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Alternative Acidizing Fluids and Their Impact on the Southern Algerian Shale Formations

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***Abstract*—**Acidification is a technique used in oil reservoirs to improve annual production, reduce the skin and increase the pressure of an oil well while eliminating the formation damage that occurs during the drilling process, completion and, amongst others, to create new channels allowing the easy circulation of oil around a producing well. This is achieved by injecting an acidizing fluid at a relatively low pressure to prevent fracturing formation. The treatment fluid used depends on the type and nature of the reservoir rock traversed as well as its petrophysical properties. In order to understand the interaction mechanisms between the treatment fluids used for the reservoir rock acidizing, several candidate wells for stimulation were selected in the large Hassi Messaoud deposit in southern Algeria. The stimulation of these wells is completed using different fluids composed mainly of HCl acid with other additives such as corrosion inhibitors, clay stabilizers and iron controllers. These treatment fluids are injected over two phases, namely with clean tube (7.5% HCl) and matrix aidizing with HCl (15%). The stimulation results obtained are variable according to the type of rock traversed and its mineralogical composition. These results show that there has been an increase in production flow and head pressure respectively from 1.99 m3 / h to 3.56 m3 / h and from 13 Kgf / cm2 to 20 kgf / cm2 in the sands formation having good petrophysical properties of (porosity = 16%) and low amount of clay (Vsh = 6%).

***Keywords*—**Acidizing, Hassi-Messaoud reservoir, tube clean, matrix stimulation.

I. Introduction

THE acidification technique is a stimulation treatment performed on oil and gas wells in order to improve the wells annual productivity drilled in low permeability and /or damaged reservoirs during the drilling fluids circulation or during completion work [1]–[3]. This technique uses large volumes of fluids composed of different ingredients each of which plays a well defined role and which are pumped into a well candidate for stimulation with certain pumping rates under a well calculated pressure. This pressure must not be greater than the formation pressure in order not to create fractures thus causing a loss of the fluids, nor less than the pressure of the drilled formation in order to prevent any migration of the fluids in the oil well [4]. In general, there are three categories of acidification fluids namely washing fluids, matrix acidification and fracturing acidification [1], [5], [6]. The first type, acid wash, the goal is a simple cleaning of the tubings and the well [7]. In this case, the most commonly used acidification fluid is hydrochloric acid (HCl) mixed with other ingredients to remove calcium carbonates, rust, and other damaging particles that limit the flow of fluids in the reservoir oil well [8]. While matrix acidification and fracturing acidification are used to restore the initial pressure of a petroleum field on the one hand and increase annual productivity on the other hand, by dissolving the particles in the productive formation that block natural fluids flows, or to dissolve the rock formation itself to enhance the existing formation, or to create new flow paths to the wellbore [1], [6], [7], [9]–[13]. The use of one or the other of the three types of acidification fluids is dictated by the nature and type of the formation through which the borehole is passing. For the carbonate formations, the appropriate fluid used hydrochloric acid (HCl) whose main objective is to dissolve the particles of the carbonate formations detached and deposited on the walls or even in the pores, to clean or to create new channels allowing the easy circulation of fluids that are the object of exploitation [14], [14]–[16]. On the other hand, in the sandstone formations, the treatment fluid consists essentially of hydrofluoric acid (HF) coupled with hydrochloric acid (HCl) in order to dissolve the particles composing the reservoir rock such as quartz, feldspar and clay particles thus allowing the free circulation of fluids stored and blocked because of the presence of these particles [5], [6], [9], [17]–[21]. Another parameter that needs to be reported and considered with care, it is the reservoir permeability that containing the fluid [14], [22]–[24]. The latter makes it possible to determine the pressure necessary to inject the acidification fluid. For formations whose permeability is high, the acidification fluid, a matrix acidizing fluid, is injected with a relatively low pressure in order to prevent fractures generation. In return, for formations whose permeability is low, the acidification fluid is injected with a relatively high pressure to create new channels.

In our study, the acidification stimulation technique was used in the Hassi Messaoud field in southern Algeria to improve annual productivity following a remarkable drop in the pressure feild. Before using the technique of stimulation by acidification, several measurements were investigated in order to follow the evolution of certain parameters which seem to be very interesting for the determination of the main causes in the production fall of the candidates wells for the stimulation.

In general, the acidification stimulation technique is affected by the following key parameters: geometry and geology of the oil reservoir, petrophysical properties (porosity and permeability), fluid properties (viscosity and density) and mineralogical properties (different clays in the reservoir rock). The main objective of this work is to study the effect of

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the different acidifying fluids used in the selected wells as candidates for the improvement of the productivity as well as the initial restoration of the permeability of the Haoud Berkaoui oil field.

