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Article

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DESIGN OF THE INTENSIFICATION METHOD WITH THE HELP OF FRACCADE SOFTWARE

The object of research in the work is the FracCADE software, with which it is possible to simulate the process of hydraulic fracturing and well field, on which the intensification method is designed. This hydraulic fracturing simulator was developed by Schlumberger Ltd. based on proven physical principles of hydraulic fracturing to optimize the treatment process and proven in practice. The system includes a range of hydraulic fracturing models, from 2D models to extensive 3D simulations with lateral communication. It includes a number of complementary modules for fracturing fluid and proppant optimization, injection scheduling, real-time monitoring, pressure equalization, production forecasting and economic evaluation. Some models allow simulating the geometry of the fracture, solving proppant concentration problems, and simulating possible shielding due to proppant covering the fracture or the dehydration process.

Hydraulic fracturing remains one of the main engineering tools for increasing the productivity of wells. The effect is achieved due to:

– creation of a conductive channel (fracture) through the damaged (contaminated) zone around the well, in order to penetrate beyond its boundaries;

– spreading of the channel (fracture) in the formation to a considerable depth in order to further increase the productivity of the well;

– creation of a channel (fracture), which would allow changing, influencing the fluid flow in the formation.

In the latter case, fracturing really becomes an effective tool that allows to manage the operation of the reservoir (in particular, change its filtering characteristics) and implement long-term strategic development programs. The concept of hydraulic fracturing is quite simple. In general, for relatively simple geology, the physical foundations of fracturing theory are fairly well developed and tested. For the most part, the difficulties boil down to two problems: the real geological conditions and the complex multidisciplinary nature of the fracturing process itself.

The process of designing fracturing in order to achieve a certain result is closely related to rock mechanics (which affects the geometric parameters of the fracture), fluid hydromechanics (in which the tasks of controlling the flow of the working fluid and placing the proppant in the fracture are solved) and chemistry, which determines the behavior of materials, which are used during hydraulic fracturing. Moreover, the hydraulic fracturing project must take into account the physical limitations imposed by the specifics of the real deposit and well. In addition, to achieve the desired results, the fracturing operation must be carried out in strict accordance with the calculations (that is, a complete cycle in which each operation plays its role).

Keywords: *FracCADE, hydraulic fracturing, fracture, permeability, proppant, viscosity, well, productive horizon.*

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1. Introduction

The oil and gas industry, as the most important component of the fuel and energy complex, plays a significant role in the development of the economy and the preservation of energy independence of the state. Therefore, the main goal of oil and gas production enterprises and companies is to maintain existing production and even increase it [1]. This can be achieved by:

– wells that are in operation (due to the increase in efficiency when using the latest intensification technologies, the increase in the volume of work on the intensification of hydrocarbon extraction and the increase in oil and gas condensate extraction);

– drilling of new wells in already explored deposits, where there are still mining and heavy mining reserves and involvement in the development of new horizons;

– drilling of wells in new fields for accelerated development of reserves that will be discovered as a result of geological exploration (primarily in the waters of the Black and Azov Seas).

The least expensive way is to increase production (intensification) of hydrocarbons at wells that are in operation. But the problem of complete production of already discovered reserves of hydrocarbon raw materials is that many fields are at the final stage of development. Therefore, the application of one or another method of intensification may already be inappropriate, ineffective or not effective at all [2]. In order to achieve a positive result in such fields, it is necessary to deeply analyze the condition of the wells, the remaining reserves, the filtration and capacity properties of the rocks – collectors, the characteristics of the deposits and their mode of operation [3]. But the main task of activities in this direction should be the involvement in the development of mining reserves, which are located in reservoirs with high lithological heterogeneity, both in terms of area and thickness of productive sections, with low filtration properties or those that have deteriorated during the development of the deposit [4].

In fact, the above-mentioned reserves, taking into account the conditions of their occurrence and the difficulty of extraction, pass into the category of heavy extraction, which require the use of specific, scientific and high-cost technologies and equipment. Therefore, *the aim of research* is to design an intensification method using the FracCADE software.

2. Materials and Methods

To perform hydraulic fracturing in a well (fracturing), it is necessary to carefully select the appropriate facilities, which must meet the following requirements [5]:

- low inflow of hydrocarbons after well development in comparison with neighboring wells that open the same horizons;
- the presence of high formation pressure, but an open reservoir with low permeability [6];
- low value of the actual productivity ratio compared to the potential productivity ratio [7];
- the thickness of the massif of rocks separating the productive layer from the water-saturated reservoirs must be sufficient to withstand the maximum expected blowout pressure during hydraulic fracturing [8];
- a significant indicator of the skin effect – S, i. e. $S>0$, which indicates the contamination of the near-outlet zone of the reservoir [9];
- the presence of a cement ring behind the production column with good adhesion both to the casing column and to rocks, especially in the interval of lithological screens that separate the productive layer from the aquifer;
- productive formations of the well are located outside the zone of influence of the injection wells and the water-gas-oil circuit, which excludes the possibility of increasing the inflow of formation water [10].

