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SAND CONTROL - METHODS AND TECHNIQUES

METÓDY A TECHNIKY POUŽÍVANÉ NA ZÁBRANU PIESKOVANIA SOND PŘI ŤAŽBE ROPY A ZEMNÉHO PLYNU

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Abstract: The need for sand control in cased hole environments is driven by geomechanics, the discipline dealing with the interaction of rocks, stresses, pressures, and temperatures a discipline in which some of oil company has extensive experience and expertise. Sand production occurs as a result of a combination of geomechanic and other factors: weak rocks and earth stresses, compacting reservoirs, shear and collapse forces, formation and environmental complexities, and general wellbore instabilities. The techniques for controlling sand production vary almost as much as the environments where they are required. Three of the most commonly used techniques are gravel packing, frac packing, and screenless completions. These techniques form the basis of the broad, unique sand control offering.

***Keywords:** sand control techniques, gravel packing*

PREFACE

Several techniques are available for minimizing sand production from oil and gas wells. The choices range from simple changes in operating practices to expensive completions, such as sand consolidation or gravel packing. The sand control method selected depends on site-specific conditions, operating practices and economic considerations. This paper introduces the available approaches to sand control.

1. AVAILABLE TECHNIQUES

Some of the sand control techniques available are (Fig. 6 and Fig. 8):

- Maintenance and workover
- Rate exclusion
- Selective completion practices
- Plastic consolidation
- High energy resin placement
- Resin coated gravel
- Stand-alone slotted liners or screens
- Gravel packing.

1.1 MAINTENANCE AND WORKOVER

Maintenance and workover is a passive approach to sand control. This method basically involves tolerating the sand production and dealing with its effects, if and when necessary. Such an approach requires bailing, washing, and cleaning of surface facilities routinely to maintain well productivity. It can be successful in specific formations and operating environments. The maintenance and workover method is primarily used where there is:

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- Minimal sand production
- Low production rates
- Economically viable well service.

1.2 RATE RESTRICTION

Restricting the well's flow rate to a level that reduces sand production is a method used occasionally. The point of the procedure is to sequentially reduce or increase the flow rate until an acceptable value of sand production is achieved. The object of this technique is to attempt to establish the maximum sand-free flow rate. It is a trial-and-error method that may have to be repeated as the reservoir pressure, flow rate, and water cut change. The problem with rate restriction is that the maximum flow rate required to establish and maintain sand free production is generally less than the flow potential of the well. Compared to the maximum rate, this may represent a significant loss in productivity and revenue.

1.3 SELECTIVE COMPLETION PRACTICES

The goal of this technique is to produce only from sections of the reservoir that are capable of withstanding the anticipated drawdown. Perforating only the higher compressive strength sections of the formation allows higher drawdown. The high compressive strength sections will likely have the most cementation and, unfortunately, the lowest permeability. While this approach might eliminate the sand production, it is flawed because the most valuable reserves will not be in communication with the well.

1.4 PLASTIC CONSOLIDATION

Plastic consolidation involves the injection of plastic resins that are attached to the formation sand grains. The resin subsequently hardens and forms a consolidated mass, binding the sand grains together at their contact points. If successful, the increase in formation compressive strength will be sufficient to withstand the drag forces while producing at the desired rates. The goal of these treatments is to consolidate about a 0,91 m (meter) radius around the well without appreciably decreasing the permeability of the rock.

Three types of resins are commercially available:

- Epoxies
- Furans (including furan/phenolic blends)
- Phenolics

The resins are in a liquid form when they enter the formation, and a catalyst or curing agent is required for hardening. Some catalysts are "internal" because they are mixed into the resin solution at the surface and require time and/or temperature to harden the resin. Other catalysts are "external" and are injected after the resin is in place. The internal catalysts have the advantage of positive placement because all resin will be in contact with the catalyst required for efficient curing. A disadvantage associated with internal catalysts is the possibility of premature hardening in the work string. The amounts of both resin and catalyst must be carefully chosen and controlled for the specific well conditions. Epoxy and phenolics can be placed with either internal or external catalysts; however, the rapid curing times of the furans (and furan/phenolic blends) require that external catalysts be used. There are two types of plastic consolidation systems:

- "Phase separation" systems
- "Overflush" systems

Phase separation systems contain only 15 to 25 % active resin in an otherwise inert solution. The resin is preferentially attracted to the sand grains, leaving the inert portion that will not otherwise affect the pore spaces. These systems use an internal catalyst. Accurate control of the plastic placement is critical because overdisplacement will result in unconsolidated sand in the critical near-wellbore area.

Phase separation consolidation may be ineffective in formations that contain more than 10 % clays. Clays, which also attract the resin, have extremely high surface area in comparison to sands. The clays will attract more resin and because phase separation systems contain only a small percentage of resin, there may not be enough resin to consolidate the sand grains.

Overflush systems contain a high percentage of active resin. When first injected, the pore spaces are completely filled with resin, and an overflush is required to push the excess resin away from the wellbore area to re-establish permeability. Only a residual amount of resin saturation, which should be concentrated at the sand contact points, should remain following the overflush. Most overflush systems use an external catalyst, although some include an internal catalyst.

All plastic consolidations require a good primary cement job to prevent the resin from channeling behind the casing. Perforation density should be a minimum of four shots per foot to reduce drawdown and improve the distribution of plastic; however, each perforation must be treated. Shaley zones should not be perforated because fluids are difficult to place in these low-permeability strata. Clean fluids are essential for plastic consolidation treatments because all solids that are in the system at the time of treatment will be "glued" in place. The perforations should be washed or surged, workover rig tanks should be scrubbed, and fluids should be filtered to 2 microns. Work strings should be cleaned with a dilute HCl acid containing sequestering agents, and pipe dope should be used sparingly on the pin only. A matrix acid treatment, which includes HF and HCl, is recommended for dirty sandstones to increase injectivity.