II. Acidizing Experiments

A. Methodology

In our study, we selected representative wells from the Hassi Messaoud region in southern Algeria to investigate the role of the acidification technique on the wells productivity based on the interaction between the different reservoir levels and fluid used as acidifier. Well selected is an oil producing, which began producing in 2000 and then dropped to less than 10 m^3/hr. In 2012 the well was selected for a reformat cleaning, in August 2013, a reformat matrix treatment was carried out, then in May 2014 a clean and clean out tube was made, which gave a gain of 1m^3/hr then relapsed to 10 m^3/hr. After trying the organic solvent (reformate) treatments which did not give an improvement as expected, this may be due to the non reactivity of the solvent with the sandstone formation [25], [26]. On this basis, there has been talk of treating the reservoir matrix with acid. In the case of matrix treatment of the candidate well in Hassi Messaoud feild in southern Algeria, the procedure for the acidification operation of the reservoir formation was carried out in two phases as follows : Cleaning the tubing liner and perforations with nitrified treated water and nitrified Tube clean (hydrochloric acid:HCl 7.5%) in the following proportions: nitrified treated water (04m^3) and nitrified Tube Clean HCl 7.5% (04m^3). The second phase is carried out using the matrix treatment with acidifying fluid containing clay coupled with HCl 5% Sandstone Acid Half Strenght with various additives. During this phase, the coiled tubing (CT) descended to the bottom (3480 m) at 20 m/min by pumping nitrified treated water to 0.3 Bpm, when it reaches the level 3432 m (mis perfos), treatment fluids are pumped as follows: 2.0 m^3 of treated water (Spacer between foam and acid) 1.2 bpm, 2.0 m^3 of preflush (Formic Acid 10%) 1.2 bpm and 2.3 m^3 of HS BJ SSAcid 1.2 bpm

B. Mineralogical Composition of the Candidate Well

The reservoir well studied is composed mainly of coarse sandstone and medium to fine sandstone, carbonate and siliceous cement and clay. It is an eruptive well with a useful height of around 11.5m, its porosity is around 7%, the average clay volume is 6.81% with an average water saturation of 27%. These data are shown in Table III below:

TABLE I
Well and Reservoir Data

Status	PPH eruptive
Reservoir	SI
Useful height	11.5m
Average useful porosity	6.67%
Average Vsh	6.81%
Average Sw	27.2%
useful height of sandstone	15.5m
Formation	sandstone

C. Well History

The production evolution from 1999 to 2014 as shown on the Fig. 1, shows us that production peaked in the early 2000s and then fluctuated in production from 1999 to 2014 ranging from 9m^3 to 13m^3 until 2006 when there is a severe drop in production. After performing a bottom well cleaning operation, an increase in the oil flow is recorded. In 2008 it was found again a lowering which required to recommend the acidification of this well. At the end of this operation, it can be seen that production has increased and then stabilized in recent years.

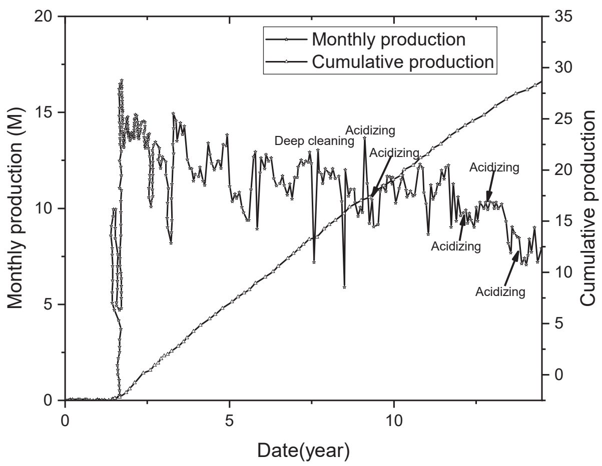

Fig. 1 Evolution of production from 1999 to 2014

D. Jaugeage Tests

Before carrying out the acidification operation, we found it useful to use some measurements to get an idea of the production parameters of a well under the operating conditions. First of all the jaugeage test, is a very important well surface operation, is first used for head pressure, line pressure, oil and gas flow (Fig. 2). This allows us to know the optimum operating parameters of this well and to evaluate it regularly in order to maximize the productivity in good conditions.

