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TECHNICAL NOTE

Using Local Gravel to Control Sand Production in a Saudi Oil Field

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Abstract. Sand production from oil and gas reservoirs is most commonly associated with unconsolidated and poorly cemented sandstones. Sand production problems are encountered throughout the world and recently are detected in Saudi Arabia. Several techniques could be used to minimize sand production such as drawdown control, installing screen liners, applying resin consolidation, gravel packing, etc. This work was conducted to investigate the possibility of using gravel packs made from gravel deposited in the central province of Saudi Arabia. Optimum gravel size, shape, crushing resistance and solubility in acids were tested. The results of the above analysis showed that the selected Saudi gravel properties meet the recommended API requirements. Furthermore, a physical model has been constructed to simulate sand control process. This model was used to study the effect of drawdown pressure, confining pressure and gravel-pack thickness on rate of fluids and sand production in a Saudi oil field. The experimental results showed that sand and fluid production are affected by the gravel pack thickness, drawdown pressure and confining pressure. Therefore, it is recommended to utilize the tested Saudi gravel in sand control applications after performing an economical feasibility study.

Introduction

Sand production is considered as one of the major problems in the petroleum industry. Every year, cleaning and work over operations related to sand production and restricted production rates cost the industry millions of dollars. Additional expenses associated with sand production include, pump maintenance, well cleaning, disposal of dirty sands, etc. Sand production occurs when the induced in-situ stresses exceed the formation in-situ strength. Formation strength is derived mainly from the natural cementing materials that adhere sand grains together. According to this strength, the sandstone formations can be classified as competent or weak and unconsolidated. In competent sandstone formations, sand production is due to shear failure. When the reservoir fluids are produced the existed shear failure surfaces are mobilized and sand debris are produced due to drag forces caused by the flow of the reservoir fluids. The produced debris (sand) then will flow into the well along with the reservoir fluids [1, 2]. In weak and unconsolidated sandstone formations, sand is produced when the drag forces caused by the flowing reservoir fluids exceed the natural inherent cohesion of the formation. The movement of sand grains leads to the establishment of sand arches [1-6] as shown in Fig. 1. In general, sand production can be classified into [7]: (i) *Transient sand production* that refers to a sand concentration decline with time at constant production rate. This type is normally encountered during clean-up after perforating or acidizing as well as after breakthrough during secondary recovery, (ii) *Continuous sand production* that is observed when production from unconsolidated sandstone reservoirs have no sand control equipment, and (iii) *Catastrophic sand production* is the worst and one that normally occurs when the reservoir fluids are excessively produced.

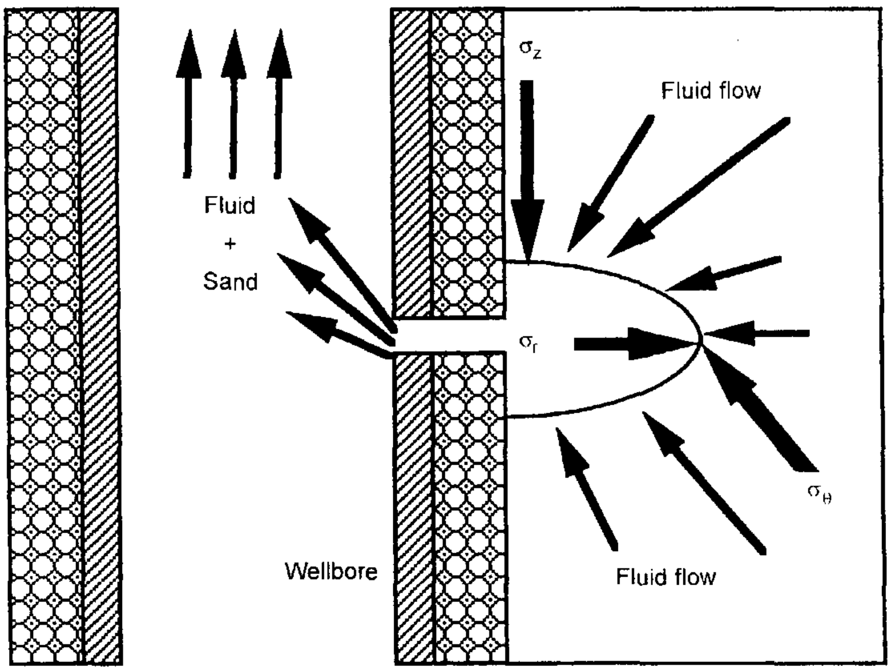

Fig. 1. Sand arch failure mechanism [1].

