DOLOMITE MINERAL EFFECTIVENESS ON THE SANDSTONE RESERVOIR PERMEABILITY

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الملخص

قد تكون تقنية تحمض تكوين الصخور المصفوفة طريقة عادية لتحسين نفاذية صخور الحجر الرملي المحيطة بحفرة البئر. يمكن لصخور الدولوميت $CaMg(CO_3)_2$ سد منطقة الدفع حول حفرة البئر والتسبب في تقليل النفاذية في خزان الحجر الرملي النفطي. وبالتالي، يمكن خفض معدل تدفق النفط بسبب وجود معادن كربونات الدولوميت في مساحة المسام. لذلك، تم فحص التغير في قيمة النفاذية ومعدل التدفق في مقياس نفاذية الصخر الرملي الذي تم إعداده عند محتوى مختلف من الدولوميت والذي يليه حقن تركيز حمض الهيدروكلوريك (HCL) بنسبة 15٪ لإزالة معدن الدولوميت و لتحسين نفاذية تكوين الحجر الرملي، تم إجراء اختبار نفاذية الرأس الثابت لقياس نفاذية خزان الحجر الرملي عند قيم تركيز مختلفة للدولوميت، وأظهرت النتائج التي تم الحصول عليها أنه عند أدنى محتوى الدولوميت (X_{min}) البالغ 26.6٪، تكون مسامية خزان الحجر الرملي بشكل كبير انخفضت إلى قيمة تساوي 21٪ حيث كانت المسامية في الأصل 42٪، وبالمثل، كان معدل تدفق المياه ونفاذية المياه 2.5 سم^3 / ثانية و12.11 دارسي على التوالي، عند عدم وجود معدن الدولوميت في الرمل، ومع ذلك، كان معدل تدفق المياه ونفاذية المياه تم خفضها إلى 1.316 سم^3/ ثانية و 8.5 دارسي على التوالي، عند محتوى الدولوميت (X_{min}) البالغ 26.6٪ من إجمالي حجم الحبوب. بالإضافة إلى ذلك، يمكن لوظيفة حقن حمض HCL أن تعيد نفاذية تكوين الحجر الرملي إلى

القيمة الأصلية البالغة 42٪. في الختام، يمكن للمعادن الصخرية الكربونية مثل الدولوميت أن تسبب ضررا لخزان الحجر الرملي. ومع ذلك، فإن حمض HCL له تأثير إيجابي ملحوظ لإزالة أضرار معادن الدولوميت من خزان الحجر الرملي المحيط بحفرة البئر.

Abstract: The matrix rock formation acidization technique might be a regular mode to improve the sandstone rock permeability surrounding the wellbore. The dolomite rock $(CaMg(CO_3)_2$ can plug the pay zone around the wellbore and cause permeability reduction action into the oil sandstone reservoir. Ergo, the oil flow rate can be cut down due to presence of the dolomite carbonate minerals into the pore space that originally was vacant of it. Therefore, the change in the permeability value and flow rate are investigated into the Sandpack permeameter set up at different dolomite content which followed by 15%wt. hydrochloric (HCL) acid concentration injection to remove dolomite mineral composition and to improve sandstone formation permeability. The constant head permeability test has been conducted to measure the permeability of the sandstone reservoir at different dolomite concentration value. The obtained results shown that at the lowest dolomite content (X_{min}) of 26.6%, the sandstone reservoir porosity substantially decreased to value equal to 21% which the porosity originally was 42%. Similarly, the water flow rate and permeability were 2.5 cc/sec and 12.11 D respectively, at the no dolomite mineral in the Sandpack, however, the water flow rate and permeability were cut down to 1.316 cc/sec and 8.5 D respectively, at dolomite content (X_{min}) of 26.6% of the total grain volume. Besides, the HCL acid injection job can return the sandstone formation permeability to the original value of 42%. In conclusion, Carbonate rock minerals such as dolomite can cause damage to the sandstone reservoir. However, the HCL acid has a remarkable

positive impact to remove the dolomite minerals damage from the sandstone reservoir surrounding the wellbore

