SMART SAND MANAGEMENT
RECONSIDERING THE BASICS

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Resumen

El enfoque tradicional para recuperar la arena sedimentada de los separadores de producción consiste en la resuspensión de los sólidos sedimentados con sistemas de inyección de agua seguido de la purga por gravedad del lodo diluido. Esto generalmente conduce a la reemulsificación, desequilibrios en el balance de agua y alteraciones de los patrones de flujo deseados en el equipo afectando los procesos de separación y, en última instancia, desalientan la operación del sistema de desarenado debido a las alteraciones ocasionadas en el proceso principal.

En general la maniobra de desarenado se realiza en modo batch y la frecuencia está determinada por cálculos empíricos o por experiencia operacional.

Además, la operación de desarenado requiere instalaciones adicionales para almacenar y tratar los efluentes generados, aumentando los requisitos de espacio, los costos de capital y operativos, y agregando complejidad general al proceso. El tanque de almacenamiento destinado a la recepción de los efluentes se convierte en el recipiente perfecto para descargar todo tipo de corrientes y drenajes, generando un efluente que es muy complicado de tratar.

El enfoque presentado aquí se basa en el concepto de "cuanto antes mejor" cuando se trata de separación, minimizando la generación de efluentes y la mezcla de corrientes complejas de tratar, lo que simplifica en última instancia los tratamientos requeridos.

Este trabajo técnico explicará por qué el enfoque tradicional es ineficaz y presentará un enfoque alternativo para tratar los sólidos producidos.

Basados en lo observado experiencias reales de campo, los resultados del enfoque tradicional para la gestión de los sólidos sedimentados en equipos son: una eliminación deficiente de sólidos, efectos de mezcla excesivos que conducen a la emulsificación y alteración de los patrones de flujo afectando la separación, etc. Estas observaciones se complementan con el desarrollo de un modelo computacional (CFD) tridimensional, multifásico y en régimen transitorio que brinda un mayor entendimiento del problema.

La solución S.M.A.R.T. presentada en este trabajo técnico se centra en la extracción continua de los sólidos sedimentados mediante un sistema de desarenado ciclónico integrado en un circuito cerrado con un sistema de deshidratación de lodos en línea para reducir el consumo de agua y la generación de efluentes que requieren tratamiento adicional.

Abstract

The traditional approach to reclaiming settled sand from production separators consists of the resuspension of the settled solids with sand jetting systems followed by gravity drainage. This generally leads to re-emulsification, water imbalances and alterations of desired flow patterns in the separator vessel which affect the separation processes and ultimately discourage the desanding operation due to the derived process upsets.

The desanding maneuver, in general, is done in batch mode and the frequency is determined by empirical calculations or operational experience.

Furthermore, the desanding operation requires additional facilities to store and treat the slop water stream, increasing space requirements, capital and operational costs, and adding overall complexity to the process. The added storage tank receiving the slop water becomes the perfect receptacle to dump all classes of streams and drainages, generating a slop stream that it is very difficult to treat.

The presented approach is based upon "the sooner-the-better" concept when it comes to separation, minimizing generated effluents and streams mixing, consequently simplifying the required treatments.

This paper will explain why the traditional approach is ineffective and will present an alternative approach to deal with the produced solids.

Based upon actual field experience and supplemented by a CFD transient 3D multiphase model, the observed results of the traditional approach are: poor solids removal, excessive mixing effects leading to emulsification and flow patterns disruption causing separation upsets.

The proposed S.M.A.R.T. solution focuses on the continuous removal of the settled solids utilizing cyclonic jetting systems in a closed loop with an inline slurry treatment system to reduce the motive water consumption and the generation of effluent streams which require additional treatment.

STANDARD DESANDING SYSTEMS

In general, the desanding systems, when provided in the separator vessels, have to be defined with few, if any, valuable data regarding solids characterization and concentration. Perhaps this is one of the main reasons why, during the design phases of the projects, solids management is frequently overlooked entailing severe consequences which endure along the life cycle of the assets incrementing operational and maintenance costs.

