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Sand Production Control in Sandstone Reservoirs Using a Modified Urea-formaldehyde Resin

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Abstract

Several techniques have been used for sand production control in sandstone reservoirs. The main objective of this research is to present a suitable resin to be used as a consolidation agent in oil reservoirs. To achieve this purpose, urea-formaldehyde resin, phenol-formaldehyde resin, and modified urea-formaldehyde resin were selected to be studied. Core samples were made by the sand sample provided from the oil fields of southern parts of Iran with an average absolute permeability of 500-600 mD and an average porosity of 15-20% combined with various percentages of each resin. The core samples are tested for permeability, porosity, and compressive strength measurement. The results show that in the consolidation process with resin, modified urea-formaldehyde resin, as a consolidating agent, is more suitable than the other two types of resin. The consolidated sand samples of this resin had a compressive strength between 3100 and 4150 psi, permeability between 980 and 6823 mD, and porosity between 8 and 98%.

Keywords: Chemical Consolidation, Resin, Permeability, Porosity, Compressive Strength

1. Introduction

About 70% of the total world's hydrocarbons are located in poorly consolidated reservoirs (Ayres and Romos, 1964; Nouri et al., 2003). These rocks are usually relatively young in geologic age and are unconsolidated because natural processes have not cemented the rock grains together by mineral deposition (Dees, 1993). As a result, many reservoirs are susceptible to sand production. This is particularly significant in cases that involve sufficient changes of in situ stresses, high oil production rates, collapse of hole cavities, and the presence of water in the formation (Abass et al., 2002; Morita et al., 1987; Kooijman et al., 1996; Wang et al., 1991). Sand production imposes high costs and many nuisances on the oil industries. Sand production might lead to the erosion of down-hole and surface equipment, thus creating severe safety problems including loss of well control, blowouts, fires, and production shut-in (Tippie and Kohlhass, 1973). Sand production might also restrict the quantity of the oil withdrawn from the reservoir leading to the need for a higher number of wells to achieve the overall hydrocarbon recovery and consequently to additional cost (Moricca et al., 1994). To produce

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oil and gas from poorly consolidated reservoirs, it is necessary to employ "sand control" methods in the wells. So far, several techniques have been used to prevent or inhibit sand movement with the fluids produced from hydrocarbon-bearing formations (Dees, 1992; Hugh and Ramos, 1995). The simplest way is to employ filter type devices (e.g., gravel packing, various filter materials, mechanical filters, and screens) which are placed in the well opposite the unconsolidated sand and prevent the movement of rock grains into the wellbore. These methods are somehow successful, but most of the time filter materials are plugged or eroded. The methods for controlling the migration of sand from unconsolidated formations are sometimes divided into mechanical and chemical classifications (Dees, 1992; Hugh and Ramos, 1995). Various sand consolidation methods have been employed to prevent or inhibit sand movement with the fluids produced from hydrocarbon-bearing earth formations. Packing the formation with resin-coated particulate solids, wetting the unconsolidated sand with a bonding resin, and placing resin-treated sand between the loose sand in the formation and the well bore to form a screen are chemical methods. The methods have met with varying degrees of success. A dispersion sand consolidation mixture is one in which a consolidating fluid consists of a hydrocarbon carrier, a resin, or a resin-forming mixture dispersed in it together with a quantity of particulate solids (Appah 2003; Dees 1993; Dees et al., 1992). The resin consolidation processes have been classified in various ways. Minimum preparation time at well site, low injection pressure, short cure time before restoring well to production, high compressive strength of resulting matrix, good resistance to deterioration from well fluids and commonly used treating fluids, and high retained permeability are desirable characteristics for a consolidation process (Appah 2003; Dees et al., 1992; Hugh and Ramos, 1995; Nguyen 2004; Nguyen, 2006; Sain, 1962). Several types of resins are presently used in the sand control art. Examples of organic resins which can be crosslinked and are suitable for use in accordance with this subject are epoxy resins, polyester resins, phenol–formaldehyde resins, urea–formaldehyde resins, furan resins, urethane resins, and mixtures of such resins, Additionally, some of the aforementioned resins are utilized as commercial processes by several companies, which are presented in Table 1 (Ayres and Romos 1964). Paraskeva et al. (2000) achieved the consolidation of the formation around the well through the in situ precipitation of a sparingly soluble salt, namely calcium phosphate. They carried out several series of experiments under diverse conditions to establish the optimum parameter values for the implementation of this method. A set of optimum conditions at 25 °C and 75 °C were determined, which showed that it is feasible to consolidate loose sand packs in oil reservoir conditions with an acceptably small decrease of the permeability. Huang (2010) introduced a new procedure for a uniform sand consolidation in the near wellbore region. In his method, sodium silicate solution and a hardener, such as one dialkyl ester of a dicarboxylic acid, were used as the consolidation fluid. The fluid system was pumped into the target zone where silica gel was uniformly generated in situ. Since silica gel formation occurred in situ, better control on the placement of the treatment was achieved and the deeper penetration of the consolidation fluid was accomplished. After the uniform consolidation of sand, to create channels or passageways to connect the formation hydrocarbons with the wellbore, a low concentration acid (e.g., hydrofluoric acid) was also pumped through and into the consolidated sand. His laboratory tests showed that the system could successfully consolidate unconsolidated zones in various reservoir conditions from about 70 °F to about 300 °F. Lahalih and Ghloum's (2010) improved the compressive strength of weak and friable formation as one of the three main requirements for a successful sand consolidation treatment. Using dune sand and Minagish well MN-117 sand immersed in 3% KCl brine and stored at 80 °C, they prepared several sand packs with several polymer formulations. Their results showed that all polymer compositions developed compressive strengths in the treated sand packs that far exceeded the minimum requirement of 140 psi and gave complete water shutoff to