Sand production from oil and gas reservoir formations can be controlled using several methods. The choice of the best applicable method depends on several factors. Among these factors is the formation type. These methods are classified as follows:

(i) *Production rate (Drawdown) control*: several researchers have found that the control of oil production rate can minimize sand production [1-4]. This technique is based on the fact that high production leads to a low bottom hole flowing pressure. This reduction in the bottom hole flowing pressure causes the induced stresses acting on the productive formation to exceed the formation in-situ strength. Therefore localized shear failures will be established in the case of consolidated sandstone and sand arch failure will occur in the case of unconsolidated sandstones and the result will be sand production, (ii) *Downhole emulsification*: this method involves the injection of an aqueous non-ionic surfactant solution into the wellbore to convert the water-oil emulsion to oil-water emulsion to decrease the carrying capacity of the fluid and at the same time retain sands within the oil phase [8], (iii) *Downhole sand consolidation:* in this method chemical solutions such as resins are injected downhole into the productive formation. When it reaches the productive formation, the injected solution will solidify and cement sand grains together. As an alternative technique, hot air is injected downhole to oxide (cook) the oil phase and provides a cementing material [9-12], and (iv) *Mechanical sand control*: when the above methods fail to control sand production, the mechanical methods are the only solution. These methods include: the installation of gravel packs, screen liners, or the gravel pre-packed screen liners [13]. Gravel packing is a mechanical technique used to control sand production. If properly designed and applied, this completion technique can provide adequate sand control throughout the life of a well.

In the present work, a sand sample was obtained from an outcrop of a Saudi oil field. In this field, hydrocarbons are produced from a poorly consolidated and/or unconsolidated sandstone formations. This field suffers a continuous sand production problem. Therefore, it is planned to select a sand control method among the previously mentioned techniques able to overcome the encountered problem in this oil field. The possibility of the applying downhole emulsification technique, drawdown (production rate) control and in-situ sand consolidation to the studied field have been presented in a separate publications [14-15]. The aim of this study is to test a local gravel for potential preparation of gravel packs to control the encountered sand production problem in the studied oil field without excessively reducing the productivity.

Experimental Results and Discussion

The experimental work conducted in this study includes: mineralogical analysis of both the formation sand and the local gravel, gravel sizing, investigation of the shape, crushing resistance and solubility in acids for the selected gravel. Furthermore, a simulated flow runs were performed using a specially designed physical model simulating the bottom hole conditions. Saline water (3.5% NaCl) was used as a displacing and displaced fluid.

Set-up of the physical model

The experimental set-up is schematically shown in Fig. 2. It consists of three main parts: Injected fluid tanks, Hoek cell, and confining pressure system. The Hoek cell is equipped with a sand-gravel pack, which has an inside diameter of 3.81 cm and 8 cm long. The sand-gravel pack can be subjected to different values of confining pressure. Two pressure gauges are installed in the inlet and the outlet of the Hoek cell to measure the pressure drop across the sand pack. The fluid and sand produced from the Hoek cell is controlled by a valve. A constant pressure system is used to supply confining pressure around the sand pack.