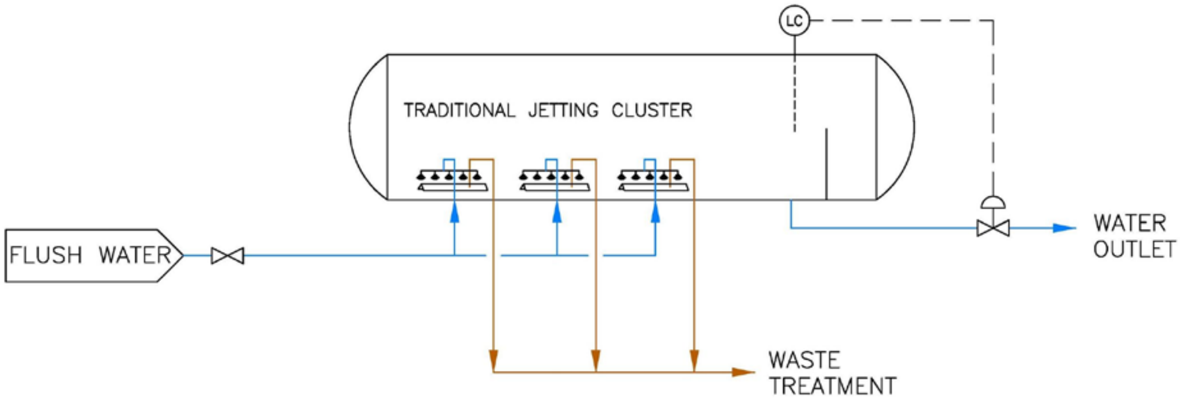
There are few published references or guidelines about the design of the desanding systems, accordingly it is not uncommon that the design aims are merely economical therefore focalized in reducing the number of involved nozzles, valves, controls, internal distributors and spray jets. Moreover, during the engineering phases, most of the focus is set in the main features of the separators so frequently desanding systems are overlooked.

The above contribute to the fact that little attention is focused on the development of effective desanding systems. Therefore, large quantities of settled and compacted solids are frequently revealed in the separation equipment when vessels are opened during plant turnarounds. These occurrences are observed even when separators are equipped with "theoretically" effective desanding systems.

The pictures below illustrate units provided with standard desanding systems at diverse fields and different operational functions where desanding systems were clearly ineffective.




The typical design of desanding systems is composed by longitudinal pipes with wash jets or perforations to resuspend the settled solids and sand pans with drains to collect and evacuate the slurry from the vessel. The diagram below schematizes the concept:
It is beyond the purpose of the present paper to serve as a design guide of the good practices for the



proper assembly of conventional sand jetting systems. All the information displayed in the paper is based upon the considerations that the sand jetting systems are properly designed and constructed accordingly.

Operators are probably well acquainted with the common process upsets derived from the use of standard sand jetting systems. Nevertheless, for the sake of completeness some of the typical operational disadvantages are listed below:

- **Water Consumption:** It requires a relatively "clean" source of water to resuspend the settled solids. The required flow rate will depend upon the size of the separator, the number of required pipe sections and the type and quantity of spray jets utilized. For instance, in a 25 m LS / LS x 4 m OD FWKO operating at around 3 bar, 7 sections of pipe containing 28 flat spray nozzles in each section are required for sand jetting. This arrangement requires a clean water source providing around 36 m3/h @ 12 bar, therefore, if each section is cleaned at least once per day for 1 minute it will consume 4,2 m3 of clean water.

- **Disruption of separator flow patterns:** In three phase separators the injected water and the purged slurry flow rates generate a water disbalance in the unit disrupting the interface dispersion band affecting the intended flow patterns therefore disturbing the separation process. Moreover, the flow patterns developed by the jets are an additional factor contributing to the disruption of the intended flow patterns in the separators.

- **Re-emulsification:** Re-suspended solids interfere with the separation process and act as emulsification agents. Therefore, to reduce the process perturbations during the desanding maneuver the system is purposed to operate in batch mode cycles for short periods of time, this is one of the reasons why the system is ineffective to remove large amounts of settled solids.

- **Diluted effluent slurry**: The gravity flow of the drained slurry between the vessel and the discharge point is determined by the pressure differential between those points, generally resulting in high flow rates, limiting the desanding cycles to control the volume of generated effluents, in return this impact on the effectiveness of the desanding cycles. Moreover, the design specifications for the desading cycles in general involve at least a desanding cycle per day or shift of a few seconds per section per unit, therefore the generated effluent volume increases rapidly distracting operators from their main operational tasks due to the need of reprocessing large volumes of a diluted slurry. For instance, in the same example as before, a FWKO of 25 m LS / LS x 4 m OD, provided with 7 x 2" nozzles to drain the fluidized slurry, the slurry flow rate could vary substantially depending on many factors such as: operating pressure of the FWKO, liquid level in FWKO and discharge vessel, distance between the two points and piping arrangement in between, present accessories, etc. Assuming some of those variables, which are dependent of each particular system, the established discharge flow rate could easily change from around 50 to 200 m3/d, therefore if the system is operated at least once per day and each drain is opened for around two minutes, then the discharged volume of slurry could easily vary between around 10 - 50 m3.

