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Prediction of Sand Production Through Porous Media: Mechanisms and Challenges to Optimising the Inefficiencies

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Abstract: One of the challenges facing drilling companies in the completion and production of oil and gas wells is sand production from the formation. The ability to predict sand production in the wells of a reservoir, to decide to use different methods of control is considered a fundamental issue. Therefore, analysis and study of sand production conditions and selecting the optimal drilling route before drilling wells are significant issues that are less considered. According to the findings of this study, due to the sand grains adhesion issue, saturation increase has caused to increase in the intermolecular uptake, and therefore moisture has been decreased. It leads to reduction in the sand production rate. Pressure increase has a direct relationship with the sand production rate due to increased induced drag forces. Moreover, phenol–formaldehyde resins provided an acceptable measurement as there are no significant changes in porosity and permeability.

Key words: Phenol–formaldehyde resins, sand production rate, moisture effect, permeability reduction, chemical consolidation.

Introduction

Sand production is one of the uncommon by-products obtained in the process of hydrocarbon formations. Reservoirs with weak integration and sandstone formations have been observed in 70% of the world's oil and gas reserves (Ben Mahmud et al., 2020; Hamian et al., 2018; Jin and Davarpanah, 2020; Leng et al., 2018; Mohammadi et al., 2018; Mirzapour et al., 2019; Srivastava and Singh, 2020; Su et al., 2015; Zhu et al., 2020). Therefore, the issue of sand formation can be divided into two groups:

1. Production of sand in sandstone reservoirs and evaluation of control methods.
2. Diagenesis and its role in the physical properties of the reservoir.

The challenging issue that might occur in petroleum industries is the phenomenon of sand production in sandstone reservoirs. This phenomenon, in which sand grains are separated from reservoir rocks occurs due to high pressures. It can impose high costs on oil companies each year (Akbary et al., 2019; Dusseault, 2011; Ebrahimian et al., 2018; Eslami et al., 2019; Gholamin and Khayatnezhad, 2020a, b; Kozhagulova et al., 2021; Nesic et al., 2020; Sun et al., 2020). The problems that sand production brings to oil companies; erosion of equipment such as pipes, pumps, valves, blocking surface equipment and inside wells such

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as pipes, need more manpower to replace and repair equipment and clean wells, and decreased permeability of the formation and consequently reduced reservoir recycling efficiency. Formation damage is a crucial issue in petroleum industries that might induce financial and environmental challenges (Davarpanah, 2018b; Davarpanah et al., 2018a, 2019, 2020; Khayatnezhad and Gholamin, 2020; Li et al., 2021; Ren and Khayatnezhad, 2021; Sun et al., 2021). Overbalanced drilling performances are considered influential operations that affect the drilling operations due to severe damage to the hydrocarbon formation. When the wellbore pressure is lower than the static formation pressure, underbalanced drilling processes occurs in the hydrocarbon formation (Davarpanah, 2019; Davarpanah and Mirshekari, 2019a; Deville et al., 2011; Khodja et al., 2010). Therefore, it is required to provide an appropriate designation to minimise the damage formation. Sand production is one of the common and critical issues during drilling performances, and it is defined as the quantities of various grain sizes, which can be transferred through the porous media. One of the main problems of sand production in hydrocarbon formation is pore throat plugging which profoundly affects hydrocarbon production. Therefore, prediction and optimisation of the sand production would be of importance as it might impose severe inefficiencies and financial proportions for petroleum industries (Davarpanah, 2020; Ranjith et al., 2014; Talaghat et al., 2009).

In contrast, solid particles or extensive sands might propose bearing loads to the hydrocarbon formation. From a technical point of view, sand production would be devoted to such problems as good instability, permeability reduction, and well equipment abrasion (Davarpanah and Mirshekari, 2018). The mechanism of sand production is schematically depicted in Figure 1.

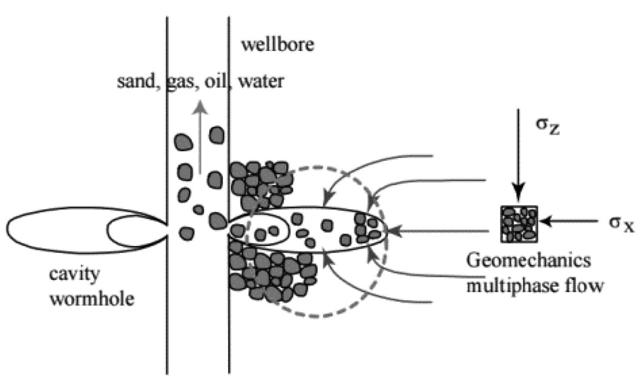

Figure 1: The mechanism of sand production in hydrocarbon formations (Roostaei et al., 2020).