Both phase separation and overflush systems require a multistage preflush to remove reservoir fluids and make the sand grain oil wet. The first stage, generally diesel oil, serves to displace the reservoir oil. Epoxy resins are incompatible with water; therefore, isopropyl alcohol follows the diesel to remove formation water. The final stage is a spacer (brine) that prevents the isopropyl alcohol from contacting the resin.

Plastic consolidation leaves the wellbore fully open. This becomes important where large outside diameter (OD) downhole completion equipment is required. Also, plastic consolidation can be done through tubing or in wells with small-diameter casing. For most applications, the problems associated with plastic consolidation outweigh the possible advantages. The permeability of a formation is always decreased by plastic consolidation. Even in successful treatments, the permeability to oil is reduced because the resin occupies a portion of the original pore space and is oil wet. The amount of resin used is based on uniform coverage of all perforations. However, perforation plugging or permeability variations often cause some perforations to take more plastic than others. In systems that use an external catalyst, there is no sand control in areas that are not contacted by both resin and catalyst.

1.5 HIGH ENERGY RESIN PLACEMENT

One of the main reasons for the lack of acceptance of chemical consolidation techniques has been difficulties in placing the resin uniformly across the entire target interval and restricted length. The uneven coverage is more severe in intervals greater than about 4,6 metres long. Causes for this are typically attributed to differences in injectivity caused by incomplete perforation clean-up during underbalanced perforating jobs or permeability variations in the formation interval length.

High-energy resin placement addresses some of these problems /1, 2/. The technique injects the resin rapidly under highly overbalanced conditions. The resin is surged into the formation at rates that will place the resin before the formation has a chance to fail. Another benefit to the rapid resin placement is that the technique appears to be less affected by permeability contrasts than the matrix treatments. This characteristic leads to more uniform placement over a long perforated interval. This method is still experimental.

1.5.1 Resin considerations

The primary difficulty in using resin systems is attaining complete and even placement of the chemicals in the formation. In lenticular formations, plastic placement may be uneven because of widely varying permeabilities, and some zones are likely to be untreated. These untreated intervals may break down during subsequent production, and the well will sand up. For this reason, plastic consolidation is suitable for interval lengths less than 3 to 4,6 metres. Longer intervals can be treated using packers to isolate and treat small sections of the zone at a time, but such operations are difficult and time consuming. Plastic consolidation treatments also do not perform well in formations with permeabilities less than about 50 md. Low permeabilities preclude injecting resins under matrix conditions and cause permeability reductions by the plastic that substantially reduce residual permeability (i.e., well productivity). The resins soften at a temperature greater than 124 °C /255 °F/ and may not provide sufficient strength at elevated temperature.

Plastic consolidation was used extensively in the late 1950s through the mid-1970s in the Gulf of Mexico; however, this technique currently represents far less than 1 % of all sand-control completions worldwide. The reasons for decreased usage include lack of suitable candidates, the placement difficulties already described, as well as tight regulations on the handling of the chemicals, which are generally quite toxic (with the furans being the least toxic of the three). These treatments tend to be costly. The main disadvantage of plastic systems in current operations is its high cost and limited completion interval length for an effective treatment, 4,6 metres or less. The latter excludes most wells. Because of its current limited use, service companies have difficulty maintaining trained crews.

Propellant gas fracturing

The use of propellant gas fracturing tools involves the conversion of solid propellant by chemical reaction into a gas in the target zone of a wellbore. The chemical propellant is changed into combustion gases by one of two different mechanisms:

- Detonation
- Flame propagation

Detonation involves a reaction characterized by a shock wave that moves rapidly through the interval to be treated. This shock wave, traveling at velocities between 4 570 m . s^{-1} and 7 620 m . s^{-1}, induces pressures ranging from 2,8 to 27 580 MPa, with pressurization rates up to 690 MPa (100,000 psi). The high-pressure surge places the resin more evenly in long formation intervals where conventional plastic consolidation, pumped at matrix, is impractical.

The reaction products are contained in place by the liquid column in the wellbore above the tool. The rapid generation of gas forces the resin placed in the annular space surrounding the tool out of the perforations and into the formation. For this process, the casing must be in good condition and properly cemented to be successful. Perforations must be clean and clear of debris, and all debris should be removed from the wellbore. Only clean sands should be perforated. Finally, if sand has been produced, the perforations should be prepacked with gravel prior to the treatment, which may be difficult.

The process involved in this type of a treatment is to first inject a preflush of mutual solvent to remove water from the target interval. Furan resin is then placed across the perforations, and the gas-generating propellant tool is placed across the entire perforated interval. Nitrogen overbalance is applied to the work string, and the propellant device is fired to inject resin above fracture pressure. The resin is then followed with an acid post-flush to harden the resin.

An advantage to this system is that resin will be placed in all perforations immediately across from the location of the gas generator tool. However, if multiple tool runs are required to treat an interval longer than about 10,97 metres, movement of the tool will make it difficult to hold the resin in position. The two other methods are These methods are designed to alleviate the problem of maintaining the resin in position.

Overbalanced perforating or surging

High-overbalanced perforating resin placement may be used if the well has not been previously perforated. If a well has existing perforations, the interval can be prepacked, and then the resin can be placed with a high-pressure surge.