- **Significant impact on ancillary services:** At the beginning of the draining cycle, the discharged slurry could present a peak concentration that rapidly decreases to lower levels, therefore large volumes of water are purged to transport in average low concentrations of solids. The peak concentration could be as high as 50 % [v/v], when the unit is routinely cleaned, but decreases rapidly few seconds after the purge initiates. Moreover, the slurry treatment facilities also receive flow streams originated in different unit operations of the process plant, hence very often long pipe runs are required to transport the slurry and this pipe system has to be designed accordingly to avoid clogging and erosion. Consequently, adequate additional facilities for transporting, storing and further treatment of the resulting highly diluted slurry are required, increasing the footprint, CAPEX and OPEX of the project.

- **Effluents recycling to main stream line:** The cost of the required facilities to receive and treat the slurry are generally overlooked until it's too late in the project, thus more often than one might suspect the expenditure is limited merely to a storage vessel to receive and recycle the stream back to the process generating a full set of derived upsets due to the reconcentration cycles of solids and chemicals.

- **Localized solids removal:** depending on the amount of drains, the pipe sections, the quantity, type and flow pattern of the selected jets; different clear area patterns are observable. Generally, the pipe sections, quantity of jets and drains, are kept to a reasonable minimum to minimize the required valves and associated pipework. Moreover, to reduce the water consumption and the operational disruptions due to the disbalances generated by the water injection and the high instantaneous flow rates established by gravity flow purging cycles, the frequency and / or extension of the cleaning cycles is also limited to a minimum. This results in large areas of the vessels that are not thoroughly cleaned by the desanding system.

- **Ineffective in services with high solids loading:** operational experience has demonstrated that in services subjected to high solids loading or when the system is not frequently operated and a thick layer of solids are allowed to settle, then the system efficiency diminishes dramatically and eventually gets clogged, moreover it is not uncommon that jets stall under a layer of sand.

- **Low Usage:** The key process indicators for which operators are evaluated are focused in the treated oil and water outlet streams and generally not related to the sludge treatment, therefore the resulting process upsets produced during the desanding cycles discourages its operation. Over time the low usage of the systems leads to solids accumulation conforming a compacted layer on the bottom of the vessels reducing even more the effectiveness of the desanding system.

As a result of the described operational issues and its economic impact, standard desanding systems, have frequently become a feature that increases the cost of the separators but due to its poor performance is seldom used in the operation.

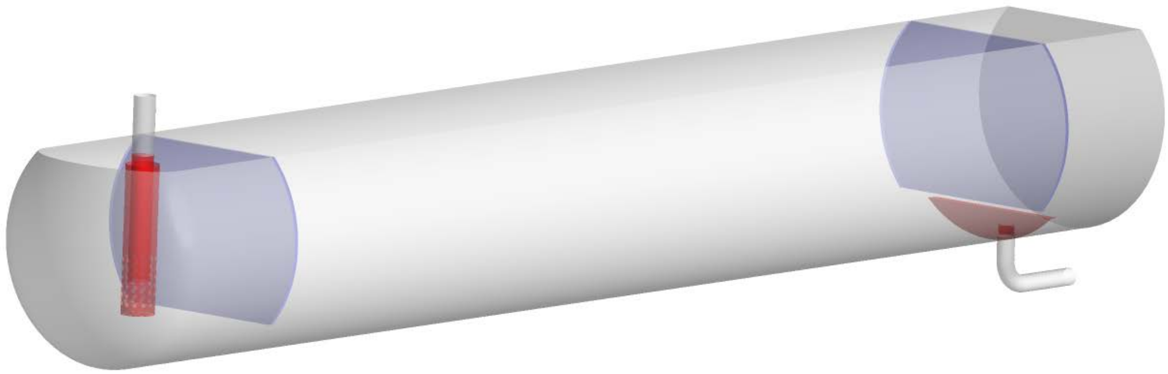
The previous arguments bring about the necessity of readdressing the solids management systems thoroughly to develop alternative solutions which could provide a smart and simple workaround to the described problems.

In the following section, the main results of the CFD modeling of a standard desanding jetting system are presented. The simulations were developed to match what was actually observed in several separators operating under real field conditions, therefore are useful to provide a thorough understanding of the settling mechanisms, preferential areas of deposition, induced perturbations and desanding effectiveness of a standard sand jetting system.

SOLIDS DEPOSITION SIMULATION

Solids settling was analyzed through 3D transient multiphase CFD simulation to determine the settlement patterns and evaluate preferential cleaning areas and cleaning periodicity.