As sand production is one of the dynamic operational processes in petroleum industries, it has costed vast expenditures to control its production. Song et al. (2020) developed a numerical model to predict and simulate the sand production mechanisms by implementing the discrete element method and particle flow codes (utilisation of computational fluid dynamics). The crucial factors in this modelling are the distribution of sand particle sizes, fluid pressure, and fluid types. According to their findings, drawdown pressure determination is critical for engineering purposes as it might impose an unfavourable rising on sand production (Song et al., 2020). Sand migration through porous media is a crucial factor that would restrict the gas-phase production from methane-hydrate reservoirs. Cohen et al. (2019) developed a numerical model to simulate sand detachment processes in gas reservoirs. It is concluded that deviatoric and isotropic stresses could be affected by the sand migration, and hydrates existence would be a stress relaxation increase. Thereby, these issues would be evaluated in further designation processes of sand control mechanisms (Cohen et al., 2019). One of the main challenges that might be challenging in producing sands in porous media is the addition of nanoparticles to polymers and water to enhance oil recovery. This phenomenon has caused nanoparticle adsorption on the formation rocks due to their minimal areas. Therefore, they can partially cover the rock surfaces and provide minerals instability in low salinity water flooding performances. This concept was evaluated by Shakiba et al. (2020) as an efficient prospective for future oil production performances. A newly developed model to investigate the particle size and fine's composition of the sand production mechanisms was proposed by Roostaei et al. (2020). It is concluded that slot apertures can control the performance flow of sand screens. Another study's findings are related to the optimisation of sand mitigation into the pore plugging issue, which should be considered in engineering designation (Roostaei et al., 2020). They found that slot apertures control sand screen performance flow. Therefore, optimisation of the size of slots aperture would be used as a sand control mechanism during multiphase flow. Moreover, it can be concluded that pore plugging would be mitigated during this process.

Due to the importance of sand control in petroleum industries, selecting the optimum method to eliminate the sand production rate virtually is crucial and should be considered. Hence, various sand production control mechanisms and their challenges during production operation from hydrocarbon formations have been evaluated in the following paper. Moreover, the considerable influence of such factors as moisture effect, chemical consolidation, and pressure effect has been investigated.

Methods

Sand control is considered an efficient and preferable method to reduce the production of sand in hydrocarbon formations. Two main phenomena have caused production of sand in the hydrocarbon formation. Rock mechanical failure and dragging forces are crucial factors to produce sands near the wellbore. If these issues were not appropriately addressed, pore plugging and formation damage would happen in the production processes. It is shown in Figure 2 (Ben Mahmud et al., 2020).

The following techniques are the main methods to control the produced sand in hydrocarbon formation. To prevent the sand flow to the surface facilities, a fully lattice pipe was placed across the production formation to adsorb the sands. As it is operated as a filter, it acts as a mechanical separation for sand production. In maintenance and workover techniques, sand production has been tolerated by the washing, bailing, and surface facilities cleaning to provide safe maintenance. It is shown in Figure 3.

Gravel packing methods are considered as an efficient method to place a slotted liner or screen mesh on the adverse side of completion intervals to prevent sand production in the formation. Gravel sizes are approximately 5-6 times bigger than median sand sizes in the formation. Therefore, it can create a downhole filter with proper permeability to allow the fluid to flow

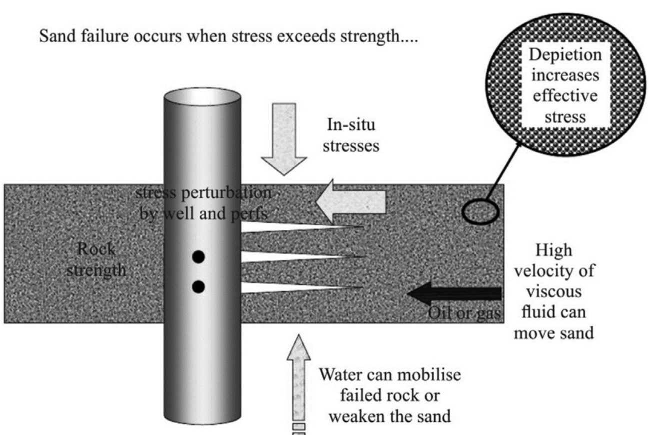

Figure 2: Sand failure mechanism in the formation (Ben Mahmud et al., 2020).