water production. Apart from that, they found that higher temperatures required higher doses of these compositions; 1.0 PV, 0.4 PV and 0.25 PV of these polymers were needed to produce the desired compressive strength at 110 °C, 80 °C, and 60°C respectively. In another work, to present a suitable resin to be used as a consolidating agent in Asmari oil wells of Ahvaz and Mansoori oil fields, Talaghat et al. (2009) selected six types of resins, including two types of epoxy resins, three types of phenol-formaldehyde resins, and a single type of acrylic resin for testing. After mixing these resins and their hardening agents with sand samples provided from Ahvaz and Mansoori oil fields at various percentages, they were tested for permeability, porosity, and compressive strength measurement. According to the results, the absolute permeability of the core samples made by modified phenol-formaldehyde resin was higher than those made by the other types of resins (range from 2,000 mD to 6,000 mD). Moreover, the porosity percentage of the core samples made by modified phenol-formaldehyde resin was within 38% to 65%. Finally, the compressive strength of the core samples made by modified phenol-formaldehyde resin was varied between 3,000 psi to 3,480 psi. Nguyen et al. (2012) considered the case of formation solids migrated in injection wells (due to the injection process or the placement of the injection wells in weak or unconsolidated formations). They introduced the consolidating treatment fluid through the injection well while the well was under injection such that the consolidating treatment fluid entered into a portion of a formation interval along the wellbore accepted injection fluid; then, the consolidating fluid was allowed to consolidate formation particulates therein. For this purpose, they performed several experiments by varying the composition of the consolidating fluid, including tackifying agent, resin, gelable composition; Zeta potential altering agent; micro dispersion agent; micro emulsion agent; and the injection flow rate.

Table 1
Different commercial available consolidation processes (Dees, 1993).

Company	Process	Base of applied resin	Range of temperatures (°F)	Range of compressive strength (psi)	Permeability to original (%)
Halliburton	Sanfix	Furan	45-400	>3200	87
Halliburton	CONPAC II	Furan	45-410	>3200	75
Halliburton	CONPAC	Furan	85 to above 290	>3200	73
Dow	K- series	Phenol- Formaldehyde	270	>3200	72
Shell	Eposand	Epoxy	105-230	>4800	65
ESSO	Sanset	Phenol- Formaldehyde	80-220	>3200	55
Chevron	-	Epoxy	60-260	>6900	47
Dow	Sandlock IV	Epoxy	Max. 180	-	-
Continental oil	Sanchek	Furan - Phenolic	-	3200	-

This paper demonstrates a sand control technique based on the consolidation process with resins that could overcome the technical limitations associated with the sand production phenomenon in oil reservoirs in Iran.

2. Materials and methods

2.1. Materials

Considering the locally produced resins and the required desirable characteristics of resins for

consolidation process, urea- formaldehyde, phenol-formaldehyde, and modified urea- formaldehyde resins were selected for testing. Brine was used as pre-flush and after flush fluids. The sand sample utilized was provided from the oil fields of the southern parts of Iran; some characteristics of the sand particles are given in Table 2. It is essential to mention that, prior to the consolidating process, sand grains in the core holder were flooded with brine and crude oil of Iranian oil field in some experiments.

Table 2
Some characteristics of sand sample from the Iranian oil fields based on data obtained from Iranian Oil Company.

No.	Characteristic	Value
1	Oil reservoir permeability	500-600
2	Oil reservoir Porosity (%)	15-20
3	Cohesive strength (MPa)	3.74-5
4	Friction angle (degree)	30-35
5	Young modulus (GPA)	5-6
6	Poison ratio	0.45-0.48
7	Components	Quartz, dolomite, calcite, clay
8	Particle size (μm)	100-1000
9	Permeability of samples (mD)	1250
10	Porosity of samples (%)	62

2.2. Experimental procedure

A mold suitable for making samples in a cylindrical form was constructed by PVC tubes. Figure 1 shows a simplified schematic of the mold used in this study. This model consists of a core holder with a length of 40 cm and a diameter of 3 cm, in which a bed of sand grains is carefully packed by means of a vibrating table. A syringe pump is used for injecting the resins and saturating the sand pack with brine and crude oil where necessary.

Sand columns were prepared by packing 150 grams of the sand sample provided from the southern parts of Iran oil fields. The consolidating composition (such as urea-formaldehyde resin) was diluted with an alcohol such as methanol in a 1 to 1.5 ratio. A volume of 7% saline solution such as sodium chloride was pre-flushed into the column, followed by 2 pore volumes of diluted consolidating composition, and an after-flush liquid of 3 pore volumes of 7% saline solution. Both pre-flush and after-flush brine contained 2% of a cationic surfactant. For curing the samples, the sand column was placed in the laboratory at ambient temperature. After curing in each experiment (24 to 48 hours), the core holder was cut. The obtained core was polished and sized for the measurement of different properties. These procedures were repeated for several experiments in each step, and each core sample was tested for three distinct properties, including the permeability, porosity, and the compressive strength as follows.