The composition of the resin solution is furfuryl alcohol resin solvent, a coupling and wetting agent. The resin catalyzes with an acid to form a furan plastic. The resin solution is positioned across an interval of planned perforations. A more dense fluid may proceed below the resin to fill a portion of the wellbore below the zone of interest. A lower density fluid may follow above the resin in the wellbore to keep the resin from floating up above the zone of interest. This technique can ensure more accurate placement of resin across the soon to be perforated interval. Operationally, the pressure in the wellbore fluid, at the depth to be perforated, is increased to a substantially greater level than the pore pressure in the formation. The applied pressure before perforating may be higher than the formation fracturing pressure. Wireline through tubing or casing guns, or tubing conveyed perforating, can all be used for perforating. Resin is forced into the new perforations upon perforating with the overbalanced pressure. Acid is injected into the perforations to convert the liquid resin into a strong plastic that will consolidate the sand. The overbalanced perforating method is currently the preferred method.

While the high-energy resin placement techniques offer an advantage over conventional matrix plastic consolidation methods, they are not widely used, and this system is plagued by many of the disadvantages of plastic consolidation:

- High cost
- Low success
- Lack of longevity

The results of high-energy plastic treatments generally have tended to be disappointing.

1.6 RESIN COATED GRAVEL

Resin-coated gravel treatments can be pumped in two different ways. The first is a dry, partially catalyzed phenolic resin-coated gravel. Thin resin coating is about 5 % of the total weight of the sand. When exposed to heat, the resin cures, resulting in a consolidated sand mass. The use of resin-coated gravel as a sand-control technique involves pumping the gravel into the well to completely fill the perforations and casing. The bottomhole temperature of the well, or injection of steam, causes the resin to complete the cure into a consolidated pack. After curing, the consolidated gravel-pack sand can be drilled out of the casing, leaving the resin-coated gravel in the perforations. The remaining consolidated gravel in the perforations acts as a permeable filter to prevent the production of formation sand. The main use of resin-coated gravel is in prepacked screens, which is discussed later.

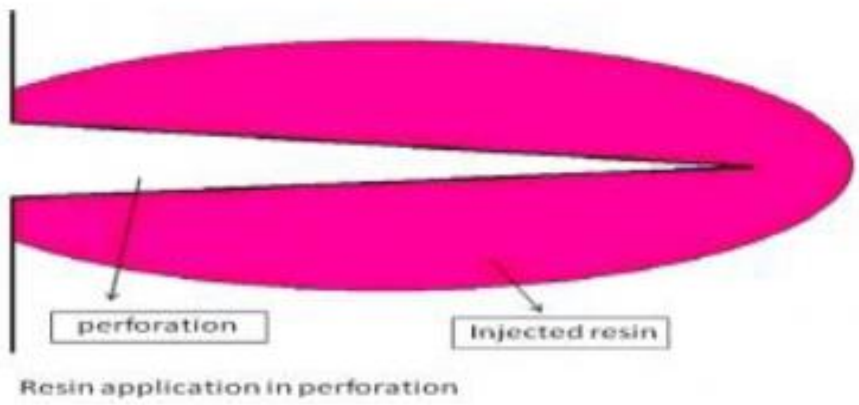

Fig. 1. *Resin application in perforation.*

Wet resins (epoxies or furans) can also be used. To pump these systems, the well is usually prepacked with gravel; then, the resin is pumped and catalyzed to harden the plastic. After curing, the consolidated plastic-sand mixture is drilled out of the well, leaving the resin-coated sand in the perforations.

Fig. 2. *Standard resin-bonded gravel products contain crushed stone.*

Although simple in concept, using resin-coated gravel can be complex. First, and most important, a successful job requires that all perforations be completely filled with the resin-coated gravel, and the gravel must cure. Complete filling of the perforations becomes increasingly difficult, as zone length and deviation from vertical increase. Second, the resin-coated gravel must cure with sufficient compressive strength. While resin-coated systems were used extensively after their development, their use today is limited. Experience with them has shown good initial success but poor longevity, as most wells do not produce sand-free for extended periods of time.

1.7 STAND-ALONE SLOTTED LINERS OR SCREENS

Slotted liners or screens have been used as the sole means of controlling formation sand production. In this service, they function as a filter. Unless the formation is a well-sorted, clean sand with a large grain size, this type of completion may have an unacceptably short producing life before the slotted liner or screen plugs with formation material. When used alone as sand exclusion devices, the slotted liners or screens are placed across the productive interval, and the formation sand mechanically bridges on the slots or openings in the wire-wrapped screen. Bridging theory and laboratory tests show that particles will bridge on a slot, provided the width of the slot is less than two particle diameters. Likewise, particles will bridge against a hole if the perforation diameter does not exceed about three particle diameters. The slots are usually 6 inches in length and may range in width from 0,3048 mm to 6,35 mm (millimeters), which is substantially large r than what metal mesh or wire - wrapped screens can provide, hence the liner only filters out the coarses t particles.