To design the fracturing, it is necessary to collect raw data:

- on the well (about the construction of the well and its part, the technical characteristics of the elements of the production string and the wellhead equipment, the type and characteristics of the perforators used for perforation, perforation intervals, the presence and characteristics of the well equipment, the quality of the cement ring behind the production string, etc.);
- by geological section and productive horizons (about lithology, presence of closely located aquifers, mechanical properties of rocks, productive capacity, reservoir pressures, hydraulic fracturing pressures of rocks, permeability, porosity, saturation, location of water-oil (WOC) and gas-oil (GOC) contacts, etc.);
- to analyze the data of existing geophysical and hydrodynamic studies.

Table 1 shows the sequence of preparatory work on the well of the studied deposit.

Table 1

The sequence of preparatory works

No.	Type of works
1	Shut off the well with formation water γ=1.14 g/cm^3
2	Mount the machine and receiving bridges at the mouth of the well
3	Dismantle fountain fittings (FA). Mount anti-missile equipment (air defense). Pressurize the operating column and anti-aircraft defense with a pressure of 150 kgf/cm^2 or up to the absorption pressure
4	Raise the PCP «funnel» of 73 mm to the surface with constant topping up of the well and laying in pump-compressor pipes (PCP) on bridges
5	Assemble the layout for patterning the production column and lower it into the well: end mill ∅115 mm, drill pipes ∅73×9.19 G-105, S-135. The layout should be lowered to a depth of 4360 m. The well should be flushed for at least one cycle. Raise the layout to the surface with the installation of drill pipes with candles
6	Lower the PCP 88.9x6.45 P-110 VAGT (Austria) into the well to a depth of 100 m. Flush the well during the cycle
7	Install a sand plug in the interval 4328–4360 m by pouring a mixture of sand and formation water fraction 100 in the amount of 352 liters of dry sand through a funnel. Lift the deflated PCP string with your finger
8	Lower the column mechanical scraper SK-140 (Romania) on drill pipes to a depth of 4300 m at a speed of no more than 15 m/min. Intervals 4250–4280 m and 4150–4180 m must be completed at least 3 times. Flush the well for at least 1.5 cycles until clear fluid comes out. Raise the scraper SK-140 with constant filling of the well
9	Lower the ∅115 mm template on drill pipes to a depth of 4300 m, not exceeding the descent speed of 15 m/min. At a depth of 4300 m, flush the well for at least 1.5 cycles until clear fluid comes out. Raise the template with constant filling of the well and laying of drill pipes on the bridges. Check the pattern for signs of scratches
10	Lower into the well: PCP shank 88.9x7.34 P-110 VA Superior – 3 m, service packer 5 1/2″ – 2.3 m, differential adapter with one hemisphere, PCP-88.9x7.34 P-110 VA Superior – 19 m, PCP ∅88.9×7.34 P-110 VA Superior – 3 m, PCP ∅88.9x7.34 P-110 VA Superior – to the mouth, as shown in Fig. 1. After 500 m of lowered pipes, perform control pressing of the PCP to a pressure of 250 kgf/cm^2. Depth of descent of the service packer on PCP ∅88.9x7.34 R-110 VA Superior – 4260 m
11	Tie the packer and verify the measure of the tool using geophysical methods, namely gamma logging (GL) and lateral logging (LL). Adjust the landing site of the packer for intensification in the interval of 4250–4275 m
12	Dismantle the preventers. Install a face plate 180×700×80×1050 and two ZM-50x1050 latches (assembled) on the mouth, which according to the passport are pressed to a pressure of 1050 kgf/cm^2
13	Fill up the pipe space and press the 89 mm PCP, the suspension adapter, the washer and two valves with a pressure of 680 kg/cm^2. Lower the initiating rod into the PCP on the logging cable, destroy the ceramic hemispheres, make sure that it passes freely below and raise the rod to the surface. Carry out a direct flushing of the well during the cycle
14	Blow up the face plate from the landing place. Land the service packer in the designated place, unload 15.5 tons of PCP weight onto the packer. Fasten the face plate and latches on the mouth. Top up the well and pipe space of the PCP to the mouth. With the open pipe space in the annular space, create a pressure of 150 kgf/cm^2 (or up to the absorption pressure with measurement of the absorption volume) to check the tightness of the packer and faceplate. With an open annular space in the pipe space, create a pressure of 150 kgf/cm^2 (or up to the absorption pressure with measurement of the absorption volume) to check the tightness of the packer

Fig. 2 shows the planned arrangement of machinery and equipment for intensification.

Table 2 shows the initial data for the design of the intensification process.

Using geological and technical data with the help of the FracCADE software complex, the fracturing design along the well was designed.

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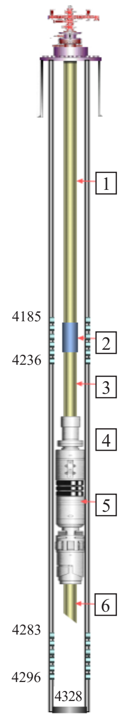

Fig. 1. Layout of underground equipment during fracturing:
1, 3 – PCP ∅88.9x7.34 R-110 VA Superior; 2 – reference pipe PCP-88.9x7.34 R-110 VA Superior – 3 m; 4 – differential adapter with one hemisphere; 5 – packer 5POM-YAGK-112-1000T; 6 – hose shank PCP-88.9x7.34 P-110 VA Superior with a bevel in the lower part

