

Laboratory studies for the momentum of liquid optimal impact on hydrocarbon formation

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Abstract – The paper presents laboratory studies of impulse water injection on the rock samples. A large number of experimental data were obtained. According to the experimental data, a regression analysis was carried out, on the basis of which qualitative correlations between factorial and resultant characteristics were revealed. Taking into account the mathematical analysis of the data obtained, graphical dependencies were constructed. As the fluid oscillation frequency increases, the amount of liquid passing through the sample of the porous medium increases, with the greatest value of fluid leakage through the rock samples reaching in the frequency range 600 ... 1000 Hertz.

Keywords – regression; analysis; factorial; result; attribute.

I. INTRODUCTION

One of the promising ways of oil recovery from hydrocarbon layers increasing and the produced water relative volume reducing is the method of liquid non-stationary pulsed into injection wells pumping and the effectiveness of which is confirmed by theoretical studies [1-13]. In this regard, there is a need to conduct laboratory studies to determine the optimal parameters for the method application.

II. MATERIALS AND METHODS

During the laboratory-experimental works, the research is conducted in two directions. In the first direction, leakage of liquid through the samples is investigated under different regime parameters. The technique is as follows. In the holder block, the layout of which is shown in Fig. 1, there are three chambers for the investigated samples installation, and all the chambers are interchangeable. In the holder, the investigated samples are installed, pre-placed in a rubber casing. Using a vibrator installed in the test chamber [2], the required frequency and fluid pressure fluctuation amplitude values are created which are recorded on photo paper. The liquid pressure value up to the test sample is regulated by means of a

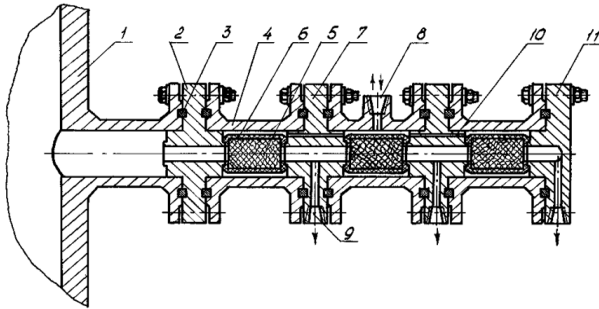
gate valve and its values are fixed according to the readings of the manometer. After the rubber casing of the test specimen in the body 4 rock pressure is created with the help of a hand operated oil pump and the fluid leakage through the test sample amount is measured volumetrically by withdrawing it from the holder through the outlet 9. Studies are carried out alternately for one, two and three test samples. The obtained values are represented in the form of graphical dependencies.

In the second direction of laboratory studies, the pressure fluctuation amplitude absorption magnitude is determined. For this purpose, strain gauges are installed in the outlets 9, the signals from which are recorded on the photographic paper by the light-beam oscillograph. Creation of the necessary values of the operating parameters (the frequency and the pressure fluctuation amplitude, the pressure up to the test sample, the rock pressure) is carried out in the same sequence. The studies are carried out alternately for three samples, the strain gauges being installed after each test sample. When carrying out the research, sand of the following granulometric composition was used as a model of a porous medium: grains diameter is in the range of 0.21... 0.42 mm. To prepare the samples, a mold was used whose internal dimensions are: the diameter is 24 mm; the length is 40 mm. The sand was sieved, washed with distilled water beforehand, and compacted in a mold using a press with a final force of 1200 N. The test was carried out using three pressure values in the test chamber $P = 1.0; 1.5; 2.0$ MPa, and at each pressure value in the test chamber, the following values of the external pressure on the samples $P_r = 0.5$ were created; 1.4; 2.3 MPa. The liquid oscillation frequency was created by means of vibrators, the value of which for all the experiments was of the same values: 200, 400, 600, 800, 1000, 1200 Hz, the error being no more than $\pm 5\%$. The results of laboratory studies are presented in Table 1, 2, 3.

III. RESULTS AND DISCUSSIONS

According to experimental data, the regression analysis was carried out, on the basis of which the qualitative correlations between the factorial and the resultant descriptors were revealed.