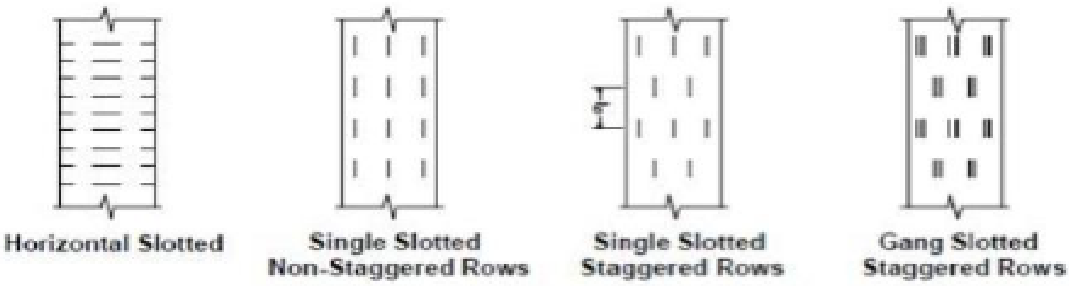

Fig. 3. *Various slot patterns.*

The slot width, or the screen gauge, is sometimes sized to be equal to the formation sand grain size at the 10-percentile point of the sieve analysis. The theory is that because the larger 10 % of the sand grains will be stopped by the openings of the screen, the larger sand will stop the remaining 90 % of the formation. The bridges formed will not be stable and may break down from time to time when the producing rate is changed or the well is shut in. Because the bridges can fail or break down, resorting of the formation sand can occur, which, over time, tends to result in plugging of the slotted liner or screen. This design fails for fine-grained sand formations because the slot width is smaller than those available for commercial slotted liners. Wire-wrapped screens can meet the design, but their width is so small that plugging and production reduction is virtually assured. When this technique is used to control formation sand, the slotted liner or screen diameter should be as large as possible to maximize inflow area and minimize the amount of resorting that can occur. Another potential disadvantage of both slotted liners and screens in high-rate wells is the possibility of erosional failure of the slotted liner or screen before a bridge can form.

Using a slotted liner or screen without gravel packing is generally not a good sand-control technique because, in most cases, the screen will eventually restrict well rates because of plugging. There are isolated situations where this use has been successful in openhole completions in high-permeability, well-sorted formations. Selected North Sea wells have performed well. Screens or slotted liners should be avoided in cased-hole completions as the sole sand-control technique because, when the annulus and perforations become filled with formation sand, production rates decrease drastically.

1.8 GRAVEL PACKING

Gravel pack is a common sand control technique used in many formations with unconsolidated or poorly consolidated sands. Sand production can often be readily achieved by proper sizing of the gravel with respect to formation sand size using well established rules. Sometimes, well consolidated formations can produce sand and hence gravel pack is employed in such formations for sand control.

There is a main factor which influences the production in gravel packed wells. It is flow restriction imposed by features of gravel pack. This factor affects the permeability and reduces it. So, gravel pack causes an excess skin which produces an extra pressure drop as a consequence of excess skin factor.

In fact, pressure drops because of the permeability changing from reservoir permeability to gravel permeability.

Gravel packing consists of placing a screen or slotted liner in a well opposite the completion interval and placing gravel concentrically around it. The gravel is actually large-grained sand that prevents sand production from the formation but allows fluids to flow into the well. The slotted liner or screen retains the gravel. The gravel is sized to be about 5 to 6 times larger than the median formation sand size. Gravel packing creates a permeable downhole filter that allows the production of the formation fluids but restricts the entry and production of formation sand. Schematics of an openhole and cased-hole gravel pack are shown in Fig. 1. If the gravel is tightly packed between the formation and the screen, the bridges formed are stable, which prevents shifting and resorting of the formation sand. If properly designed and executed, a gravel pack will maintain its permeability under a broad range of producing conditions.

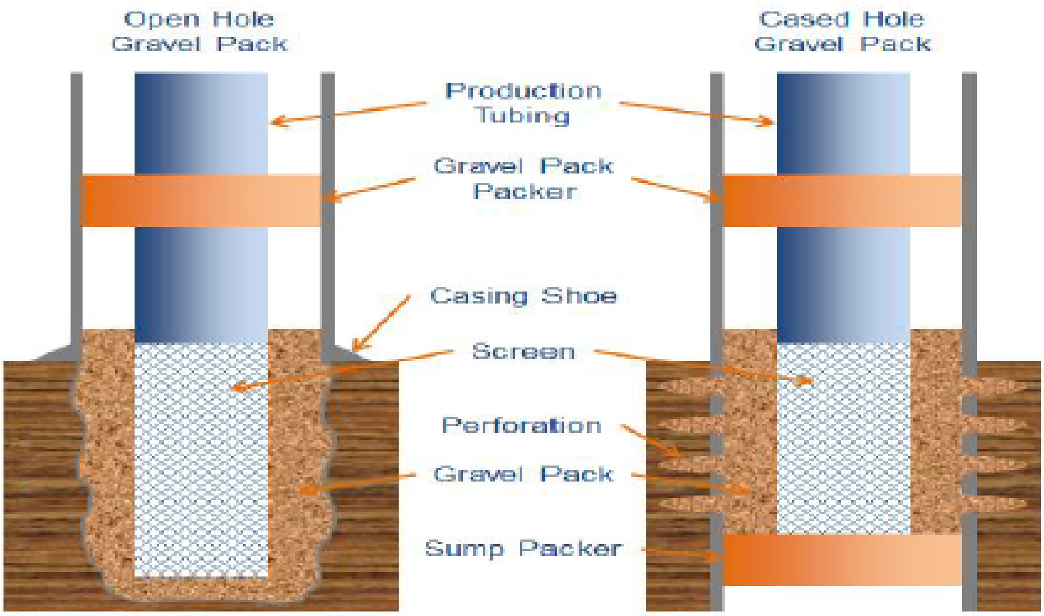

Fig. 4. *Openhole and cased-hole gravel packs.*

Gravel packing is currently the most widely used sand-control technique for completing wells. More than 90 % of all sand-control completions are gravel packs. Because of its flexibility, almost any well at any deviation can be gravel packed. The exception is tubingless completions where clearances do not permit the use of conventional tools. Some tubingless completion gravel packs have been performed, but their success was poor.

2. GUIDELINES FOR SELECTING SAND KONTROL

There are many alternatives for sand control. Each alternative has its advantages and disadvantages. Even techniques that are not widely used may have a potential application in which its use might be superior to others. Gravel packing is currently the most widely used technique. The cost to gravel pack is directly related to rig costs. Gravel-packed completions from floating drilling rigs may cost in excess of 2 million €. However, should remedial operations be required on a gravel pack, the screen and completion assembly must be removed from the well, which could involve a lengthy fishing job and related problems. Sand consolidation and resin-coated sand are attractive for tubingless completions because no mechanical equipment is left in the hole; however, the following conditions all present problems with the plastic systems:

- Low permeability
- Small-interval length
- High temperatures
- Completion longevity (wells sanded up or low productivity).