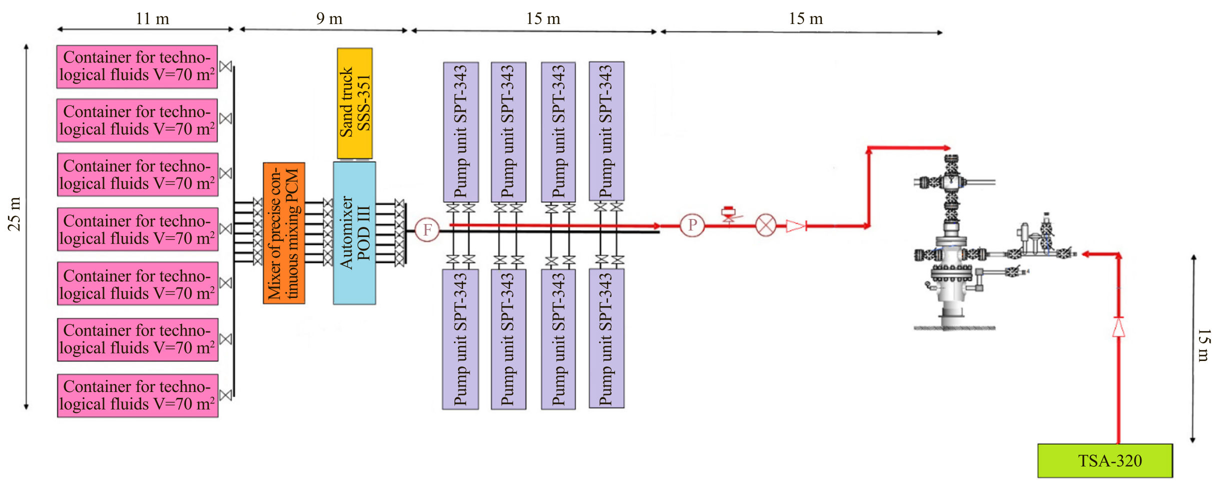

Fig. 2. Scheme of placement of machinery and equipment for intensification (fracturing): —— low pressure line; ➞ high pressure line 4″; ⋈ low pressure valve; ⊗ high pressure valve 4″; ▷ check valve; (P) flow meter; transfer pump; pressure relief valve

Table 2

Initial data for fracturing

Parameter	Value	Measurement unit
Upper border of perforation	4283.00	m
Lower border of perforation	4296.00	m
Artificial bump	4362.00	m
PCP length	4253.00	m
Packer installation depth	4250.00	m
Inner PCP diameter	74.22	mm
Inner casing string diameter	119.00	mm
Pressing	930.00	bar
Maximum pressure	845.45	bar
Download speed during the main process	3.20	m^3/min
Space volume before the perforation interval	18.10	m^3
Proppant type	30/60 BoroProp 20/40 SinLit S100	

3. Results and Discussion

The first stage of modeling is the determination of fluid stability, shear rate, and the concentration of destructor B-1 0.6 kg/m^3 at 70 °C.

Fig. 3 shows the result of testing the intensification fluid for stability, and it is established that the stability time of the fluid will be 1 hour 20 minutes, and the crosslinking time will be 3 minutes.

Fig. 4 shows the result of shear rate testing of the intensification fluid.

As a result of the calculated testing of fluids for intensification, the optimal composition and characteristics of the fracturing fluid were selected.

The next step is to download the data shown in the Table 2.

Fig. 5 shows the result of intensification fluid testing at a concentration of destructor B-1 of 0.6 kg/m^3 at 70 °C.

The first stage of intensification using the specified method is mini fracturing, during which, at the first stage, an injection test is performed to determine well acceptability, fracture closure pressure, and reservoir pressure assessment (when radial flow is achieved). In the second stage, a low-concentration proppant pack is injected using the main fracturing fluid, which allows to set the working and maximum pressure, check the permeability of the perforation holes of the perforation interval, set the fracture closing pressure and determine the effectiveness of the main fracturing fluid. Determining the efficiency of the main fluid is the most important parameter for conducting main fracturing, which depends on the rate of injection, filtration and viscosity of the fracturing fluid. Table 3 indicates the type of fluid used as a breaker (destructor). The breaker is used to clean the fracture from fracturing fluid. Breakers reduce the viscosity of the fluid by breaking the bonds between the polymer molecules, thus reducing the molecular weight of the fluid, and cause the degradation of the gel.

According to the Table 3, the time required for intensification, taking into account the stage of mini fracturing, is 43 minutes and 44 seconds.

For hydraulic fracturing, it is planned to use a total of 256.4 m^3 of water and the required amount of chemical reagents listed in the Table 4.

