Efficiency Testing of Oil Field Downhole Desanders

C. Langbauer*, M. Hartl*, S. Gall**, L. Volker**, C. Decker**, L. Koller**, S. Hönig**
*Montanuniversität Leoben, Chair of Petroleum and Geothermal Energy Recovery, Austria,
**OMV Austria Exploration & Production GmbH, Gänserndorf, Austria

Abstract

Tense economic situations push the demand for low-cost oil production, which is especially challenging for production in mature oil fields. Increase in the meantime between failure and limitation of equipment damage is essential. A significant number of long producing fields is suffering under sand production. The objective of the proposed paper is to show the development process and the testing procedure of an effective downhole desander for sucker rod pumps.

In weak reservoir zones in most situations, the strategy to prevent equipment from suffering under sand production is sand exclusion using a gravel pack. Nevertheless, a certain amount of small grains still enters the wellbore and may damage the sucker rod pumping system over time. During the last year, several different downhole desander configurations were tested at the Pump Testing Facility at the Montanuniversitaet Leoben. Various types and sizes of downhole desanders were tested under different strokes per minute under near field conditions to find the optimum and most efficient design for the field application.

The test results have shown that the design and the pumping speed are the most significant influencing parameters on efficiency. On the one hand, bad design in combination with a wrong selected pumping speed can reduce the sand separation efficiency to lower than 50 percent. On the other hand, if all parameters are chosen carefully, the sand separation efficiency can be 95 percent or higher. The grain size distribution, in addition, is determined as essential parameters for properly selecting adjacent equipment. This paper will present the testing configurations, the development of the high-efficiency downhole desander and sensitivity analysis on the design.

The sensitivity analysis, performed for several downhole desander types, has shown the high dependency of the sand separation efficiency on the major design parameters. Proper selection of the components and operating parameters will contribute to an increase in the meantime between failures.

Introduction

Throughout the last decade, the oil industry has seen both the highest oil price ever, as well as oil price, drops to the prize level of thirty years ago. For example, the oil price dropped from 100$ per bbl to about 30$ per bbl in 2016. To withstand such uncertain situations, oil companies prepare themselves by increasing their overall efficiency and improving the mean time between failures. Nowadays, almost 60 percent of all oil wells are assisted by some artificial lift system. A significant share is using sucker rod pumps, due to its relatively low investment and operation costs. An overwhelming number of the world's oil wells are in sandstone formations, where 25 to 35 percent thereof are prone to sand production (Walton, I.C., Atwood, D. C., Halleck, P. M., Bianco, L. C, 2013). This fact confirms the requirement of innovative sand production management solutions.

Sucker rod pumping systems can be split into three major components: the surface pump jack, the sucker rod string, and the downhole pump. The surface pump jack itself is not influenced by sand production at all. The sucker rod string is suffering under sand production as soon as sand is present at the sliding interface between the rod string and the tubing. Excessive wear will end up in leaking tubing string or a broken rod string. The downhole pump itself is affected most by sand production.

Tight ball seats and optimum clearance at the downhole pump's plunger ensure high volumetric efficiency. Clearance ensures lubrication for the plunger movement. Clearance size is determined by fluid viscosity, water cut and the grain-size of the produced sand. Typically, one must allow for about 2-5 percent of the production volume as slippage (i.e., losses) (Chambliss, R. K., 2001). Even if in the design process of the clearance accounts for sand production, due to the inhomogeneous grain-size distribution of naturally occurring solids, sand will eventually migrate into the clearance between barrel and plunger. Figure 1a indicates severe damage to the plunger surface, caused by sand production.

a) Plunger surface damage (Don-Nan, Ed., 2018)

b) Ball valve seat damage (Langbauer, 2017)

Figure 1: Sand production failures at the downhole pump

The two ball seats in the downhole pump, the standing valve, and the traveling valve, can sustain severe damage (Figure 1b) by sand production. During the closing process of these valves, caused by the high differential pressure across the valve, the fluid velocity is exceptionally high. Sand, especially quartzite sand, is jetted against the seat and eroding it, even the seat is made of special, highly erosion resistant material.

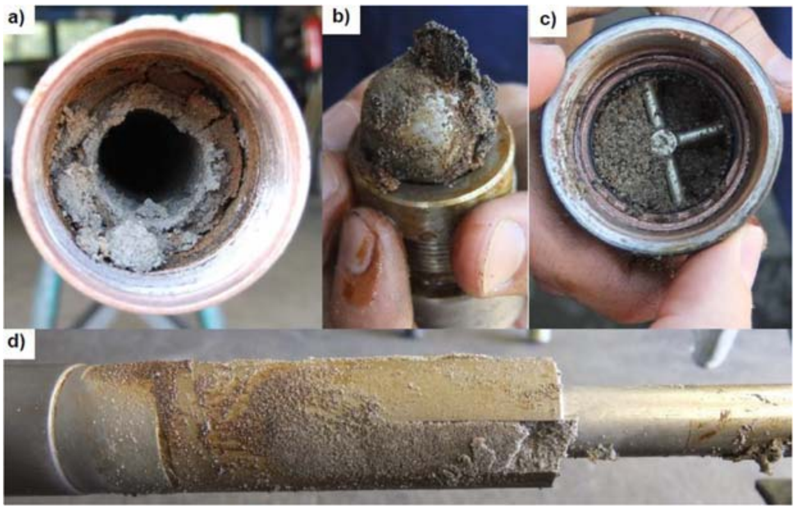


Figure 2: Sever sand accumulations at the downhole pump (Langbauer, 2017)

Furthermore, during the downstroke, sand in the produced fluid may accumulate at the upper end of the plunger. Both, sand migration into the clearance and accumulation at the top of the plunger may happen. These accumulations may cause the entire pump to be stuck and may halt production. Longer pump shut down periods, and high water cut well, where the caring capacity of the fluid is too low to suspend the co-produced sand, may accelerate this type of failure (Figure 2).

The formation solids produced with the downhole fluid, travel to the surface and through the following production facilities if they are not hindered from entering the production tubing. These solids may then reach various stages in the oil treatment process. Problems start with the erosion of controls and instruments. Additionally, treatment processes involving various vessels can be negatively affected.

Causes of Sand Production

Two essential failure mechanisms lead to sand production, mechanical failures of the rock and chemical changes with the onset of water production (Zhou, S., Sun, F., 2016).

The rock experiences stress throughout all the earth's crust. The overburden load is typical of most considerable magnitude σ_v. The magnitude depends mainly on the geological processes, acting in the wellbore vicinity, pore pressure, and depth. It is desirable to know about the local stresses and rock strength, to avoid excessive well-bore breakouts that lead to high sand production. The presence of the wellbore disturbs the initial stress distribution. The mechanical failures result by local stress relocations, leading to stress concentrations at the wellbore's wall perpendicular to the maximum horizontal stress direction σ_{max} that is in direction of minimum horizontal stress σ_{min}.