The right technique must be selected for the well completion at hand. As a first approach, assume that the well will be gravel packed. If it is not appropriate, for whatever reason, review other alternatives.

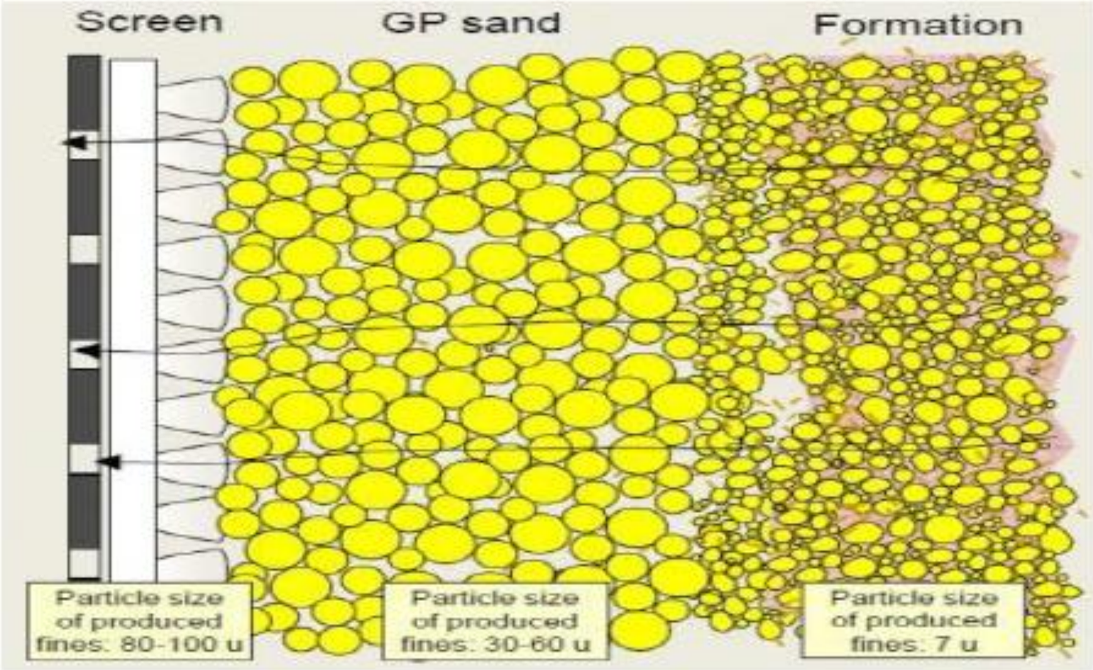

Fig. 5. *Sand control refers to managing/minimizing sand and fine production during petroleum production. An illustration of sand control by screen with gravel pack.*

3. COMPARISON OF TECHNOLOGIES

Maintenance and workover is a passive approach to sand control. This method basically involves tolerating the sand production and dealing with its effects as and when necessary. Such an approach requires bailing, washing, and cleaning of surface facilities on a routine basis to maintain well productivity. This approach can be successful in specific formation and operating environments. The maintenance and work over method is primarily used where sand production is limited, production rates are low, risk of performing some service is low and economically feasible, or in marginal wells where the expense of other sand control techniques cannot be justified. Of importance are the formation characteristics, which determine how much sand is produced and the effects on safety and productivity.

Gravel pack well productivity is sensitive to the permeability of the gravel pack sand. To ensure maximum well productivity only high quality gravel pack sand should be used. The API RP582 establishes rigid specifications for acceptable properties of sands used for gravel packing. These specifications focus on ensuring the maximum permeability and longevity of the sand under typical well production and treatment conditions.

Although naturally occurring quartz sand is the most common gravel pack material used, a number of alternative materials for gravel pack applications exist. These alternative materials include resin coated sand, garnet, glass beads, and aluminum oxides. Each of these materials offers specific properties that are beneficial for given applications and well conditions. The cost of the materials will range from 2 to 3 times the price of common quartz sand.

The specifications define minimum acceptable standards for the size and shape of the grains, the amount of fines and impurities, acid solubility, and crush resistance. Only a few naturally occurring sands are capable of meeting the API specifications without excessive processing. These sands are characterized by their high quartz content and consistency in grain size.

Tab. 1. *Comparison of technologies.*

Criteria	Gravel pack	Resin coated gravel without screens	Resin injection
Pressure	> 6,9 MPa	17,2 – 22,8 MPa	Up to 22,8 MPa
Temperature	> 65,56 °C	< 121,11 °C	< 121,11 °C
% of sand control	75%	5%	10%