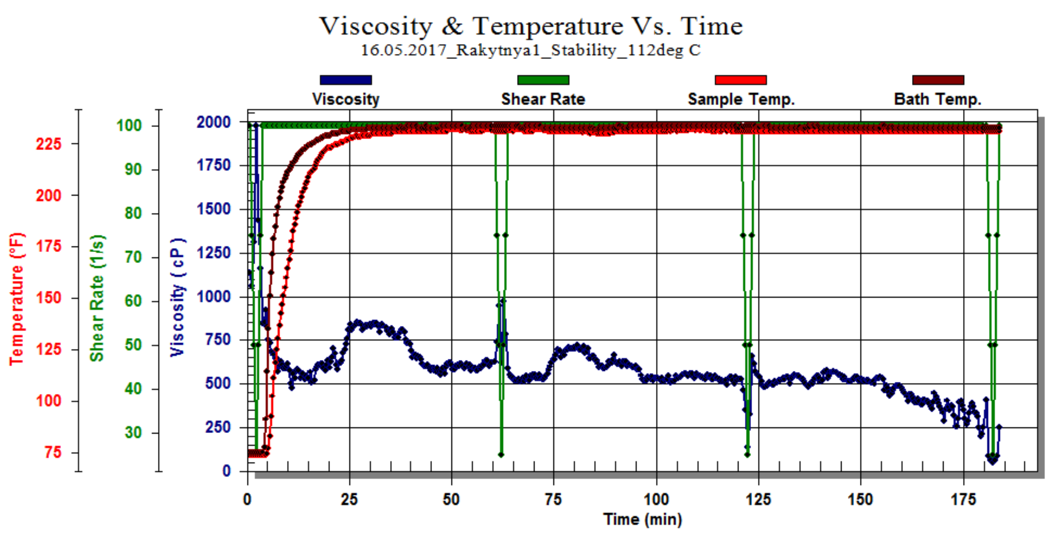

Fig. 3. The result of testing the intensification fluid for stability

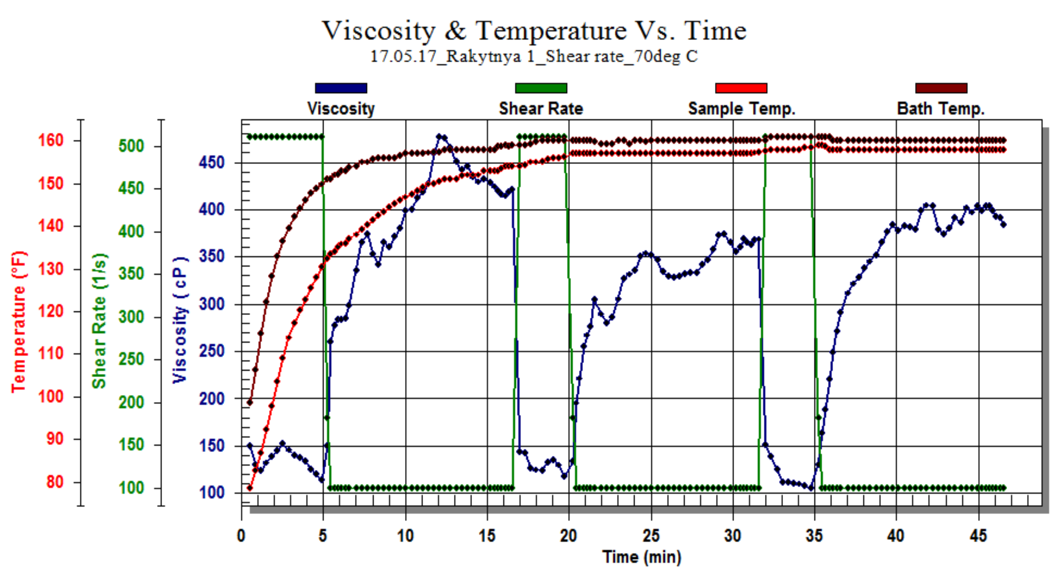

Fig. 4. The result of shear rate testing of the intensification fluid

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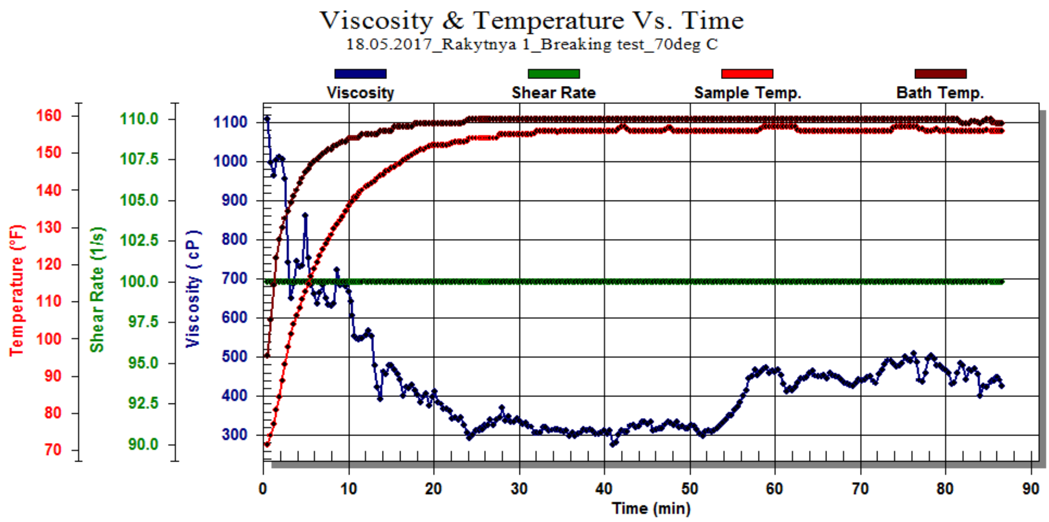

Fig. 5. The result of intensification fluid testing at the concentration of destructor B-1 of 0.6 kg/m^3 at 70 °C

