SPE 107690

A Comparison of Methodologies for Handling Produced Sand and Solids to Achieve Sustainable Hydrocarbon Production

C.H. Rawlins, SPE, University of Missouri-Rolla, and T.J. Hewett, SPE, Krebs Engineers

This paper was prepared for presentation at the European Formation Damage Conference held in Scheveningen, The Netherlands, 30 May–1 June 2007.

Abstract

All oil and gas wells produce sand or solids in varying types and amounts. The size and concentration of natural solids (i.e., formation sand) and artificial solids (i.e., workover debris) determine their net effect on production equipment and the resulting management of hydrocarbon production. Conventional exclusion methodology prevents solids from entering the wellbore but may adversely affect inflow production due to skin buildup. Inclusion methodology allows the solids to be produced with well fluids for surface separation and handling. A comparison of the performance, operability, cost impact, and effect of solids on the production rate is made for both methods through application examples. The goal is to show that the increased production resulting from allowing solids to be produced in some high sand rate wells allows more sustainable hydrocarbon production with a cost benefit compared with downhole exclusion for certain producing regions.

Introduction

All oil and gas wells produce some amount of solids along with hydrocarbon fluids. However, these solids may be present in insufficient quantities, concentrations, or sizes to significantly impact production. When the amount of solids or the size of the particles leads to lost production due to equipment downtime or reduced inflow, a control method is required to restore production to an economically sustainable level.

Traditionally solids (sand) control equipment is used to prevent sand from entering the wellbore and it can be termed *exclusionary*. Exclusion methods include mechanical retention (screen or slotted liner), gravel packs, chemical consolidation, or a combination of these techniques.[1] The selection of the best method depends on the well and reservoir conditions, intervention costs, production life, and the treatment that will provide the maximum sustained productivity. A significant number of technical resources are available for the optimal selection of subsurface exclusion equipment.[1]

An alternative to keeping solids in the formation is to produce solids with the well fluids and then separate them at the surface facility. This technique is termed *inclusionary* because the solids freely flow with the reservoir fluids to the surface. Principally this method allows produced solids to enter the wellbore and travel up the wellstring for removal pre or post choke, or at the production facilities. A multiphase desander separates the solids from the well fluids at the choke (pre or post) or prior to the separator vessels.

Most E&P companies have started to embrace a wider view of solids control by including surface sand handling as part of their portfolio. BP recently put in place a program called "Beyond Sand Control (BSC)," which looks at where and how to best manage sand from the reservoir face to ultimate disposal of sand at the surface.[2] Shell has adopted an integrated system team made of completion and facilities engineers to determine the optimum location for controlling sand production, subsurface or surface, considering CAPEX, OPEX, risk, and HSE.[3]

The overarching principal drive for using an exclusion or inclusion method for sand control is sustained production. Downhole sand exclusion protects production tubulars, wellhead chokes, flow lines, and facilities equipment. However, the buildup of solids near the wellbore increases skin damage, which reduces inflow. Allowing the sand to flow freely with the well fluids reduces skin damage thus sustaining (or increasing) inflow. Flowing solids may lead to erosion of tubulars, chokes, and flow lines, and will eventually fill up production separators, all which lead to production downtime. A comparison of exclusion and inclusion methodologies is the focus of this paper.

Source of Produced Solids

In comparing downhole exclusion versus topsides separation methodologies for produced solids, it is necessary to clarify the exact nature of the solids being treated. For the purposes of the present article, produced solids are defined as inorganic, insoluble particulate materials accompanying hydrocarbon fluids production. These solids can be produced from oil, natural gas, water, or multiphase wells.

Hydrocarbon fluids may also produce organic semi-soluble deformable particulates (typically as colloids or gels), such as asphaltenes, paraffin waxes, and resins.[4] These materials have a specific gravity near that of the hydrocarbon fluid and an agglomeration tendency that precludes effective treatment by screening or separation. A solvent-based remedy is required to restore inflow production.

Inorganic materials may precipitate due to temperature/pressure changes in the wellbore or mixing of injected fluids with reservoir fluid.[4] Examples of such precipitates are carbonates ($CaCO_3$) and sulfates ($BaSO_4$). The precipitates generally form a continuous scale in reservoir rock pore structure or wellbore equipment, and thus discrete particles are only present in very dilute quantities when flow shear or mechanical abrasion removes them from the surface on which they form. Homogeneously formed free-floating scale particulates are thermodynamically unstable and thus they are also present in very dilute quantities. While precipitated crystalline scale can severely reduce inflow, the treatment mechanism is generally chemical (acid or chelating agent), thus downhole exclusion or topsides separation is not a feasible methodology.