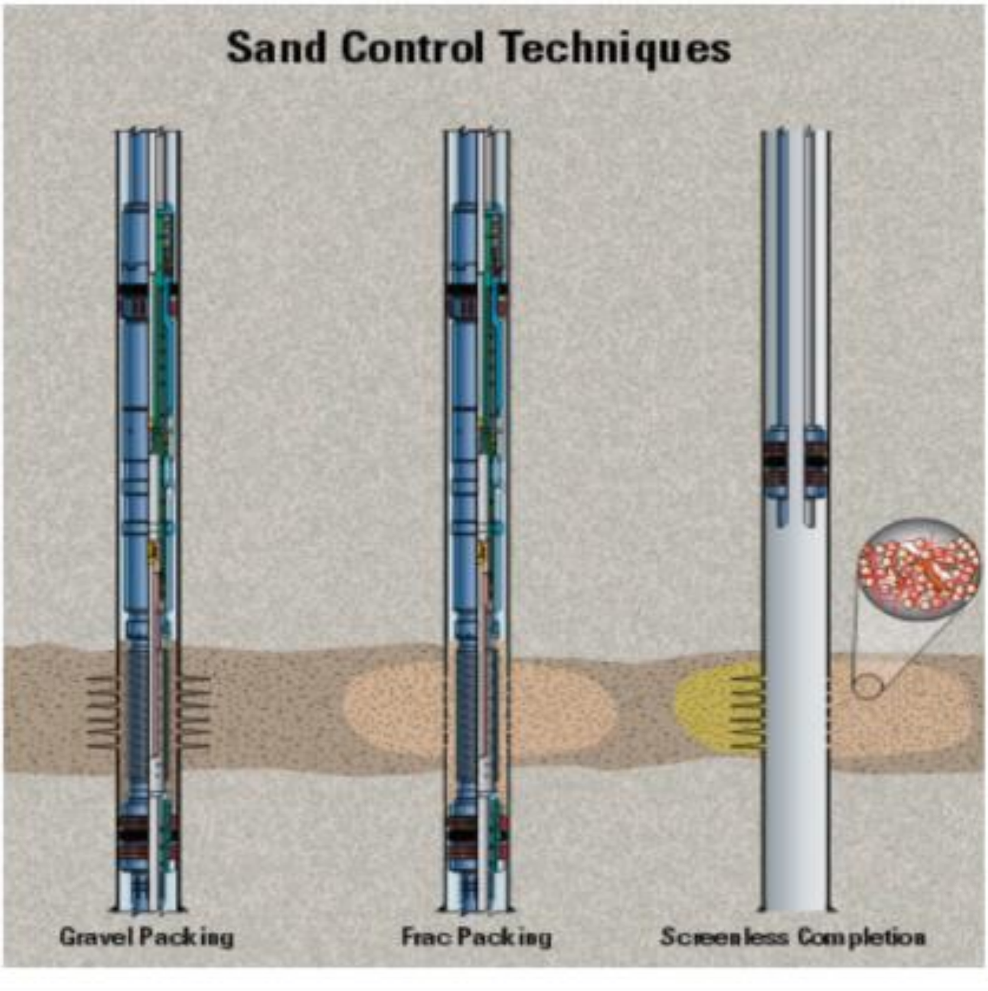

Fig. 6. *Some of Sand Control Techniques.*

4. LATEST MODERN TECHNOLOGIES FOR SAND CONTROL

In today's competitive marketplace, oil and gas industry operators are continually searching to find new and improved means of working in a smarter manner and reducing costs. Such a commitment creates challenges and a requirement to rethink best practices at almost every stage of the process, especially as the industry seeks to exploit ever more difficult reserves. A key question in the drive for enhanced production is how best to control and manage sand, and the recent introduction of a number of new technologies in this field have significantly improved performance with associated cost savings. Below the text are listed some of the latest modern technologies for sand control:

Shape memory polymers (SMP): SMP is manufactured to a desired shape and size, placed on the outside of base pipe. When exposed to bottom hole temperatures and a catalyst, it expands to its original shape to fully contact the borehole wall (Fig. 7). It provides a positive stress on the formation to stabilize the near wellbore region and control sand migration.