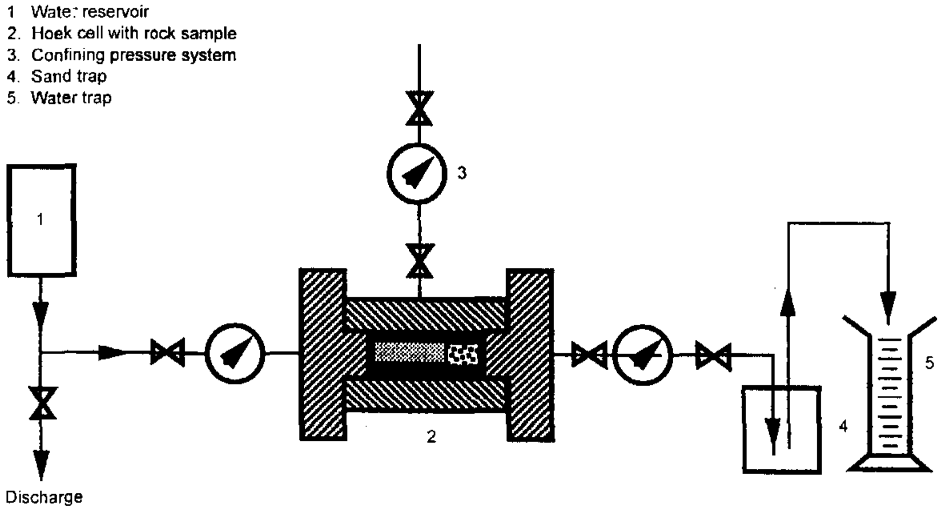

Fig. 2. Experimental set-up used in sand production study.

Properties of reservoir sand

In order to determine the optimum gravel packing size, granulometric analysis of the sand sample obtained from the field was performed using a calibrated ASTM sieves plus pan has been stacked in series. A split of 650 g had been poured onto the top sieve. The set of sieves had been placed in a sieves shaker and shacked for 15 minutes. After that, the sieves are unloaded and brushed thoroughly. The weight of sand retained in each sieve had been weighed and the percentage values had been calculated and plotted versus the used mesh size as shown in Fig. 3. X-ray analysis has shown that this formation sand is mainly composed from quartz.

Properties of the local gravel

The American Petroleum Institute Specifications for oil well gravel packing (RP-58) was followed during the analysis stage of the selected local gravel. The granulometric analysis of the studied reservoir sand (Fig. 3) have shown that the fifty percentile sand (D50) equal to 0.40 mm. According to Saucier rule [16] the optimum gravel size equal to

6 times the fifty percentile of the reservoir sand. Thus, 8/12 mesh size was the optimum gravel size for the reservoir under consideration. The shape of the gravel (roundness and sphericity) is greatly affecting the ability of a gravel pack to control formation sand. Microscopic analysis of the local gravel showed that the average sphericity and the average roundness values are 0.69 and 0.60 respectively. Crushing resistance of the selected gravel was determined by the determination of fines percentage generated after the application of an axial stress on a specific amount of gravel using a crushing cell and a compression machine for two minutes. A maximum value of 20% fines by weight of the tested gravel was found at a maximum axial stress of 9 MPa as shown in Fig. 4. X-ray analysis of the selected gravel has shown that it is mainly composed from quartz and traces of kaolinite, bayrite, iron oxide and gypsum. 24 hours solubility of the selected gravel in 12% HCl - 3% HF acid was 9% by weight while the 30 minutes solubility in the same acid was 1.8% by weight of the initial gravel sample as shown in Fig. 5.

