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Predicting Sand Production Rate from Oil and Gas Reservoir Using Mohr Coulomb Failure Criteria

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ABSTRACT: Sand production is the basic problem in the petroleum industry. Each year huge sum of money is spent on well cleaning and repair operation associated with sand production. Sand production becomes a problem when it reduces or stops hydrocarbon production, erodes surface and down hole equipment or casing collapse disposal problems. The research investigates the possibility of helping the Production Engineer to know when sand control is needed to produce a well. The work was made possible by developing a mathematical model to predict the failure of sands. The Mohr coulomb failure criteria is a simple way of presenting how shear stresses act and fail more conveniently and are used to predict sand failure. The wellbore area stresses and the stress value were obtained and analysed and then predicted using the Mohr coulomb failure criteria. The stresses obtained were able to indicate high risk areas of sand production. The pressure drop across the gravel packed completion was evaluated using the equations as proposed by Jones, Blount and Glaze. The major stresses that cause sand failure were established. It was observed that depletion in reservoir pore pressure and high flow rate increase sand production. The study can help oil production company to decide when a well is producing sand and recommend sand control methods.

KEYWORDS: Sand Production, Sand Deposition, Sand Prediction, Sand Control.

I. INTRODUCTION

Predicting sand production rate from oil and gas wells is a technology designed to know when sand control is needed to produce a well. Sand control involves different techniques used to bring sand production within acceptable limits. The practical limits for discovering sand in a centrifuge sample (or shake-out test) is often assumed to be 0.1% of the liquid, or 600 lb/1000 bbl (1.64 kg/m³). This is generally the limit in U. S. Gulf Coast. In other parts of the world where production rates, well head pressure, and operating costs are higher, the limit is basically set at about 10 lb/1000 bbl (28 g/m³), or 0.002% in oil wells with high gas-oil ratio (GORs) (>10,000 scf/bbl), the limit is sometimes set as low as 5 lb/2000 bbl (14 g/m³) in view of the high well head velocities achieved. Most known constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO₂), mainly in the form of quartz and There are some sands found which are basically carbonates. (Siim Sepp, 2020).

SAND PRODUCTION

Production of sand during the production process of oil or gas is seen in recent times to be at depths of 17-22,000 ft in the TUS Caloosa trend and a depth of 17,000 ft offshore of Louisiana, while in the Niger Delta of Nigeria, sand production is predominantly at a reservoir depths ranged between 7,500 and 12,800 ft in a stacked series of anticlinal or dip and fault. At an earlier time sand production was thought to be non-existent at depths greater than 10,000 ft. Materials produced from the

well, along with producing fluid, contain fines and load bearing sand particles. Production of fines is beneficial and is mostly not required to stop because their production is improving the near wellbore permeability but load bearing sand production is really causing the problem. Total overburden of overlying rock is supported by formation grains and fluid present in the grains. As the production proceeds, the pressure depletion causes the reduction in support by fluid pressure and hence less support is provided by the grains, it leads the formation grains to break. At some points, the formation starts crushing and sand grains will be producing towards the wellbore. Consequently due to high stress and fluid velocity they become fine sand particles and produce at surface along with reservoir fluids. Surface is also going to subside due to compaction of formation. (Aborisade, 2013).

IMPACTS OF SAND PRODUCTION TO THE ENVIRONMENT

Disposal of produced sands is expensive because of strict regulations due to concerns on safety and the environment. The discharge of untreated sand production is hazardous to the environment such as land and water pollution which destroyed the ecosystem, discharge poisonous substances to the environment. (Isehunwa, 2010).

EFFECTS OF SAND PRODUCTION TO OIL COMPANY

There could be loss of oil production and hence revenue due to formation sand and fines plugging or reduced well productivity. In addition to damaging pumps and downhole equipment, erosion of casing and surface facilities might also occur. Sand failure can cause wellbore-stability problems, reduced production, and in extreme cases, loss of wells. (Isehunwa, 2010).