Inorganic particulates that are produced with sufficient sizes and concentrations to require exclusion or separation treatment are generally termed *produced solids*. This type of solid material can be broadly classified into two categories: indigenous (natural) and foreign material (artificial).

Natural.

Natural solids arise from the indigenous reservoir material. Broadly these are sands, which are detrital grains of mineral oxides (i.e., SiO_2), and clays, which are hydrous aluminum silicates that may be detrital or authigenic.[4] Sand particles are the load-bearing solids of the formation, while fines (clay) are not part of the mechanical structure.[2] Of key interest are their particular physical properties that can be exploited for exclusion or separation. These properties include size (distribution), shape, density, and concentration. Table 1 lists the properties for some natural solids.

Table 1 – Physical Properties of Natural Solids

Property	Sand	Clay
Specific Gravity	2.5-2.9	2.6-2.8
Shape Factor	0.2-0.5	0.1-0.3
Size Range (µm)	50-1000	5-30
Conc. (ppmv)	5-100	<1

The majority of sand produced is silica-based, which has a specific gravity averaging 2.65. These particles have high angularity leading to poor shape factors (approach to roundness).[5] The angularity helps in grain-to-grain locking necessary for good gravel pack filtering. However, the high surface area due to angularity has been shown to detrimentally stabilize oil emulsion, making oil-water separation more difficult. In addition, an increase in particle sharpness increases the erosion potential.[6] The average size varies from well to well, even within the same formation, but typically sand particles are 50-100 µm. Solids concentration will vary day to day within the same well, but under good controlled conditions a sand prone well may produce 5 ppmv sand. Even at this concentration, a 10,000 BPD (1590 m^3/d) well will produce 5 BPD (0.8m^3/d) sand, which is more than 2,100 kg! Clay material has a similar specific gravity but a smaller particle size and lower concentration. The plate-like structure of clay along with its very fine particle size makes it difficult to separate particles <10µm with gravity-based techniques. Therefore, the very fine particles will flow through the production system with the oil phase.

Figure 1 shows an optical micrograph of sand separated by a multiphase desander at the surface facility of a producing well in Austria. This application is detailed in the Application Examples section. The sand has a specific gravity of 2.65 as measured by pycnometry and an average particle size of 67 µm. The sand is nearly pure silica as indicated by the white/clear coloration, and it has high angularity with a shape factor near 0.3.

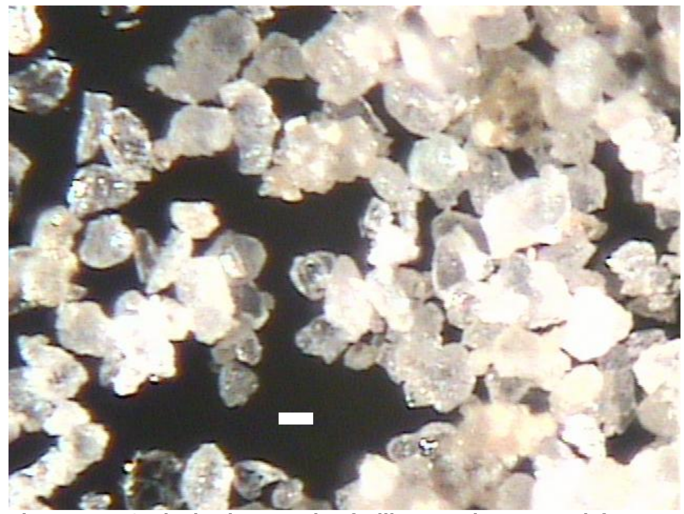

Figure 1 – Optical micrograph of silica sand separated from an Austria oil well. The white bar is 50µm.

Sand and clay from the reservoir can be generated from workover operations, degradation of the formation rock, or transportation by fluid flow from deeper in the reservoir. Production and workover operations lead to residual drilling debris and breakdown of the formation rock near the wellbore by hydraulic fracturing or acid stimulation. Natural solids generated by workover methods may have a very high initial concentration (up to 1 vol.%) after production is resumed, but the rapidly taper off within a few days to a background level <1 ppmv. Therefore, the effects of this type of natural solids are temporary.

Solids produced by fluid shear degradation of the formation face or from transport deeper in the reservoir have a much longer impact on production. High fluid velocities through the formation pores shear sand and clay particles from the formation matrix and transport these particles to the wellbore. The amount of sand transported reaches a steady state resulting in constant production of sand at generally 5-10 ppmv. Sand production spikes are associated with multiphase flow where transient pressure events impart high instantaneous forces on the formation matrix, or when the fluid front switches from oil to water (i.e., water breakthrough). These events can push the sand concentration to 100 ppmv for short periods.