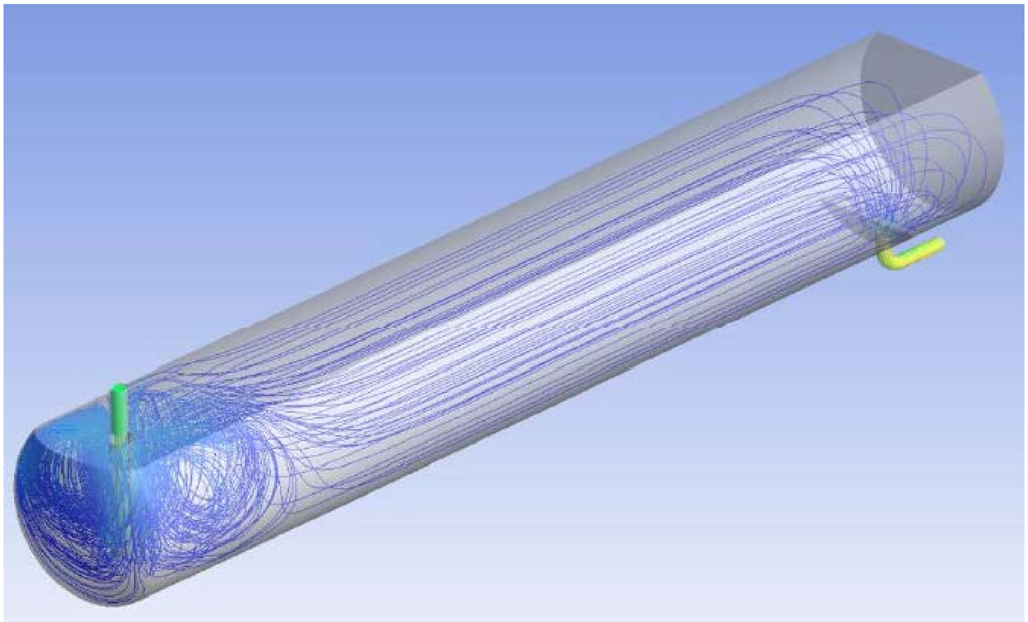
A 2800 mm OD x 17600 mm T/T FWKO with an inlet distributor and perforated normalizer baffles with 40% free area was the base case for the simulation. The perforated plates were considered as porous jumps to simplify the mesh. The cleaning system was not considered in this stage for simplicity. Original mesh contained 1.5 million elements, with prismatic, tetrahedral and hexahedral elements. Tetrahedral elements were further converted into polyhedral elements. A finer meshing was required in the inlet and outlet sections.



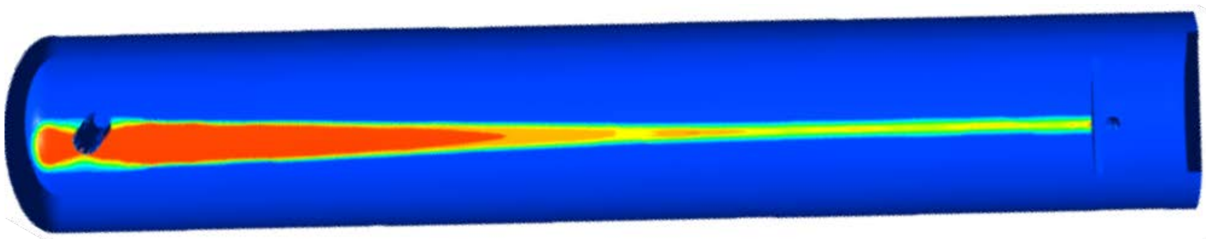
A Euler-Euler model was used, considering the fluid as mainly water with a density of 1,000 kg/m^3 and a viscosity of 1 cP. The model assumed solids particles of 800 μm, to match the average size of a particle distribution curve from a CHOPS field with particles ranging from 100 μm to 1500 μm, and a density of 2,040 kg/m^3 due to an impregnated oil layer.

