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RESEARCH PAPER

An experimental study to quantify sand production during oil recovery from unconsolidated quicksand formations

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Abstract: To obtain a comprehensive understanding on sand production and main factors affecting sand production in unconsolidated quicksand oil reservoirs during their production stage, the sand production processes under different conditions have been modelled. The modelling experiment was carried out on unconsolidated sand formation model made of water washed white sand, clay (kaolinite) and distilled water, by using a newly developed sanding modelling apparatus. The effects of drag force acting on the formation and formation cementation on sand production were analysed. The experimental results show sand and oil production rates both increase with the rise of drag force acting on the formation and decrease with the increase of cement content, and the sand production rate even approaches zero at high cement content. The reservoir with higher pressure is more likely to produce sand during development due to higher drag force, and drag force and effective formation stress jointly affect oil production. Therefore, the sand production rate can be estimated according to clay content, and proper sanding prevention measures can be taken correspondingly. In some cases, sand production in oil reservoirs can be much greater than that in gas reservoirs.

Key words: quicksand reservoir; sand production; oil recovery; clay content; cementation degree; drag force

Introduction

Sand production has become a challenge in oil industry due to associated severe issues such as erosion of production equipment, well plugging, productivity depletion, and threats to well stability[1]. Apart from these primary issues, mixing of sand with the oil produced is also critical in term of the required costly sand separation treatments[2]. This implies the required better understanding on the sand production mechanism, particularly from unconsolidated and weakly-consolidated sand reservoirs through more descriptive and precise quantitative measurements. This however needs a proper identification of the influences on sand production, involving formation properties such as moisture, clay content[3–4] and effective stresses[5–6], and operating properties such as injection pressure[7] and well size[8]. Studies found that the properties of cementation material and the initial drag force after production were dominant factors[3, 9–10]. Ranjith et al.[3] found that the rate of sand production increases with the increasing drag force and reduces with the increasing clay content or cementation phase. This however has not been tested for oil reservoirs. Isehunwa et al.[11] carried out numerical simulations and pointed out more factors including oil production rate, oil viscosity, formation grain size and density, control sand production. They found that sand production increases with oil viscosity and production rate and reduces with formation density and grain size. Numerical study by Carlson et al.[12] showed that sand production in oil formations was highly dependent on the formation's compressive strength. Importantly, though compressive strength of any geological formation is controlled by the cementation materials in the formation, their effect on sand production has not yet been appropriately studied.

In this study, a newly-developed sand production cell has been used to simulate the sand production process in unconsolidated quicksand formations. A series of experimental studies were conducted using this cell to investigate the sand production mechanism and analyse how the formation drag force and cementation affect the sand production in various surrounding conditions.

1. Experiment methodology

1.1. Experiment equipment

The newly-developed sand production cell (with a maximum 300 kPa standing pressure) located in the Deep Earth Energy Research Laboratory at Monash University was modified to study sand production in oil recovery (Fig. 1).

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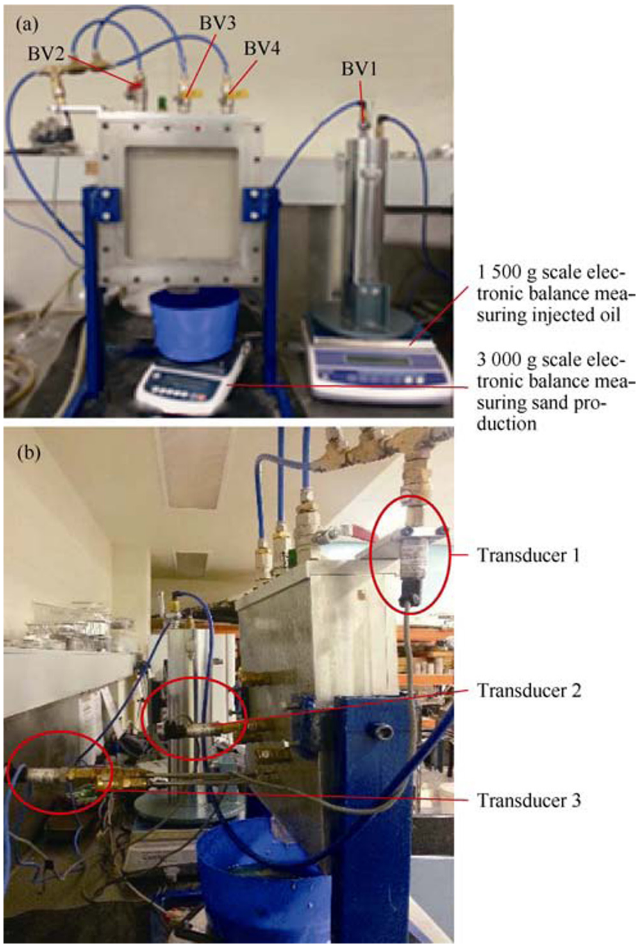