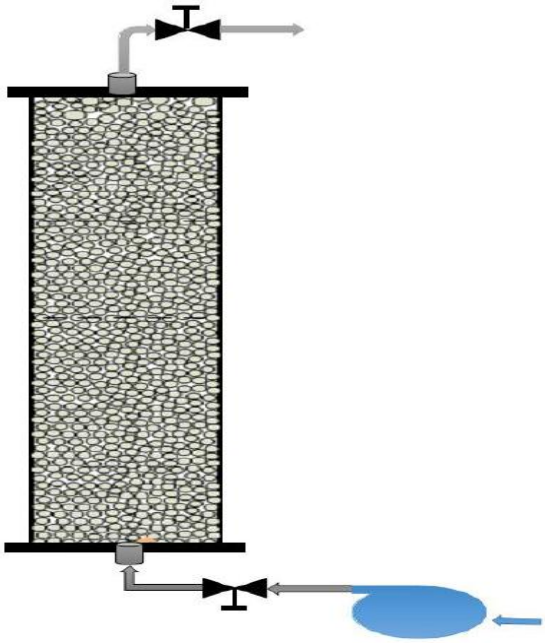

Figure 1
A simplified schematic of the cylindrical mold for making the samples.

2.3. Permeability measurement

Permeability is a measure of the ease with which fluids will flow through a porous rock (www.encyclopedia.com, 2003). In this work, an experimental apparatus, as shown in Figure 2, was designed and constructed for measuring the permeability of the core samples. The procedure for measuring the permeability of the core samples is given below.

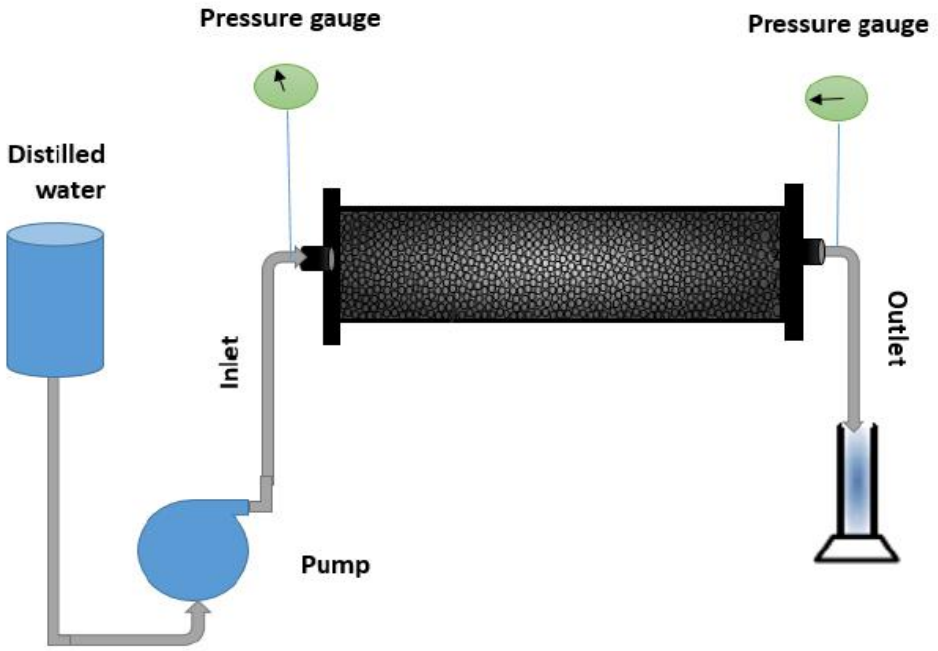

Figure 2
An experimental setup apparatus for permeability measurement.

Each core sample with a length of 15 cm and a diameter of 2.8 cm is placed in the apparatus, and water is pressurized to flow through the core sample by a pump. In each run, the required parameters such as the inlet and outlet pressure, volume flow rate of water, and cross-sectional area of the sample are recorded. To prevent radial flow through the core, it is coated with an RTV adhesive and a Teflon band. The absolute permeability is calculated using Darcy's equation:

$$k = \frac{v\mu L}{S\Delta P} \tag{1}$$

where, k is the permeability of the sample, and S is cross sectional area of the sample; L stands for the length of the sample, and Δp represents pressure drop; v is the volume flow rate of fluid travel through the core sample, and μ denotes the viscosity of fluid (www.encyclopedia.com, 2003).

2.4. Porosity measurement

Porosity is the ratio of the volume of openings (voids) to the total volume of materials. In this work, the porosity of the core samples was determined by two different methods, including gravitational and helium method (Abass, 2002). Gravitational method is utilized in order to determine the porosity of the core samples. In this method, the core sample is put into a cylinder and weighed (w_1). Then, the cylinder is filled with water such that the core sample is completely immersed in water. After 72 hours, water is depleted and the cylinder is reweighed (w_2). Finally, the core sample porosity (ϕ) is calculated using the following equation.

$$\varphi = \frac{w_2 - w_1}{\rho V} \tag{2}$$

where, V is the volume of core sample (ASTM E9-89a, 2000).