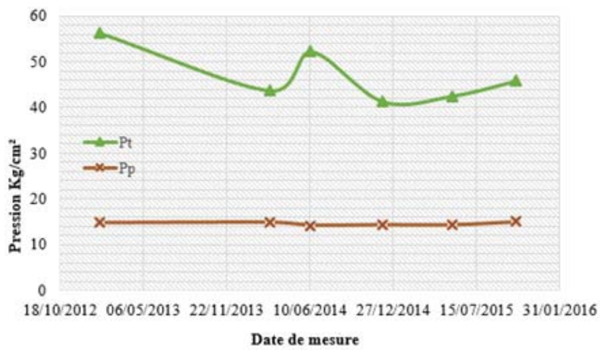

Fig. 2 Pressure Evolution from 2012 to 2016

The results obtained show that the head pressure decreases from October 2012 until November 2013, then this pressure is accentuated by reaching a peak of 52.52 kg/cm^2 which corresponds to a stimulation by the acid. At the end of the operation, this pressure relapses to 41.30 kg/cm^2 and then increases to 45 kg/cm^2 in 2016 (see Fig. 3).

About the oil and gas flow, the results presented in Fig. 4 show that the oil flow drops from 2012 to 2014 the date corresponding to the stimulation by acidification where we notice a slight increase of production flow then the flow stabilizes until 2016. This is due in fact to the new channels creation (wormhole) allowing easy circulation of fluids [27], [28].

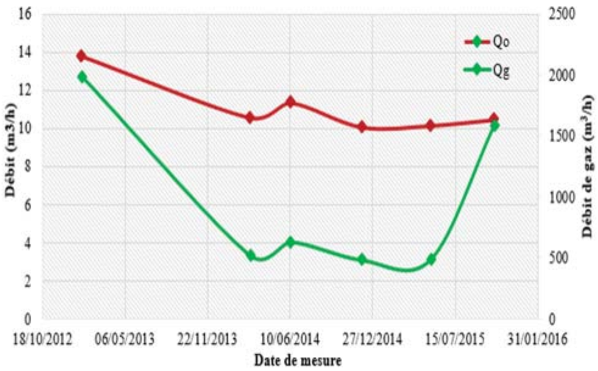

Fig. 3 Oil and gas flow rate evolution from 2012 TO 2016

From Figs. 2 and 3, it can be seen that oil flow and head pressure change concomitantly, indicating that head pressure influences production. This drop in oil and gas production from the candidate well to the stimulation is probably due to the drop in reservoir pressure [29], [30]. In order to follow the evolution of the pressure over the years, we examine the results of the additional tests previously carried out on the well BKHE1, the results obtained are presented on the Fig. 4. These measurements give us information on the different pressures PFD-CM (Dynamic bottom pressure taken at the measurement coast ie at an altitude of 3400m), PFS-CM (Static bottom pressure), PFS-CR (Measurement of the static bottom pressure at a coast taken as a reference).

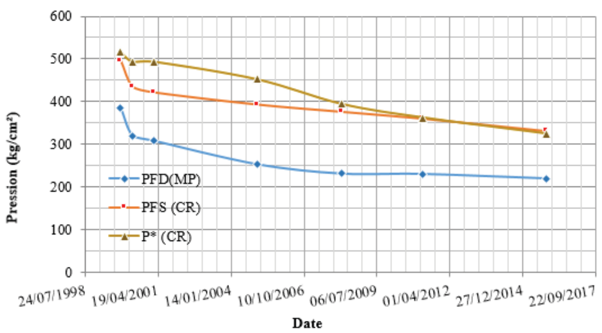

Fig. 4 Information on the different pressure

According to the results obtained by the used technique (see Fig. 4), we notice that the pressure decreases from the production beginning until 2009, then begins to stabilize until September 2016. The static pressure, meanwhile, decreases considerably during the first years of production (1998-2001), then this fall begins to decrease and which is represented graphically by a low slope until the year 2017. It should also be noted that the dynamic bottom pressure is correlated with that of the static bottom.