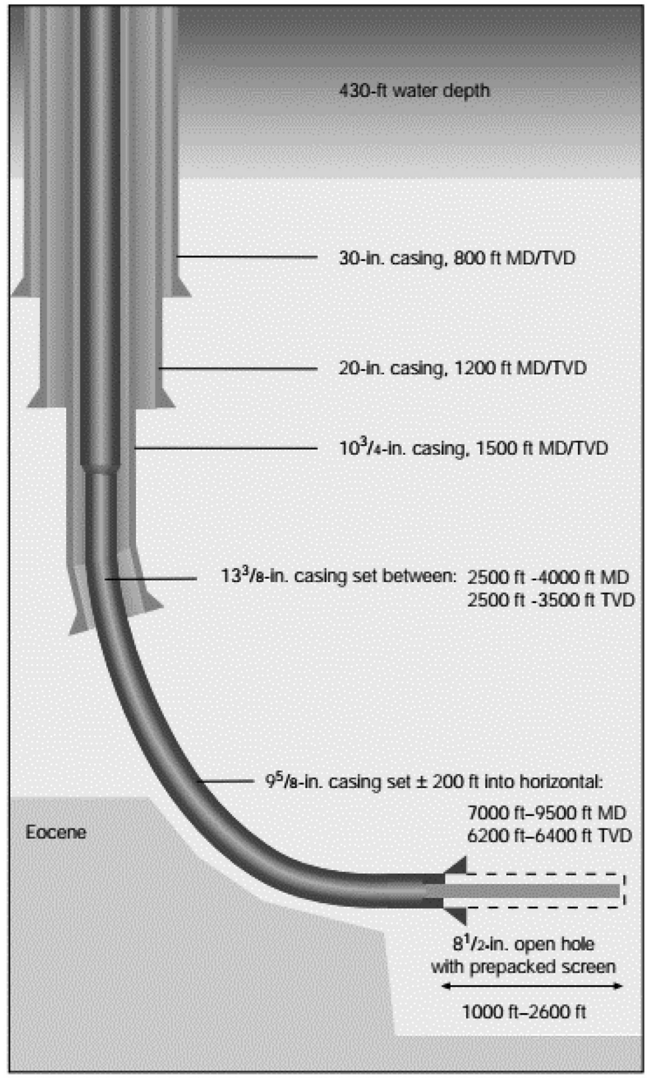

Figure 3: Plastic consolidation method (Ben Mahmud et al., 2020).

through the filters and restrict sand flow. The schematic of gravel packing is shown in Figure 4.

Results and Discussion

Effect of Chemical Consolidation

Chemical consolidation is one of the efficient methods to control sand production. Talaghat et al. (2009) experimentally investigated the profound impact of different resins as the consolidation agent to select the optimum agent for sand production control. The provided core samples from the Asmari oilfield were evaluated at different resin types and concentrations to observe the porosity, comprehensive strength, and permeability. They concluded that phenol–formaldehyde resins provided acceptable measurements as there are no significant changes in porosity and permeability. The