2.5. Compressive strength measurement

Compressive strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength which withstands loads tending to elongate. The measurements of compressive strength are affected by the specific test method and conditions of the measurement. Compressive strengths are usually reported in relationship to a specific technical standard (www.encyclopedia.com, 2003). In this work, the compressive strength of the samples was measured by Instron press apparatus using the ASTM E9-89a procedure (this experiment was conducted in Strength of Materials Laboratory, Civil Engineering Department of Shiraz University). Considering this approach, the samples are compressed until the crushing or fracturing is occurring. Thus, the compressive strength will be determined by dividing the maximum stress upon the cross sectional area at or before failure. The core samples with a length:diameter ratio of 2 were used in this research for the determination of the compressive strength.

According to ASTM E9-89a (2000) procedure, for test specimens the following steps are carried out:

a: Measure the diameter of the specimen with a micrometer along the gage section and calculate the average cross-sectional area of the specimen gage section.

b: Clean the ends of the specimen and fixture bearing blocks with acetone or another suitable solvent to remove all traces of grease and oil.

c: Place the specimen in the test fixture and carefully align the specimen to the fixture to ensure concentric loading. Also, check that the specimen loading/reaction surfaces mate with the respective surfaces of the fixture. If the fixture has side supports, the specimen sides should contact the support mechanism with the clamping pressure recommended by the fixture manufacturer, or as determined during the fixture verification tests. If screws are used to adjust side support pressure, it is recommended that a torque wrench be utilized to ensure consistent pressure. If required, attach the extensometer or other transducers, or both, to the specimen gage section. The gage length must be at least one half or preferably one diameter away from the ends of the specimen.

d: Set the load range of the testing machine so that the maximum expected load is at least one third of the range selected. After the specimen has been installed and aligned, and the strain- or deflection-measuring transducer installed, activate the recording device(s) and initiate the test at the prescribed rate. Continue the test at a uniform rate until the test has been completed.

e: For a material that fails in compression by crushing or fracturing, the compressive strength is the maximum stress at or before fracture, as determined by dividing the maximum load by the cross-sectional area.

3. Results and discussion

To select an appropriate resin as a stabilizing factor in the reservoir oil, the effect of 3 types of various resins, including phenol-formaldehyde, urea- formaldehyde, and modified urea-formaldehyde resins at different percentage (10 to 90%) of resin on the performance of stabilization are investigated by measuring the permeability, porosity, and compressive strength. The comparison result between the permeability measurements of pure resin is shown in Figure 3.

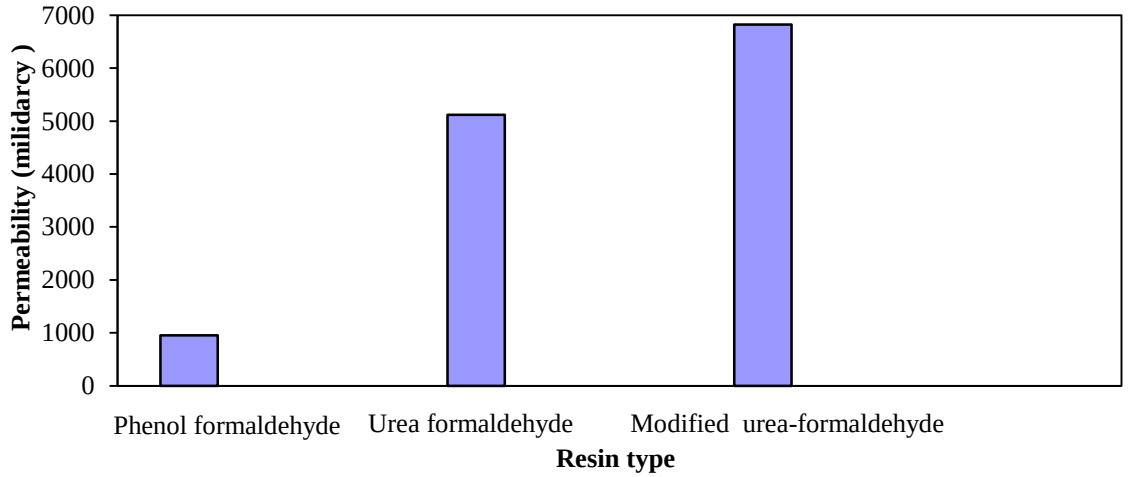

Figure 3
Comparison of permeability for different types of pure resins.

By observing this figure, it is clear that the absolute permeability of the core samples was made only by pure modified urea-formaldehyde resin is higher than those made by phenol-formaldehyde and urea-formaldehyde resins. Moreover, the comparison results of the permeability measurement of the sample cores made from various resins at different percentages are illustrated in Figures 4-6. According to these figures, the permeability decreases for different resins as the resin percentage increases in the core samples.