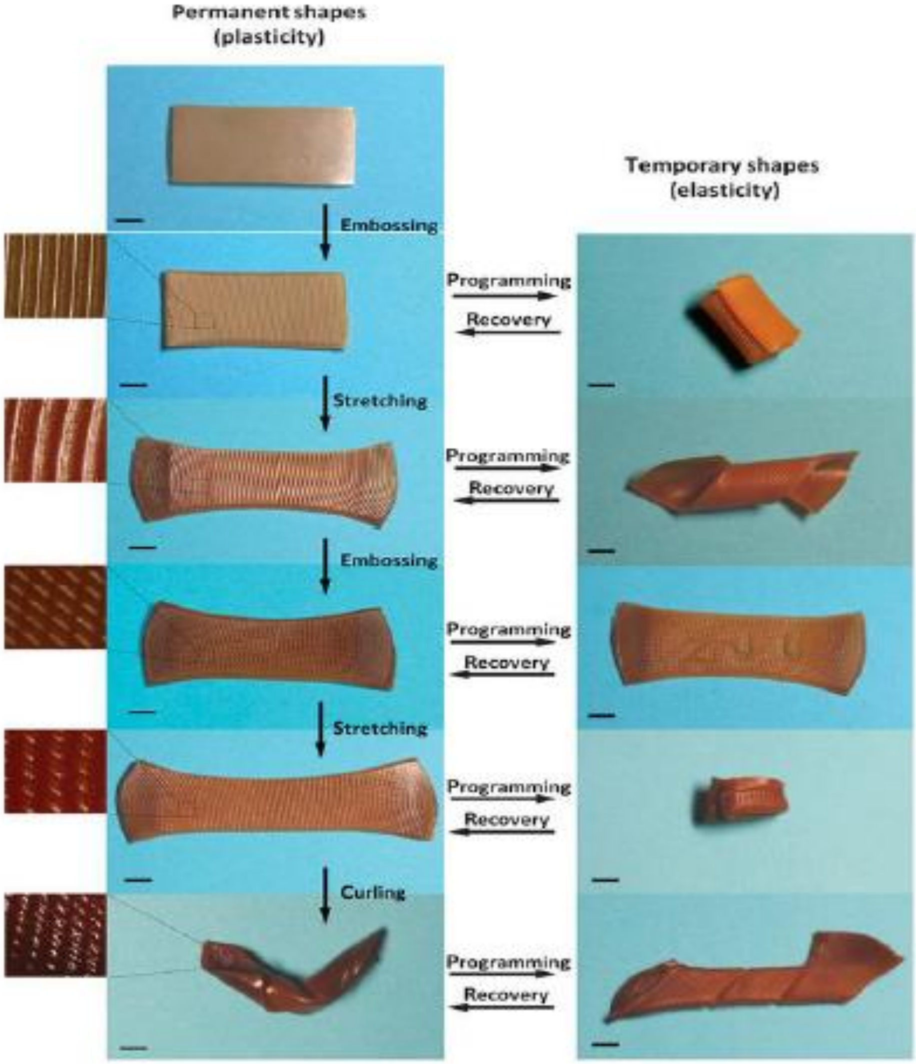

Fig. 7. *Demonstration of complex shape manipulation via cumulative plasticity effect and shape memory effect.*

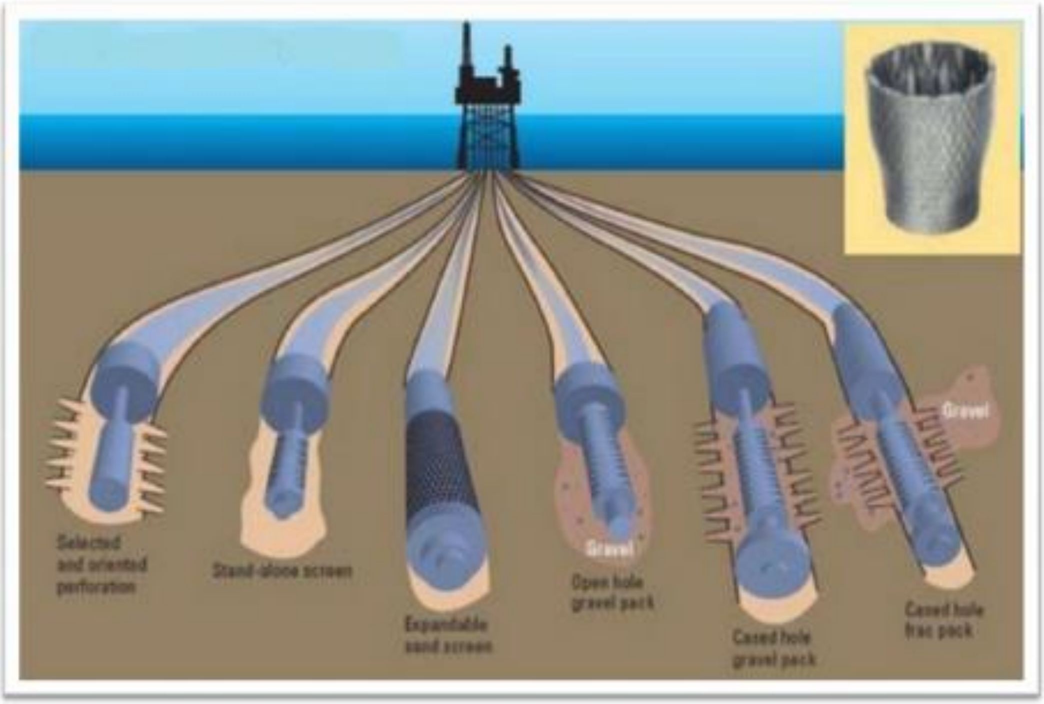

Fig. 8. *Sand Control Completion.*

Expandable sand-screen systems (ESS): ESS is contacting the formation directly, preventing sand movement and reducing skin development (Fig.8 and Fig. 9).

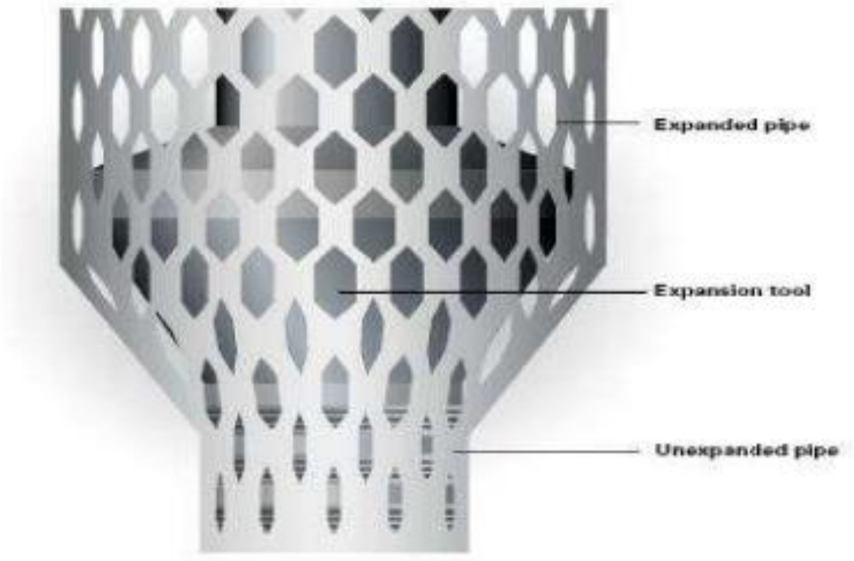

Fig. 9. *Expandable sand green.*

Nanoparticle Technology: Nanoparticle fines migration control additive. The in organic nano crystals are capable of fixating formation fines, such as colloidal silica, charged and non-charged particles and expandable and non-expandable clays on to propant particles (Fig. 10 and Fig. 11).