Keywords: Matrix acidizing, dolomite, sandstone reservoir, permeability

Introduction

One of the most important stimulation modes is the matrix rock formation acidization technique that has been being extensively utilized since 1930s. This technique relies on the acid solution that is injected into the oil/gas pay zone. The pressure of injection acid may be below fracturing pressure of the formation (McLeod, 1984) throughout the perforations in order to remove the small rock pieces (minerals) that cause plugging to the formation reservoir which leads to the permeability reduction around the wellbore (Economides, *at. al*. 1994). Consequently, the plugged sandstone formation can be a barrier that influences the distribution of the fluid through the porous media. In other words, this rock formation is defined as a damaged pay zone (Economides and Nolte, 1989). In respect of the way, the near low permeable region around the well directly reveals a negative impact on the oil production rate. Therefore, the low permeability and pressure difference between wellbore and reservoir have dramatically been altered throughout the production period which is attributed to urgent demand for matrix acidization processing (Yu et al. 2011; Garrouch and Jennings, 2017). Hence, the engineers would discover a probable mode to take off the existed damages or innovating novel alternative ways to allow the oil flows conveniently (Hung et al. 1989;). So, in the oil and gas industries, the appropriate methodology is the acidizing technique as a result of its high implementation and its substantial compatibility to all sorts of the rock formation (Rabbani, et. al., 2018). Consequently, to overcome the shortcoming factor that may has a capacity devastation influence onto production fluids flow rates. This technically mode claims matrix acidizing in order to simultaneously dissolve and scatter the rock tiny minerals away while making connections of wormholes into the formation zone (Guimarães et al. 2017). One of the essential targets of this laboratory research is to boost the formation permeability as well as remove the carbonate rock minerals from the sandstone formation reservoir (Ghommem et al. 2016). Consequently, the acid treatment can occur new tunnels amongst interconnected void spaces with additional high permeability value compared to the original rock permeability (Medina et al. 2015). Therefore, the principle objective of the acidization applications is to extremely enhance the producer wells by eliminating damages that are attributed to the drilling jobs and the precipitation of travelling rock minerals through flowing fluids towards wellbore side or to improve the physical factor such as permeability and porosity rather than influence a large section of the reservoir (Economides, at. al. 1994; Babaei and Sedighi 2017).

The natural clay of bentonite (montmorillonite), calcite, siderite, sodium feldspar (albite), quartz, kaolinite, dolomite, orthoclase and others are known as the natural minerals that associate the sandstone reservoir pores space. In addition, the mentioned minerals may invade the rock reservoir due to drilling fluid (mud), cementing and well completion. Moreover, sand rock reservoir occasionally contains carbonate rock such as dolomite (calcium-magnesium carbonate) ($CaMg(CO_3)_2$) and limestone (Calcite) ($CaCO_3$) minerals which located into the void space, as a result of this phenomena the minerals induce the restriction of the reservoir fluid flow (Economides and Nolte, 1989). The chemicals might be dissolved in the reservoir water and precipitate in the formation pore space as a result of conditions change or the mixture of incompatible waters. These chemicals precipitation is called scale formation which can be present in the perforations and in the regions surrounding the wellbore. The calcite rock ($CaCO_3$) (calcium carbonate) is one of the most common minerals that causes formation damage problem which follows by permeability reduction (Cowen and Weintritt, 1976). In case of reservoir permeability criteria, the rock formation with greater than 10 md of permeability may be susceptibe to the acidization process. On the other hand, the reservoir formation permeability less than unity md might strongly be nominee for fracture acidization job (Rabbani, et. al., 2018).

Formation damage is defined as the negative change in the permeability value formation immediately surrounding the wellbore. In other words, it is skin effect which is technically to denote any decrease in the value pressure drop at the wellbore as compared to ideal flow pressure performance. Moreover, the formation that is not stable can occur in the reservoir which is slightly consolidated or it may be failed due to reservoir pressure depletion or water production onset. One of the most important methods to measure the skin effect is the well test analysis (Jun and Minglu, 2009). Well testing is a worldwide operation method that is used in order to measure two of the most essential parameters which are the skin effect (damage) and pressure difference due to damage as well as the reservoir formation characteristics behavior and its problem such as low fluid flow rate (Zhao, et. al., 2015). The build up test analysis and drawdown test analysis are the common well testing operations which use for petroleum and gas industries. It can collect the useful information about well damage data from the reservoir and wellbore information bank (Dai Weihua and Yuguo 2006; Azamifard et al. 2016).