II. MATERIALS AND METHODS

Failure criteria has been proposed for rocks under stress by the foremost generally accepted Mohr-Coulomb process that failure occurs most often as a result of shear stress. Mohr circle (figure 1) is a simple way of presenting how shear stresses act.

The Mohr's circle is designed for various conditions. A line based on the friction angle is designed passing through the origin of friable sands and tangent to circle for the uni axial compressive test. This line forms the failure envelope and if a Mohr's circle goes significantly above it then it is certain we would encounter sand failure if production is under such conditions. fig. 1a and 1b illustrate the Mohr-Coulomb failure envelopes respectively.

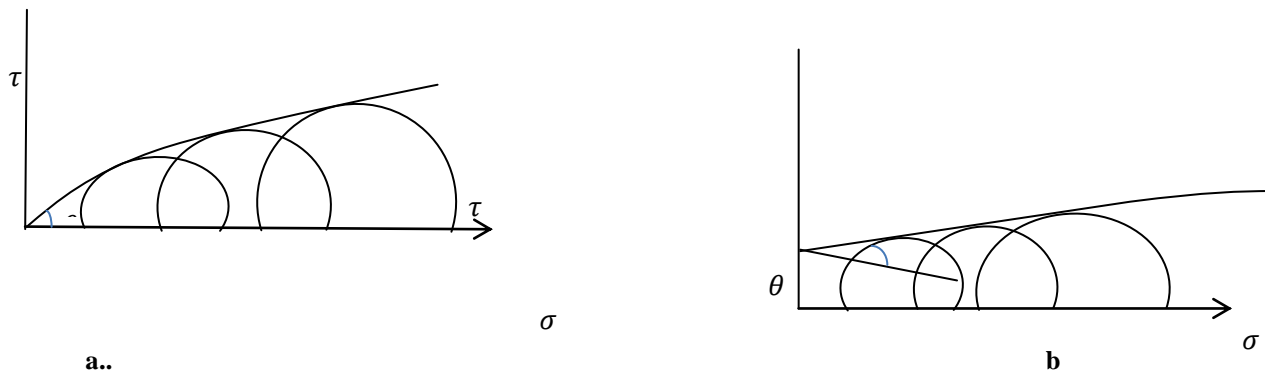


Fig 1. a. Failure Envelope based on Mohr's Circle b. Coulomb Failure Envelope



III. RESULTS AND DISCUSSION

Wellbore Area Stresses

The introduction of a borehole into undisturbed rock distorts the stress field in the overall region of the wellbore. Hubert and Willis have shown that elastic theory can be applied to approximate size of the resulting stress and the effects are examined under two different conditions (Hubert & Willis, 1957).

1. If the rock is totally unconsolidated.

11. If the rock has uniaxial compressive strength of 400psi

Then the data was simulated in four wells under different condition and the result presented in table 1.

Table 1. Wellbore Area Stresses Simulation Results

Condition		Borehole Stresses (Psi)		
		σ_r	σ_θ	σ_z
Initial shut-in	1	+1555	+455	+503
Initial flowing	2	+950	+603	+651
Final shut-in	3	+1000	+554	+602
Final flowing	4	-100	+653	+701

According to Mohr-Coloumb failure Criteria wellbore area stresses and the stress values used to predict sand production rate from oil and gas reservoir. When the following conditions are met.

From the simulated equation results it can be seen that as the reservoir pore pressure decreases:

- i. The tangential grain-to-grain compressive stress increases
- ii. The difference between the maximum and the minimum principal stress on the sand face, therefore increases
- iii. The support of the grains in the radial direction decreases.
- iv. These effects tend to destabilizes the sand and causes shear type which result in sand failure.

Therefore this well is producing sand and there is need for sand control method to be implemented.