Table 3

Procedure for injecting fluids during intensification

No.	Stage	Proppant concentration, kg/m^3	Mixture volume, m^3	Total mixture, m^3	Pure fluid, m^3	Mixture consumption, m^3/min	Proppant amount per stage, kg	Total proppant, kg	Breaker, concentration, kg/m^3	Stage time, hh:mm:ss
1	L35 injection test	0	19.0	19.0	19.0	3.2	0	0	0 of NG-B2-0.5 of NG-BK	0:05:56
2	Stop. Record ICCP (instantaneous fracture closure pressure)	0	0.0	19.0	0.0	3.2	0	0	0 of NG-B2-0 of NG-BK	0:00:00
3	HCL acid 13 %	0	3.0	22.0	3.0	0.5	0	0	0 of NG-B2-0 of NG-BK	0:06:00
4	Buffer XL35HTD	0	8.0	30.0	8.0	3.2	0	0	0.2 of NG-B2-0 of NG-BK	0:02:30
5	Proppant pack XL35HTD 30/60 BoroProp	150	3.5	33.5	3.3	3.2	500	500	0.2 of NG-B2-0 of NG-BK	0:01:05
6	Buffer XL35HTD	0	12.0	45.5	12.0	3.2	0	500	0.2 of NG-B2-0 of NG-BK	0:03:45
7	Pushing L35	0	19.0	64.5	19.0	3.2	0	500	0 of NG-B2-0.5 of NG-BK	0:05:56
8	Stop. ICCP record	0	0.0	64.5	0.0	3.2	0	500	0 of NG-BK-0 of MISTAKE	0:00:00
9	Buffer XL35HTD	0	40.0	104.5	40.0	3.2	0	500	0.2 of NG-B2-0 of NG-BK	0:12:30
10	Proppant stage XL35HTD 30/60 BoroProp	120	12.5	117.0	12.0	3.2	1440	1940	0.3 of NG-B2-0 of NG-BK	0:03:53
11	Proppant stage XL35HTD 30/60 BoroProp	240	13.0	129.9	12.0	3.2	2880	4820	0.3 of NG-B2-0 of NG-BK	0:04:02
12	Proppant stage XL35HTD 30/60 BoroProp	360	11.2	141.1	10.0	3.2	3600	8420	0.3 of NG-B2-0 of NG-BK	0:03:29
13	Proppant stage XL35HTD 30/60 BoroProp	480	11.6	152.7	10.0	3.2	4800	13220	0.4 of NG-B2-0 of NG-BK	0:03:37
14	Proppant stage XL35HTD 30/60 BoroProp	600	14.4	167.1	12.0	3.2	7200	20420	0.5 of NG-B2-0 of NG-BK	0:04:29
15	Proppant stage XL35HTD 20/40 SinLit	720	14.6	181.7	12.0	3.2	8640	29060	0.6 of NG-B2-0 of NG-BK	0:04:33
16	Proppant stage XL35HTD 20/40 SinLit	800	4.9	186.6	4.0	3.2	3200	32260	1 of NG-B2-0.3 of NG-BK	0:01:32
17	Pushing L35	0	18.1	204.7	18.1	3.2	0	32260	0 of NG-B2-1 of NG-BK	0:05:39 0:43:44

Table 4

Required amount of chemical reagents

Type of chemical reagent	Value	Type of chemical reagent	Value
NG BioD – Bactricide	16.3 kg	NG-B2 Encapsulated breaker	44.1 kg
NG NE-1 Non-Emulsifier	256 l	NG-BK Live breaker	20.2 kg
NG CS-2 Clay Stabilizer	256 l	XL-4 Crosslinker	812.0 kg
NG GS-1 Temp Stabilizer	256 l	XL-6 Crosslinker	54.1 kg
NG SG-1 Salt Stabilizer	128.2 kg	HCL 13 %	3000 l
WGA NG-1 – Gelling agent	1077.0 kg	–	–
30/60 BoroProp	20419.5 kg	–	–
20/40 SinLit	11840.0 kg	–	–
S100	00000.0 kg	–	–

Table 5 shows the results of modeling the fracture geometry, obtained using hydraulic fracturing software.

According to the simulation results, the fracture half-length of 110.2 m, a propped half-length of 102 m, a total height of 43.6 m, and a total propped height of 20 m. The vertical depth to the upper limit of the fracture is 4272.6 m, and to the lower limit – 4316.2 m. The equivalent number of multiple fracks formed is 1. The maximum fracture width is 0.387 cm, and the average width is 0.197 cm. The average proppant concentration is 3.2 kg/m^2.

Table 6 shows the results of simulation of fracture conductivity parameters obtained using FracCADE. According to the simulation results, the average fracture conductivity is 157.0 mD·m, the average fracture width (closed on the proppant) is 0.387 cm, the dimensionless conductivity is 1.4, the relative formation permeability is 1 mD, the proppant damage factor is 0.65.

According to the simulation results, the effective pressure of the model is 79.3 kgf/cm^2. This pressure corresponds to the pressure at which the fracture starts to form. The hydraulic fracturing closure pressure at the well is 617.9 kgf/cm^2, which corresponds to the pressure at which the fracture closes after fluid injection. The closing pressure gradient is 14.62 kPa/m, it characterizes the rate of reduction of the closing pressure with the fracture length. The hydrostatic pressure is 421.3 kgf/cm^2, which corresponds to the pressure of the fluid column above the wellbore fracture. The average pressure at the mouth is 566.3 kgf/cm^2, which corresponds to the pressure of fracture formation and propagation at an average flow of fluid. The formation pressure is 210 kgf/cm^2, which corresponds to the pressure in the formation. The maximum pressure at the mouth is 631.6 kgf/cm^2. This pressure corresponds to the maximum pressure that will be reached during the hydraulic fracturing operation.