Since there are minerals such as dolomite and limestone are present in the sandstone reservoir, it may acids such as hydrochloric acid and hydrofluoric acid would be used to dissolve these rock minerals to get rid of them from the pore space. Consequently, the fact minerals solubility in the sandstone formation substantially depends on their location within the geological reservoir rock structure. Therefore, the petrographic investigations study might be an assistance technique in understanding the susceptible of the reservoir rock to the acid treating during matrix acidizing implementation. Subsequently, it is a remarkable to mention the following: Hydrochloric acid (HCl) solubility, the solubility of the rock such as dolomite and calcite (limestone) (Wang and Schechter, 1993; Khalil at. el., 2017) in the hydrochloric acid is ordinary considered to act the carbonate rock minerals content in the sandstone reservoir. This suggestion has to be taken into account throughout the researches such as the laboratory and petrographic study. Similarly, hydrofluoric acid (HF) can react with calcite ($CaCO_3$) to produce a calcium fluoride CaF_2 which is a considered insoluble product and it can precipitate in the porous media close to the wellbore that is its roll to cause damage again (Economides and Nolte, 1989).

However, it is important to remind that preflush of hydrochloric acid with about 15% wt. can be an assistant factor to avoid contact between carbonate rock (dolomite and limestone) and hydrofluoric acid (HF). Consequently, firstly, it is recommended to inject the hydrochloric acid in the sandstone. The reason, it may be done to avoid the probable insoluble precipitation of reaction products during removing carbonate rock minerals of dolomite and limestone from the sandstone reservoir rock. Actually, the insoluble substances are sodium hexafluorosilicate (Na_2SiF_6) or potassium hexafluorosilicate (K_2SiF_6) which would be formed from the cations reaction in the formation brine water with solubilized salts as well as calcium fluoride (CaF_2) that may be formed upon hydrofluoric acid reaction with carbonates (calcite and dolomite) during matrix acidizing applications. Therefore, the main function of hydrofluoric acid (HF) generally is to get rid of the aluminosilicate (primarily clays and feldspar) fines from sandstone formations (Economides and Nolte, 1989).

1- Experiment setup

1.1 Material

The reservoir rock of dolomite grinding samples have been collected from Geology department, Laboratory, Faculty of science, Bani Waleed university. The glass pieces (quartz) sample was obtained from the Laboratory of Oil & Gas Department, Faculty of Engineering, Bani Waleed university. The glass pieces have been used to simulate the sandstone reservoir rock. In addition, the Hydrochloric acid (HCL) with concentration 15% wt. and sodium chloride salt were collected from chemical department, Education Faculty, Bani Waleed university.

1.2 Apparatus

The different sizes of pipes, taps, accumulators, tanks and other supplements (graduated cylinders, beakers, funnel, stirring rod, magnifying class, electronic balance, Erlenmeyer flasks) have been bought from different markets around Bani Waleed city in order to fabricate the complete experiment setup.

3 Trial Methodology

3.1 Acid and Carbonate Minerals Reaction Stoichiometry

The sandstone rock treatment requires a particular HCl preflush solvent to dissolve the whole presented soluble carbonate minerals in the pore space of the sand rock. According to the reactants relative ratio (stoichiometry of the reaction) the dissolving power concept may be found out. Therefore, the required magnitude of acid that might be estimated is actually based on the minerals magnitude which might be removed by a given acid amount. Consequently, the procedure of the acid preflush volume calculation for dolomite mineral can be as follows:

3.1.1 Hydrochloric Acid and dolomite reaction

Hydrochloric Acid + Calcium Magnesium Carbonate ------ Calcium Chloride + Magnesium Chloride + Carbone Dioxide + Water