Mohr's Circle Value Base on Failure Envelope

A case study of four different wells were done and the data are plotted, shear stress versus compressive stress for unconsolidated and friable formation as shown in figures 2a and 2b

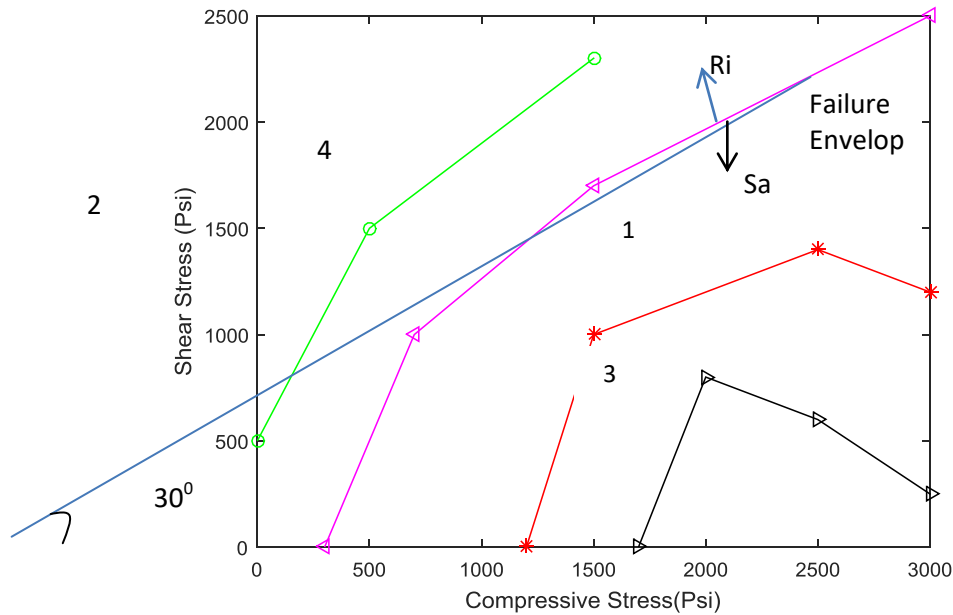


Figure 2a. Plot of Shear Stress versus Compressive Stress for Unconsolidated Sand.