Table 7 shows the general results of the design of the intensification method for the well of the studied field.

In general, the simulation of hydraulic fracturing of the well was successful. The fracture has formed and is able to pass the fluid in full, which is shown in Fig. 6.

Fig. 7 shows the graphical dependence of the effective pressure that will occur during injection. According to the value of the given pressure, the most appropriate model of fracture development is selected – limited or radial.

Fig. 8 shows the predicted shape and geometry of the fracture. As a result of fracturing modeling, one fracture is formed with the following geometric parameters: half-length – 110.2 m, total height – 43.6 m, and maximum fracture width – 0.387 cm.

Table 5

Fracture Geometry Summary

Parameter	Value	Parameter	Value
Fracture Half-Length (m)	110.2	Propped Half-Length (m)	102
Total Fracture Height (m)	43.6	Total Propped Height (m)	20
Depth to Fracture Top (m)	4272.6	Depth to Propped Fracture Top (m)	4279.2
Depth to Fracture Bottom (m)	4316.2	Depth to Propped Fracture Bottom (m)	4299.2
Equivalent Number of Multiple Fracs	1.0	Max. Fracture Width (cm)	0.387
Fracture Slurry Efficiency	0.288	Average Fracture Width (cm)	0.197
–	–	Average Proppant Concentration (kg/m^2)	3.2

Table 6

Fracture Conductivity Summary

Parameter	Value	Parameter	Value
Average Conductivity (mD·m)	157.0	Maximum Value of the Crack Width (Closed on Proppant) (cm)	0.387
Dimensionless Conductivity	1.4	Relative Formation Permeability (mD)	1.0
Proppant Damage Factor	0.65	Undamaged Proppant Perm at Stress (mD)	118918
Apparent Damage Factor	–	Proppant Perm with Prop Damage (mD)	41621
Total Damage Factor	0.65	Proppant Perm with Total Damage (mD)	41621
Effective Propped Length (m)	–	Proppant Embedment (mm)	–

Table 7

Operations Summary

Parameter	Value	Parameter	Value
Total Clean Fluid Pumped (m^3)	130.12	Total Proppant Pumped (kg)	31760
Total Slurry Pumped (m^3)	140.14	Total Proppant in Fracture (kg)	31360
Pad Volume (m^3)	40.00	Average Hydraulic Horsepower (kW)	3002
Pad Fraction (% of Slurry Volume)	32.8	Maximum Hydraulic Horsepower (kW)	3348
Pad Fraction (% of Clean Volume)	35.7	Average Feed Rate of the Mixture (m^3/min)	3.18
Primary Fluid Type	YF 135RGD	Primary Proppant Type	Boro 30/60
Secondary Fluid Type	–	Secondary Proppant Type	20/40 Sintered