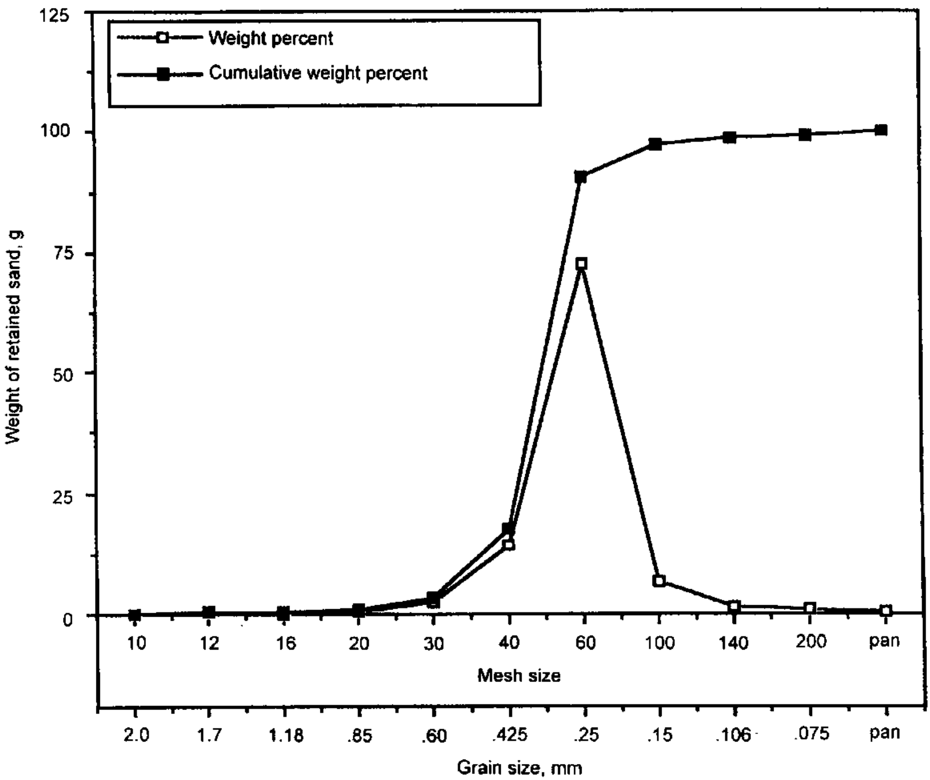

Fig. 3. Granulomteric analysis of the tested formation sand.

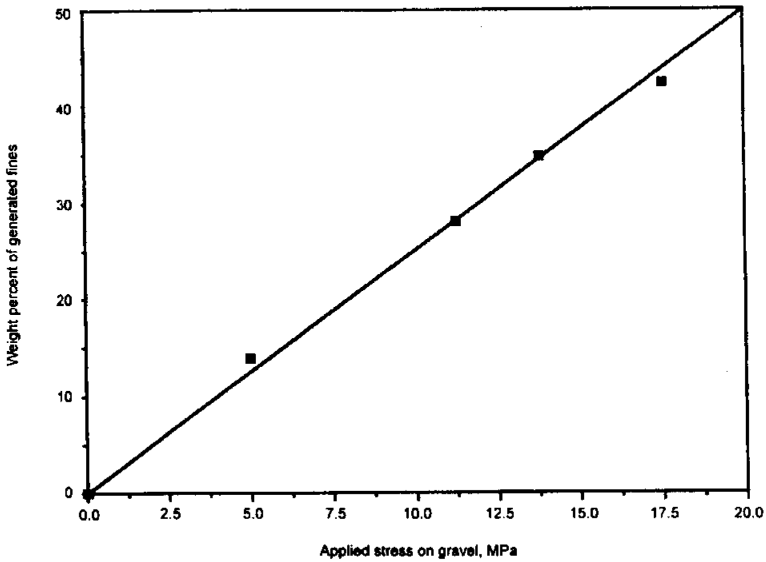

Fig. 4. Crushing resistance of the tested Saudi gravel.

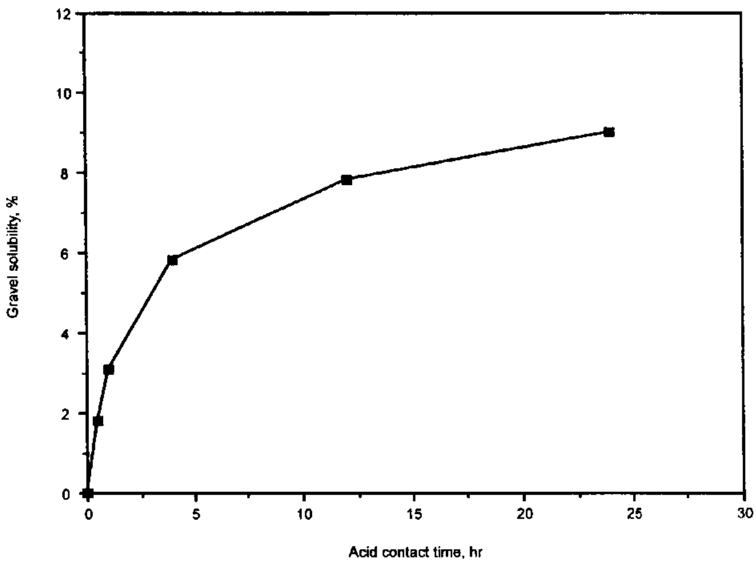

Fig. 5. Solubility of the tested Saudi gravel in 12% HCI - 3% HF acid.