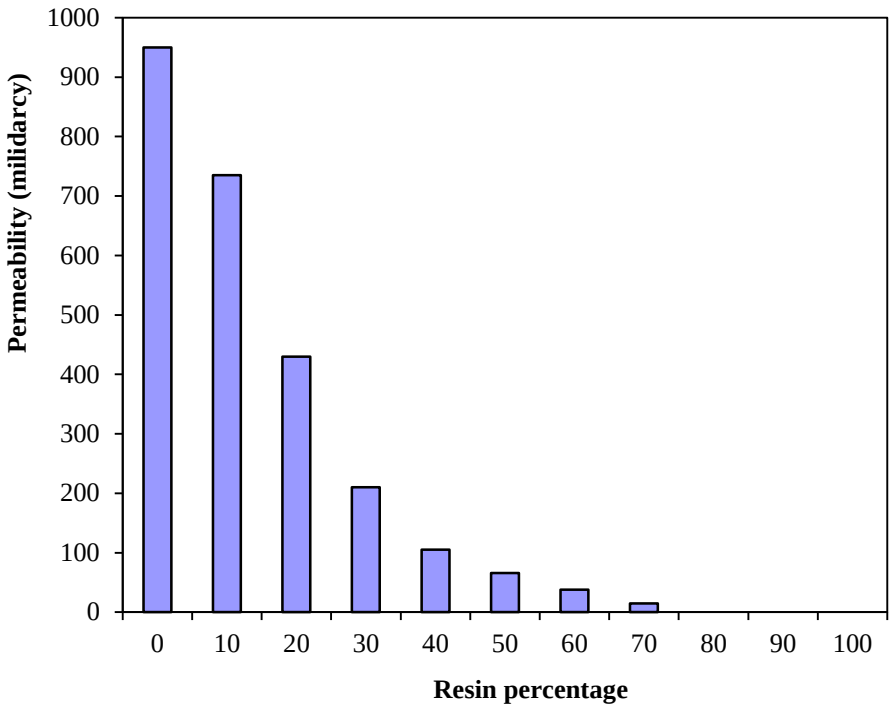

Figure 4
Variations of permeability against phenol-formaldehyde resin percentage.

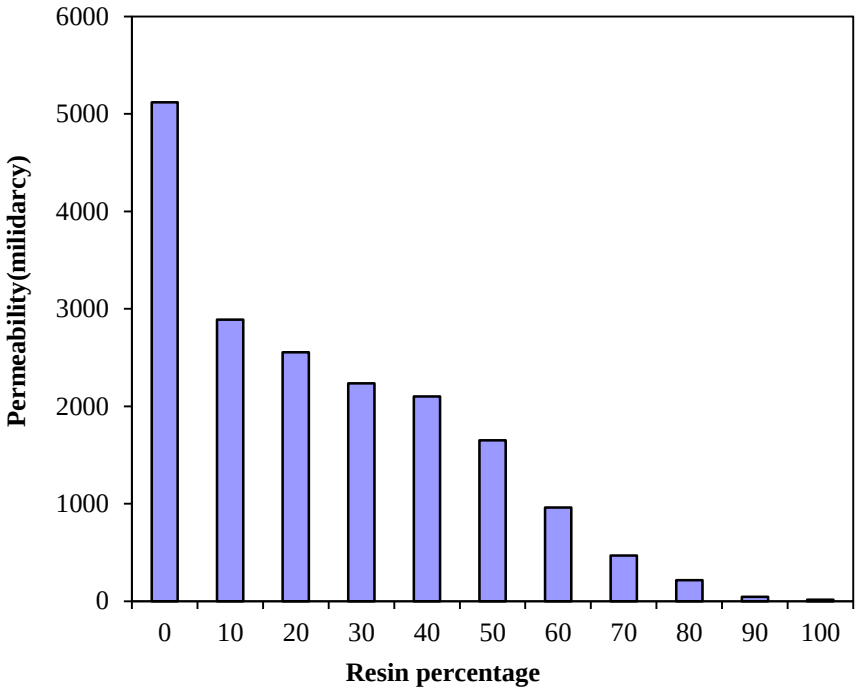

Figure 5
Variations of permeability against urea-formaldehyde resin percentage.

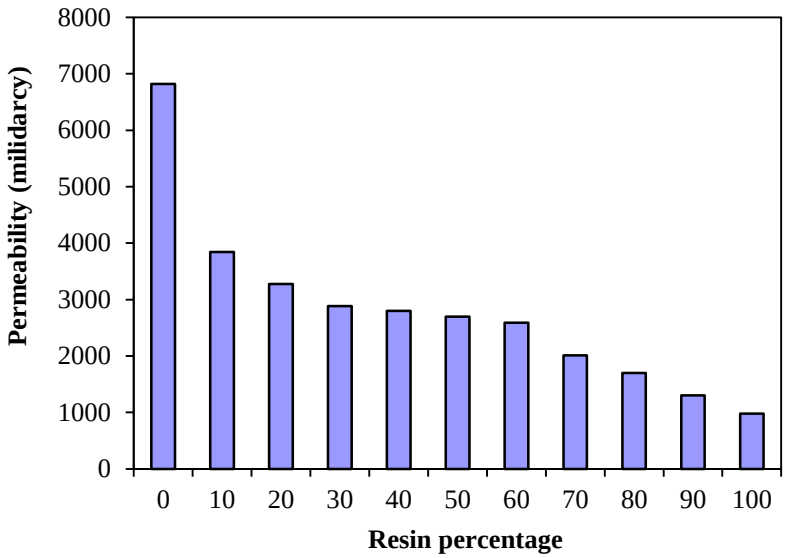

Figure 6
Variations of permeability against modified urea-formaldehyde resin percentage.