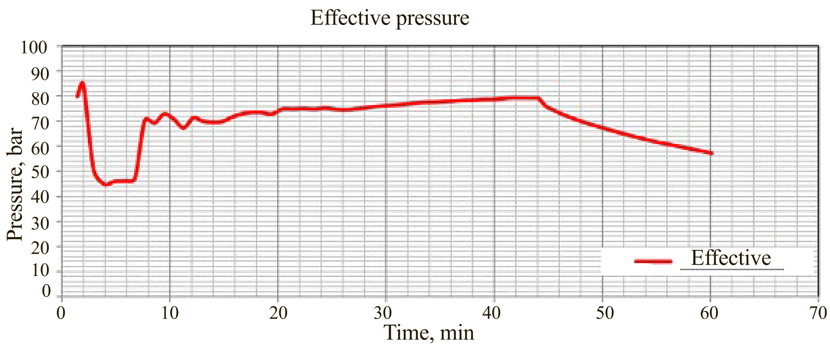

Fig. 6. Graphic dependence of fracture formation

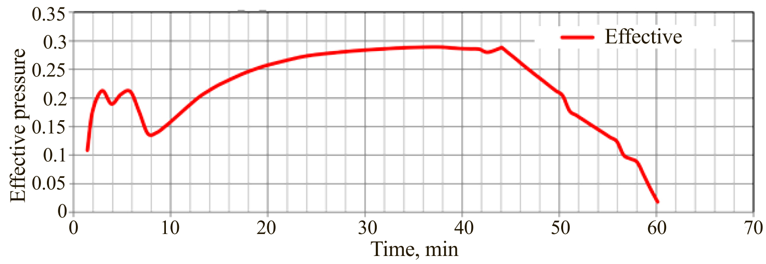

Fig. 7. Graphic dependence of the passage of fluid through the formed fracture

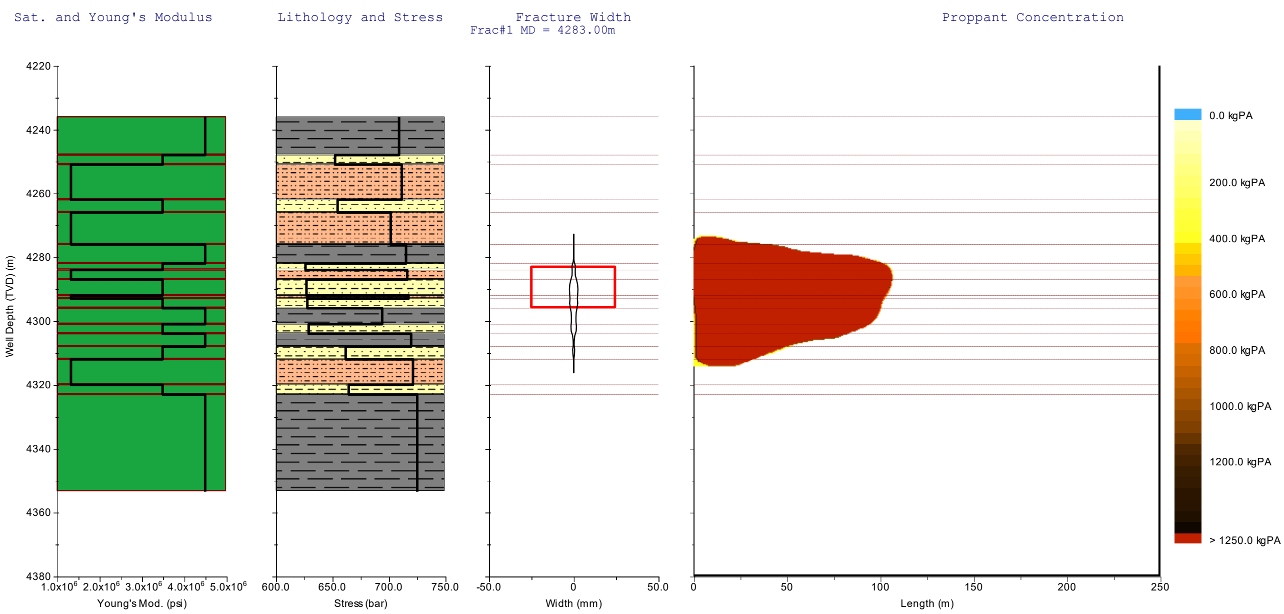

Fig. 8. Predicted shape and geometry of the fracture during fracturing modeling

A fracture is formed in the formation under fluid pressure. At the beginning, the fracture has the greatest height and width, but then, with a greater distance from the well – deep into the formation, these parameters decrease significantly, reaching their peak. Also, the profile of the formed fracture has a different configuration in width. This is because intensification affects the fracture differently at different points. A fracture always propagates along the path of least resistance.

The most important parameter that affects the flow rate after fracturing is the value of the fracture conductivity. The average value of the conductivity of the fracture is 157.0 mD·m, although a section is formed with a higher value (more than 244 mD·m), in particular, this applies to the central part of the fracture, as shown in Fig. 9.

Dimensionless conductivity *FCD* is used to estimate the potential productivity of a fracture and depending on its value (*FCD*) the conductivity of the fracture is analyzed:

If $FCD \sim 2$, then optimal operation of the collector will occur for the given amount of proppant.

If $FCD > 10$, then obtain infinite fracture conductivity, limited by the size of the reservoir.

If $FCD < 0.5$, then obtain limited fracture conductivity.

As a result of the simulation, it is possible to obtain the parameter of dimensionless conductivity, the value of which is equal to 1.4, and the relative permeability of the formation is 1 mD.

The use of a calibrated wedging agent and achieving its calculated concentration in the fracture is also important for improving the fracture. Proppant injection is carried out with an increase in its concentration at each subsequent stage in order to obtain a uniform concentration at the end of injection, which is equal to the concentration of the last pack of proppant injected into the formation. Fig. 10 shows the fracture profile and the change in proppant concentration along its length.

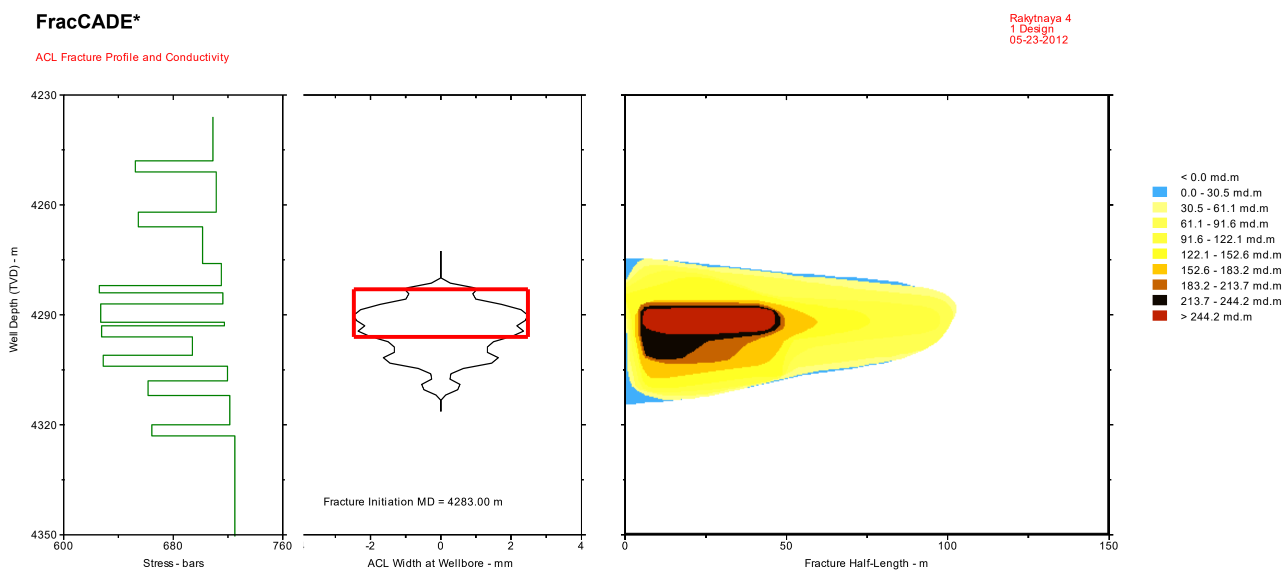

Fig. 9. Fracture profile and its longitudinal conductivity as a result of fracturing simulation