Various failure criterion for compressive and tensile failure exist. For compressive failures, the widely accepted and most used one is the linear Mohr-Coulomb failure criterion. The Mohr-Coulomb failure criterion uses the effective stress. The effective stress σ' is based on the total stress σ, which is corrected by the pore pressure *p* and the compressibility of the grains C_g and the bulk rock C_b (Eq.1).

$$\sigma' = \sigma - \left(1 - \frac{C_g}{C_b}\right).p \qquad \text{(Eq.1)}$$

The Mohr-Coulomb failure criterion relates the shear stress τ to the normal stress σ present in a rock portion and considers the local cohesion *c* and the internal angle of friction φ (Eq.2).

$$\tau = c + \sigma.\tan(\varphi) \qquad \text{(Eq.2)}$$

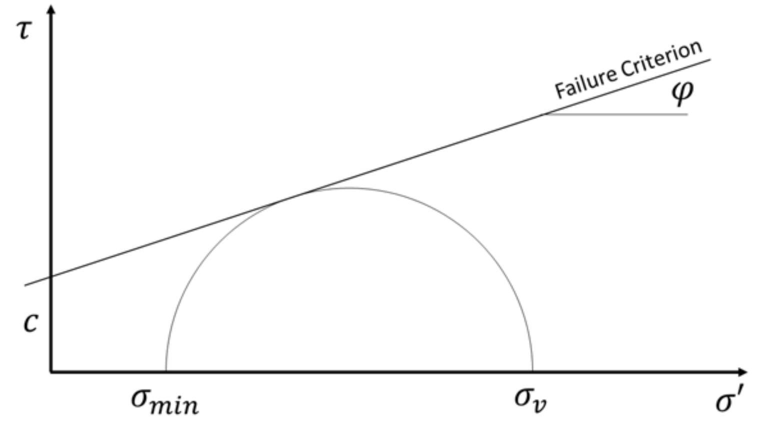


Figure 3: Mohr-Coulomb Failure Criterion

According to Mohr-Coulomb, failure will occur, when stresses are of such a magnitude, that the half circle inscribed in Figure 3 shifts to the left and over the failure criterion's envelope.

Such a failure may occur in two situations:

- As pore pressure increases, caused by, e.g. water injection, the effective stress will decrease. Both σ'_v and σ'_{min} are shifted to the left by the same amount. The shear stress does not change and failure occurs.
- A pore pressure decrease can lead to rock failures as well. The preconditions are a porous and elastic reservoir with a lateral extension to thickness ratio of 10:1, where the rock behaves according to the poroelastic theory in a normal faulting regime. In such a reservoir the overburden stress does not change with pore pressure, but the least principal stress changes. In terms of the Mohr failure criterion, failure will occur as soon as the circle grows above the failure criterion (Zoback, M.D., 2011).

Mechanical failures, due to the alteration of the stress field typically results in transient sand production at the very beginning of production, as shown in Figure 4. As stress fields and the wellbore stabilize again, lower levels of sand production are reached. Towards the end of their lifetime, fields tend to show stronger sand production again.

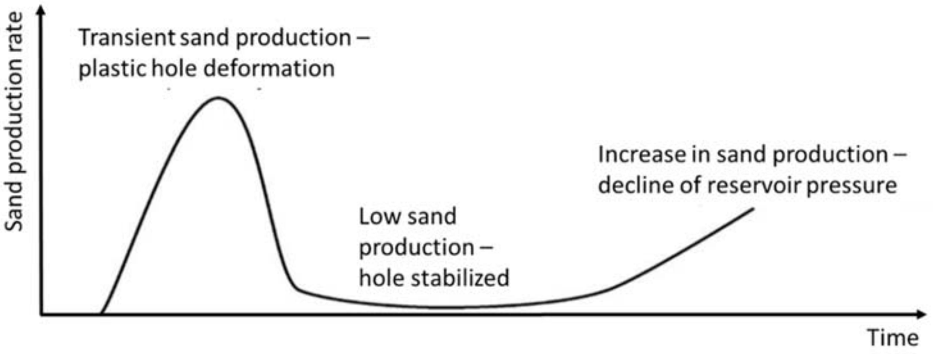


Figure 4: Sand production over a well life-time (Bellarby, J., 2010)

Chemical changes, to both the actual grains and matrix, may decrease rock strength and cause sand production at this stage. An increase in water cut decreases the capillary pressure, resulting in easier and faster movement of water through the rock, making fines transport more likely.

Mitigation of Sand Production

Nowadays, besides the initial design of the perforations to perforate only the most robust sand interval, optimize the charge density, and account for the downhole in situ stress directions, there are several techniques available to mitigate sand production:

- Cope with sand production by adapting the production equipment accordingly
- Stabilization of the reservoir formation by using chemicals
- Installation of gravel packs, sand screens, and downhole desanders

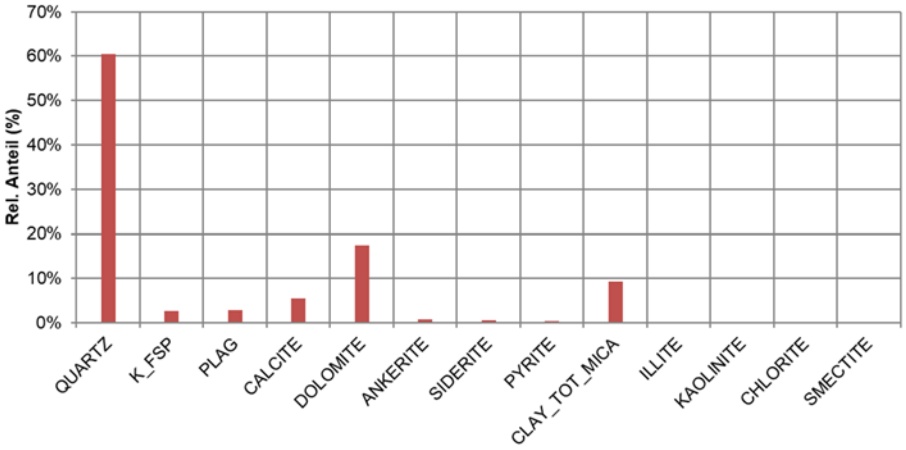


Figure 5: Reservoir sand mineralogy

Sand, produced from reservoirs, is typically a mixture of various minerals. The most substantial fractions are represented by more than 60 percent of quartz and 15 percent of carbonate minerals (Figure 5). Quartz is on position seven on the Mohs' hardness scale. Most iron-based metals have a lower hardness. That means produced sand can cause severe damage to metal surfaces.