$4HCl + CaMg(CO_3)_2$ ------------ $CaCl_2 + MgCl_2 + 2CO_2 + 2H_2O$

3.2 Amounts and Dissolving Power

3.2.1 Gravimetric dissolving power of HCl at 100% wt.

$$\beta_{100} = \frac{\mathrm{m}_{min}}{\mathrm{m}_{ac}}$$

3.2.2 Gravimetric dissolving power of HCl at 15% wt.

$$\beta_{15} = (\beta_{100})(0.15)$$

3.2.3 Volumetric dissolving power at 15% wt. of acid

$$X = \beta_{15}\left(\frac{\rho_{ac}}{\rho_{min}}\right)$$

ρ_{ac} and ρ_{min} are the acid and mineral densities, gm/cc

3.2.4 Acid volume required to dissolve all minerals,

$$V_{ac} = \frac{V_{min}}{X}$$

$$V_{min} = Y\%\, V_P$$

Y is 10, 20, 30, 40 and 50

X_{min} is the mineral content in the sandstone rock sample

$$X_{min} = \frac{V_{min}}{Total\ solid\ volume}$$

3.3 Porosity Measurement

The dry Sandpack is weighted two times. Firstly, it is weighted when it is dry (without water). Secondly, it is weighted while it is completely saturated with distilled water. The difference between weights is represent the pore volume. Therefore, the porosity can be measured by the following relationship:

$$\emptyset = \frac{\text{Disstilled water volume}}{\text{Bulk volume}}$$

3.4 Permeability Measurement

The sandpack permeability is measured according ASTM D 2434 international standard. It indicates to the flow of water through sand grains which refers to the hydraulic conductivity measurement that can be conducted in the laboratory as a constant head permeability test (Nijp, et. al., 2017; Reynolds et al., 2002; Klute, 1986; Dirksen, 1999) (**Figure 1)**. The length and diameter of sandpack holder is 45 cm 8.4 cm respectively. The following relationship depicts the permeability coefficient and water flow rate.

$$K = \frac{V\,L}{t\,A\,h}$$

V stand for water volume, cc, A is the x-sec area, K is the hydraulic conductivity, t is the time, sec, L is the difference in piezometers inlet, cm and h is the difference in piezometers head, cm. So, the next equation can be used to estimate permeability coefficient:

$$k = \frac{\mu\, K}{\rho\, g}$$

g is the gravitational constant, [981 cm/sec^2], μ is the viscosity of the flowing water, [gm/(sec. cm], k is the permeability coefficient, [cm^2]

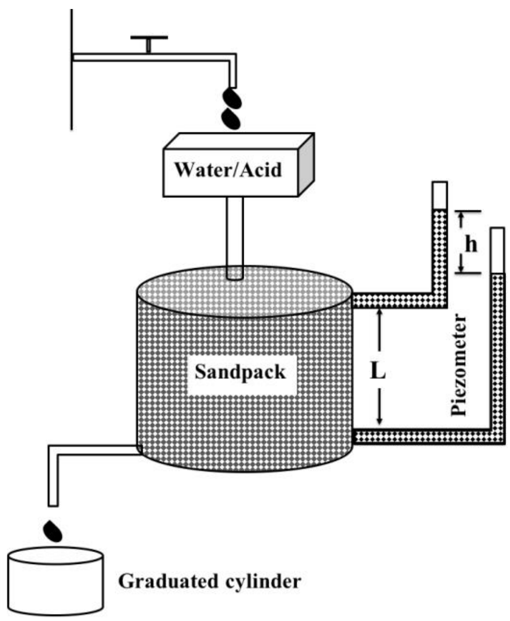

Figure 1: Matrix acidization treatment Set-up/Cons. Head permeability test

3.5 Dolomite and Sandpack Preparation

Carbonate rock samples have been washed by distilled water, cleaned and dried in the oven. The both samples were mixed with glass (quartz) pieces (sandstone rock) and introduced in the sand holder (permeameter) slowly till the holder is completely filled up. The dolomite content in the sandstone reservoir which simulate the plugged (damaged) zone may be summarized in the Table 1.

Table 1: Permeameter, dolomite and acid properties.