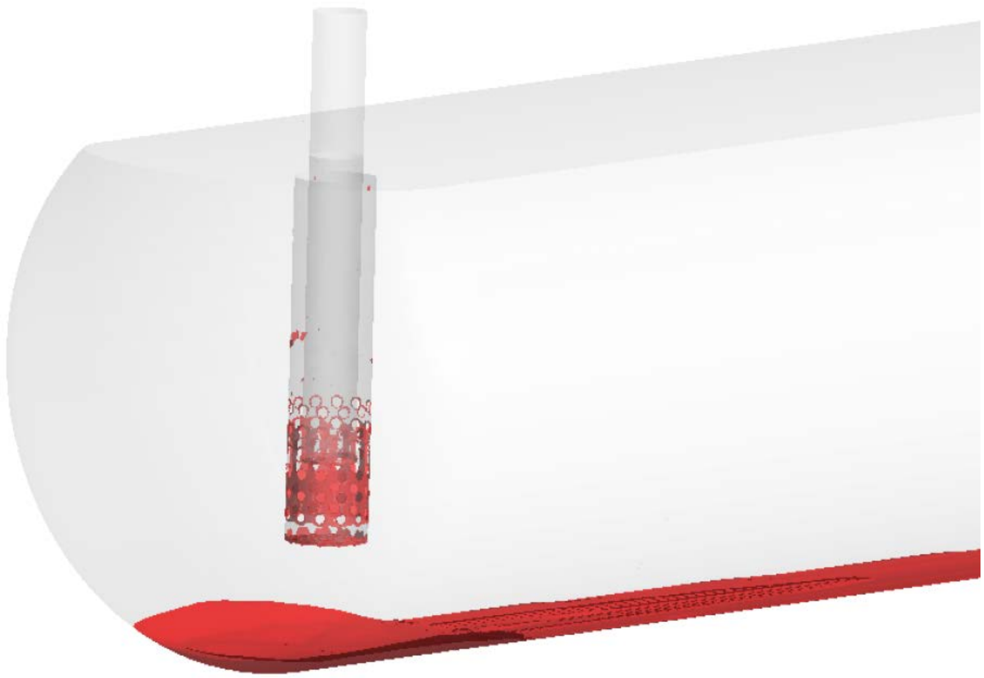
The design basis for the model could be easily altered for different conditions and the simulation could be reran to determine different settlement patterns to match the solids characterization. In the presented case the model was developed to match the observed settlement patterns in the equipment under real operational conditions in the field environment.

Turbulence was modeled with SST and the fluid was considered as incompressible with isothermal behavior. Boundary conditions were correspondent with 4,000 m^3/d inlet flow.



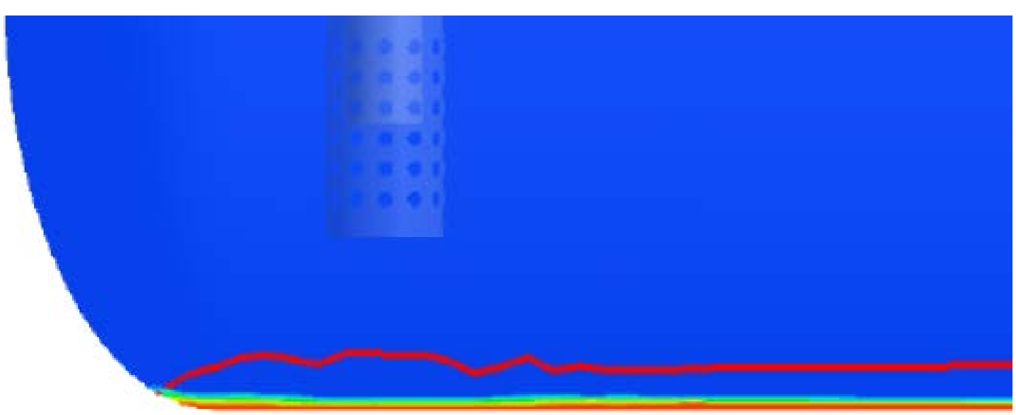
Streamline analysis shows high turbulence in the inlet zone and stability between the perforated plates. This stability is of paramount importance for the separation process.





