Development of a hydraulic classifier used to obtain various sand fractions

A E Verisokin¹, A P Yanukyan² and P M Sorokin²

¹ North Caucasian Federal University, Institute of Oil and Gas, 1, Pushkin Str., Stavropol, 355009, Russia
² Tyumen industrial University, 49/3, Republiki Str., Tyumen, 625000, Russia

E-mail: verisokin.aleksandr@mail.ru

Abstract. The principle of crack filler selection depending on the crack depth and closing stress is presented. The study of existing classifiers and proposed a more effective device for sand sieving. The main elements of the classifier are presented and the principle of its operation is described.

1. Introduction

Due to the increase in the proportion of oil reserves in low-permeability reservoirs with adverse physical and geological conditions its extraction requires the use of new technologies, materials and techniques [1]. One effective way of increasing the production of oil from low permeable collectors is hydraulic fracturing [2]. To carry out efficient fracturing under low-permeability reservoirs, permeability less than 0.01 μm is necessary to create the greatest possible extent of cracks to expand the field of drainage wells by increasing the mass of injected proppant material.

2. Materials and methods

As a granular proppant, sand or ceramic proppant is often used. The proppant has high strength, sphericity and roundness, conductivity and permeability. In turn, sand is much cheaper. The analysis showed that a well calibrated sand may be used during hydraulic fracturing at a depth of 3000 m, where the compression stress does not exceed 40 MPa. If sand is ground, it can withstand closure pressures of up to 55 MPa. Such a natural crack filler is called "super sand". Based on numerous studies, the principle of choosing a filler of a crack was developed, which is presented in Figure 1.

The main advantage of sand is its low cost. Russian oil companies have used ceramic proppant even at shallow depths where white sand can be used. This leads to a rise in the cost of the process of hydraulic fracturing. In our country, there are grades of sand of various roundedness and strength. To study the conductivity of sand of different fractional composition allows the installation presented in [3]. To conduct research on a test bench, it is necessary to break the sand into fractions of 0.2 - 0.4 mm, 0.4 - 0.8 mm, 0.7 - 1.2 mm, 0.8 - 1.6 mm. To develop an effective classifier, existing devices were investigated and their shortcomings revealed.
3. Research results

The characteristics of a stationary hydraulic classifier have been studied, which has the following disadvantages: high metal consumption, complexity in manufacturing and installation [4].

A centrifugal hydraulic classifier was studied, consisting of a cylindrical body turning into a conical one with inlet and drain pipes, which does not allow obtaining sand of the exact fraction [5]:

- it is possible to obtain only a large fraction with the discharge of the remaining part into the drain, which reduces the efficiency of the process;
- it is necessary to measure the flow rate to the feeding rate of the condensed liquid through the bottom and the drain pipes to maintain the optimum water level inside the housing and ensure the continuity of the process.

Known hydraulic classifier cone, consisting of a housing tube for supplying the initial mass, a nozzle for discharging fine product and a pipe for discharging condensed product [5]. The disadvantages of the design include the following:

- classification of granular material occurs only for one fraction, which is impractical because in some cases smaller fractions are also used, for example, in the oil and gas industry for installing gravel filters or for hydraulic fracturing.

The analysis of the hydraulic classifier of fine-grained materials, reveals the following disadvantage [5]:

- the presence of two independent streams supplied to different chambers causes uncertainty in the operation of the device.

A more advanced device for the hydraulic classification of fine-grained materials was developed, which is illustrated in the figure. 2 [5].

![Figure 1. The principle of selecting the type of proppants](image)
The device consists of a loading hopper 1, on the bottom of which a water supply pipe 2 is installed, connected through a valve 3 with a supply pipe 4. A drain 5 is additionally connected to the inlet pipe 2 with a nozzle 6 extending into the cavity of the loading hopper 1, which is connected to the housing 7. At the lower end constriction is provided, at the bottom 8. In the constriction, there is a classification chamber 9 with a window 10, inside which a receiving and separating chamber 11 with a flange 12 is mounted, extending at the bottom 13 in the classification chamber 9 and exiting into the cavity of the feed hopper 1. The inlet pipe 2 of the water supply is equipped with a jet nozzle 14, which extends into the axial channel of the receiving and separation chamber 11. Axially symmetrically to the casing 7, an enrichment chamber 15 is installed, covering with a gap the upper end of the classification chamber 9 and provided with a cut-out 16. A flange 17 is mounted on the outside of the enrichment chamber 15 for connection with the counter flange 18 of the casing 7. The annular gap between the housing 7 and the enrichment chamber 15 is closed by the seal 19. The enrichment chamber 15 is equipped with a discharge pipe 20. The housing 7 is equipped with a soil collector 21 for the middle fraction, the cavity of which through the cut-out 16 in the body of the enrichment chamber 15 is connected with its axial channel. Below is a soil collector 22 for a large fraction, the axial channel of which through the window 10 in the classification chamber 9 is constantly connected with its axial channel. The design of the device provides for the possibility of the sequential dismantling of enrichment 15, reception and separation 11 and classification 9 chambers. The inner diameter of the axial channel of the receiving and separating chamber 11 is consistent with the flow rate of the supplied water and the known diametrical sizes of the grains of sand. The inner diameter of the axial channel of the classification chamber 9 is designed with a prerequisite for lifting average particle sand fraction which is discharged through the cut-out 16 into the soil collector 21. The diameter of the axial channel of the enrichment chamber 15 is selected from the condition of maintaining the speed of the upward flow, sufficient to transport small fractions to the outlet pipe 20.