D, cm	L, cm	V, cc	B_{15}	ρ_{ac}
8.400	45.5	2521.5	0.1893	1.07
ρ_{min}	X, cc_{min}/cc_{ac}	ϕ	Vp, cc	Vs, cc
2.8673	0.07064	0.42	1059	1462

4 Results and Discussion

The treatment of matrix might consist of eliminating the damage which impairs the permeability of the formation. Consequently, it can be noticeable from the plot of dolomite content (X_{min}) versus sandstone formation porosity, the porosity decreases with increase of the amount of damaging $CaMgCO_2$ mineral (Figure 2). The original porosity was 42% (without carbonate minerals). However, in the first experiment, the dolomite content (X_{min}) is set at 6.8%, the sandstone reservoir porosity substantially decreased to value equal to 37.5% which attributed to pore plugging. Similarly, the pore volume of the sand formation decreased with increased of the carbonate rock compositions ($CaMgCO_2$) that leads to formation damage as shown in the **Figure 3**.

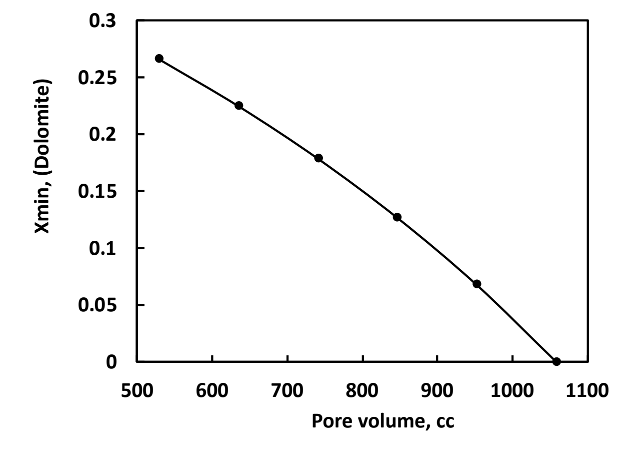

Figure 3: Pore volume reduction due to dolomite

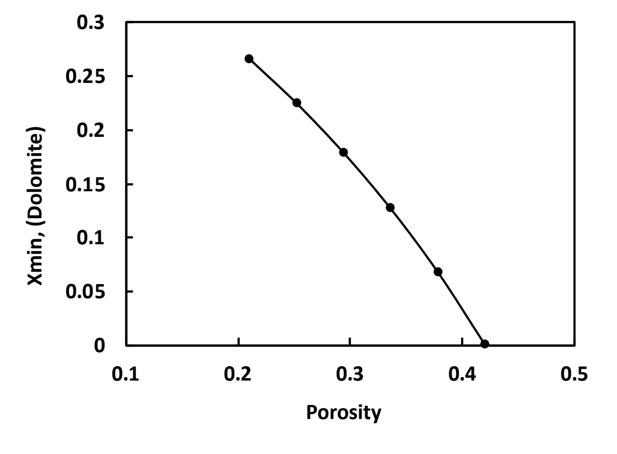

Figure 2: Porosity reduction due to dolomite damage

In addition, the permeability of the sand rock reservoir is dramatically decreased at each increased $CaMgCO_2$ different volumes (Figure 4). As shown by the zero-volume value of minerals, the permeability at the highest value of 12.11 D. On the other hand, the permeability is measured at 8.51 D which reflects the presence of damage due to high dolomite compositions content in the sandstone reservoir pore space. Consequently, the formation permeability is directly affected by carbonate rock compounds such as calcium magnesium carbonate.