Fluid flow through sand-gravel packing

Figure 6 shows the relationship between the applied confining pressure and the fluid flow rate through the sand-gravel pack. It can be seen that the flow rate decreases as the confining pressure increases. This decrease in the flow rate is attributed to pore space decrease due to sand compaction and sand redistribution in the pore space of the gravel pack caused by the increased values of the applied confining pressure. A gravel pack thickness of 3.81 cm was found to be the optimum thickness for the studied cases shown in Fig. 7. At a gravel pack thickness of 3.81 cm only 0.5% sand by weight of produced fluids was recorded at a pressure drop of 0.345 MPa and a confining pressure equal to 2.03 MPa. At small gravel packing thickness, sand will migrate easily though the pack, while at bigger gravel packing thickness sand may bridge in the pores of the gravel pack restricting the flow passages of the reservoir fluids. Fig. 8 shows the relationship between the drawdown pressure and the amount of sand produced expressed as a percent by weight of the produced fluids. Initially when the flow was started there was no sand production because the stresses were equally distributed on throughout the sand-gravel pack. When the drawdown pressure was increased furthermore, the equilibrium state was disturbed and sand start to move through the system and a sand arch was established. The existing stresses acting on the sand-gravel pack are redistributed itself and equilibrium was achieved again. When the drawdown pressure was increased furthermore, the sand production cycle was repeated itself again as shown in Fig. 9. Therefore, drawdown pressure is an important factor that should be controlled to minimize sand production through a sand-gravel packing system.

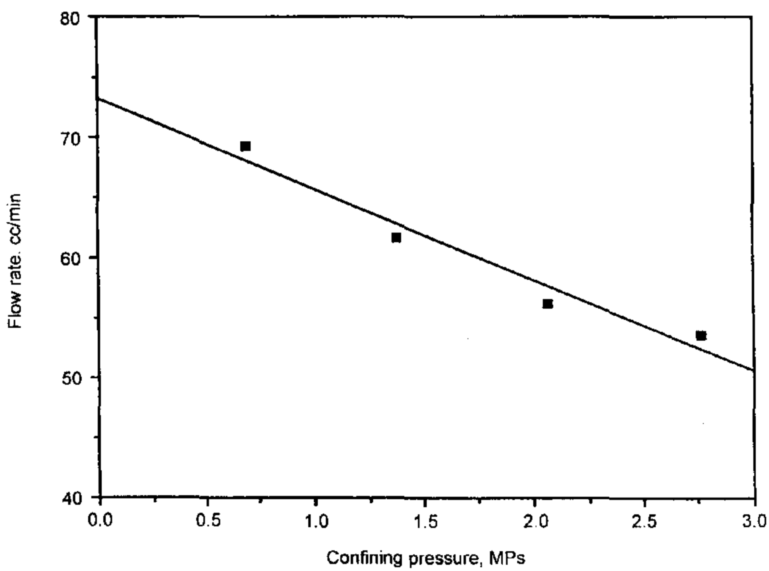

Fig. 6. Relationship between confining pressure and flow rate for the tested Saudi gravel at 2.54 cm thickness and $\Delta P = 0.1379$ Mpa.