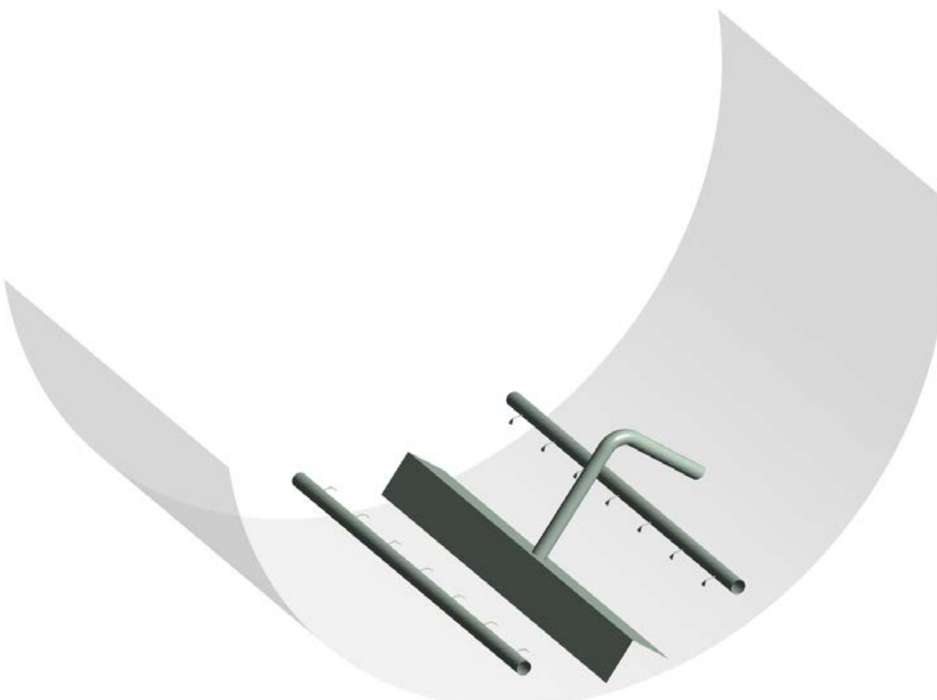
Solid's volume fraction shows a preferred settling zone near the inlet distributor but well into the stability zone between the perforated plates. This preferred settling zone will vary with different solid's particle distributions in the inlet stream.

The settling rate can be obtained from this simulation, which can be used to determine the cleaning cycle required for this particular process. The following figure shows the accumulated solids height after 8 hours of operation, equivalent to 0.65 m^3 of sand, obtained from projection of simulation result.



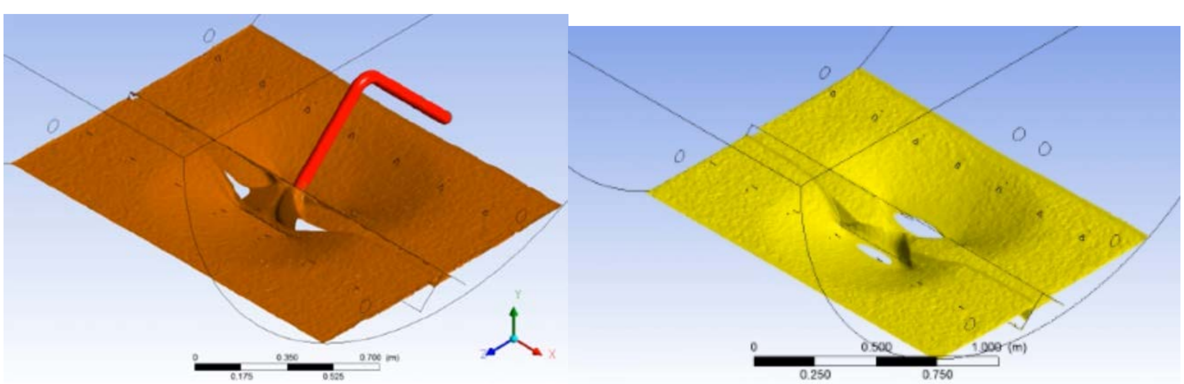
SOLIDS REMOVAL SIMULATION

By setting focus on a fraction of the separator the solids removal efficiency and flow patterns disruption can be analyzed. A layer of settled solids can be used as an initial condition for the simulation. To account for adjacent sections, a periodicity condition is set at each side of the control volume. The original mesh contained 13.6 million elements with tetrahedral elements. Tetrahedral elements were further converted into polyhedral elements. A finer meshing was required in the jet's vicinity.