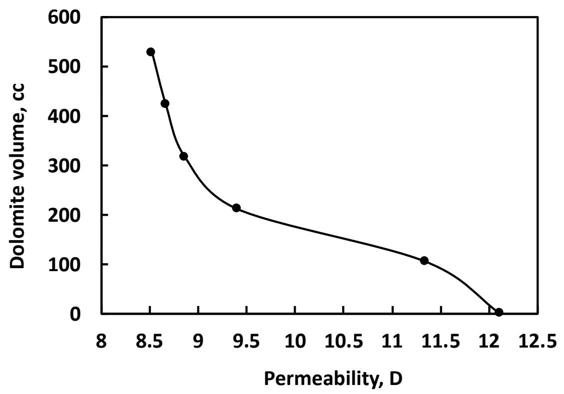

Figure 4: Dolomite volume effectiveness on the

Moreover, the relationship between distilled water flow rate and formation permeability can be displayed in the Figure 5. The flow rate is drastically influenced by reservoir permeability change, so, the flow rate is at the highest value of 2.5 cc/min at the original permeability of 12.11 D, however, it is at the lowest rate of 1.31 cc/min when the permeability is 8.51 D. This is in agreement with the results that obtained from the relationships between flow rate and $CaMgCO_2$ concentration (X_{min}) as shown in Figure 6. The flow rate is inversely proportional relationship with the minerals content in the sandstone reservoir as a result of presence of dolomite rock which in role cause damage to the formation. At zero minerals content, the flow is at the highest rate but in the presence of the minerals the negative impact can be noted on the flow rate.

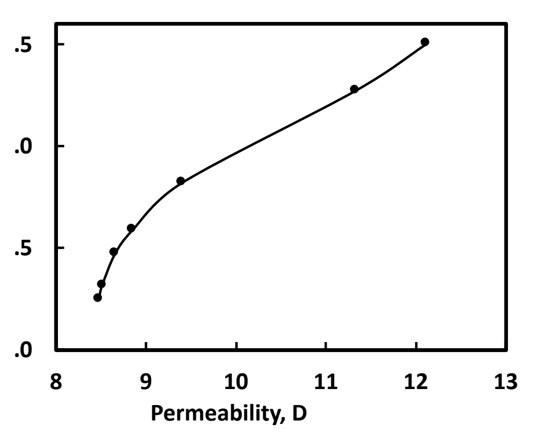

Figure 5: Permeability effectiveness on the

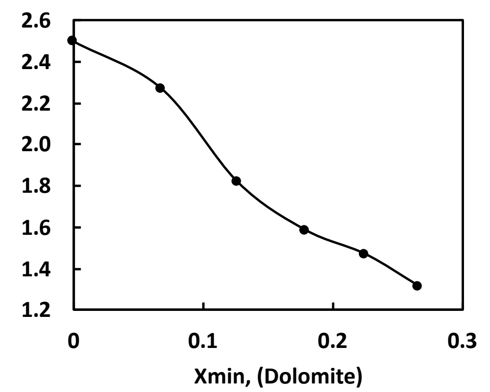

Figure 6: Dolomite effectiveness on the water flow rate

On the other hand, matrix acidization treatment might have a positive impact on the flow rate, because the minerals that cause formation damage can be eliminated by using the hydrogen chloride acid injection into the sand formation at a regular concentration equal to 15 wt%. Therefore, the HCl acid injection substantially has a remarkable influence on the dolomite rock concentration (X_{min}) that causes damage to sandstone reservoir rock as depicted in the Figure 7. In the case of the acid concentration gradually increases from minimum value of 1499 cc crossponding to dolomite level of 6.8% to the maximum value of 7495 cc which is crossponding to dolomite level of 26.6%, this can be described as productively job because the HCl has an ability to remove the damage from the sand rock as a result of the acid and carbonate rock minerals reaction (Figure 8).

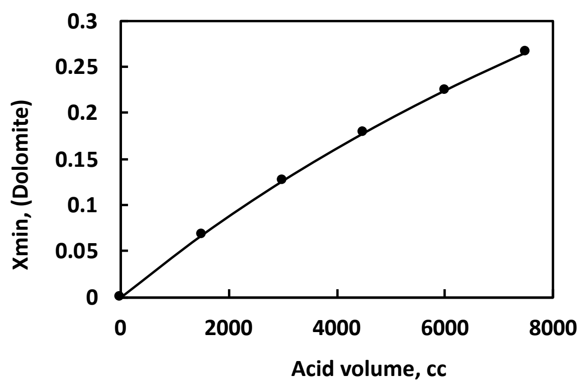

Figure 7: Acid volume required for dolomite rock

Conclusion

The sandstone formation can be damaged by dolomite rock mineral during production life. Therefore, the permeability value formation might be absolutely reduced when the dolomite invades the pay zone. Similarly, the flow rate may be cut down due to pore volume reduction as a result of presence of dolomite composition. However, the matrix rock formation acidization technique is the proper work to maintain sandstone rock permeability. The HCL acid concentration equal to 15% wt. can reflect a positive impact on the oil flow rate in the oil industry.

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