Predicting the rate of natural solids production is difficult due to the challenge of obtaining robust data from the formation face and surrounding volume. A number of models are available to predict the onset of sanding, but the actual rate has a high amount of uncertainty. Sand monitoring and measurement devices are available to detect catastrophic sanding events or provide on-line measurement of sand concentration. These instruments are necessary in the case of gravel pack failure or to predict the onset of critical sand rates with drawdown. Failure of a gravel pack or screen will result in the production of a large amount of reservoir material built up in the well skin outside the pack plus the associated gravel pack sand. This type of event can be catastrophic to production leading to rapid erosion, well shut-in, lost production, and costly workover.

Artificial.

Artificial solids are foreign material introduced by external (human) intervention. This is a broad category that can include fracture sand, drill mud, cement fines, corrosion products, gravel pack material, and injection fines. Sand from hydraulic fracturing and mud particles from overbalanced drilling have a very high concentration (1-3 vol.%) immediately after workover. This drops to near zero ppmv once the reservoir fluids have flushed the well skin. Gravel pack solids are produced only upon catastrophic failure. A gravel pack does allow small particles of formation material to pass.

Corrosion products have a low concentration level. As the total surface area of metal in the wellbore is very large, they may be produced for months or years. Insufficient filtering of injection water generates injection fines. These fines can migrate through the formation to report into the production well fluids. The amount produced is proportional to the amount injected plus the amount picked up by the fluid as it travels through the reservoir. Physical properties of some of these solids are listed in Table 2.

Table 2 – Physical Properties of Artificial Solids

Property	Frac Sand	Corrosion Products	Gravel Pack
Specific Gravity	2.6-3.6	5.5-6.0	2.6-3.0
Shape Factor	0.5-0.9	0.1-0.5	0.5-0.9
Size Range (µm)	150-2000	10-10000	250-3500
Conc. (ppmv)	0-10000	<2	0 (unless failure)

Artificial solids have a higher specific gravity compared with natural solids due to their engineered properties of high strength and hardness. Frac sand and gravel pack sand also have a high shape factor for flowability and controllable packing. The particle sizes are also much larger, again due to their design purpose. The concentration of artificial solids is very transient. Frac sand is normally only present for a few days after workover. Gravel pack sand is not normally present except for the case of gravel pack failure when it can spike to a very high concentration for a short period of time.

Generally treatment of artificial solids can be handled as a planned event, especially in the case of hydraulic fracturing or overbalanced drilling. Gravel pack failure is not generally predicted, but the fraction of gravel pack sand reporting to the wellbore is only a small percentage compared with the formation sand.

Methodologies for Controlling Produced Solids

A wide variety of tools is available to the production engineer for controlling produced solids. These include production limits to maintain sand inflow at a level below a damaging threshold, placement of downhole equipment to prevent sand ingress from the reservoir face, conventional facilities for removing sand that reports to the surface, and separation focused unit process equipment at the surface facilities to improve the robustness of topsides operation.

Production Limits.

The simplest method of solids management is to adopt a conservative approach of "Zero Sand Production."[7-10] This approach attempts to establish a maximum sand-free production rate based on drawdown criteria. Using well tests, a map of reservoir pressure versus bottomhole pressure determines the regions of sand free production. While the approach requires minimal CAPEX, it has the drawback of reducing inflow, hence directly reducing revenue. In addition, the sand production map is a moving target, and any change in the well production profile requires re-determining the map boundaries. Sand monitoring and measurement instruments can detect changes in sand production or actual quantities of sand produced. These instruments can be used as a go/no-go gauge for optimizing drawdown while minimizing sand production.[11-14] Another approach is dilution of the produced sand. If a single or small group of wells in a large field are the only sand producers, then they can be co-mingled with low sanding wells to dilute the overall sand effect.

Downhole Equipment.

In order to maximize hydrocarbon production, the most common method of sand control is installation of equipment to exclude sand from entering the wellbore. Mechanical retention in the form of screens or slotted liners restrains sand from entering with well fluids. Spherical particles will not flow continuously through rectangular slots twice as wide as the diameter of the particle, as long as they flow in sufficient concentration and bridge across the opening due to grain-to-grain contact.[1] A screen or slotted-liner is seldom used without gravel packing. Placing clean, accurately sized gravel around the periphery of the screen allows for a larger screening area, and the gravel is more robust to erosion than the screen/slotted-liner material. Due to their popularity and frequent installation, gravel pack equipment and techniques have been exhaustively studied and are the primary choice for sand control.[15-17]

Chemical sand control techniques are available to cement the formation sand grains together for a radius several feet from the wellbore. Plastic consolidation using epoxies, furans, or phenolic resins form a bond between the existing formation particles creating a filter barrier to sand inflow.[1] This method requires multiple steps to install, such as acid clean, pre-flush, and injection of the resin and catalyst.

