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The Influence of Composite Wave Field Fluctuation Parameters Matching to Permeability of Low Permeability Reservoirs

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Abstract

There are essential differences in the influence rules of the binary composite wave generated by the combination of artificial resonance wave and hydraulic impulse wave to two-phase fluid flow of low permeability reservoirs porous media oil-water. When the fluctuation parameters of binary composite wave field reaching the optimal matching, the binary composite wave will have a good synergetic effect on two-phase fluid flow of oil-water, and the improvement effect on two-phase fluid flow of low permeability reservoirs oil-water will generate resonance effect which is far more effective than unary wave field. If the fluctuation parameters of binary composite wave field are not matched well, bad synergetic effect on two-phase fluid flow of oil-water will be generated ,not only it can't raise the improvement effect on two-phase fluid flow of oil-water, but also it will make the improvement effect below unary wave field. Even there will be an inhibition effect on fluid flow of oil-water, which reduces the displacement efficiency and the availability of low permeability reservoirs water injection's development. By using the indoor fluctuation oil recovery simulation experiment device, the influence rules of displacement vibration wave and hydraulic impulse binary composite wave field to low permeability reservoirs oil-water single phase and two-phase fluid flow feature were studied. The influence rules of amplitude, frequency, work cycle and the other important parameters of composite wave to the permeability of oil-water single phase was intensively studied. Finally the mechanism of the synergetic effect generated by composite wave to two-phase fluid flow of low permeability reservoirs was analyzed.

Keywords: *low permeability reservoirs; binary composite wave; fluctuation parameters; permeability.*

1. Introduction

By using various physics theory and method, the permeability and the ability of fluid flowing in reservoirs could be improved, the output of oil wells and water injection rate of water well could be increased. This is so called physical methods dealing with oil layer increasing production and injection technology (or called physical methods improving crude oil recovery efficiency technology). As an important part of physical methods to oil recovery, wave field oil recovery technology has features as well-adapted, obvious effectiveness of oil extended and water control, simple technology and low cost, no pollution to oil layer *etc*. It is suit

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for oil layer (especially for low permeability reservoirs which is quite sensitive to pollution) with no damage disposition. However, onefold wave field has limited effects on stimulation to oil layer's permeability. How to combine at least two wave fields acting on oil layer? To the matching of composite wave field parameters, what effects will it has on changing permeability of low permeability reservoirs? All those will be the studying direction of petroleum science and technology workers.

2. Experiment Device

DS-300-3-04 electro vibration experiment system (Figure 1) is composed by DS-300-3-04 electro vibration apparatus, SA1-3 power amplifier, S4 slip table, RC-200 digital vibration controller and FJ-200 draught fan .RC-200 digital vibration system control DS-300-3-04 electro vibration by computers, the frequency and the intensity of vibration can be changed by setting.

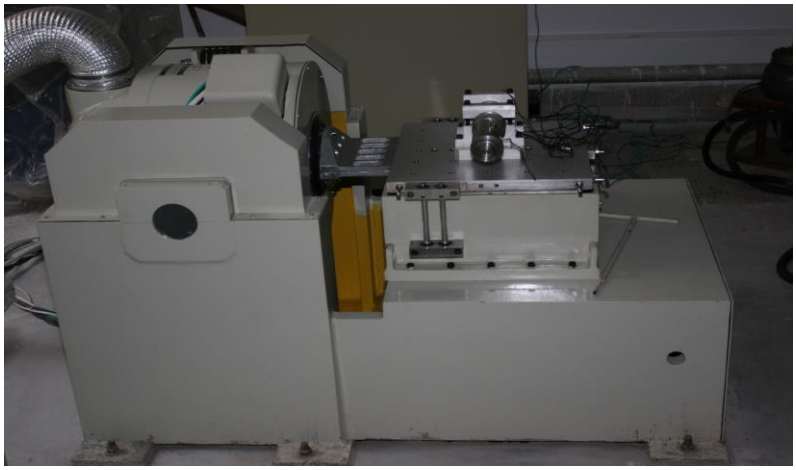

Figure 1. Photograph of DS-300-3-04 Electro Vibration Apparatus

3. Experimental Design Thought

3.1 Experimental Purpose

The artificial resonance wave and hydraulic impulse wave are made to affect on the core at the same time to study the effect on composite wave field to the permeability of core aqueous phase and oil phase and the effect on the recovery efficiency of core water-oil displacement and the saturability of residual oil. The experimental result of recovery efficiency and residual oil's saturability were compared with the effect of composite wave field to the permeability of water phase and oil phase.