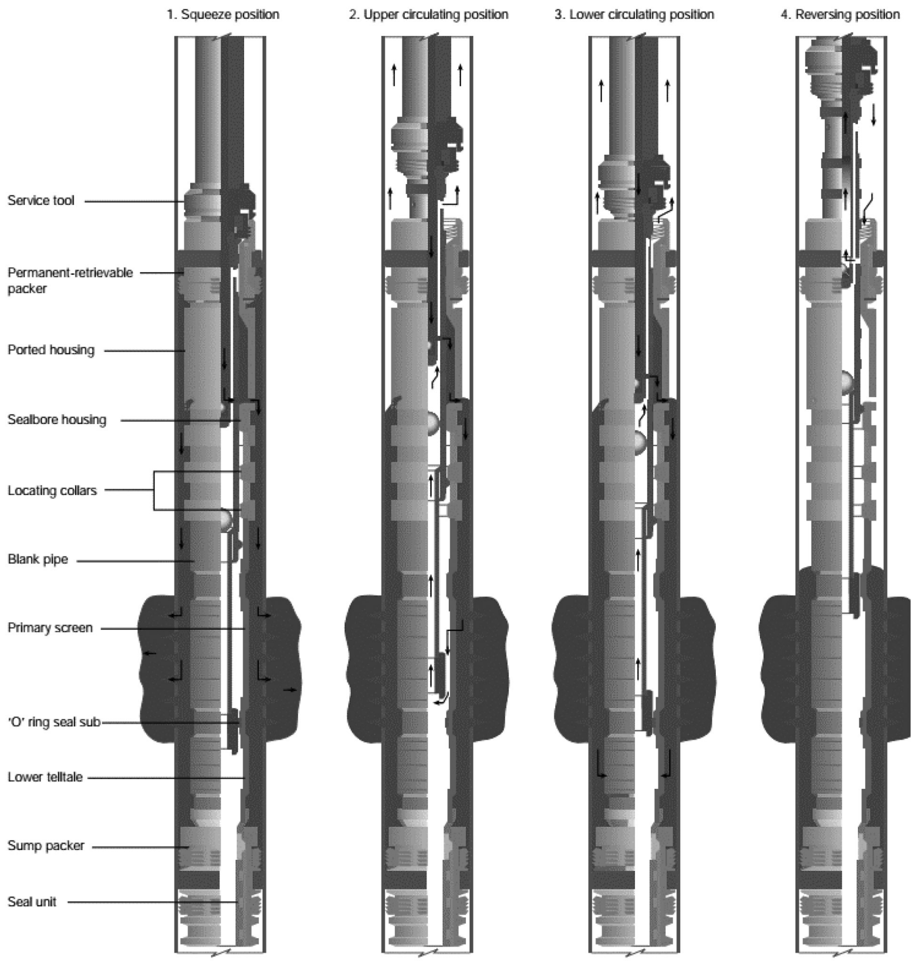

Figure 4: Schematic of gravel packing system.

effect of sand concentration for phenol–formaldehyde resins to measure compressive strength is shown in Figure 5 (Talaghat et al., 2009).

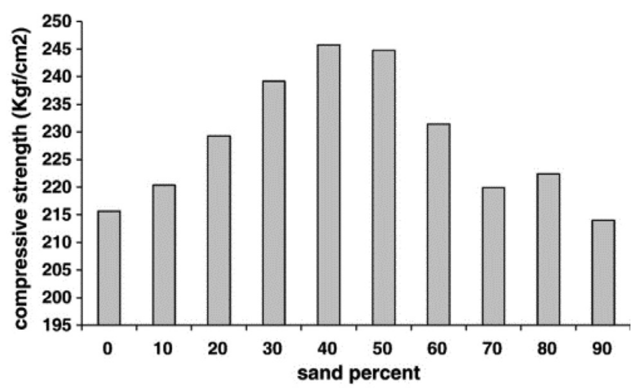

Figure 5: Compressive strength versus sand percent for phenol–formaldehyde resins (Talaghat et al., 2009).

Effect of Moisture and Pressure

The temperature has a vitally important impact on the cumulative sand production regarding the sands' adhesion property. Therefore, as shown in Figure 6, higher pressures have caused more sands to produce more sands. Another influential parameter on sand production is the moisture effect that has an adverse impact on sand production. Due to the sand grains adhesion issue, saturation increase has caused increased intermolecular uptake, and therefore moisture has been decreased. It leads to reduce the sand production rate. This issue was investigated by Papamichos et al. (2001).

Pressure Effect

To evaluate the sand production rate's pressure effect, the test must be performed after the sands are completely dried to eliminate the moisture effect. As shown in Figure 7, a pressure range from 150 to 200 KPa was considered on the injection processes. Pressure increase has a direct relationship with a sand production rate due to increased induced drag forces. This concept was investigated by Yim et al. (1994).

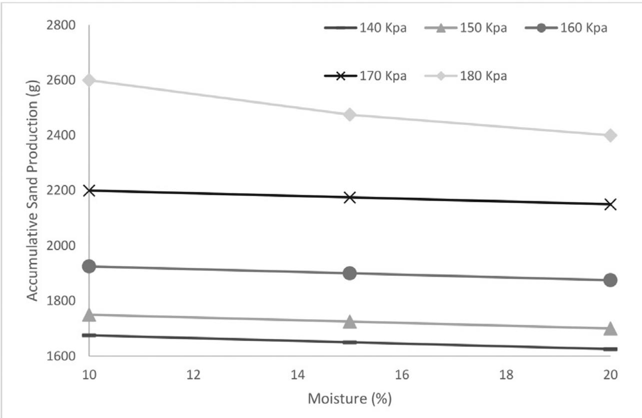

Figure 6: Effect of moisture and pressure on accumulative sand production.