Many combinations or offshoots of the above techniques can be used for effective sand control. Expandable and multi-path screens offer greater flexibility and throughput compared with conventional screen liners.[17-18] Pre-coated gravel can be injected to confirm good placement of the consolidating resin. Frac pack incorporates the benefits of hydraulic fracture stimulation with gravel packing. All of these techniques are exclusion methods because they seek to restrain the reservoir material from entering the wellbore.

Surface Facilities: Conventional.

Conventional surface facility design incorporates equipment to handle normal sand production adequately. This equipment includes erosion resistant choke design and materials, impact tees in flow lines, profile instrumentation in separators, and sand jet or suction devices for free water knockout (FWKO), 2-phase, 3-phase, and heater-treater separators. All of these techniques, while growing in robustness with proper material selection and improved fluid flow design, still require manual intervention for maintenance. While sand is produced at a steady-state low concentration (<5 ppmv), conventional facilities design will operate satisfactorily between maintenance intervals. However, in the case of transient solid production (i.e., frac flow-back, gravel pack failure, reservoir subsidence leading to formation sand spikes, etc. where solids concentration may jump to 1000 ppmv), these techniques require immediate personnel intervention to prevent shutdown.

Chokes and flowlines must be protected from erosive conditions that lead to catastrophic failure. The relatively simplistic API RP 14E guideline sets limits of flow production velocity, in which an increase in solids concentration leads to a decrease in flow velocity. To allow for conservative operation in the case of solids concentration spikes and to prevent erosive failure, production must be reduced.

Solids cause multiple problems in production separators. As large solids (>50 µm) settle in separating vessels, the residence time for oil-water separation is decreased resulting in a decrease of throughput. Periodic shutdown requiring manual removal of solids may be required to restore the production rate. In addition, settled solids form a layer in which sulfate-reducing bacteria grow resulting in accelerated corrosion. Small solids (10-30 µm) also report to the oil-water interface where they stabilize emulsions, further reducing separator efficiency.[6] Large solids that travel through the separator (due to short-circuiting or reduced residence time) report to the water treating circuit, where they fill up flotation cells and erode deoiling hydrocyclones. Finally, these solids will report to the disposal well leading to increased injection backpressure.

Surface Facilities: Separation Focused.

In 1995, the first wellhead desanding hydrocyclone was tested at the BP Wytch Farm production facility.[19-20] This test culminated the work of a joint industry project to develop a multiphase version of a desanding hydrocyclone for continuous removal of solids prior to the production wellhead. The first few commercial units were used for well cleanup applications such as coiled tubing wash and frac flowback capture.[19,21] Operating prior to the choke, these units were built to 10,000 psi (68,950 kPa) rating and handled up to 15,000 BPD (700 m³/d) condensate and 3 MM m³/d gas (105 MMSCFD). Handling up to 1 lb/bbl (2.85 kg/m³) of solids, the units separated 95-98% of the solids down to 10µm. Multiphase desanders have now been installed in more than 50 surface facilities, both onshore and offshore, with design ratings from 150 lb. ANSI to 12,000 psi API. Installations have been made both upstream and downstream of the wellhead choke, in heavy oil, HPHT, gas-condensate, and gas-only applications.

The driving factor for development of the multiphase desander was to extend the operability of hydrocyclonic technology upstream of the production separator. Since the 1960s, desanding hydrocyclones have been used to remove sand from produced water prior to injection. Multiphase desanders operate based on a combination of hydraulic and pneumatic cyclonic principles.[22] As with all cyclonic devices, pressure energy is converted to radial and tangential acceleration to impart centrifugal forces on the contained fluids. The increased forces accelerate the separation of phases with different densities. In the case of a multiphase desander, solids are separated from the gas-liquid mixture. The forces imparted are 400-1000 times greater than gravity, leading to rapid separation of solids from fluids and also rendering the cyclone unaffected by external motion or orientation. Cyclonic technology has the highest throughput-to-size ratio of any type of static separation equipment resulting in a small installed size and weight.[27]

Surface multiphase desanding has found use as a well service tool or as a part of the facilities processing equipment. As a service tool, it is installed upstream of the choke for the removal of solids from workover operations. Applications include frac flowback, coiled tubing washout, under-balanced drilling, or acid washing. In serving as part of the facilities, the multiphase desander is installed just after the choke. The only difference in design (pre or post choke) is the pressure rating of the vessels. Operability of the multiphase desander is the same regardless of the pressure rating. Removal of solids prior to the wellhead protects the choke, flowline, and all facility separation equipment. Removal of solids after the choke allows for a lower pressure rating design while protecting facility separation equipment.