3.2 Experimental Design Thought

The work program of composite wave field fluctuation parameters are designed with orthogonal design. Firstly, set relevant parameters (frequency, acceleration), open artificial resonance wave generator. Then start vibration after setting hydraulic impulse wave device's parameters(frequency, static and dynamic pressure of vibration).The device's opening interval should be less than 3min, at this moment, the artificial resonance wave and hydraulic impulse wave are affecting the core at the same time. Installation diagram of composite wave field common affecting on

the core is shown in Figure 3, Orthogonal experiment table used by parameters analysis is shown in table1.

Figure 2. Photograph of SA1-3 Power Amplifier

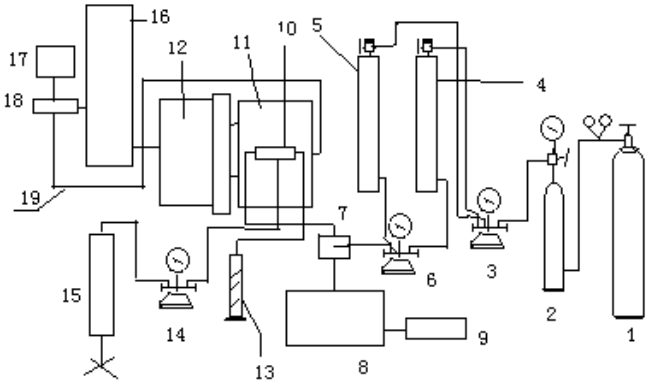

Figure 3. Installation Diagram of Vibration Experiment with Two Coupled Waves

Nitrogen gas cylinder 2.Buffer tank 3. Inlet pressure gauges 4.Water storage tank 5. Oil storage tank 6.Outlet pressure gauges 7.Pressure sensor 8.High frequency pulse servo system 9. Control meter 10.Core holder 11.Test tube 12.Electrodynamic vibration 13.Vibration table surface 14.Ring crush gauges 15.Ring crush system 16. SA1-3 power amplifier 17.RC-200 control meter 18.Control computer 19.Piezoelectric sensor

Table 1. Design of $L_9(3^4)$ Orthogonal Experiment

line number / test number	1	2	3	4
1	1	1	1	1
2	1	2	2	2
3	1	3	3	3

4	2	1	2	3
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	3
9	3	3	2	1

According to table1, considering the parameters of artificial resonance wave and hydraulic impulse wave experiment, and water-oil displacement experiment, here comes table2 The orthogonal experiment scheme. The vibration parameters of artificial resonance wave: frequency f, vibration acceleration a; The vibration parameters of hydraulic impulse wave: frequency f, vibration static pressure P0 ,dynamic pressure P. Experiment was conducted 9 times totally.

Table 2. Parameters of Vibration Experiment

factor / number	A a(G)	B f(Hz)	C P0(MPa)	D P(MPa)
1	0.1	40	2	1
2	0.1	60	5	1.5
3	0.1	80	8	2
4	0.2	40	5	2
5	0.2	60	8	1
6	0.2	80	2	1.5
7	0.5	40	8	1.5
8	0.5	60	2	2
9	0.5	80	5	1

4. Experiment Result

Measure water permeability of part core without vibration, then measure it again with composite vibration under the stable condition, the results are shown in table3.In the table3,SX means water without vibration, SXZD means water with vibration.

Table 3. Increased Value of Water Permeability

Test number	Core number	Composite motion parameters	Core state	Permeability(mD)	Permeability variation(mD)
1	B51	0	SX	10.56178	-1.115914
		(0.1,40,2,1)	SXZD	9.445866	
2	B52	0	SX	9.037071	0.445726
		(0.1,60,5,1.5)	SXZD	9.482797	
3	B53	0	SX	8.75432	0.206571
		(0.1,80,8,2)	SXZD	8.960891	

4	B54	0	SX	6.635749	-0.276318
		(0.2,40,5,2)	SXZD	6.359431	
5	B55	0	SX	6.900027	-0.506869
		(0.2,60,8,1)	SXZD	6.393158	
6	B56	0	SX	10.39082	-0.4094
		(0.2,80,2,1.5)	SXZD	9.98142	
7	B57	0	SX	9.67944	-2.54865
		(0.5,40,8,1.5)	SXZD	7.13079	
8	B58	0	SX	9.910303	-0.24459
		(0.5,60,2,2)	SXZD	9.665713	
9	B59	0	SX	14.35783	-1.42366
		(0.5,80,5,1)	SXZD	14.93417	

Orthogonal analyzing table3 comes table4.

Measure oil permeability of part core without vibration, then measure it again with composite vibration under the stable condition, the results are shown in table5.In the table5,YX means oil without vibration; YXZD means oil with vibration.