The most preferred strategy is to prevent equipment from suffering under sand production by sand exclusion using gravel packs and sand screens. For the design of sand control methods, the grain size distribution of the formation grains is essential. Typically, ratios between multiple distribution classes such as D10 - describing the smallest 10 percent of all particles, are used for the design of a gravel pack. Figure 6 shown an averaged grain size distribution of a typical sandstone reservoir. Is can be seen that the D10 diameter is about 0,07mm, which is the basis for the gravel pack design. Too fine gravel sand tends to cause higher pressure losses known as skin as too coarse gravel sand in the pack will lead to migration of small sand grains from the formation into the wellbore.

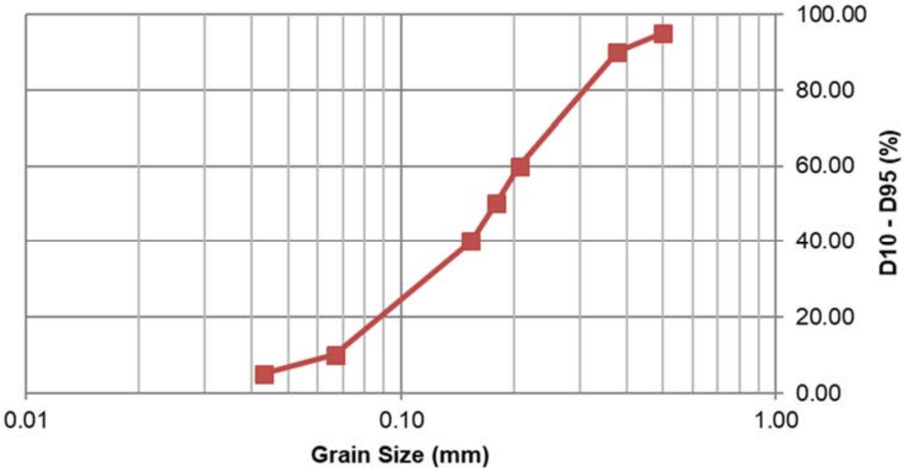


Figure 6: Reservoir sand averaged grain size distribution

Nevertheless, even within a well-designed gravel pack, a certain amount of small grains still enters the wellbore and may damage the sucker rod pumping system over time. The typical clearance or plunger fit range is from 0,025 mm to 0,1 mm. The grain size that enters the well through the gravel pack exactly matches the size of the plunger fit. As a result, the grains may enter the clearance and destroy the plunger's surface.

To prevent the plunger from unwanted destruction downhole desanders that are installed below the intake of the sucker rod pump can be used. The operating principles are the following:

- The solids tangentially enter the intake above the swirl vanes, shown in Figure 7.
- While passing through the swirl vanes, rotational movement is imposed onto the fluid-particle mixture. The swirl section area narrows and causes the fluid to accelerate.
- Abruptly amidst the end of the swirl sits the pump intake, prompting rapid redirection of the fluid. The separation of the solids is based on the condition that they cannot follow this rapid change of direction. The rotary fluid movement forces the heavier solids towards the wall and increases the distance to the intake.
- The fluid flow direction is diverted into the suction pipe towards the pump. The separated solids cannot follow this change in direction and sink towards the bottom of the separator and in the adjacent sand tubes or the bottom of the wellbore.

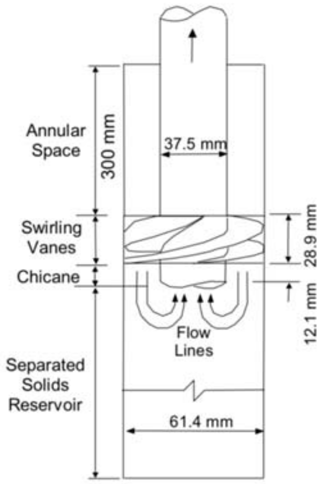


Figure 7: Swirl Tube Separator (Martins, J.A., Rosa, E. S., Souza, R.,2005)

The sand storage capacity in the sand tubes or the wellbore, below the perforations, is limited. Therefore, downhole desanders should not be a standalone solution. Rather, they should be used in combination with a conventional sand control method or for formations with only a very limited tendency towards sand production.

Testing Objective

Existing downhole desander solution for sucker rod pumps are already available at the market today. These come along with some limitations:

- Solutions wholly made out of carbon steel prompting severe reliability concerns in terms of corrosion.
- Commercially available downhole desander require the installation of both, a gas anchor in connection with the downhole desander if gas needs to be separated.
- The proposed analytical model, developed for the design of the downhole desander tested, suggests that the commercially available downhole desander design is not the most efficient one (Rippl, H., 2017)

Therefore, the objective downhole desander is made out of high alloy/ stainless steel to circumvent corrosion failures and can be directly incorporated into the stainless steel gas anchor housing.

The task of the presented downhole desander experiments is to verify the design, found by the analytical model of H.Rippl (2017). The primary criterion is the sand separation efficiency, which is the portion of sand lifted by the pump, based on the total amount of sand initially in the liquid.

The analytical model places particular emphasis on the design of the vanes used to redirect the liquid flow into a rotary movement. The existing solutions rely on rather ”simple” redirection for this purpose. The newly designed downhole desander now relies on sophisticatedly designed vanes that should provide the best separation efficiency at minimal pressure loss. Furthermore, the new design proposes the use of a specifically calculated separation distance next to the vane’s outlet that in theory should together with an additional device to facilitate particle separation, guarantee a high separation efficiency. The particle loaded part of the stream should move down towards the sand tubes, allowing for the sedimentation of the sand. The mainstream without or fewer particles is diverted by 180° and reaches the inlet of the sucker rod pump.

The most significant influencing parameters on the separation efficiency are design, fluid viscosity, density contrast between fluid and particles, particle size and pumping speed (Rippl, H., 2017; J. A. Martins, E. S. Rosa, and R. Souza, 2005)

Experimental Setup

Testing the proposed downhole desander requires some preparation at the pump testing facility:

- Formation sand substitute definition
- Changes to the pump setup for allowing the sand dosage
- Dosing of the correct amount of sand into the system

Pump Testing Facility Preparation:

The Pump Testing Facility is the result of the active collaboration of the Montanuniversitaet Leoben and OMV. The development of new technologies in the field influences the regular field operations is very costly, time-consuming and has an impact on HSSE. To overcome these limitations, the Pump Testing Facility was designed and constructed. The main objectives were a low-risk evaluation of new technology, low-cost equipment testing under standardized conditions and optimization as well as fast development of innovations (Figure 8).