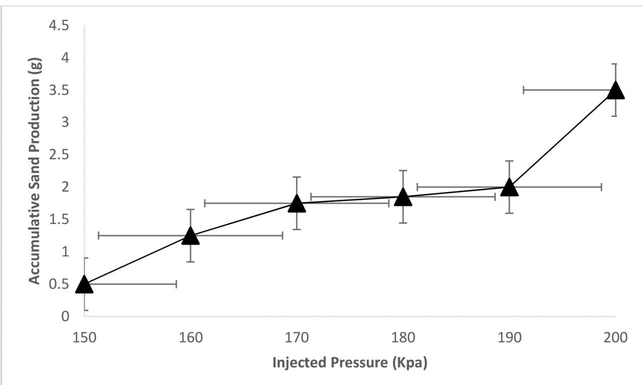

Figure 7: Pressure effect on the sand production rate.

Li et al. (2019) propose a new sand production control system to optimise the sand production rate in clayey silt hydrate reservoirs. In this system, a nodal system analysis technique was implemented to evaluate the migration of sand particles through production wells. In this system, gravel size, borehole blockage, and maximum sand production rate value were evaluated (Li et al., 2019). Moreover, high compressive strength and excellent stability against the movement of reservoir and excitation fluids are obtained in the tank with the minimum reduction of permeability. Salehi et al. (2019) proposed a chemical-based method using chromium triacetate hydrogel/polyacrylamide to consider the sand production in the synthetic sandpack system. They concluded that the hydrogel increase has caused to increase the sandpack compressive strength. This increase related to the polymer concentration and cross-linker enhancement would cause a positive impact on the sandpack compressive strength (Salehi et al., 2019). Unfortunately, due to the lack of knowledge about sand production control issues, the relevant managers do not know how to prevent and deal with them. There are parameters in sand control and method selection, for which, we have enough information about the effect of each, the sand control method can be effectively utilised. These parameters include two categories of technical and non-technical parameters. Some of the technical parameters are the dimensions of the formation grains, permeability, refined grains, the length of the production distance of well conditions, water salinity, production rate, temperature, and bottom-hole pressure. The leading causes of sand production are upsetting the tension balance formations, the emergence of kinetic force, reducing reservoir pressure, and reducing rock stiffness. According to the relationships and equations in elasticity, when a well is drilled in the environment, the stress distribution around the cavity is disrupted. This stress disturbance around the well can be large enough to exceed the resistance around the hole. In this case, the material, which has passed through the elastic band and entered the plastic stage, will no longer be able to remain next to other materials. In the case of oil and gas reservoirs, the issue is more complicated. In these cases, the porous medium is saturated with a pressurised fluid. At this time, if a hole is created in the well during drilling operations, the internal reservoir fluid, due to its high pressure, tends to move to the low-pressure point. The parameters affecting the sand production can be divided into three categories: executive parameters, uncontrollable parameters and operational parameters. Executive parameters include factors such as surface stresses, local fluid velocities, and saturation characteristics that increase the displacement of solids. The effect of simultaneous blocking pressure and permeable fluid pressure is another crucial parameter that should be considered.

Conclusion

Considering the study of all methods and the study of reservoir pressure drop in sandstone reservoirs, it seems that the method of the expandable sand screen is more appropriate than all other methods to prevent the production of sand with oil, especially if the goal is to operate with a high rate of a well. For new wells that have a problem of sand production completed with this new method, it is also suggested that this method could be used as one of the most efficient methods to increase the production flow for sandstone reservoirs or reservoirs that have a high probability of water coning. The main findings of this study are:

- Due to the sand grains adhesion issue, saturation increase has caused increased intermolecular uptake, and therefore moisture has been decreased. This leads to reduction in the sand production rate.
- Pressure increase has a direct relationship with a sand production rate due to increased induced drag forces. Phenol–formaldehyde resins provided an acceptable measurement as there are no significant changes in porosity and permeability.

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