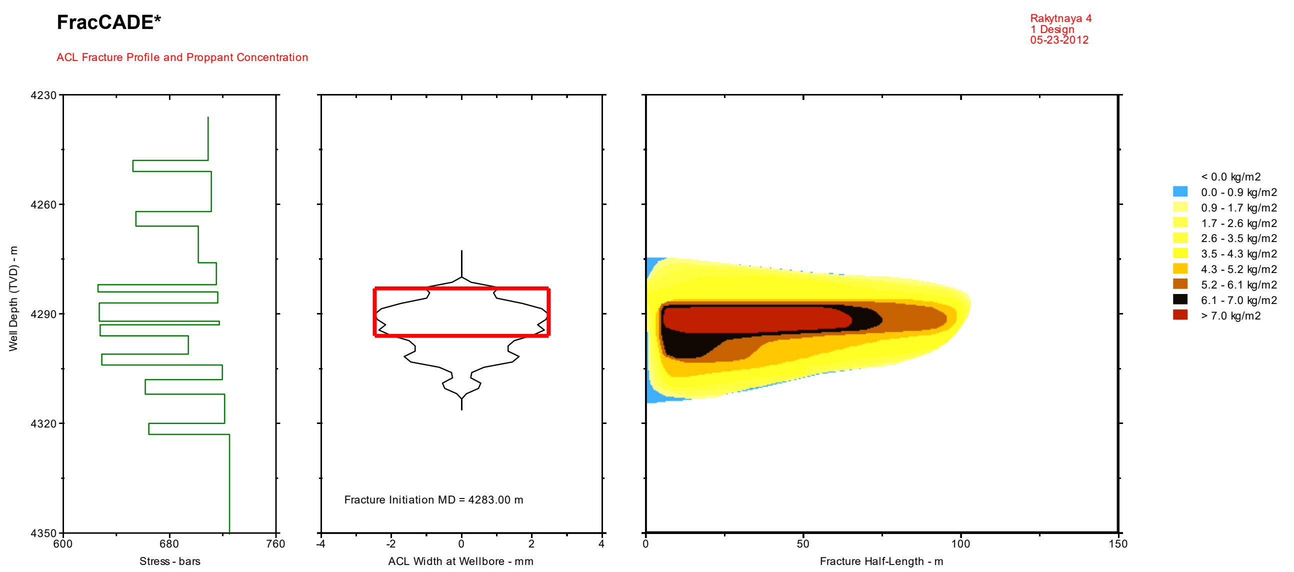

Fig. 10. Fracture profile and change in proppant concentration along its length as a result of fracturing simulation

As a result of modeling, after the completion of hydraulic fracturing, uniform filling of the central part of the fracture with a mixture with a concentration of more than 5.2 kg/m^2 over a length of 95 m was achieved.

Predicted fracture geometry, fracture conductivity, and proppant concentration change along the length will be used to evaluate fracturing performance.

Therefore, with the help of FracCADE, fracturing can be designed in such a way as to maximize the fracturing area and increase the hydrocarbon flow. It is also possible to optimize fracturing costs by selecting optimal process parameters and reducing risks. And choose the optimal process parameters, such as the amount of fluid and proppant, injection pressure, and others.

The introduction of martial law in Ukraine affected the conduct of the experiment as follows:

– *Changes in logistics*. Due to the closure of some roads and railways, difficulties arose with the delivery of equipment and materials for the experiment. It was also more difficult to ensure the safety of the participants of the experiment during their movement.

– *Change in access to information*. Due to the blocking of some Internet resources, the participants of the experiment could not get access to the necessary information. It was also more difficult to analyze the obtained results.

– *Change in the mood of the participants*. Martial law led to increased anxiety and stress in many people, which could have affected the results of the experiment.

Despite these difficulties, the experiment was carried out in full. The obtained results will be implemented on the territory of Poltava Region under exactly the conditions that were considered.

4. Conclusions

First of all, when designing a hydraulic fracturing system, it is necessary to obtain a better value of the *FCD* dimensionless conductivity. The greater the *FCD* value, the higher the potential conductivity of the fracture, which ultimately leads to an increase in well productivity.

Another factor is the fracture that will form. In our case, the fracture is long enough (its half-length is 136.9 m) and

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high (the total height of the fracture is 36.5 m) and has a sufficient width, which is from 0.2 mm to 3.7 mm with an average value of 1.5 mm. The fracture was formed at a fairly high average pressure at the wellhead (565 kgf/cm^2), which contributes to effective sealing of the fracture after fracturing is completed.

As a result of the design, the fracture will have an optimal profile, length and conductivity and will provide maximum fluid flow.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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Data availability

The manuscript has no associated data.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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