Together a testing unit was developed that can simulate the oil and gas flow under real well conditions up to a depth of about 500 meters. The developed pump testing facility comprises of a 6 5/8", 8-meter long casing string and is installed in a 10-meter deep shaft. The Pump Testing Facility itself consists of a modular design for allowing the highest flexibility of testing new technology. The actual capabilities are:

- Performance and wear testing of artificial lift systems
- Testing under vertical and deviated conditions
- Simulation of oil and gas production
- An easy variation of well & reservoir parameters – e.g., dynamic liquid levels, the influence of scales, sand, GOR, etc.
- Evaluation of energy consumption, pump efficiency under sandy and gassy conditions
- Test alternative rod string materials (wires, plastics)
- Etc..

Figure 8: Pump Testing Facility

To perform the downhole desander tests at the Pump Testing Facility, some adjustments were necessary to match the experiment's requirements. One of the major influencing parameters on the sand separation efficiency is the pumping speed. To enable testing at various pump speeds, a 3.75in tubing pump was installed. This pump size, together with the drive system of the Pump Testing Facility allows testing off the developed 1.50in and 2.25in downhole desander as well as commercial products.

The installed string consists, from top to bottom, out of the 3.75in barrel, standing valve, 2ft extension, X-over, and a 1m long 3 ½" tubing, followed by the tested downhole desander. Bellow the downhole desander a 1m long 2 7/8" tubing, acting as the sand tube is installed. Finally, a 20mm pipe connects the sand tube to the outside of the pressure vessel and a gate valve to extract the sand (Figure 9).

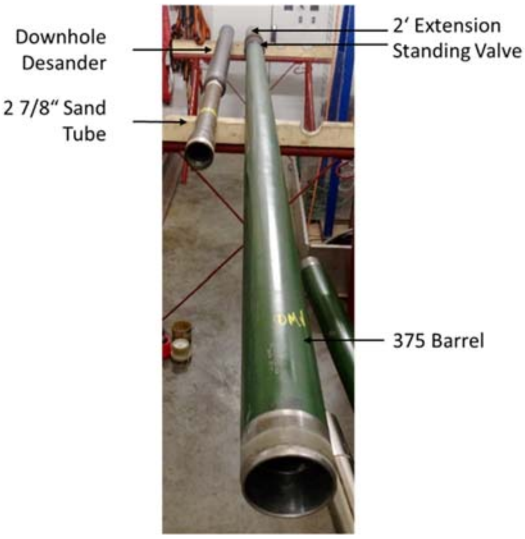


Figure 9: Installation

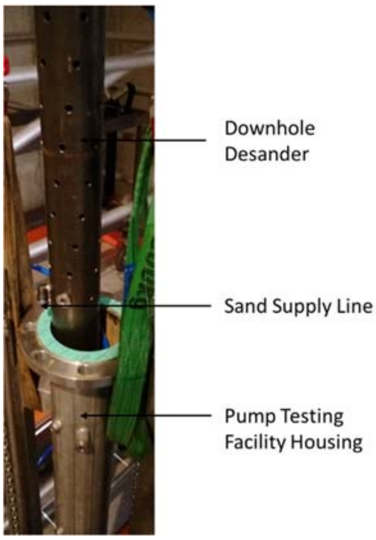


Figure 10: Sand dosage position

Dosing of the correct amount of sand into the system:

In order to resemble field conditions, and allow for a controlled environment in which the evaluation of the desander design is conducted, the "produced" formation sand must be dosed continuously and in reproducible quantities into the pressured intake stem of the desander. A sand portion of 0.1 w% is selected. As sand is an abrasive medium with a tendency to bridge building continuous dosing, it is a somewhat tricky process, and a suitable solution is not found on the market. Therefore, a 15l batch mixture of water, xanthan, and sand were prepared for each test. A peristaltic pump continuously injected the mixture into the downhole desander (Figure 10).

For water-based muds in drilling, Xanthan gum is a widely used solution to keep fines afloat during a stop of circulation. The polymer forms a gel keeping fines afloat. Furthermore, it shows a non-Newtonian shear thinning behavior ensuring the water sand mixture stays pumpable. As a change in fluid viscosity will alter the performance of a desander, it is desired to add a minimal quantity of Xanthan to the overall system. A Xanthan concentration for the water/Xanthan/sand mixture was determined in the laboratory to be five grams of Xanthan per liter of water.

At such a Xanthan concentration, sand stayed suspended in the mixture until the Xanthan biodegraded. (i.e., the sand stayed afloat without movement for at least 24 hours) Furthermore, the dilution factor, at which no effects of the Xanthan where noticeable anymore was determined. At a dilution of 1:20 (0.05) in terms of Xanthan mixture to pure water, no Xanthan effects where noticeable anymore.

Formation sand substitute definition:

It was impossible to get the required amount of reservoir sand for the experiments. As a result, substitute sand was required. The commercial product Flairstone 0-1mm, having a slightly coarser grain size distribution is used instead (Figure 11).