Figure 2. Device for hydraulic classification of fine-grained material
Apparatus for fractional sieving and hydraulic classification of fine-grained materials is as follows. Open the valve 3 to supply water to the cavity of the device. Sand is fed into the loading hopper 1 with a different fraction and a stream of water flowing from the bubbler nozzle 6 into the cavity of the loading hopper 1, a pulp is created which enters the axial channel of the receiving and separation chamber 11 through the annular gap between its walls and the body of the jet nozzle 14. The pulp through this annular gap enters the axial channel of the receiving and separation chamber 11 and is transported upward at a certain upward flow rate. The upstream velocity should prevent large fractions from settling down. The pulp stream leaves the axial channel of the receiving and separation chamber 11 into the axial channel of the classification chamber 9, having a larger diameter. Particles of coarse sand come out of the pulp stream and through the window 10 enter the soil collector 22. Then the pulp stream, freed from the coarse fraction, moves into the axial channel of the enrichment chamber 15 with a decrease in the flow rate. Particles of sand of medium fraction through the cut-out 16 in the body of the enrichment chamber 15 fall into the soil collector 21, where they accumulate. The depleted pulp stream, having a fine fraction, enters the outlet pipe 20 through the axial channel of the enrichment chamber 15. The upward flow rate must be sufficient to move all the small particles to be discharged to the fine fraction dump. The sand of different fractional composition is supplied to the loading hopper 1 periodically in separate portions as it is fed for sorting into the receiving and separation chamber 11. When filling the soil collectors 21 and 22 with medium and large fractions of sand, the sorting process is stopped by closing the valve 3, the water is drained from the device through crane in the housing 7 (not shown in the figure). The soil collector 21 is opened sequentially and the middle fraction is removed, then the soil collector 22 is opened and a large fraction of sand is taken. Close the lids on the soil collectors 21 and 22 and repeat the sorting process by analogy with the previously described [9].

The overall dimensions of soil collectors 21 and 22 make it possible to obtain medium and large fractions in a volume of about 0.5 - 0.7 tons of each of them in one cycle.

4. Conclusion
Using the proposed classifier will provide advantages over existing analogues:
- the ability to provide a technological process with sieving sand into several fractions;
- the ability to obtain fractions of various sizes depending on the fractional composition of the initial product by increasing or decreasing the flow of water;
- the possibility of replacing worn-out cells with new ones;
- the possibility of switching to sieving sand of various fractional composition by changing the diameters of the chambers and changing the flow rate of the supplied water.

References
[1] Zakirov A, Fadeev A, Gabidullin Sh, Cherepanov D, Petrov A, Zotov A, Arzhevitin D and Garifullin R 2019 New fluid for hydraulic fracturing in complicated geological conditions Oil industry 1 58 - 60
[2] Shipilov A, Babkina N, Menshikov I 2018 Study of the properties of a process fluid for hydraulic fracturing based on a viscoelastic surfactant Oil industry 3 30 - 33
[3] Verisokin A 2018 The proppant test procedure for hydraulic fracturing Science and Technology in the gas industry 2 62-69
[4] Kupavikh K S, Nutskova M V 2016 Ecological features of oil well repair at low - permeability reservoir. International Journal of Applied Engineering Research
[5] Verisokin A, Petrenko V, Varyagov S and Fedorova N 2019 Development of a hydraulic classifier used to obtain various sand fractions Science and Technology in the gas industry 4 66-70
[6] Verisokin A, Vasil’yev V and Gun’kina T 2019 Packer design research used in hydraulic fracturing IOP Conf. Series: Earth and Environmental Science 378 7