The initial few dozen installations of multiphase desanders occurred in critical applications where downhole equipment provided insufficient protection to topsides equipment. With increased use and improved prediction models, the multiphase desander has become a valuable tool in overall sand management.

Comparison of Subsurface and Surface Methods

Guidelines for the selection of the proper subsurface sand control methods is the subject of several books and papers.[1,15,24-26] A comparison of subsurface exclusion technologies with inclusive surface separation is needed as an aid to the design of a whole well sand control approach. As gravel packing is the most widely used subsurface sand control method, it will be compared with surface multiphase desanding. The primary areas of comparison are performance, installation, and cost with the goal of producing a selection map delineating the optimized region for each well type.

Equipment performance includes separation efficiency, lifetime, and failure mode. A gravel pack is designed to form a barrier on which the formation sand particles will bridge across, thus preventing further sand ingress to the screen and into the wellbore. The gravel pack should allow the production of fine particles, which if built up at the interface will lower productivity. Separation efficiency is determined from the "cut size." Above this size the particles will be retained by the gravel pack, while below this size the particles will flow through with the well fluids. Spherical particles will not flow continuously through rectangular slots (i.e., screens) twice as wide as the diameter of the particle or through circular holes three times their size.[1] Using this criteria as the upper limit of particle size reporting with the well fluid, the cut size will be one-half the width of the screen or slotted liner aperture. Slotted liners are typically manufactured with a 0.25 mm and larger aperture, while V-wire wrapped screens vary upward from 0.1mm.[27] Therefore, it is reasonable to expect that particles up to 50-125µm can report through a gravel pack installation under normal conditions. The settling velocity of this particle size range (based on silica sand in 45 API oil) is less than 1.6 m/s. Hence, under normal production conditions, all solids reporting to the wellbore will be carried to the surface. The amount of sand produced will vary with the particle size distribution of the formation. A reasonable level of steady-state sand production is <1 ppmv.[10] A failure in the gravel pack will lead to a significant spike in sand concentration and size.

Gravel pack failures occur due to screen erosion, plugging and screen collapse, high drawdown leading to screen collapse, or incorrect placement, with screen erosion listed as the dominant failure mode.[9,15,25] Screen erosion is generally not an immediate failure and is evident as a gradual increase in sand concentration and size until the amount becomes detrimental to production. Based on a multi-thousand well database, screen-only completions have a failure rate of 0.056 failures/well/year compared with open-hole gravel packs at 0.02 failures/well/year and cased-hole gravel packs at 0.011 failures/well/year.[15]

Gravel pack cost includes initial installation, workover cost and downtime when failure occurs, and inflow reduction due to skin formation. Installation and workover costs vary by region, well location (onshore/offshore), well depth, and reservoir conditions. No public database exists to compare these direct CAPEX costs. Inflow reduction due to skin formation can be estimated by a change in well productivity.[27] A newly installed gravel pack will, by design, reduce productivity as the process of screening sand particles also reduces the overall flow area through which well fluids report. As formation fines build up on the gravel pack or screen face, productivity is further reduced. To reestablish the PI, drawdown must be increased. However, too high a drawdown will collapse the screen. At a constant drawdown the inflow may be reduced by at least 25% for a new installation. Without a change in drawdown pressure, the inflow may completely shut off as the fines coat the gravel pack face.

The performance of a multiphase desander is based on its ability to convert pressure energy to fluid velocity needed for separation. While a desander is a static device, it requires pressure drop (energy) to operate. The minimum pressure drop is typically 5 psi (35 kPa). The pressure drop upper limit is not limited by performance but by erosive wear of the desander internals. A pressure drop of 725 psi (5000 kPa) has been used for short-term applications,[21] but generally the pressure is kept near 50 psi (345 kPa) to allow for long life while providing turndown capability.