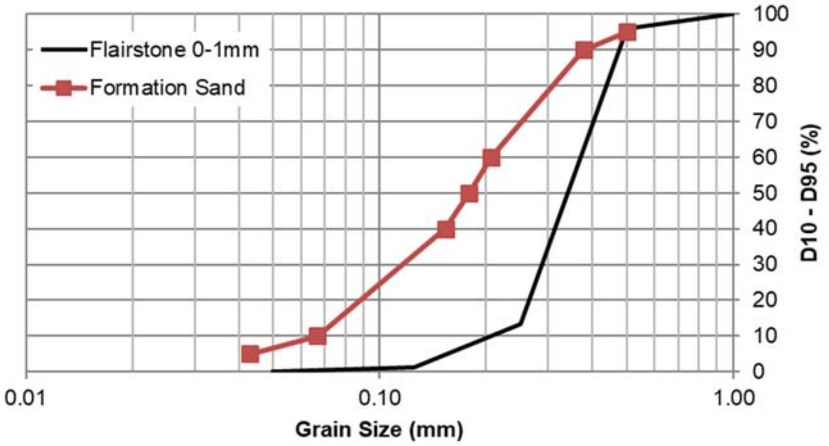


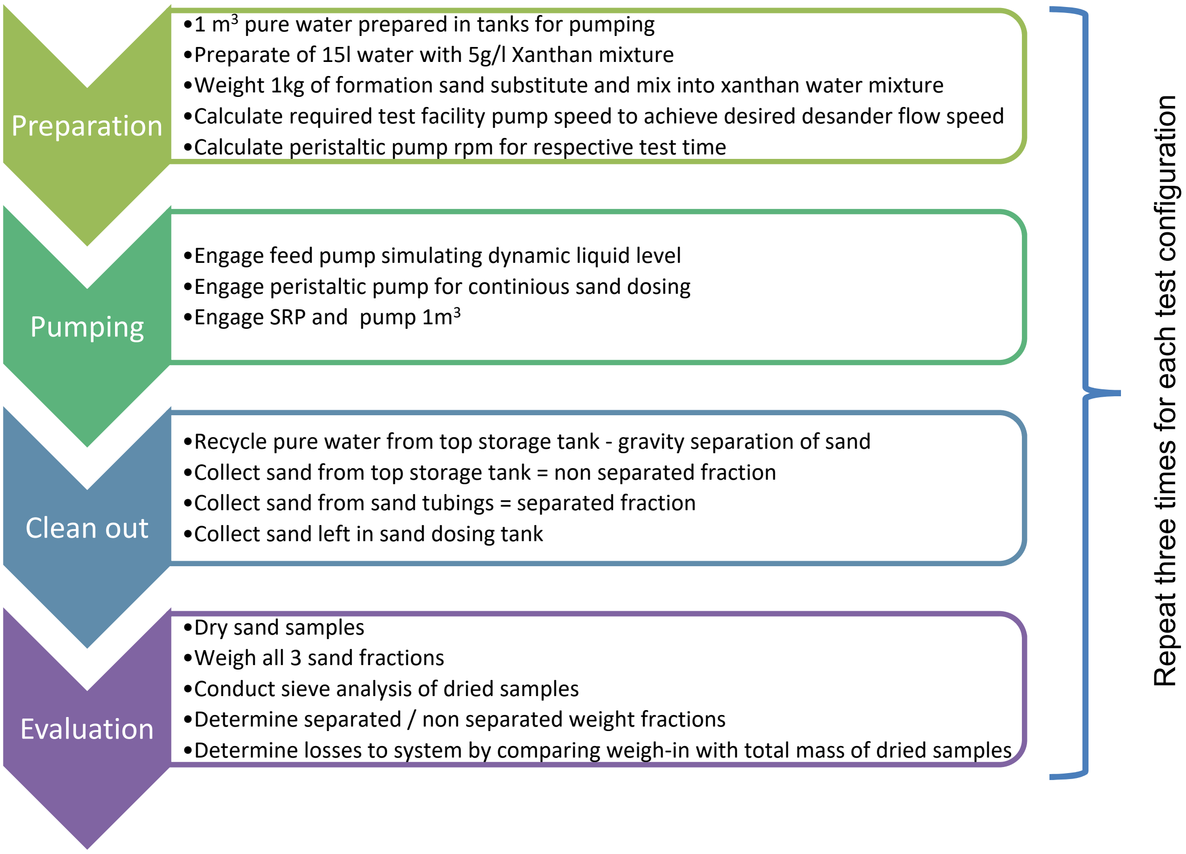
Figure 11: Reservoir sand averaged and Flairstone grain size distribution

Testing Procedure

To ensure reproducible and valid test results, we developed a standardized test procedure that must ensure:

- A fixed mass percentage of 0.1w% of sand dosage during one test cycle
- A minimal amount of lost sand in the test assembly and during sand retrieval
- A pump speed that matches the designed flow speed through the desander

Figure 12 documents the applied test procedure in detail.



- 1 m^3 pure water prepared in tanks for pumping
- Preparate of 15l water with 5g/l Xanthan mixture
- Weight 1kg of formation sand substitute and mix into xanthan water mixture
- Calculate required test facility pump speed to achieve desired desander flow speed
- Calculate peristaltic pump rpm for respective test time

- Engage feed pump simulating dynamic liquid level
- Engage peristaltic pump for continious sand dosing
- Engage SRP and pump 1m^3

- Recycle pure water from top storage tank - gravity separation of sand
- Collect sand from top storage tank = non separated fraction
- Collect sand from sand tubings = separated fraction
- Collect sand left in sand dosing tank

- Dry sand samples
- Weigh all 3 sand fractions
- Conduct sieve analysis of dried samples
- Determine separated / non separated weight fractions
- Determine losses to system by comparing weigh-in with total mass of dried samples

Figure 12: Schematic desander testing procedure

As outlined in Figure 12, 15 liters of water with five g/l Xanthan added was used as a carrier fluid for one kilogram of sand to achieve 0.1 w% sand added throughout our experiment. (i.e., 1kg of sand per 1000kg water pumped) Therefore, the dilution factor for the Xanthan solution, in our experimental setup is 1.5:100 (0.015). Hence, no effects on the separation performance of the desanders using Xanthan in our dosing solution are expected.

Calculating the required Pump Plunger Speeds:

A 3.75in tubing pump was installed at the Pump Testing Facility. By varying the actual pump plunger speed, the flowrates of smaller pump sizes could be mirrored. Thereby, it was enabled to match the pump size specific design flow rate of the tested downhole desanders.

The premise for the calculation is that the flow rate through the downhole desander must match the one for the designed pump rate and pump size. Therefore, the required pump plunger speed for the 3.75in pump is calculated as:

$$v_{test} = v_{design} * A_{design}/A_{375} \qquad \text{(Eq.3)}$$

Where v_{test} is the pump plunger speed to be set on the Pump Testing Facility, v_{design} is the designed pump plunger speed for a specific downhole desander, A_{design} is the inside cross-sectional area of the pump the downhole desander is designed for and A_{375} is the inside cross-sectional area of the 3.75in pump.

The tested downhole desanders are designed for 2.25in and 1.5in pumps. The respective test pump plunger speeds are shown in Table 1. These base pump plunger speed can be varied to test a desanders sensitivity to speed changes. During the tests, the pump plunger speed was kept constant.

Table 1: Required test pump rate

Pump type	Design plunger speed (m/s)	Reduction factor (A_{design}/A_{375} *100%)	Test pump plunger speed (m/s)
2.25in	0.569	36%	0.205
1.5in	0.5	16%	0.08

Continuously Dosing the Sand:

As flow rates vary depending on the test conditions and downhole desander type, the flow rate of the sand slurry through the peristaltic pump needs adjustment as well. The flow rate must ensure that the complete slurry is evenly injected into the desander intake over the complete test cycle.

The peristaltic pump uses a variable speed drive where RPM's are user adjustable. To determine the relationship between RPM and pump flow rate, five data points where collected. For each of these data points, pump time, RPM set and pumped mass were collected. Thereof, a correlation for RPM and flow rate was constructed as shown in Figure 13.

Based on the correlation, the peristaltic pump's speed can be adjusted to pump the 15 liters of sand slurry in the time required in every test case to pump the test volume of 1 m^3 of water.