For all three cases, the matrix of the full factor experiment 2^3 [3] was made. The regression equations represented the dependence of $q = \varphi(f, P, P_r)$ in linear form. The significance of the regression coefficients was verified with the help of Student's t-test and in all three cases the combination of fP and fP_r factors does not affect the resultant descriptor.



1 – test string; 2 – thrust flange; 3 – sealing cup; 4 – body; 5 – specimen under investigation; 6 – rubber casing; 7 – intermediate flange; 8 – outlet for connection with hand operated oil pump; 9 – outlets for liquid volume measuring and strain gauges installation; 10 – channels for the inner cavity of the bodies interconnection; 11 – end flange.

Fig. 1. Holder Block

TABLE I. FLUID LEAKAGE AMOUNT THROUGH ONE SAMPLE OF A POROUS MEDIUM ($Q \times 10^{-4} \text{ m}^3/\text{SEC.}$)

Liquid oscillation frequency $f, \text{ Hz}$	P_1			P_2			P_3		
	P_{r1}	P_{r2}	P_{r3}	P_{r1}	P_{r2}	P_{r3}	P_{r1}	P_{r2}	P_{r3}
200	0.0323	0.0312	0.0301	0.0418	0.0397	0.0372	0.0462	0.0433	0.0418
400	0.0434	0.0421	0.0413	0.0486	0.0413	0.0396	0.0511	0.0495	0.0482
600	0.0562	0.0522	0.0502	0.0598	0.0564	0.0549	0.0623	0.0601	0.0588
800	0.0687	0.0603	0.0596	0.0712	0.0676	0.0661	0.0766	0.0722	0.0703
1000	0.0623	0.0613	0.0584	0.0716	0.0669	0.0656	0.0754	0.0713	0.0689
1200	0.0618	0.0592	0.0580	0.0704	0.0663	0.0650	0.0751	0.0711	0.0682
1400	0.0611	0.0598	0.0563	0.0693	0.0654	0.0632	0.0741	0.0709	0.0682
1600	0.0602	0.0576	0.0560	0.0690	0.0658	0.0614	0.0733	0.0686	0.0680

TABLE II. FLUID LEAKAGE AMOUNT THROUGH TWO SAMPLES OF A POROUS MEDIUM ($Q \times 10^{-5} \text{ m}^3/\text{SEC.}$)

Liquid oscillation frequency $f, \text{ Hz}$	P_1			P_2			P_3		
	P_{r1}	P_{r2}	P_{r3}	P_{r1}	P_{r2}	P_{r3}	P_{r1}	P_{r2}	P_{r3}
200	0.172	0.141	0.120	0.211	0.201	0.186	0.267	0.229	0.201
400	0.218	0.168	0.141	0.262	0.246	0.211	0.310	0.269	0.248
600	0.264	0.201	0.183	0.293	0.282	0.265	0.345	0.297	0.282

TABLE II., cont.

800	0.297	0.242	0.212	0.324	0.283	0.272	0.366	0.312	0.303
1000	0.302	0.241	0.210	0.304	0.280	0.264	0.368	0.312	0.294
1200	0.296	0.232	0.201	0.286	0.279	0.264	0.346	0.311	0.291
1400	0.286	0.234	0.193	0.276	0.271	0.263	0.337	0.305	0.288
1600	0.272	0.221	0.191	0.264	0.265	0.258	0.331	0.298	0.286

TABLE III. FLUID LEAKAGE AMOUNT THROUGH THREE SAMPLES OF A POROUS MEDIUM ($Q \times 10^{-6} \text{ m}^3/\text{SEC.}$)

Liquid oscillation frequency $f, \text{ Hz}$	P_1			P_2			P_3		
	P_{r1}	P_{r2}	P_{r3}	P_{r1}	P_{r2}	P_{r3}	P_{r1}	P_{r2}	P_{r3}
200	0.882	0.863	0.845	0.925	0.897	0.872	1.002	0.981	0.962
400	0.928	0.894	0.868	0.966	0.932	0.912	1.035	0.919	0.989
600	0.967	0.936	0.921	0.999	0.987	0.985	1.086	1.065	1.034
800	0.983	0.966	0.945	1.031	0.982	0.964	1.121	1.093	1.051
1000	0.972	0.963	0.936	1.020	0.984	0.963	1.116	1.077	1.053
1200	0.973	0.942	0.936	1.004	0.976	0.956	1.100	1.076	1.052
1400	0.967	0.940	0.925	1.006	0.964	0.948	1.094	1.061	1.044
1600	0.956	0.932	0.921	0.986	0.957	0.943	1.093	1.052	1.033