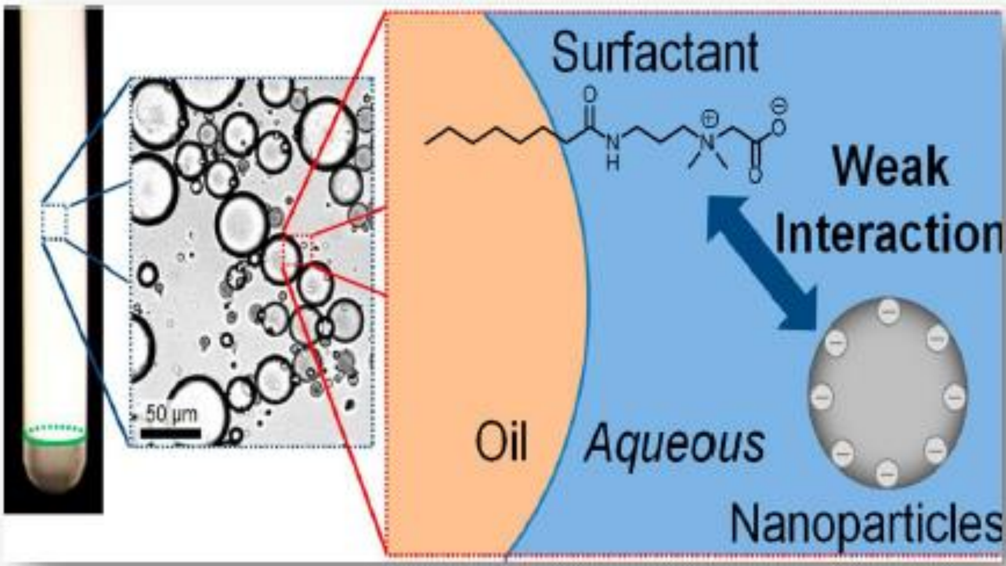

Fig. 10. *Nanoparticle Technology in the sand kontrol.*

Note to Figure 10. An oil-in-seawater emulsion stabilized with surfactant molecules and nanoparticles acting in synergy, depicted at three scales: a macro-scale view of an emulsion-filled test-tube (left), a microscope image of small spherical oil droplets (center), and a graphic of the nano-scale oil droplet configuration with a surfactant molecule and approaching nanoparticle (right). The surfactant molecules allow formation of smaller oil droplets, and the nanoparticles help stabilize the droplets. When surfactant molecules weakly interact with the nanoparticles, their synergy is strongest.

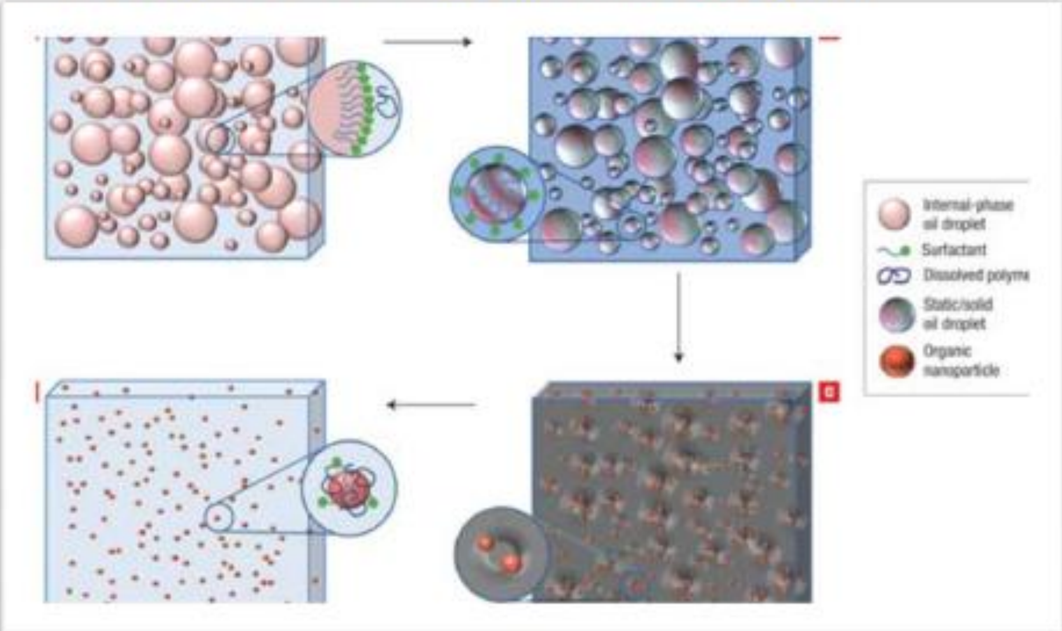

Fig. 11. *Nanoparticle Technology uses in the sand control.*

Note to Figure 11 a, Oil-in-water emulsion; organic compound dissolved in internal-phase oil droplets. Enlarged area: homogeneous, surfactant-stabilized oil droplet and dissolved polymer. b, Frozen oil-in-water emulsion; static/solid oil droplets within a solidified continuous phase. Enlarged area: organic compound inhomogeneously distributed within the frozen oil droplet and associated surfactant. c, Emulsion-templated porous solid after freeze-drying. Enlarged area: organic *nanoparticles within open pores. d, Organic nanodispersion after addition of water. Enlarged area: surfactant- and polymer-stabilized organic nanoparticle.*

CONCLUSION

Sand control screens are sophisticated screened pipe joints positioned in the wellbore directly opposite formation perforations serve to block out sand while allowing the flow through of oil or water. Halliburton screen technology offers operators every conceivable advantage: precise particle size control, high strength and durability, excellent corrosion resistance, high pressure tolerance, increased containment capacity, superior erosion resistance and excellent backwash efficiency. All this, along with the advantages of automatic verification and real-time manipulation of screen gauge.

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