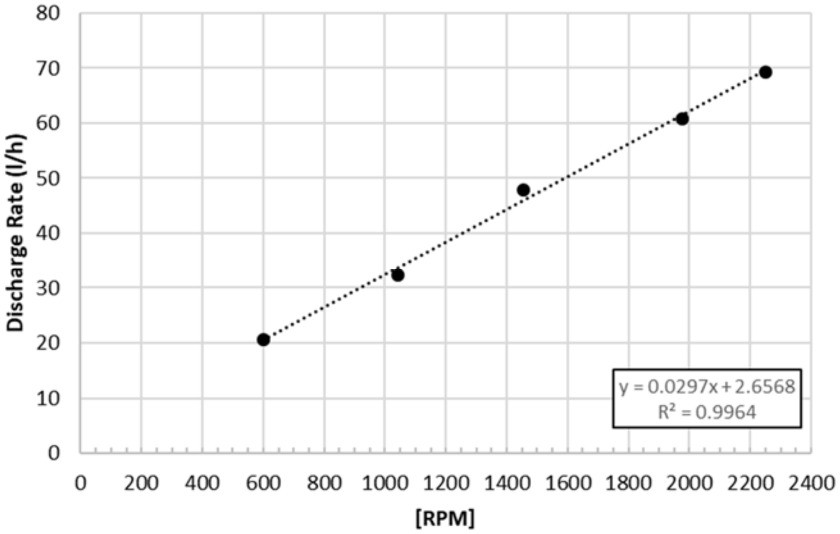


Figure 13: Peristaltic pump RPM to flow rate correlation

Pumping the Test Runs:

The desander test runs are conducted with the parameters specified in the preceding sections. To simulate downhole conditions, the centrifugal pump used as a feed pump from the storage tank to the Pump Testing Facility provides a feed pressure. Throughout the tests, 3 bar feed pressure was selected, thereby, simulating a dynamic liquid level of 30m above pump intake. No artificial backpressure is applied at the pump outlet. However, due to the length of the hose between the storage tank and the pump outlet, we observed backpressure at the pump outlet of 18bar for standard test cases. With the variation in pump plunger speed and therefore flow rate, a pressure range from 5bar to 26bar was observed.

Clean out and Test Evaluation:

Once the test volume of 1m^3 is pumped, the water is drained from the facilities upper storage tank. It is essential, to skim the water off from the top, as the sand produced from "downhole" settles to the bottom of the tank. Once the water is drained, the sand is vacuumed from the tank, stored, and labeled in sample containers. The share of sand that is collected from the tank is the portion not separated by the desander.

Separated sand is collected from sand tubings via a purge valve. Finally, yet importantly, leftover sand in the dosing tank is cleaned out and stored.

The three sample containers are forwarded to sieve analysis. There the samples are dried and weighed individually. For the separated and non-separated sand, a sieve analysis is determined to allow for the computation of separation efficiency for respective grain size fractions. Summing up all three weights including the leftovers from the dosing tank and comparing to the initial sand weight does give the losses in the test system.

Conducted Tests:

Figure 14 depicts the tested desander variations, namely:

- A classic gas anchor as a reference point to benchmark sand separation performance
- A commercially available downhole desander for a 2.25in pump
- A new OMV desander design for both a 2.25in pump and a 1.5in pump

All of the desanders, design and speed variations are rated both in terms of overall sand separation efficiency and efficiency in terms of grain size windows from 50µm to 1000µm.

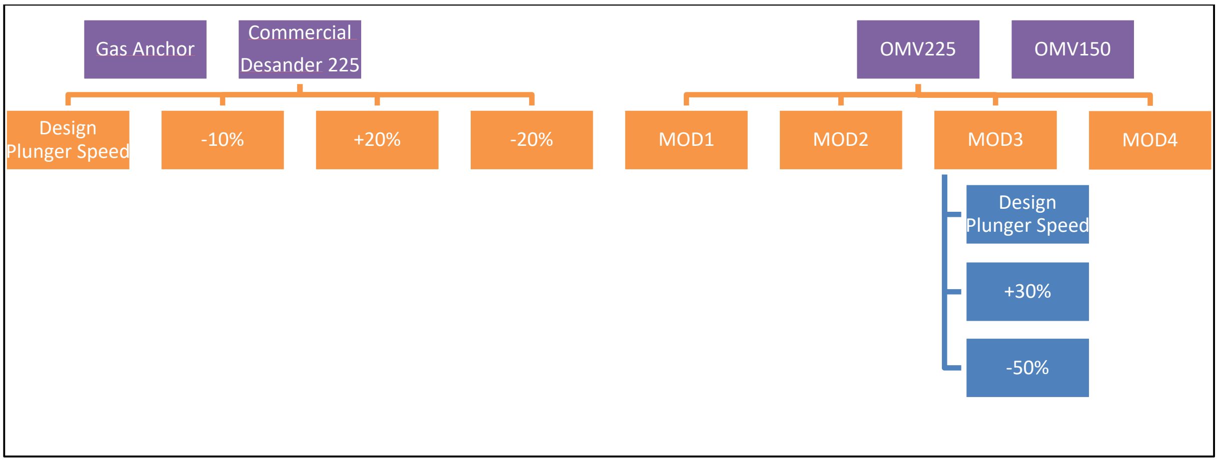


Figure 14: Test matrix

Gas anchor test as a benchmark

The evaluation principle is shown based on the tested gas anchor. A standard gas anchor for a 2.25in pump was tested in terms of its ability to separate sand from the production stream as per the test procedure defined previously.

Table 2: Evaluation table for the gas anchor benchmark

Separated sample		Run 1	Run 2	Run 3	
Sieve No.	Grain Size (µm)	Amount sep. (g)	Amount sep (g)	Amount sep (g)	**Separation rate Gas Anchor 225**
2	>63	0,68	0,38	0,27	4%
3	>125	35,43	40,95	33,87	22%
4	>250	43,9	182,76	136,78	25%
5	>500	1,07	16,01	13,75	56%
Non-separated sample		Run 1	Run 2	Run 3	
Sieve No.	Grain Size (µm)	Amount pass. (g)	Amount pass. (g)	Amount pass. (g)	**Pass Rate Gas Anchor 225**
2	>63	12,48	12,02	8,36	96%
3	>125	105,11	141,61	145,99	78%
4	>250	104,6	509,63	618,72	75%
5	>500	1,07	7,98	12,91	44%
				Total Sep. Performance	**23%**

In total, three tests are run for each downhole desander type, and results are averaged to get to the separation efficiency. The tests were run at the 2.25in design plunger speed shown in Table 1; respectively the actually calculated pump speeds for the 2.25in pump.

Table 2 shows the relevant numbers to evaluate the separation performance of a desander. Samples from all three test runs for a gas anchor are separated in the sieve analysis, and the respective fractions are weighed. From the shown results, an average separation and pass rate for every fraction is calculated, as shown in the last column by:

$$Sep_{rate} = \frac{\sum_{i=1}^{3} amount_{sep\ i}}{\sum_{i=1}^{3} amount_{sep\ i} + amount_{pass\ i}} * 100\% \qquad \text{(Eq.4)}$$

The separation performance of the gas anchor itself is with 23 percent very poor.