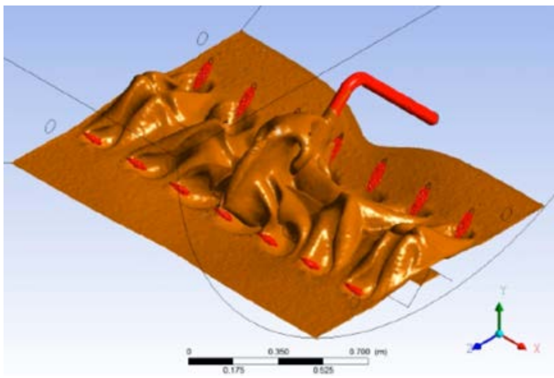


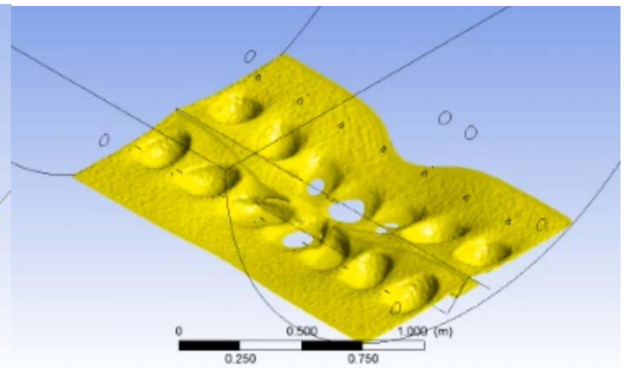
The desanding maneuver was modeled considering an initial period of solids extraction solely by gravity drainage established by the differential pressure between the separator and the sump followed then by a period which incorporates the injection of water jets. During the whole operation the slurry nozzles were maintained opened with an outlet flow rate of 50 m^3/h.

The following figures illustrates the initial cleaning period in which the solids are removed from a small area close to the outlet nozzle and no solids resuspension is observed.



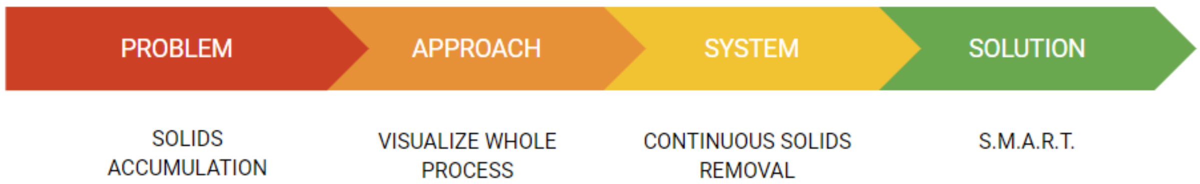
When the jets are incorporated, during the second period, the solids removal area is increased, but the small settled solids are resuspended in the fluid, in detriment of the solid removal efficiency during the cleaning period and favoring emulsification. In addition, the high velocity near the jets, which present a flow rate of 0.95 m^3/h each, can induce the formation of mechanical emulsions that furthermore decrease separation efficiency.



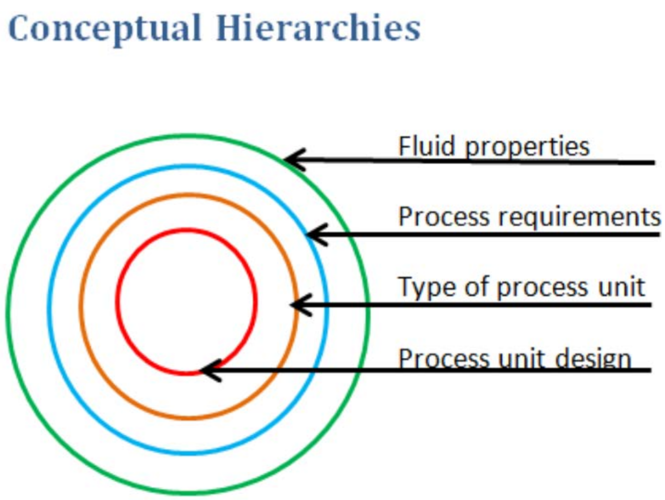


After finalizing the jetting cycle, it could be observed that the sand removal system is only effective in an equivalent circular zone of 120 cm diameter centered in the exit nozzle, composed by smaller circular areas around the zone impacted by each jet.

PROPOSED APPROACH



The **S**and **M**anagement **A**ctive **R**emoval **T**reatment is based on the following principles to be applied hierarchically:



A. *Know Fluids Properties:* understand thoroughly the media comprising of all its elements.

B. *Know Process Requirements:* apply basic science (physics, thermodynamics, chemistry) to define the process parameters, KPIs and represent the system accordingly.