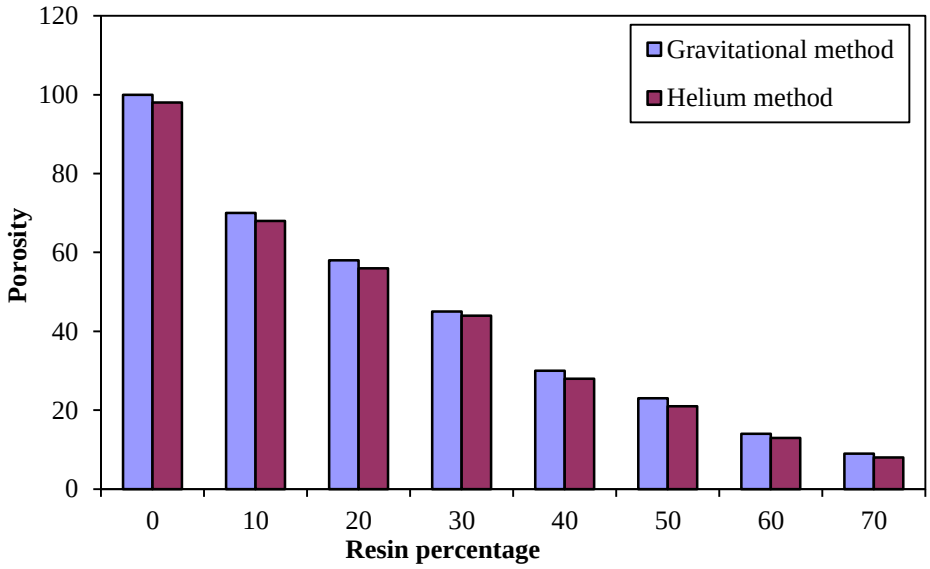

Figure 7
Variations of porosity against modified urea-formaldehyde resin percentage.

Figure 7 presents the effect of resin percentage on the porosity measurements. It is obvious that the porosity percentage of the core samples made by modified urea-formaldehyde resin is within 35% to 68%. As shown in Figure 7, the porosity values obtained by two different methods of water and helium are in good agreement. The results of compressive strength measurement for the core samples made from pure resin are shown in Figure 8. As can be seen from this figure, the compressive strength of the core samples made by pure modified urea-formaldehyde resin is higher than that of the two others. Furthermore, the results of compressive strength measurement of the core samples made from various percentages of modified urea-formaldehyde are shown in Figure 9.

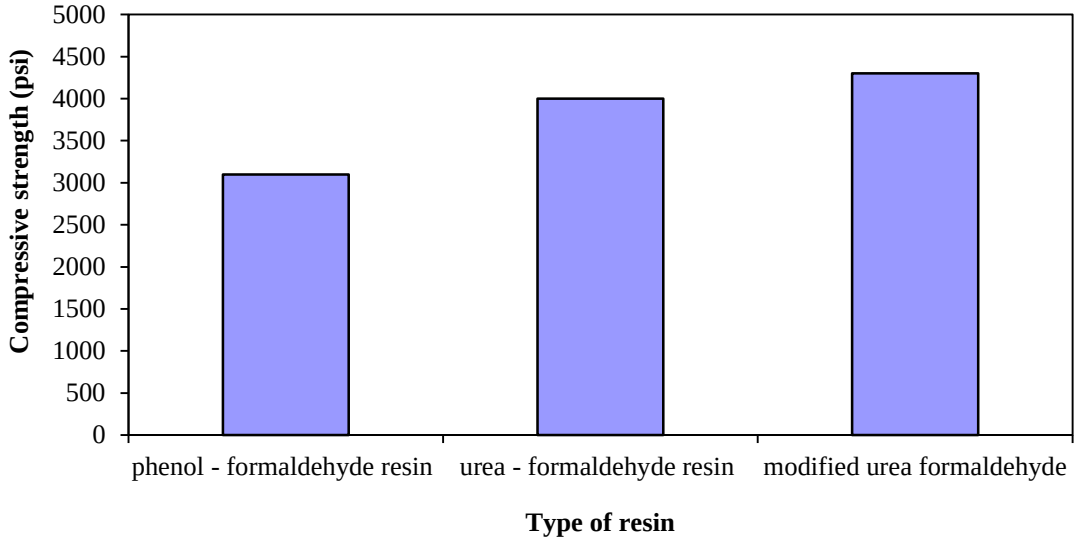

Figure 8
Compressive strength for various pure resins.

According to Figure 9, the compressive strength of the core samples made by the modified urea-formaldehyde resin is between 3000 to 4000 psi. Also, the compressive strength of the core samples increases as the resin percentage increases in the core samples.