Desander Design Type Tests

Figure 15 presents the design modifications of the intake section of the pump.

Figure 15: Downhole Desander intake section modifications

For the sake of keeping this manuscript shorter, the findings for the various tested types of downhole desanders are summarized in Table 3.

The following test series serves to benchmark the new proposed OMV downhole desander design types against the gas anchor and the commercially available design. Opposed to the commercial design, the initial OMV design proposes a certain separation length after the swirl vanes, to accomplish improved small grain size separation. As the new design is based mainly on analytical simulations, it needs to be validated.

Table 3 separation performance for various desander types

Separation performance for grain size fractions and total separation performance for desander types

Grain Size (µm)	Gas Anchor 225	Commercial 225	OMV 225	OMV225 MOD1	OMV225 MOD2	OMV225 MOD3	OMV225 MOD4	OMV 150
>63	4%	85%	13%	15%	12%	59%	69%	48%
>125	22%	90%	43%	53%	46%	81%	84%	80%
>250	25%	97%	67%	79%	75%	93%	94%	98%
>500	56%	97%	95%	91%	96%	97%	85%	97%
Total sep. performance	**23%**	**96%**	**63%**	**72%**	**69%**	**90%**	**91%**	**94%**

As shown in Table 3, the initial iteration of the proposed design did show disappointing separation results. The identified cause being the length and form of the newly designed separation distance. Redesigned separation areas for MOD1 and MOD2 as shown in Figure 15 did show improvements in separation efficiency. However, not nearly at the level of the commercially available solution. Finally, the design riveted back to one without separation distance. Those two designs, MOD3 and MOD4, did show overall separation performances at the level of the commercial solution. Rescaling the best case design to a 1.5 in the pump did not show adverse effects on separation performance.

As MOD3 showed a significantly better separation efficiency in the >500µm grain size range, this design was chosen for further sensitivity analysis in terms of pump speed variations.

Pump Plunger Speed Sensitivity Analysis

To account for varying operating conditions of the sucker rod pump in the field, both the commercial downhole desander as well as the best case OMV design where evaluated at pump speeds deviating from their design speed. Speed variations are limited by the specifications and power of the Pump Test Facility. The commercially available downhole desander was tested at plunger speeds of +/- 20% of the 2.25in design speed, shown in Table 1. Whereas, MOD3 was tested at +30 and -50% of the design speed.

Table 4 total separation performance with pump speed variations

Test type	Total Separation Perf.
Separation perf. commercial 225	96%
Separation perf. C225 +20%	89%
Separation perf. C225 -20%	95%
Separation perf. OMV225 MOD3	90%
Separation perf. MOD3 +30%	90%
Separation perf. MOD3 -50%	94%

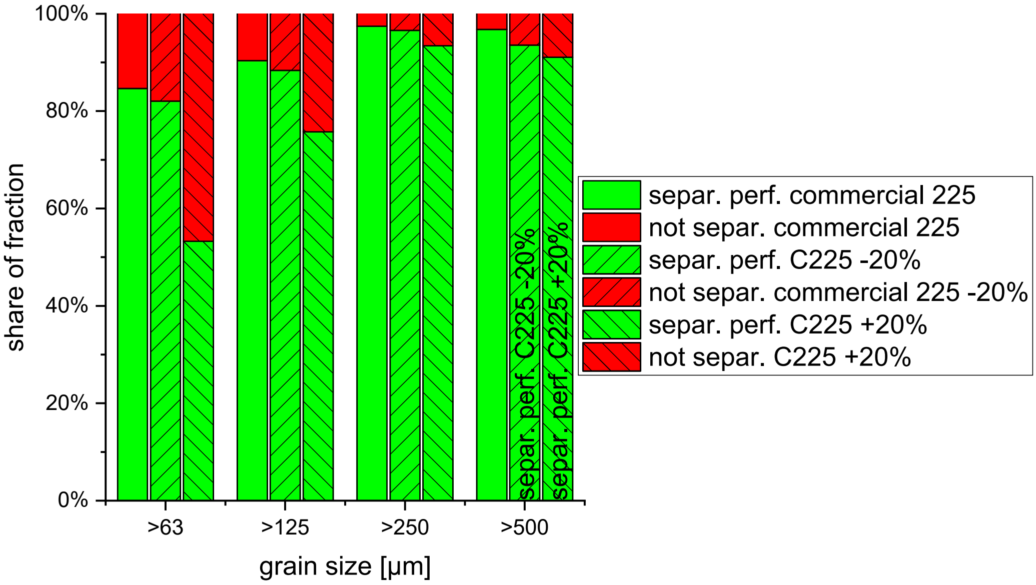


Figure 16: Separation performance for grain size windows (commercial desander)

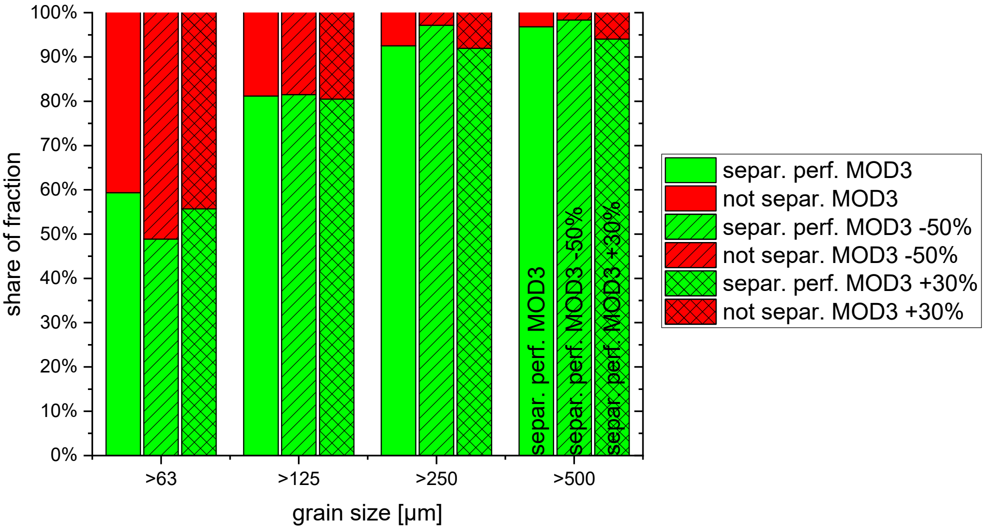


Figure 17: Separation performance for grain size windows (MOD3)

Preliminary Results of Field Applications

As downhole equipment is not only selected by its efficiency on a lab test, a field test of various downhole desander is conducted in parallel and lasts on. The field test should not only give operational insight in the handling of downhole desanders during workover operation but as well prove the theoretical idea of improving pump run life by excluding the sand from entering the pump in the wellbore. For the field test, eight wells in the field, which experienced increased sand volumes in their produced fluids and low run life of the downhole equipment were selected. As installation of prototype downhole desanders started already in 2016, first data reveals an improvement of run life on two wells. As all wells are continuously tested for their sand content in the liquid production, not a single test revealed solids in the production fluid above the minimal sampling threshold of 0.01 w% after installation of the downhole desander.