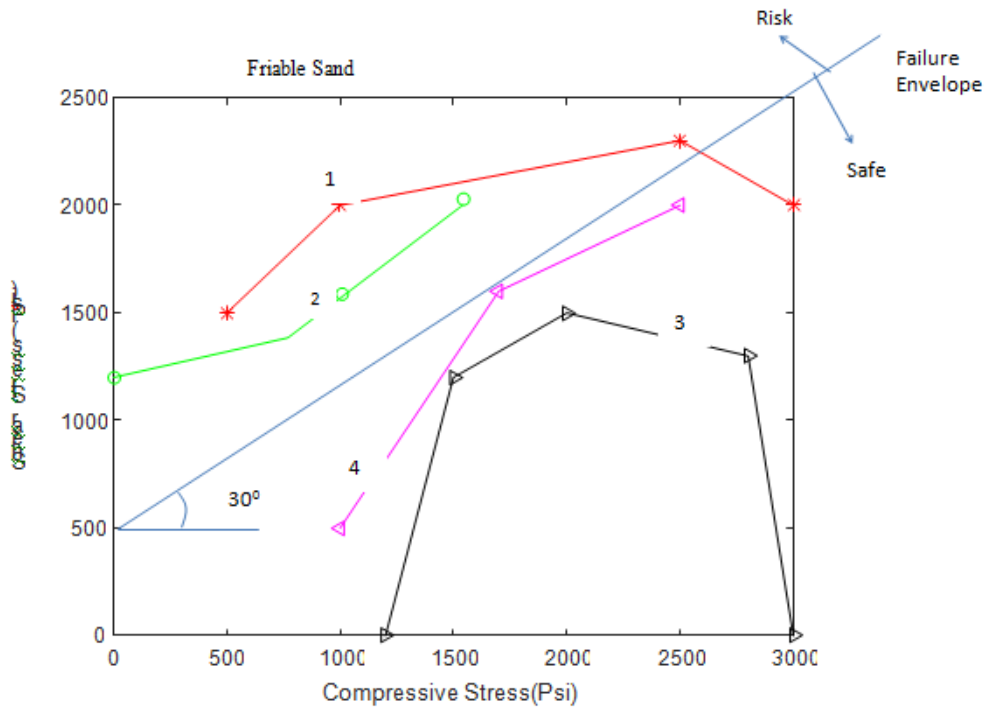


Figure 2b: Plot of Shear Stress versus Compressive Stress Friable Sand.

For an Unconsolidated rock the failure envelope passes through the origin since the Mohrs circle for all conditions investigated across the left failure envelope projected encounter high risk of sand production in figure 2a. Initially, well (1,4) were sand production free, as reservoir depleted sand production is encountered in figure 2a. Well 2 is on high risk zone, a perforated completion can be used initially but careful observation can be undertaken for indications of increasing sand production with reservoir depleted in figure 2a. For Friable sand with a uniaxial compressive strength of 2000psi. There is high risk of sand production for well (1, 2) a perforated completion can be used initially but thorough monitoring should be undertaken for indications of rapid sand production with reservoir depletion in figure 2b

IV. PRESSURE DROP ACROSS GRAVEL PACK SIMULATION

Gravel packing is the most widely used method of sand control. The purpose of designing properly a gravel pack is that it should be able to stop sand production and allow formation fluids to flow through it. When the gravel pack is installed is bring about pressure drop. Here we evaluate the pressure drop. The Drill Stem Test and the Pressure Volume Temperature analysis together with the completion data are simulated with the various production rate for the following results.

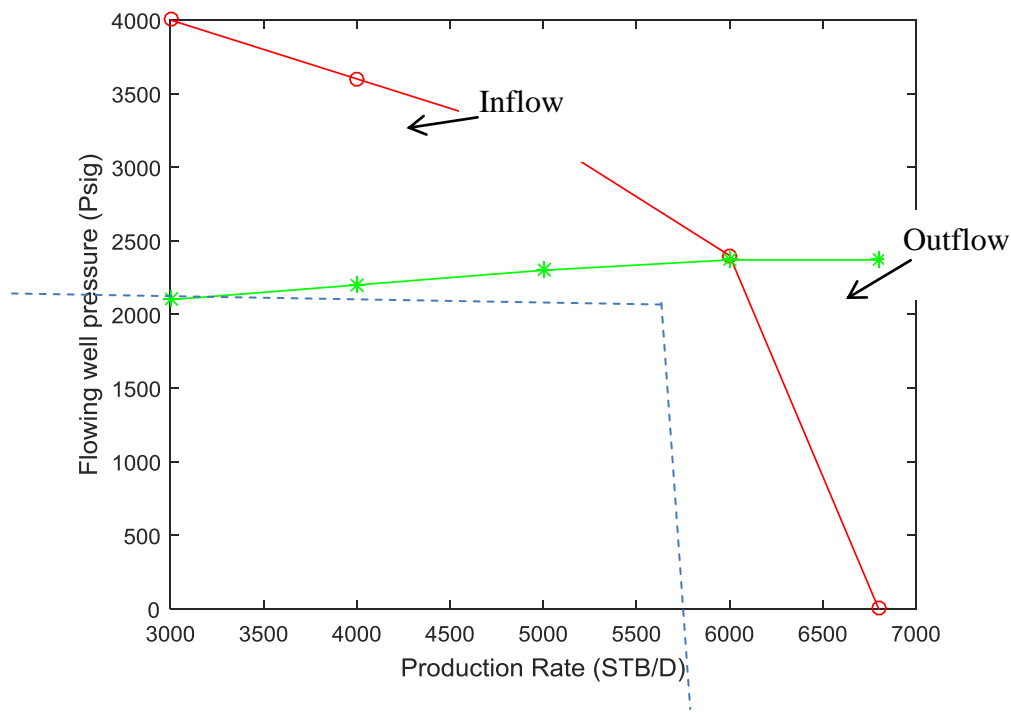


Figure 3. Plot of Inflow versus Outflow for the Grave Pack Oil Well.