The hypothesis on the adequacy of the proposed models was tested using Fischer's F-criterion. The regression equations are as follows:

$$q_1 = (-0.000324 + 0.00000983f + 0.0271P + 0.0301P_r - 0.0125P_r - 0.00000494fP_r) \times 10^{-4}; \quad (1)$$

$$q_2 = (0.08213 + 0.000021f + 0.09038P + 0.09735P_r - 0.0447P_r - 0.000015fP_r) \times 10^{-5}; \quad (2)$$

$$q_3 = (-0.78906 + 0.000028f + 0.09696P + 0.10805P_r - 0.0489P_r - 0.00002fP_r) \times 10^{-6}; \quad (3)$$

The experimental graphical dependencies $q = \varphi(f)$ (when $P = 1 \text{ MPa}$ and $P_r = 0.5 \text{ MPa}$) are shown in the Fig. 2, 3, 4. After analyzing the results, it was revealed that with the increase in the fluid fluctuations frequency the amount of fluid passing through the porous medium sample increases, with the highest value q reaching in the frequency range of 600...1000 Hz. As to the value of pressures, namely their influence on q , the conducted laboratory studies confirm the theoretical results of the majority of authors.

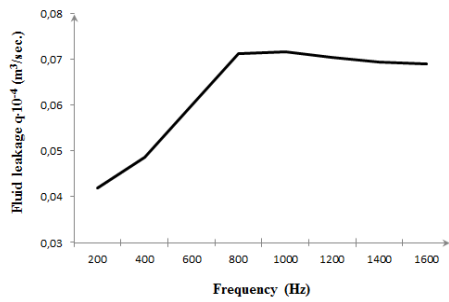


Fig. 2. Fluid leakage through one sample of the porous medium dependence from fluid oscillation frequency (f , Hz) when $P= 1 \text{ MPa}$, $P_r = 0.5 \text{ MPa}$.

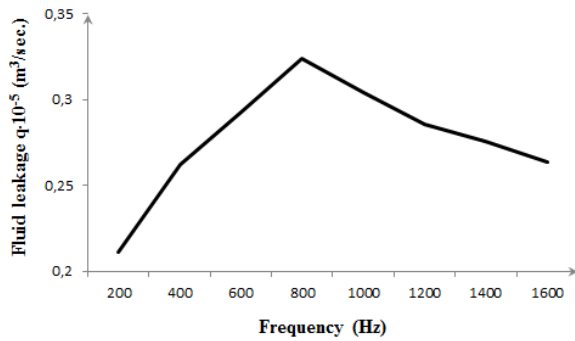


Fig. 3. Fluid leakage through two samples of the porous medium dependence from fluid oscillation frequency (f , Hz) when $P= 1 \text{ MPa}$, $P_r = 0.5 \text{ MPa}$.

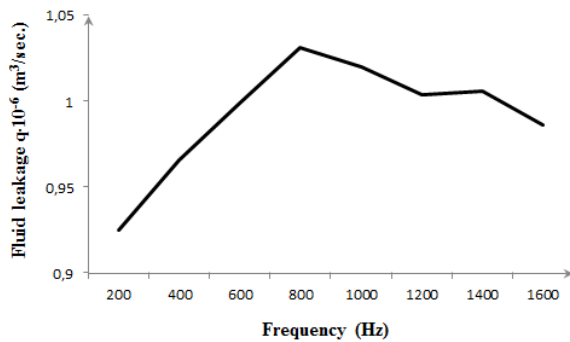


Fig. 4. Fluid leakage through three samples of the porous medium dependence from fluid oscillation frequency (f , Hz) when $P= 1 \text{ MPa}$, $P_r = 0.5 \text{ MPa}$.