A key factor to desander operability is resilience to changes in the solids concentration, solids top size, and fluid flow rate. A 75 mm (3") multiphase desander can separate solids down to 10 µm diameter up to a concentration range of 1 vol.% (10,000 ppmv) and a solids top size of 10 mm. A 500 mm (20") multiphase desander has a separation size of 35 µm up to a concentration range of 3 vol.% solids (30,000 ppmv) and a solids top size of 25 mm. A multiphase desander separating 5 ppmv sand at 50 µm from continuous operation can experience an instantaneous surge of 1000 ppmv of solids to 1000 µm due to a gravel pack failure without a change of separation efficiency. Automation of the associated collection system would ensure continuous handling of the separated solids. Desander throughput is proportional to the diameter, with a 75 mm (3") unit handling 5000 BLPD (795 m^3/d) and a 500 mm (20") unit handling 50000 BLPD (7950 m^3/d), each with a 50% gas void fraction. These values represent the upper boundary of operation, while a turndown of 5:1 is reasonable for continued performance.

Based on the properties listed previously for natural and artificial solids, a multiphase desander can effectively separate all solids >10 µm regardless of type. This estimation is based on a solid density of 2.65 g/cm^3, liquid density of 0.9 g/cm^3, pressure drop of 50 psi (345 kPa), and fluid viscosity of 1.0 cP. Solid and liquid densities do not vary greatly from the values stated. However, fluid viscosity can vary from 0.5-10000 cP depending upon the water cut, temperature, % dissolved gas, and oil viscosity. The advantage of placing a desander in multiphase flow is that the % dissolved gas, water cut, and temperature are conducive to lowering the fluid viscosity. Efficient separation of solids in a multiphase mixture with <10 cP viscosity can be done effectively. Separation of fine solids from cold, dead, heavy oil cannot be done effectively with a desander.

Desander installation and operating costs include material, piping, assembly, monitoring instrumentation, consumable liner, and pressure drop. Raw material costs for a desander (i.e. vessels, piping, valves, instruments, etc.) will be more than a gravel pack. However, the cost of installing the equipment is much less, pending well depth and location. The only desander consumable is the cyclone wear liners or inserts. Under most operating conditions (i.e., average pressure drop), the desander liners require change-out every three to five years. The pressure drop consumed by a desander for operation can be considered a cost if the well fluids require artificial lift. While desanders impart no restriction on the flow of fluids into the wellbore, the backpressure added to the lift mechanism consumes energy. In free-flowing wells, the desander takes part of the pressure drop normally lost across the choke, and therefore no external energy is consumed.

A significant number of factors must be considered in defining the optimum producing region for subsurface versus surface sand handling. Well factors include depth, location, and number on the manifold. Producing factors include gas and liquid flow rate, available pressure, produced sand concentration, and particle size. The source of solids can be used to make the first delineation. Artificial solids produced through workover operations <u>cannot</u> be treated through downhole exclusion. Frac sand, drill mud, and corrosion products must be removed from the wellbore, and therefore must be separated at the surface. This can be done with a multiphase desander or capture vessel. The selection map shown in Figure 2 is only valid for comparing techniques to treat natural produced solids.

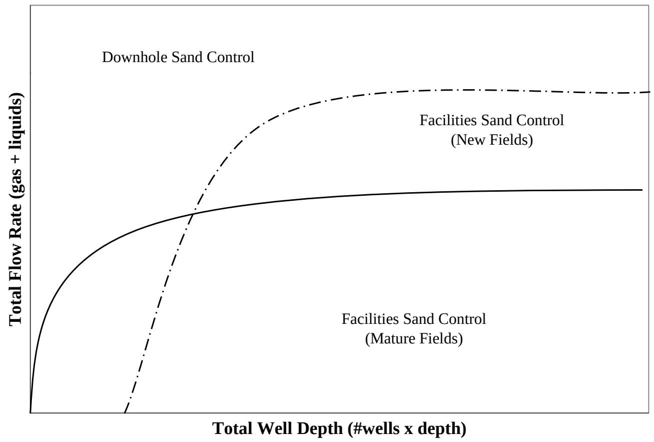

Figure 2 – Selection map for comparing subsurface versus surface sand handling of natural produced solids (sand).

