of the formed fractures for specific mining and geological conditions. The description of the main indicators of the properties of the propping material for hydraulic fracturing is given. To prevent undesirable consequences when using various proppants in a number of Russian fields, testing was carried out for the proppant compliance with the ANI RP-56 standard, the results of which are shown in the article. Shown that it can be seen that the type of proppant and its physicochemical characteristics significantly affect the permeability of the hydraulic fracture. Therefore, only after conducting studies to assess the permeability in conditions close to reservoir conditions in the well, it is possible to select the type of proppant for hydraulic fracturing, potentially the most effective for specific mining and geological conditions. Concluded that the correct choice of proppant material for hydraulic fracturing minimizes the percentage of the probability of fracture of the proppant grains in the hydraulic fracture, as well as the removal of proppant grains into the wellbore, which ultimately has a positive effect on the well operation during development and operation in design mode.

1. Introduction
In connection with the commissioning of low-permeability and marginal oil and gas reservoirs in the oil and gas fields of Russia, the method of hydraulic fracturing of productive formations is most widely used for stimulating oil and gas production.

This can be clearly seen in the fields of Western Siberia, where over 1200 hydraulic fracturing operations have been performed over the past 5 years. Moreover, during this period of time, the same number of new wells were drilled. It should be noted that the highest efficiency of oil production intensification was obtained in horizontal wells and in sidetracks. Currently, about 50% of daily oil production falls on wells treated using hydraulic fracturing technology.
One of the most important issues of hydraulic fracturing is fixing the created fracture with an appropriate granular material to ensure increased reservoir productivity and fracture permeability for a long time. Currently, the most widely used proppant material is strong and rounded quartz sand or artificial proppant.

2. Theoretical part
Requirements for propping material for hydraulic fracturing are primarily determined by the mining and geological conditions of the productive sections of specific fields.

First of all, the proppant must reliably maintain the hydraulic fracture in the open state and maintain its permeability to formation fluids, while it is especially important to use proppant of calibrated particle size distribution to ensure the required permeability. Oversized proppant particles can infiltrate and become clogged with smaller particles from the reservoir during production.

There can be a significant difference in the size of the pore channels between the proppant particles of different grain shapes (round and non-round). For example, with cubic packing of rounded proppant grains, the pore diameter can be 0.41 times the diameter of the proppant grains, whereas with the hexagonal (densest) packing of non-rounded proppant grains, the pore diameter is only 0.15 times the diameter of the proppant grains. It follows from this that the filtration area for cubic packing of grains is 2.7 times larger than for hexagonal packing. The most permeable cubic proppant packing is achieved through the use of more rounded and spherical proppant grains.

The risk of creating a low-permeability packing of proppants in a hydraulic fracture from materials with low skeletal strength can significantly affect the final productivity of the well.

Therefore, when preparing a proppant for hydraulic fracturing, it is necessary to check the fracture strength of the proppant grains when creating a pressure equal to the rock pressure, which is characterized by the percentage of destroyed particles.

The degree of solubility in acid is necessarily used as an indicator of the volume of impurities of carbonates, feldspar and iron oxides present in the proppant. Solubility in acid must be controlled so that voids do not form in the proppant pack along the hydraulic fracture during acidizing of the bottomhole formation zone.

Specialists of the American Petroleum Institute (API) have developed technical requirements and test methods for proppants for hydraulic fracturing in the API RP-56 standard, where the main indicators of the proppant quality are established (grain size distribution, roundness and sphericity of grains, solubility in clay acid, salt and clay content, strength under uniaxial compression), and the level of these indicators is also determined.

The main indicators of the properties of the proppant for hydraulic fracturing include the following:

- particle size distribution - is determined by sieve analysis and ensures that the proppant meets the requirements of hydraulic fracturing efficiency;
- sphericity and roundness of the proppant grains - affects the packing density in the hydraulic fracture and its permeability to formation fluids;
- strength of the proppant grains under uniaxial compression – characterizes the resistance of the proppant to the hydraulic fracture closure pressure and determines the skeletal fracture strength of the proppant;
- solubility of the proppant in acid – determines the content of quartz impurities or the mineral composition of the proppant.

