Egyptian Journal of Petroleum (2015) 24, 113–118

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Egyptian Journal of Petroleum

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FULL LENGTH ARTICLE

Sand production prediction using ratio of shear modulus to bulk compressibility (case study)

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Received 24 November 2013; accepted 15 January 2014
Available online 15 June 2015

KEYWORDS

Oil and gas reservoir;
Sand prediction;
Mechanical properties log;
Empirical correlation

Abstract Sand production is a serious problem widely existing in oil/gas production. The problems resulting from sand influx include abrasion of downhole tubular/casing, subsurface safety valve and surface equipment; casing/tubing buckling, failure of casing or liners from removal of surrounding formation, compaction and erosion; and loss of production caused by sand bridging in tubing and/or flow lines. There are several methods for predicting sand production. The methods include use of production data, well logs, laboratory testing, acoustic, intrusive sand monitoring devices, and analogy. The methodologies are reviewed and the data needed for predicting sand production are enumerated. The technique used in this paper involves the calculation of shear modulus, bulk compressibility, and the ratio of shear modulus to bulk compressibility. The shear modulus to bulk compressibility ratio has been related empirically to sand influx. This Mechanical Properties Log method works 81% of the time. This technique is supported with examples and case studies from regions around the world known for sand production. The authors collected the information of the "Kaki and Bushgan Oilfield in Iran", set a sand production prediction to predict sand production potential. The technique has been successfully applied in reservoirs and results have been compared with testing data.

1. Introduction

Over 70% of world's oil and gas reserves are contained in sand formations where sand production is likely to become a problem during the life of the well [1]. Numerous solutions to halt sand production from oil and gas wells have been attempted, with various degrees of success. The most prevalent remedy is the gravel-pack completion, which blocks the influx of loose sand with specially selected gravel held in place by screens. This method is particularly expensive but not nearly as costly as losing a producer. Therefore, it is vital to know whether a well will produce sand before it is placed on production. The economic implications of sand problems are critical enough to require continuous improvement in sand-control techniques and sand production prediction methods. When developing a sandstone oil or gas reservoir, a prediction of sand production is required to evaluate the necessity of sand control [2].

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Peer review under responsibility of Egyptian Petroleum Research Institute.

http://dx.doi.org/10.1016/j.ejpe.2015.05.002
1110-0621

Nomenclature

C_b	Bulk compressibility	ΔP_p	Reservoir pressure depletion
CDP	Critical drawdown pressure	$\Delta\sigma_h$	Change in minimum horizontal stresses
DST	Drill stem test	$\Delta\sigma_H$	Change in maximum horizontal stresses
E	Young's modulus	σ_H	Horizontal maximum stress (Intermediate stress)
G	Shear modulus	σ_h	Horizontal minimum stress (Minimum stress)
TWC	Thick-walled cylinder	σ_v	Vertical overburden stress (Maximum stress)
UCS	Unconfined Compressive Strength	υ	Poisson's ratio

2. Sand production

The classification of field measurements of sand production is considered an essential part of sand prediction. A classification is developed, based on field observations, to allow for a better comparison and interpretation of sand production events.

2.1. Types of sand production

2.1.1. Transient sand production

Transient sand production refers to a sand concentration declining with time under constant well production conditions. This phenomenon is frequently observed during clean-up after perforating or acidizing, after bean-up [3] and after water breakthrough. Fig. 1, shows field example with a sand volume 1 L and decline period [4].

2.1.2. Continuous sand production

In a great number of fields, continuous levels of sand production are observed [3]. Part of the continuously produced sand settles inside the wellbore and increases the hold-up depth. Depending on the lifting capacity of the fluid flow and the sand concentration (part of) the (perforated) producing interval may eventually be blocked [4].

2.1.3. Catastrophic sand production

Catastrophic sand production refers to events where a high rate sand influx causes the well to suddenly choke and/or die. Two catastrophic failure scenarios can be imagined. The first one corresponds to slugs of sand creating sand bridges of moderate volume in tubing or choke, e.g. during or after bean-up and shut-in operations. The second one refers to a massive influx of sand, filling and obstructing the wellbore [4].

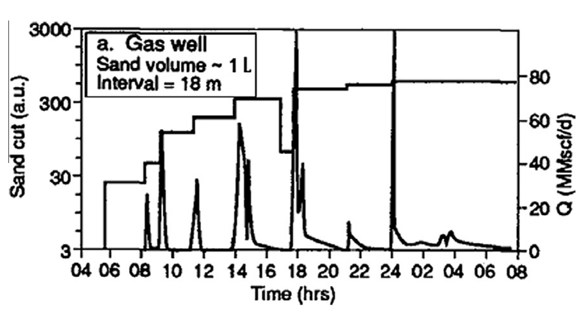

Figure 1 Transient sand production with a sand volume 1 L and decline period [4].

2.1.4. Sand production mechanisms

Mechanisms causing sand production are related to the following: formation strength, flow stability, viscous drag forces, and pressure drop in the wellbore. Operators cope with sand production in many ways. One way of accomplishing this goal is to limit production rates to levels that avoid sand production. In some cases this is the most cost effective method of sand control, but in many cases low production rates are uneconomical. Several factors lead to sand production. The most critical factors are: (1) formation strength; (2) in-situ stress; and (3) production rate [1].

2.1.5. Formation strength

The hydrocarbon production process is associated with reservoir depletion which results in a decrease of reservoir pore pressure. Consequently, the effective overburden pressure defined as total overburden pressure minus pore pressure, increases. Formation collapse is most likely if the effective stress exceeds the formation strength.

2.1.6. Changing in-situ stresses

Generally, the in-situ stresses can be estimated. The horizontal minimum stress (σ_h) can be measured from formation integrity test (leak-off) and the overburden stress (σ_v) from overburden density data. In a relatively relaxed geologic region such as a young deltaic sedimentary basin, the minimum and intermediate stresses tend to be approximately equal. However, in general, the intermediate stress (σ_H) is about 10% more than the minimum stress [5].

During the life of an oil field, in-situ stresses in the reservoir will change as the reservoir pressure depletes. Assuming no lateral strain on the border of the reservoir during depletion, Eq. (1) can be used to evaluate the change in the in-situ stresses.

$$\Delta\sigma_H = \Delta\sigma_h = \alpha \frac{1-2\upsilon}{1-\upsilon} \Delta P_p \tag{1}$$

where and are the change in maximum and minimum horizontal stresses only, is reservoir pressure depletion, is Poisson's Ratio, and α is Biot's poroelastic constant [6].

2.1.7. Production rate

An increase in the production rate leads to a large fluid pressure gradient near the wellbore, and tends to draw sand into the wellbore. The mechanism that causes a consolidated sand to fail is believed to result from a combination of pressure and fluid flow. Because these mechanisms are closely tied to each other, determining actual mechanism may be a moot point [7].