The key factors for comparison are the total well depth and total flow rate. The total well depth is the number of wells multiplied by their individual depth. A high total well depth can result from many shallow wells or a few deep wells. Both situations have high costs associated with downhole sand control (i.e., gravel pack). For mature fields, which have a high water cut and high solids production leading to lower profitability, a central multiphase desander treating many wells is more economical compared with installation of multiple gravel packs. For new installations with a high total well depth, the range of effective treatment with multiphase desanders extends to a higher total flow rate. This is because gravel pack failures follow the traditional bathtub curve model, and in a new installation with many individual wells, the chance that one or more wells will experience gravel pack failure early in production is high (increases with flow rate). Therefore, to prevent the cost of a re-work of one or more gravel packs, a central multiphase desander is recommended. For low total well depth and high production volume, installation of a few gravel packs is deemed more cost effective. At very high producing volumes, even with multiple wells, downhole sand control is more cost effective because the size of the facilities desander may lead to a cost prohibitive design. This map is provided as a guideline for discussion because the boundary points require quantification for effective use. Each E&P company knows its associated costs with the installation of downhole equipment and facility equipment, therefore should be able to quantify each map region accurately.

Application Examples

Two applications previously detailed show a comprehensive surface facilities approach taken for handling produced sand in place of downhole intervention.

The South Pass 78 platform in the Gulf of Mexico handles fluids from 41 wells routed from three production platforms.[28] As the wells increased in watercut, the amount of solids also increased leading to interference with the water treating equipment (flotation cell and CPI), oil-water separation (by stabilizing emulsion pads in the oil treater), and erosion of the LACT meter. These problems led to monthly facilities shutdown for maintenance. The primary LP separator has a cone bottom design and does not experience a reduction in residence time. Instead of installing gravel packs on 41 high watercut wells, a central facilities approach was chosen as the most economical and flexible alternative. A multi-liner desander separating system was installed after the LP separator on the 20,000 BPD (3179 m³/d) water stream and the 15,000 BPD (2385 m³/d) oil stream, with each system operating at 35-40 psi (241-276 kPa) pressure drop. The water desanders are designed to remove 500 ppmv sand with a mean diameter of 50 µm and density of 2.51 g/cm³. At operating conditions, the separation size is 9 µm, leading to a solids recovery >99%. The oil desanders are designed to remove 100 ppmv sand with a mean diameter of 10 µm and density of 2.29 g/cm³. At operating conditions (oil viscosity is 2.0 cP), the separation size is 16 µm resulting in 65% total solids recovery. Performance of each desander was confirmed upon commissioning. The actual concentration of the solids in the water phase was much higher than the design criteria (~1000 ppmv), as was the top particle size. A few percent of the feed solids were up to 12.5 mm (0.5 inch) diameter, which led to occasional plugging of the desander liners. Figure 3 shows a photograph of the water stream desander installed in-line between the LP separator and the water treating equipment.

Figure 3 – A 20,000 BPD desander for removing solids >10 µm from the water stream after a production separator.

The separated solids are collected into an integral accumulating chamber on each respective desander. The slurry from each accumulator is dumped (based on level measurement) to a common dewatering bin where the sand is collected and the fluids return to the LP separator. The dewatered sand has <1 wt.% oil on dry sand and <10 vol.% water. The dewatering bin is portable and serves as a device to transport the sand to shore and ultimately a landfill (U.S. Dept. of Transportation-approved design). The dewatering/transport bin has an internal volume of 2.5 m³ (88 ft³), which stores ~3000 kg (6600 lbs) of sand, equivalent to five days of production.

Another example is the RAG GA-field in eastern Austria, which is a mature oilfield experiencing a decline in oil and gas production accompanied with an increase in water and solids production.[29] The wells in this field produce 28-30 API oil with sucker rod pumps. The conventional method used to enhance production was to workover the gravel pack, or to allow each well to produce until it was no longer viable.

As an alternative to its traditional approach, in 2005 RAG installed a multiphase desander system at the outlet of a sucker rod pump on a well producing ~50 ppmv solids. The ability of the desander to handle all the produced solids allowed for removal of the well gravel pack, resulting in increased oil production. An unexpected increase in oil-water separation performance was experienced in the downstream separator due to oil droplet coalescence experienced within the hydrocyclone.

Due to the marginal producing nature of the field, the desanding system requirements were compact size (lower transport and installation cost), low CAPEX, and high turndown capability. For cold weather protection, the desanding system was placed in a purpose built enclosure. The well on which the desander was installed had a liquid flow rate of 30-300 m^3/d (189-1887 BPD) with 80-99% watercut, and a normal gas rate of 100-1,000 m^3/d (3531-35315 ft^3/d). The operating pressure was 4-7 bar (400-700 kPa) with a temperature of 30 °C (86 °F).

The system enclosure contained a desanding hydrocyclone vessel with three 2-inch (50 mm) liners, an accumulator vessel, and a holding bin with a porous collection bag. The holding bin had a collection volume of ~0.7 m^3, and operated on wheels and rails for easy removal by one operator. The reusable collection bag filled with sand every 4-10 days, upon which they were removed for dumping at a disposal site. The water from the collected sand was directed to the wellhead cellar. Figure 4 shows the system enclosure, along with removal of the collected solids.