The use of proppants with parameters that do not meet the API RP-56 technical requirements may cause undesirable consequences after fracturing. In this case, the grains of the proppant begin to break up, the stability of the structure is disturbed, and the reverse removal of the destroyed proppant into the wellbore begins. With the reverse removal of proppant material during production, negative phenomena arise:

- local loss of fracture conductivity occurs, causing a decrease in hydraulic fracturing efficiency;
- possible abrasive wear of tubing, wellhead equipment, valves and flow lines;
- there is a significant decrease in well productivity.
3. Practical value and results
To prevent undesirable consequences when using various proppants in a number of Russian fields, testing was carried out for the proppant compliance with the ANI RP-56 standard, the results of which are shown in the table.

Table 1. Results of experimental studies of various proppants for hydraulic fracturing.

| Indicators quality                  | Indicator values according to ANI RP-56 | Kazan standard sand (Russia) | Volgograd sand (Russia) | North White sand (USA) | Proppant (USA) |
|------------------------------------|----------------------------------------|------------------------------|-------------------------|------------------------|----------------|
| Fractional composition, mm         | 0.4-0.8                                 | 0.4-0.8                      | 0.4-0.8                 | 0.4-0.8                | 0.4-0.8        |
| Main fraction content, % wt.       | not less 90                             | 96                           | 83                      | 92                     | 97             |
| Solubility in acid, % wt.          | no more 3 at 12 % HCl                    | 0.3 at 12 % HCl              | 0.8 at 12 % HCl         | 0.6 at 12 % HCl        | 4.0 at 3 % HF + 12 % HCl |
| Sphericity, scale units            | 0.6                                     | 0.7                          | 0.5                     | 0.8                    | 0.8            |
| Roundness, scale units             | 0.6                                     | 0.8                          | 0.5                     | 0.8                    | 0.8            |
| Resistance to hydraulic fracture closure, % of destroyed particles, % of pressure of hydraulic fracture closure | no more 14 when compressed 28 MPa | 10 at 28 MPa | 16 at 28 MPa | 4 at 28 MPa | 3 at 52 MPa |
| API Compliance                     | match                                   | not match                    | match                   | match                  | match          |

It should be noted that the API RP-56 standard does not take into account the magnitude of the fluid pressure drop in the hydraulic fracture, as well as the fluid viscosity at reservoir temperature and does not reflect the physical processes occurring in the hydraulic fracture of a real productive oil and gas reservoir. A characteristic of the formation of a highly conductive packing of a fixer in a hydraulic fracture at a certain temperature and pressure is permeability to formation fluids – a generalizing indicator of the quality of the proppant.

The figure shows the graphs of the dependences of the proppant packing permeability in the hydraulic fracture (Darcy) on the hydraulic fracture closure pressure (MPa) to compare the type of proppant of one fraction (0.8-0.4 mm) using the example of proppant (USA), Northern White sand (USA), Kazan sand (Russia) and Volgograd sand (Russia). The permeability of the hydraulic fracture was determined using a device designed by JSC NPO Burenie, which simulates a hydraulic fracture.
Figure 1. Influence of proppant type for permeability in the formation fracture after hydraulic fracturing.

From the graphs shown in the figure, it can be seen that the type of proppant and its physicochemical characteristics significantly affect the permeability of the hydraulic fracture. Therefore, only after conducting studies to assess the permeability in conditions close to reservoir conditions in the well, it is possible to select the type of proppant for hydraulic fracturing, potentially the most effective for specific mining and geological conditions. It should be stated that the correct choice of proppant material for hydraulic fracturing minimizes the percentage of the probability of fracture of the proppant grains in the hydraulic fracture, as well as the removal of proppant grains into the wellbore, which ultimately has a positive effect on the well operation during development and operation in design mode.

4. Conclusions
The results of the studies and experiments performed allow us to draw the following conclusions:

1. Depending on the mining and geological conditions of hydraulic fracturing, it is necessary to carry out a set of studies to assess the effectiveness of proppants for hydraulic fracturing for any industrially produced fractions (8/16, 12/20, 16/30, 20/40, 40/70 mesh.) proppant materials.

2. After evaluating and comparing the proppant parameters with the parameters of the API RP-56 standard, it is necessary to check the proppant performance in reservoir conditions on a rig simulating a hydraulic fracture under the influence of rock pressure and temperature in reservoir conditions.

3. Based on the results of experimental studies, a generalizing indicator of the quality of the proppant is calculated - the permeability for formation fluids in the hydraulic fracture.

4. Issuance of recommendations on the choice of the type of proppant for hydraulic fracturing (sand, proppant, etc.) and its fractional composition for the mining and geological conditions of hydraulic fracturing in various fields.

5. The complex of investigations of the proppant material serves as a guarantee of long-term and efficient operation of wells after hydraulic fracturing.

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