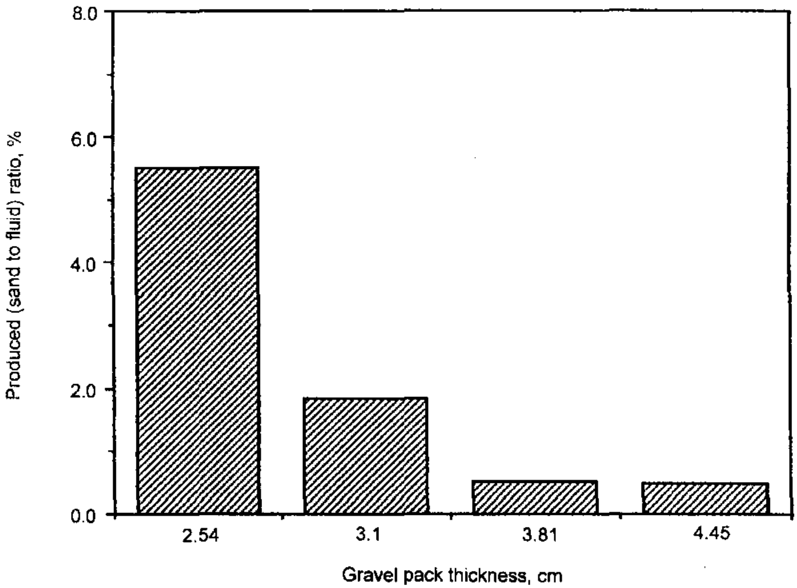

Fig. 7. Relationship between gravel pack thickness and produced (sand to fluid) ratio at $\Delta P = 0.345$ Mpa and confining pressure = 2.03 Mpa.

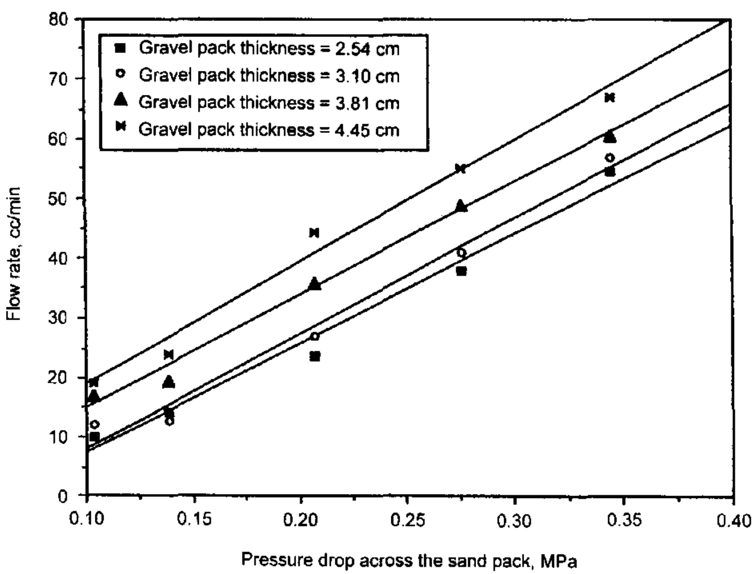

Fig. 8. Relationship between pressure drop and flow rate for the tested Saudi gravel at various packing thickness.