During the second stage of laboratory studies, the preparation and composition of the porous medium samples were similar to the first stage. The fluid pressure change amplitude was recorded after each sample. Experiments were carried out at a liquid pressure up to the samples of 2.0 MPa, liquid fluctuations frequency of 1000 Hz, and the pressure on samples value was 1.0; 2.0; 3.0 MPa. The results are shown in Fig. 5.

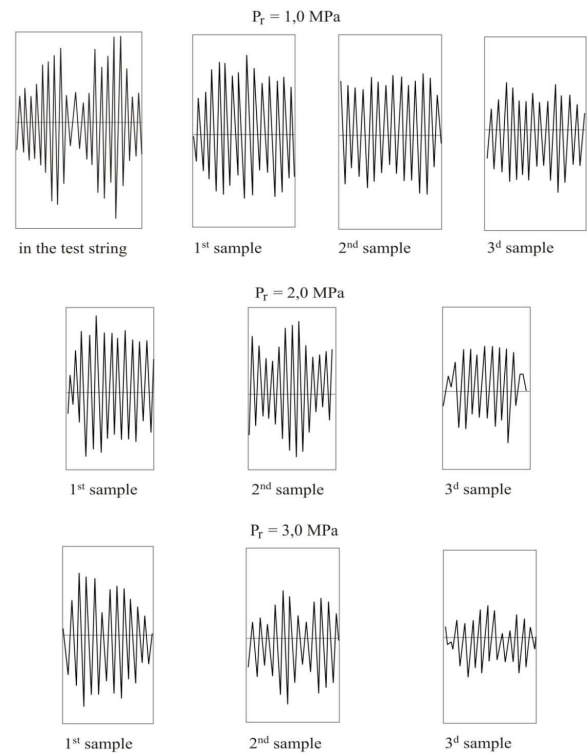


Fig. 5. Pressure fluctuations amplitude changing for different external pressure values on the porous medium samples.

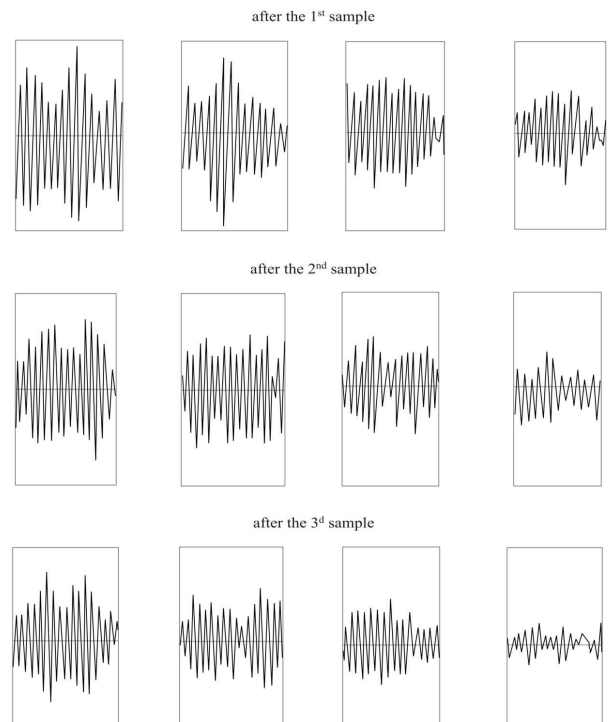


Fig. 6. Pressure fluctuation amplitude change at different liquid oscillation frequency values ($P = 2.0 \text{ MPa}$, $P_r = 1.5 \text{ MPa}$).

IV. CONCLUSION

On the basis of a detailed analysis of the pressure fluctuation amplitude variation, the following conclusions can be drawn. With the oscillations penetration depth increasing the pressure fluctuations amplitude absorption corresponds to linear reduction, and with rock pressure increase the linear change of absorption is distorted.

Fig. 6 shows the results of pressure fluctuation amplitude changes at different fluid fluctuations frequency values (at $P = 2.0\text{MPa}$ and $P_r = 1.5\text{MPa}$). The obtained data, after their comparison, allow us to draw the following conclusion. The smallest absorption is typical for the oscillation frequency in the range of 0... 1000 Hz.

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