As a matter of fact, since the resins act as the inter-granular bonding materials (the same as cement), a larger amount of resin causes smaller pore volumes, narrower pore channels, and stronger bonds among the sand grains ,which means lesser porosity and permeability, but higher compressive strength. Finally, the experimental results confirm that the optimum modified urea-formaldehyde resin loading regarding the three response parameters, including compressive strength, porosity, and absolute permeability of the core samples is between 20 to 30%. The results also show that, for the consolidation process with resin, the modified urea-formaldehyde resin is more suitable consolidating agent than the other two types of resin; this resin was possible to produce consolidated sand samples with a compressive strength between 3100 and 4150 psi, permeability between 980 and 6823 mD, and porosity between 8% and 98%. Based on the data obtained from Iranian oil company, the average absolute permeability and average porosity for unconsolidated Iranian oil fields are 500-600 mD and 15-20% respectively (see Table 2). The acceptable compressive strength is 3000 psi (see Table 1) for consolidation with resin. Because the compressive strength of the samples is higher and the reservoir is thus more resistant during production, the sand is not separated from the reservoir during production and cannot be entered into wells. The resin-coated pack sand combines the advantage of packing and consolidating. It provides a rigid matrix with permeability higher than that of the formation, has no obstruction in the casing, and is particularly adapted to older wells producing sand. Therefore, these consolidated sand samples can be used with greater porosity and permeability characteristics in Iranian oil reservoirs. In another work, to present a suitable resin to be used as the consolidating agent in Iranian oil fields, Dehghani et al. (Dehghani et al., 2013) selected two types of resins, including an epoxy resin (ML 503) and resole phenol-formaldehyde resin (CF 306) for testing. Additionally, in order to reduce the viscosity of the resins, a solvent was added to them. All the testing was performed using 70 grams of sand. Their results showed that, for the consolidation process with resins, it was possible to produce consolidated sand samples with a compressive strength between 740 and 1330 psi, permeability between 3000 and 4100 mD, and porosity between 27 and 34.5%. Finally,

their results showed that the optimum consolidating process was achieved for the sand samples containing 30 wt.% of ML 503, and resulted in a compressive strength in excess of 1300 psi, permeability of 3400 mD, and porosity of31%.

At the end, it was concluded that the consolidation process with epoxy resin (ML 503) was the most efficient method according to National Iranian South Oil Company standards. However, for field scale applications an economical proof is also needed.

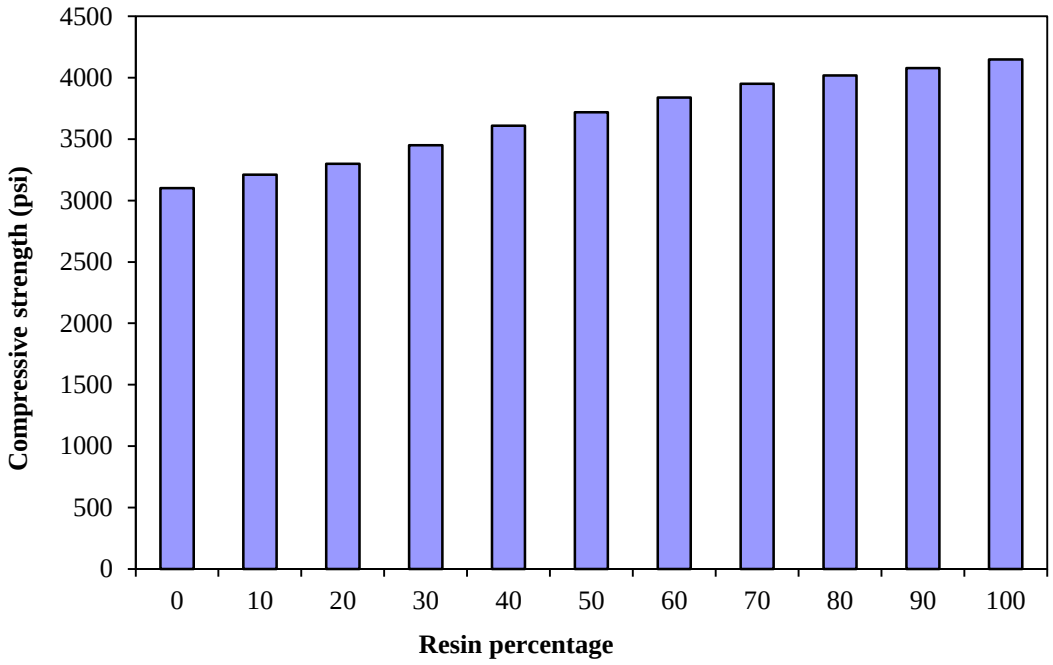

Figure 9
Compressive strength against modified urea-formaldehyde resin percentage

4. Conclusions

In this study, in order to obtain the desired stabilization process for sand production control in Iranian oil field, a technique based on the consolidation process with resins was described. In the sand production control based on consolidation with resin, three various types of resins, including urea-formaldehyde, phenol-formaldehyde, and modified urea-formaldehyde resins were selected for testing. The consolidation processes with resins show that the core samples made by modified urea-formaldehyde present superior performance compared to the other resins. In addition, it is possible to produce sand consolidations with acceptable properties such as permeability, porosity, and compressive strength. Finally, in this method, increasing the weight percentage of the resins decreases permeability and porosity, but raises compressive strength.