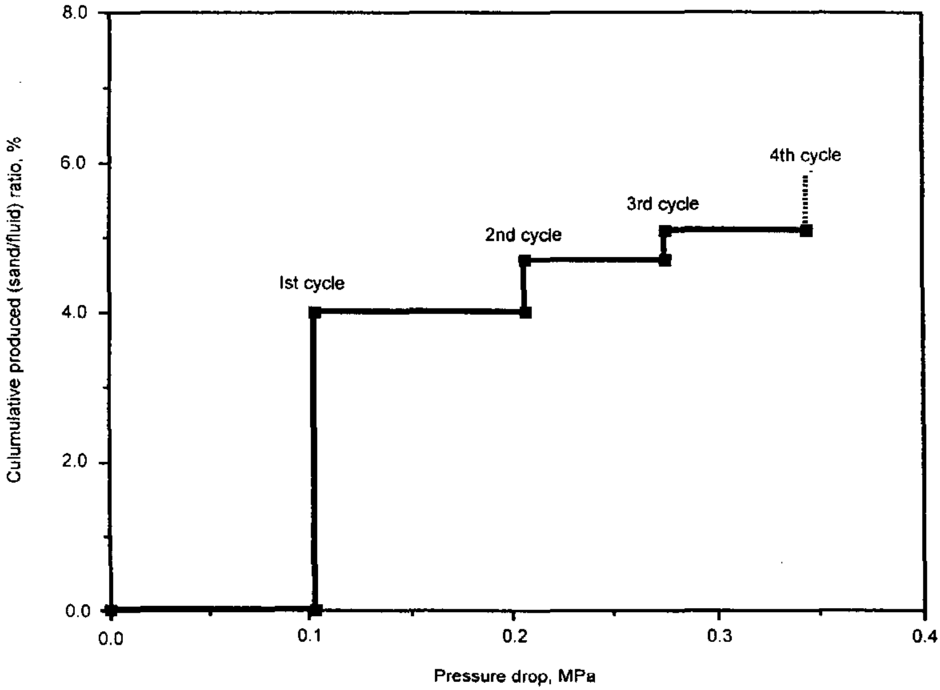

Fig. 9. Effect of pressure drop increase on sand control process using local gravel pack of 2.54 cm thickness.

Conclusion

Based on the analysis of the experimental work conducted in this study, the following conclusions are arrived with:

1. Sand production from unconsolidated sandstone formations is strongly affected by the flow rate, confining (compaction) pressure, drawdown pressure and gravel pack thickness.
2. The tested Saudi gravel satisfies the API requirements for gravel packing properties including, mineralogy, roundness, sphericity, crushing resistance, acid solubility and sand filtering ability.
3. Sand-free flow rates can be achieved from the tested Saudi reservoir if the reservoir sand is mechanically controlled using a 8/12 gravel packing system prepared from the tested Saudi gravel.
4. More investigation is required concerning the effect of heavy oil flow on packing made form the local gravel.

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استخدام حصى محلي للتحكم في إنتاج الرمل من مكمن بترول سعودي

عادل محمد حميده و مساعد بن ناصر العواد

قسم هندسة النفط، كلية الهندسة، جامعة الملك سعود ص.ب : ٨٠٠،

الرياض ١١٤٢١، المملكة العربية السعودية

(استلم في ٢٣/٠١/٢٠٠٠م ، قبل للنشر في ٠٥/٠٦/٢٠٠٠م)

ملخص البحث . إن إنتاج الرمل من حقول البترول والغاز غالبا ما يكون في المكامن ذات الطبقات الرملية المفككة أو الضعيفة التماسك . تواجه مشكلة إنتاج الرمل العديد من دول العالم كما أنها بدأت في الظهور حديثا في بعض حقول البترول السعودية . وللتغلب على تلك المشكلة يمكن استخدام تقنيات عديدة مثل التحكم في الإنتاج ، تركيب شبكات تصفية في قاع البئر ، تصليب الطبقات باستخدام مواد لاحمة أو استخدام حشوات حصوية .

إن الهدف من هذا البحث هو دراسة إمكانية استخدام حشوات من الحصى المترسب في المنطقة الوسطى في المملكة العربية السعودية . وتم تقويم ذلك الحصى بتحديد الحجم المثالي ، الشكل ، مقاومة التهشم والذوبان في الأحماض . وأظهرت نتائج الدراسة أن الحصى السعودي الذي تم اختياره يطابق متطلبات معهد البترول الأمريكي.

وتم عمل نموذج فيزيائي لمحاكاة عمليات التحكم في إنتاج الرمل . واستخدم هذا النموذج لدراسة تأثير الانخفاض في الضغط المسامي ، الضغط الحاصر وسمك الحشوة الحصوية على معدل إنتاج الرمل والسوائل تحت ظروف مكمن بترولي سعودي . وأظهرت نتائج الدراسة أن إنتاج الرمل والسوائل يعتمد بشكل كبير على تلك العوامل . وعلى هذا فإنه يوصي باستخدام الحصى السعودي الذي تم اختباره في مجال تطبيقات التحكم في إنتاج الرمل وذلك بعد عمل دراسة جدوى اقتصادية .