Figure 4 – Dewatered solids removal for dumping after separation from wellstream fluids with a desander.

The initial goal for this application was to reduce the effects that increased sand production was having on the production facility. Increasing watercut led to increasing sand production, which in turn resulted in the plugging of flow lines and separation equipment. A wellhead desanding hydrocyclone allowed the field to increase production while decreasing operating and maintenance costs within the battery. Increased oil production and reduced maintenance costs resulted in a two-month payback for this installation.

Surface Facilities Sand Handling System Design

The decision to incorporate solids handling into a surface facility operation requires more than just separation. The separated solids may require central collection, cleaning, measurement and monitoring, storage, and transport to the final disposal site. Surface facilities sand handling can be delineated into five unit process areas: separation, collection, cleaning, dewatering, and haulage.[28]

- Separation is the unit process of diverting the solids and liquids contained in a mixed slurry stream to different locations. Solids can be removed from well fluids with a gravity vessel (i.e., FWKO with a sand jet), desanding hydrocyclone, sand trap, or filter system.
- Upon separation, the solids must be collected into a central location and physically isolated from the production process. Gathering the solids to a central location minimizes the pressure letdown points involving sand (i.e. reduces wear areas), and allows for common subsequent processing. Collection can be accomplished with a simple device such as a desander accumulator vessel or a dedicated sump tank. Physical isolation from the production process may require significant pressure letdown, and thus an appropriate wear resistant slurry valve must be used.
- In many locations, the sand may require cleaning of adsorbed oil or chemicals subsequent to disposal. Dedicated sand cleaning systems based on attrition scrubbing with or without chemicals, or thermal treatment, are available as modular add-on packages or integrated into the separation system.[30]
- The total volume of sand slurry transported to disposal can be greatly reduced by dewatering. This involves removing liquids from the collected (cleaned) solids slurry. A range of systems are available for dewatering including a sand drainage bag, filter press, or centrifuge. The final product should have less than 10 vol.% liquid.
- Haulage encompasses the removal, hauling, and disposal of the solids. The design of the haulage system will be dependent upon the location (land-based or offshore) and disposal requirements (i.e., disposal well, overboard, landfill, road surfacing, etc.). In many cases, the solids may be mixed with water and disposed overboard or injected into wells.

Surface facility designs incorporating solids handling unit processes for both onshore and offshore fields have been documented increasingly in the past 5-10 years as approaches are taken to increase equipment robustness and minimize downtime.[19-21,28-30] This work has led to the recognition of facilities sand handling as its own interest area in the SPE

Production Systems and Facilities technical interest group (TIG).

Conclusions

The first industry-wide workshop to address a comprehensive approach to solids handling from downhole generation to topsides disposal was held by the Gulf Coast Section of SPE in 2002.[3] This conference hosted speakers to discuss sub-surface sand management, sand monitoring & measurement, flow-line erosion, facilities design, separation, cleaning, transport, and disposal. Attendee response showed that the greatest needs in sand handling methodology were seabed separation and disposal, integration of subsurface and surface sand management, and increasing the robustness of surface facilities to sand production.

E&P companies have begun to address the need to integrate surface sand management into their sand control portfolio. Equal merit is being given to facilities with sand separation or downhole exclusion technologies to determine which approach provides sustained hydrocarbon production. Gravel packs and screens have a well-established knowledge base for installation and operation. While providing sand protection in the majority of wells, these techniques still allow for the production of sand below 50-125 µm diameter under normal operation. In the case of a failure, the sand amount and particle size can increase rapidly leading to production restrictions. The need for a topsides technology that can protect surface facilities equipment (i.e., chokes, flowlines, pumps, separation equipment, etc.) led to the development of the multiphase desander for solids removal at the wellhead. Since implementation of this technology 12 years ago, the multiphase desander has found repeated use as a well service tool for the collection of solids from workover operations and as a permanently installed device to protect surface facilities equipment.

A comparison of performance and operability shows the multiphase desander to be more cost effective than gravel packs for mature fields. The multiphase desander allows higher well productivity by eliminating the inflow reduction associated with gravel pack skin, and as the number of wells requiring gravel packs increases, a central multiphase desander will become more cost advantageous by a combination of reduced installation costs and production increases. Multiphase desander and associated solids handling systems installed in the Gulf of Mexico and Austria over the past several years have shown the flexibility of the technology and the simplicity of operation.

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