Major design constraints for tool handling was a maximum outside diameter of 108 mm for allowing enough clearance between the downhole desander and the casing. This clearance is not only triggered by the casing inside diameter but as well by the inside diameter of washover tools for fishing operations. Based on the tests at the Pump Testing Facilities, the downhole desanders on stock were altered to the optimum design. In a continuous process, candidate wells are identified, and downhole desanders are installed whenever a well is worked over due to the failure of the downhole installation. One additional advantage of the downhole desander and as well the improvement of the standard gas anchor is the material change on its outer shell. While before the downhole desander development carbon steel was used for the gas anchor, field experience revealed that the corrosion inhibition by chemicals does not work below the intake of the gas anchor. This led multiple times to a decreasing wall thickness of the downhole desander and eventually to broken gas anchors calling for fishing operations. With the change to corrosion-resistant alloys for the outer shell, this problem is solved as well.

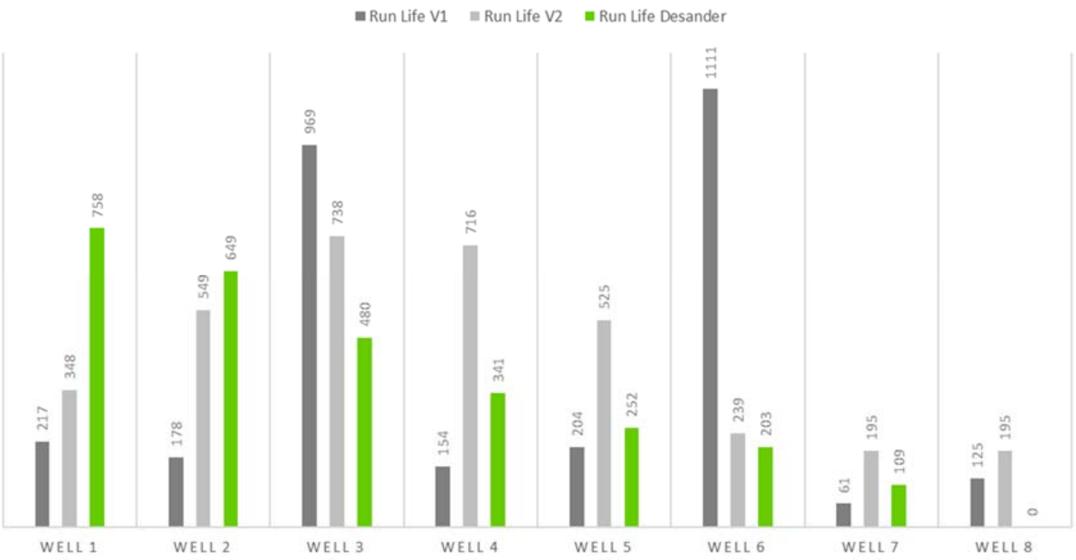


Figure 18: Run life improved by downhole desanders in days

In figure 18, the well performance before and after downhole desander installation in run life of the installation in days is shown. While Well 1 and 2 already surpassed their previous lifetime, Well 8 instantly failed after workover. One possible conclusion could be major sand production because of a casing leak, which immediately filled up the sand tubes and the downhole desander and blocks production. Although run life does not only rely on sand production, it is taken as one indicator of performance until pumps are recovered and the wear of well components can be analyzed.

Conclusion

The sensitivity analysis, performed for several downhole desander types, yields an ideal new downhole desander design, with minimal sensitivity to pump plunger speed variations and satisfactory separation efficiency. The benefits of such a new design over the commercially available solution are:

- Robust separation efficiency over a broad pump speed range
- In-house manufacturing as an integral part of a gas anchor in a high-alloy steel version, especially resistant to corrosion

The tested desanders are not supposed to replace conventional sand control methods fully. However, they complement conventional installations perfectly and can protect sucker rod installations in cases, where sand production volume does not justify conventional installations.

The sensitivity analysis, performed for several downhole desander types, has shown the high dependency of the sand separation efficiency on the major design parameters. Proper selection of the components and operating parameters will contribute to an increase in the meantime between failures.

The results do not exactly match the results of the work of Mr. Rippl. The reasons might be for instance that the selected sand’s grain size distribution for the tests did not exactly match the one selected for the design calculations. In addition, the analytical approach used has some limitations and does not exactly match the real flow conditions in the downhole desander.

References

Bellarby, J., Well completion design, Reprinted., ser. Developments in petroleum science. Amsterdam: Elsevier, 2010, Vol. 56, ISBN: 978-0-444-53210-7. p.147

Chambliss, R. K., “Plunger leakage and viscous drag for beam pump systems”, Master Thesis, Texas Tech University, Lubbock Tex., 2001. https://ttuir.tdl.org/bitstream/handle/2346/13650/31295017999573.pdf?sequence=1& isAllowed=y

Don-Nan, Ed., Case Study: Sand Diverter: Sand Diverter more than doubles rod pump run time in sandy wells for Permian Basin operator, 2018, https://www.don-nan.com/case-study-sand-diverter

Langbauer, C., Artificial Lift Systems Practical: Sucker Rod Pump, Leoben, 2017

Martins, J.A., Rosa, E. S., Souza, R., Experimental Analysis of Swirl Tubes as Downhole Desander Device”, in SPE Latin American and Caribbean Petroleum Engineering Conference, 2005-06-20. DOI: 10.2118/94673-MS

Rippl, H., Möglichkeiten der Feststoffabscheidung durch Massenträgheitseffekte in einer Drallströmung”, Bachelor Thesis, Technische Universität Wien, Vienna, 2017

Walton, I.C., Atwood, D. C., Halleck, P. M., Bianco, L. C., “Perforating Unconsolidated Sands: An Experimental and Theoretical Investigation”, SPE Drilling & Completion, Vol.17, No.03, pp.141–150, 2013, ISSN:1064-6671. DOI:10.2118/79041-PA

Zhou, S., Sun, F., Sand management of unconsolidated sandstone reservoir. Singapore: Wiley Blackwell, 2016, ISBN: 978-1-118-96189-6, http://onlinelibrary.wiley.com/book/10.1002/9781118961865

Zoback, M.D., Reservoir Geomechanics, 5. Print. Cambridge: Cambridge Univ. Press, 2011, ISBN: 978-0-521-77069-9