Acknowledgements

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Nomenclatures

K	:Permeability of sample (Darcy)
L	:Length of the sample (cm)

S	:Cross sectional area of the sample (cm^2)
V	:Volume of core sample (cm^3)
Δp	:Pressure drop (bar)
ρ	:Water density (g/cm^3)
v	:Volume flow rate of fluid travel through the core sample (cm^3/s)
μ	:Viscosity of fluid (cP)
φ	:Porosity (dimensionless)

References

Abass, H.H., Nasr-El-Din, H.A., and BaTaweel, M.H., Sand Control: Sand Characterization, Failure Mechanisms and Completion Methods, SPE Paper 77686 presented at the SPE Annual Technical Conference and Exhibition San Antonio, Texas, 2002.

Appah, D., Sand Consolidation Experience in Niger Delta, IE (I) Journal-CH, Vol. 84, p. 1-4, 2003.

Ayres, H.J. and Romos J., Guideline to Sand Control, Technical Report (F-3077), Halliburton Co. Service, 1964.

Dees, J.M., Sand Control in the Wells with Gas Generator and Resin, United States Patent 5101900, 1992.

Dees, J.M., Method of Sand Consolidation with Resin, United States Patent 5178218, 1993.

Dees, J. M., Begnaud, W. J., and Sahar, N. L., Sand Control with Resin and Explosive, United States Patent 5145013, 1992.

Dehghani, A., Rahmanifard, H., and Mowla, D., Experimental Investigation of Sand Consolidation Techniques: Resin Injection and In-situ Combustion, Journal of Oil, Gas and Coal Technology, Vol. 6, No. 6, pp. 689- 704, 2013.

Huang, T., Methods of Underground Formation Consolidation, United States Patent 0038085A1, 2010.

Hugh, J.A. and Ramos, J., Guidelines to Sand Control, Report, Halliburton Services from Halliburton Co., 1995.

Kooijman, A.P., Van den Hoek, P.J., Bree, Ph. De., Kenter, C.J., Zheng, B.V.Z., and Khodaverdian, M., Horizontal Wellbore Stability and Sand Production in Weakly Consolidated Sandstones, SPE Paper 36419 Presented at the SPE Annual Technical Conference and Exhibition Denver, Colorado, 1996.

Lahalih, S.M. and Ghloum, E.F., Polymer Compositions for Sand Consolidation in Oil Wells', SPE Paper 136024 presented at the SPE Production and Operations Conference and Exhibition, held in Tunis, Tunisia, 2010.

Moricca, G., Ripa, G., Sanfilippo, F., and Santarelli, F. J., Basin Scale Rock Mechanics: Field Observations of Sand Production, SPE Paper 28066 Presented at the SPE/ISRM Rock Mechanics in Petroleum Engineering Conference Delft, The Netherlands, 1994.

Morita, N., Whitfill, D.L., Fedde, Ø.P., and Løvik, T.H., Parametric Study of Sand Production Prediction, Analytical Approach, SPE Paper 16990 Presented at the 62nd Annual Technical Conference and Exhibition of the Society of Petroleum Engineers Dallas, Texas, 1987.

Nguyen, P.D., Methods Of Completing Wells In Unconsolidated Formations, United States Patent 6776236, 2004.

Nguyen, P.D., Methods for Forming A Permeable And Stable Mass in a Subterranean Formation, United States Patent 6997259, 2006.

Nguyen, P.D., Rickman, R.D., Dusterhoft, R.G., Weaver, J.D., Tiffin, D., and Hurst, G., Methods and Compositions for Sand Control in Injection Wells, United States Patent 0043082A1, 2012.

Nouri, A., Vaziri, H., Belhaj, H., and Islam, R., Effect of Volumetric Failure on Sand Production in Oil- Wellbore, SPE Paper 84448 Presented at the SPE Asia Pacific Oil and Gas Conference and Exhibition Jakarta, Indonesia, 2003.

Paraskeva, C.A., Charalambous, P.C., Stokka, L.E., Klepetsanis, P.G., Koutsoukos, P.G., Read, P., Ostvold, T., and Payatakes, A.C., Sandbed Consolidation with Mineral Precipitation, Journal of Colloid and Interface Science, 15 December, Vol. 232, No. 2, p.326–339, 2000.

Porosity and Permeability, World of Earth Science, Encyclopedia.com,13 Jan. 2016, <http://www.encyclopedia.com>, 2003.

Sain, H.H., Sand Consolidation With A Base-Catalyzed Plastic, API Paper No. 926-7-F, Spring Meeting, Southern District, Houston, Texas, 1962.

Standard Test Methods of Compression Testing of Metallic Materials at Room Temperature ASTM E9-89a, Reapproved 2000.

Talaghat, M.R., Esmaeilzadeh, F., and Mowla1, D., Sand Production Control by Chemical Consolidation, Journal of Petroleum Science and Engineering, Vol. 67, p.34–40, 2009.

Tippie, D.B. and Kohlhass, C.A., Effect Of Flow Rate on Stability Of Unconsolidated Producing Sands, SPE Paper 4533 Presented at the 48th Annual Fall Meeting of the Society of Petroleum Engineers of AIME Las Vegas, Nevada, 1973.

Wang, Z., Peden, J.M., and Damasena, E.S.H., The Prediction Of Operating Conditions to Constrain Sand Production From a Gas Well, SPE Paper 21681 Presented at the Production Operations Symposium Oklahoma City, 1991.