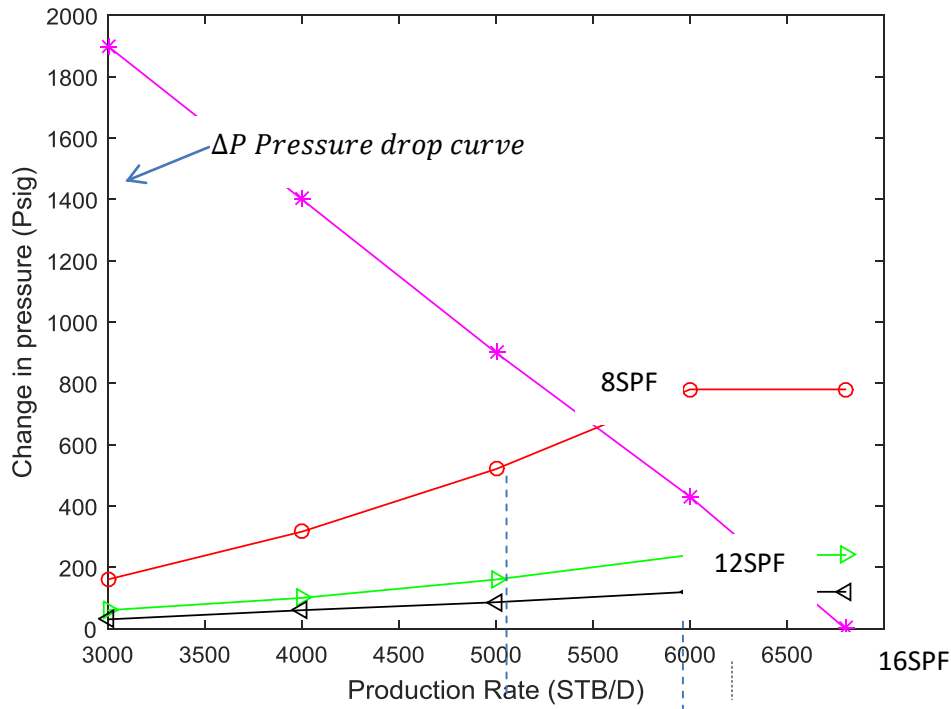


Figure 4. Plot of Pressure Drop versus Producing Rate for Perforation Densities of 8,12 and 16SPF.

- i. From figure 4, it can be observed that at every production rate, the pressure drop across the gravel pack decreases with a rise in perforating density
- ii. The well system pressure drop curve and the gravel pack curve intersect at a point at which the rate can be evaluated (figure 4).
- iii. The high rates 6600b/d is achieved at a perforating density of 16SPF (figure 4).
- iv. The inflow and the outflow curves intersection give a producing rate, $q_o=6100\text{b/d}$, assuming there is no pressure drop across the completion after examination (figure 3).
- v. For 12SPF and 16SPF, the well does not flow if the pressure drop limit should not exceed 400psi (figure 4).

V. CONCLUSION

Conclusion is drain from the investigation

- i. The mathematical models of tangential stress, axial stress and radial stress was established which help to predict the failure of sand base on Mohr coulomb failure criteria.
- ii. It was observed that high flow rate increases rock deformation and failure thereby increases sand production. However, high oil production can be maintained with a good sand control method in place.
- iii. Good conductive perforation and consolidation treatment can be maintain during sand control which bring about good permeability of oil production.

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