Table 4. Quadrature Analysis of Increased Water Permeability

Factor / Test number	1 A(acceleration g)	2 B (frequency Hz)	3 C (hydrostatic pressure MPa)	4 D (dynamic pressure MPa)	Index: Permeability variation of water(mD)
1	1	1	1	1	-1.115914
2	1	2	2	2	0.445726
3	1	3	3	3	0.206571
4	2	1	2	3	-0.276318
5	2	2	3	1	-0.506869
6	2	3	1	2	-0.4094
7	3	1	3	2	-2.54865
8	3	2	1	3	-0.24459
9	3	3	2	1	-1.42366
K_1	-0.463617	-3.940882	-1.769904	-3.046443	Summation of all factor index
K_2	-1.192587	-0.305733	-1.254252	-2.512324	
K_3	-4.2169	-1.626489	-2.848948	-0.314337	
$K_1/3$	-0.154539	-1.313627	-0.589968	-1.015481	Average of all factor index
$K_2/3$	-0.397529	-0.101911	-0.418084	-0.8374413	
$K_3/3$	-1.4056333	-0.542163	-0.949649	-0.104779	
Range	1.25109433	1.2117163	0.5315653	0.910702	The best program is: $A_1 B_2 C_2 D_2$
Optimized program	A_1	B_2	C_2	D_2	

Table 5. Increased Value of Oil Permeability

Test number	Core number	Composite motion parameters	Core state	Permeability(mD)	Permeability variation(mD)
1	A81	0	YX	9.704015	0.387405
		(0.1,40,2,1)	YXZD	10.09142	
2	A82	0	YX	10.61837	-0.769177
		(0.1,60,5,1.5)	YXZD	9.849193	
3	A83	0	YX	8.752165	-0.20633
		(0.1,80,8,2)	YXZD	8.545835	
4	A84	0	YX	9.373004	0.43486
		(0.2,40,5,2)	YXZD	9.807864	
5	A85	0	YX	8.187829	0.056753
		(0.2,60,8,1)	YXZD	8.244582	
6	A86	0	YX	7.532471	-0.043072
		(0.2,80,2,1.5)	YXZD	7.489399	
7	A87	0	YX	8.67463	0.4458
		(0.5,40,8,1.5)	YXZD	9.12043	
8	A88	0	YX	7.065666	-1.664204
		(0.5,60,2,2)	YXZD	5.401462	
9	A89	0	YX	10.56178	-1.115914
		(0.5,80,5,1)	YXZD	9.445866	

Orthogonal analyzing table5 comes table6

Table 6. Quadrature Analysis of Increased Oil Permeability

Factor / Test number	1 A (acceleration g)	2 B (frequency Hz)	3 C (hydrostatic pressure MPa)	4 D (dynamic pressure MPa)	Index Permeability variation(mD)
1	1	1	1	1	0.387405
2	1	2	2	2	-0.769177
3	1	3	3	3	-0.206331
4	2	1	2	3	0.43486
5	2	2	3	1	0.056753
6	2	3	1	2	-0.043072
7	3	1	3	2	0.4458
8	3	2	1	3	-1.664204
9	3	3	2	1	-1.115914

K_1 K_2 K_3	-0.588103 0.448541 -2.334318	1.268065 -2.376628 -1.365317	-1.319871 -1.450231 0.296222	-0.671756 -0.366449 -1.435675	Summation of all factor index
$K_1/3$ $K_2/3$ $K_3/3$	-0.1960343 0.14951367 -0.778106	0.4226883 -0.792209 -0.455106	-0.439957 -0.48341 0.0987407	-0.2239187 -0.1221497 -0.4785583	Average of all factor index
Range	0.92761967	1.2148977	0.582151	0.35640867	The best program is: A_3 B_1 C_3 D_2
Optimized program	A_3	B_1	C_3	D_2	

5. Conclusion and Understanding

(1).There are some influences which the two coupled waves affact oil-water single permeability. When resonance wave and impulse wave are matched under certain fluctuation parameters, there is an improvement effect on core's permeability (Core B52's water permeability is increased from 9.03707mD to 9.482797mD, and water permeability increment is 0.445726mD; Core A87's oil permeability is increased from 8.67463mD to 9.12043mD, and oil permeability increment is 0.4458mD).That is to say, when matching under certain parameters, there is an improvement effect on core permeability.

(2).There isn't always an improvement effect under any condition. Unsuitable wave parameters may reduce the core's permeability (Core A82's oil permeability reduced from 10.61837mD to 9.849193mD, and oil permeability decrement is 0.769177mD; Core B51's water permeability increased from 10.56178mD to 9.445866mD, and water permeability decrement is 1.115914mD).

(3).How to choose composite wave fluctuation parameters to increase core permeability to the most degree needs further research.

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