Fig. 1. Sand production cell.

The cell has three inbuilt pressure transducers at the top, middle and bottom and can therefore be used to identify the pressure changes inside the cell with sand production[3]. The pressure measurements obtained from the transducers are recorded in a computer using an advanced data acquisition system. Two balances with scales of 3 000 g and 1 500 g were used to measure the sand production rate from the reservoir and the oil injection rate into the reservoir formation. The weight data acquired from the balance were transferred to the computer using Datacom DC 500 software to provide a weight-time series. The injected oil pressure was adjusted using a pressure regulator to obtain different drag force conditions. A high-precision digital camera was also utilised to record the sand production process in each test.

1.2. Sand used for experiments

The sand used was from the washed white sand group and the particle size distribution curve is shown in Fig. 2. The uniformity coefficient of the sand is 1.67. According to the standard[13], the sand has a uniform particle size distribution.

1.3. Experiment conditions

The experiment conditions are listed in Table 1. Based on the sand production data from the preliminary experiments, a 5-mm outlet was chosen, as the duration for sand production is too long for a smaller outlet size. All pressures in the experiments are gauge pressures.

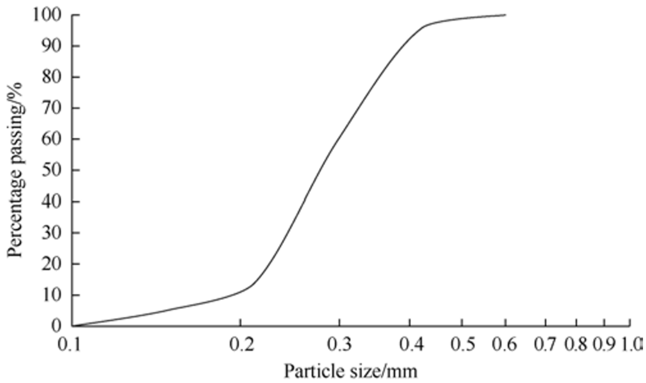

Fig. 2. Particle size distribution of the sand used.

Table 1. Experiment conditions

SN	Injected fluid	Clay/%	Injection pressure/kPa
1	Oil	5	50
2		5	100
3		5	150
4		5	200
5		10	100
6		15	100
7	Gas	5	100
8		5	150
9		5	200

Note: Moisture (wt.) = 5%

1.4. Experiment procedure

In order to create the oil reservoir formation, totally 4 kg sand (mixed with required clay content and 5% distilled water) was put into the cell to achieve the same uniform bulk density for each test. Each sample was compacted into three layers, each layer being compacted with 25 blows with a 2.7 kg rammer dropping from a height of 300 mm. After making the first soil layer, its top soil surface was disturbed and then the second layer was poured on to it and the same procedure for compaction was repeated. The third layer was then poured on and compacted similarly. After all the soil was poured and compacted into the cell, the top lid of the cell was placed in its position and the bolts were tightened fully to prevent any oil leakage during the test.

When the sand formation was ready and it was necessary to create a drag force for sand production to occur. The required drag force was created by increasing the pore pressure in the formation by injecting oil at a predetermined pressure. Oil was injected using a pressurised oil reservoir placed on a 1.5 kg scale, and then opened the first valve BV_1 to release oil from the reservoir. The pressure could be adjusted to the required value using the pressure regulator. Once the required pressure was adjusted using the regulator, the valves BV_2, BV_3, BV_4 (to ensure an even pressure distribution) were