1) Production Logging Tool Measurement (PLT): PLT is a tool used to assess downhole problems when there have been anomalies in surface production flow. It also allows the constitution of each perforation level and the nature of the constitution effluent [31], [32]. The Table II, shows the PLT measurement results performed on the candidate well before the stimulation technique. The obtained PLT measurement makes it possible to follow the pressure evolution in the case where a drop in production is observed, and that the well liner (WL) control did not represent any necessary constraint to recommend moving onto the acidizing technique. The results indicated that The reservoir is decomposed into six (6) zones, the data of each zone relate to: oil flow "Qo", gas flow "Qg", dynamic bottom pressure "PFD", temperature the dynamic bottom "TFD" and the oil participation rate (%) (see Table II):

We note that the dynamic pressures obtained by the PLT technique is relatively stable. The shape of the temperature curve obtained by this technique clearly indicates that the production comes mainly from the N_4 level as shown on the Fig. 5. It should also be noted that the level N_4 corresponding to the depth 3430.00 m-3432.00 m participates with a high oil content (72%), and a high oil flow rate 10.95m^3/ h while the other levels N_2 and N_3, N_5 and N_6 show a low to very low participation rate as shown in the table above.

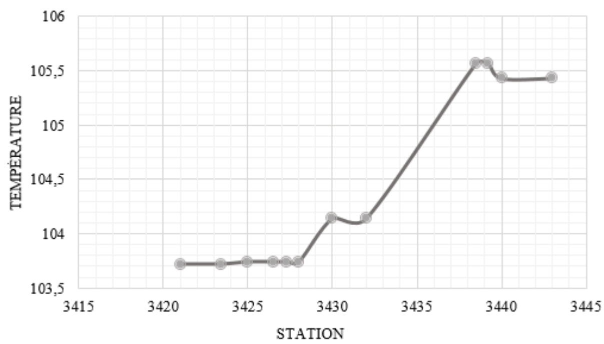

Fig. 5 Evolution of the temperature according to the different levels of the productive layer

The results of the matrix treatment with the acidifying acid containing clay and others additives coupled with 5% HCl are shown in Table II. The comparison between the parameters is presented in Table III below. Matrix treatment using acidizing allowed to improve production from 10.06 m^3/h to 10.14 m^3/h.

The comparison of the results with the latest measurement of 24/09/2011, shows a selective participation after acidification, with the fourth B_4 bench as the best producer, while the B1 saw its participation improved from 4.66% to 11.69%. The N_2 bench participates with 12.05% while the other banks N_1, N_5 and N_6 contribute slightly.

TABLE II
PRODUCTION LOGGING TOOL MESURE

Reservoir	Productive zones(m)		Qo	Qg	SBP	TFD	Participation rate Oil
			m^3/h	m^3/h	Kg/cm^2	°C	%
	NI	3421 3423.40	0.68	110.42	223	103.72	4.66
	N2	3425 3426.50	1.76	284.51	223.39	103.74	12.05
	N3	3427.30 3428.00	1.03	165.96	223.45	103.74	7.05
SI	N4	3430 3432	10.53	1705.39	223.68	104.14	72.12
	N5	3438.5 3439.20	0.059	9.65	224.15	105.57	0.40
	N6	3440 3443	0.54	87.60	224.35	105.43	3.70

TABLE III
COMPARISON BETWEEN THE PARAMETERS OF THE WELL BEFORE AND AFTER STIMULATION

Level	Perforations (m)		PLT before acidizing			PLT after acidizing		
N1	3421.00	3423.40	1.14	11.69	194.06	0,68	4.66	110.42
N2	3425.00	3426.50	1.19	12.21	201.62	1.76	12.05	284.51
N3	3427.30	3428.00	0.72	7.38	122.24	1.03	7.05	165.96
N4	3430.00	3432.00	6.69	68.62	1133.35	10.53	72.12	1705.3
N5	3438.50	3439.20	0.00	0.00	00	0.059	0.40	9.65
N6	3440.00	3443.00	0.008	0.08	1.40	0.54	3.70	87.60

III. CONCLUSION

On the basis of the obtained results, it should be noted that there was an increase in the production rate and the head pressure, which increases respectively from 1.99 m^3/h to 3.56 m^3/h and from 13 Kgf/cm^2 to 20kgf/cm2. Although The reservoir is mainly composed of sandstone, the stimulation with a clay-based acid gave a significant result, this is probably due to the characteristics of the reservoir having a good porosity which exceeds 16% with a low presence in clay whose content does not exceed 7%.

NOMENCLATURE

- Vsh: Shale volume (%)
- PFD-CM: Dynamic bottom pressure taken at the measurement coast
- PFS-CM: Static bottom pressure
- PFS-CR: Measurement of the static bottom pressure at a coast taken as a reference
- Q_o: Oil flow rate (m^3/h)
- Q_g: Gas flow rate (m^3/h)
- SBP: Static bottom pressure (Kg/cm^2)
- SBT: Static bottom Temperature (°C)
- Sw: Water saturation (%)
- PLT: Production Logging Tool mesure
- PPH: Eruptive well oil

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