C. *Define Process / Equipment:* elaborate the adequate process and integrate it with the proper unit operations.

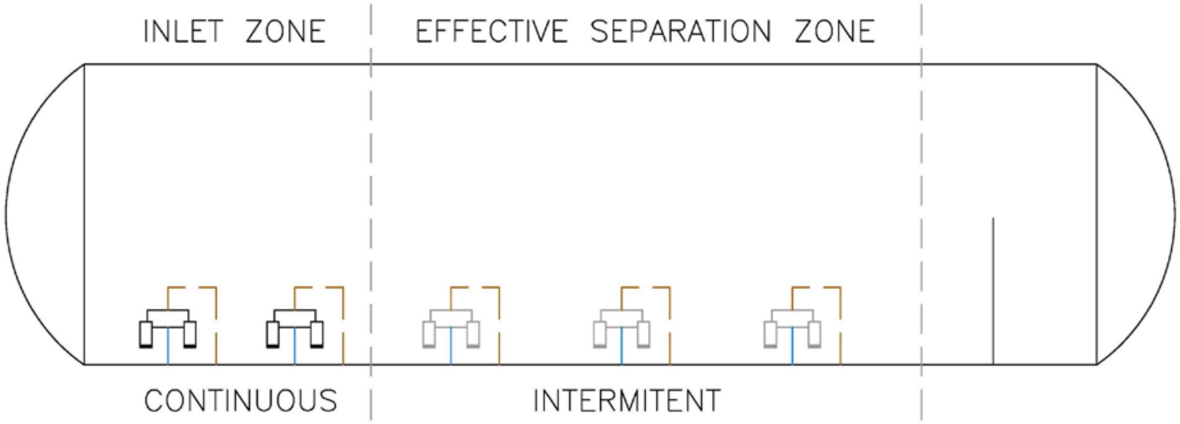
D. *Design Process Unit:* design the unit/s for the particular problem

Where A. and B. define the boundary conditions and are fixed parameters that cannot be changed; C. and D. are the areas of optimization design and engineering creativity.

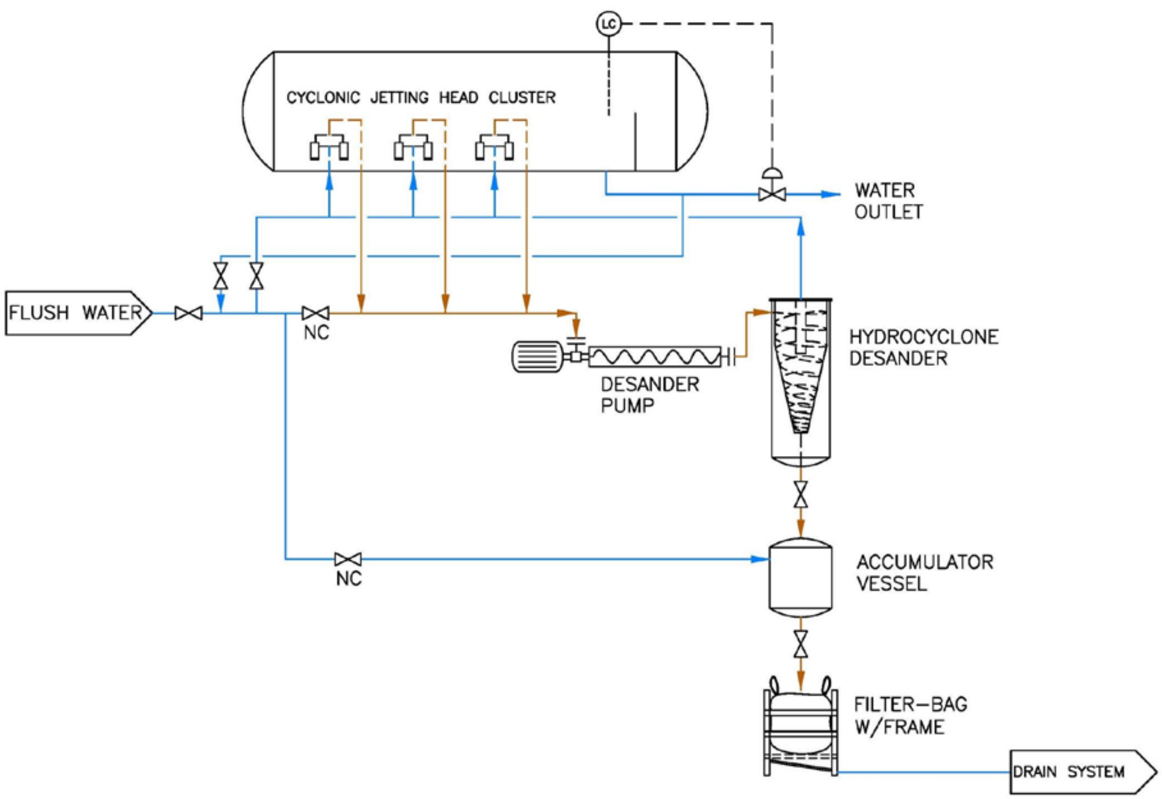
Many times, the projects begin the other way around at D. with the requirement of a determined process or equipment proposed to solve a particular problem without fully assessing A. and B. which determine the media and the physics phenomena which in turn may dramatically impair the selection of certain process alternatives.

Applying the principles of the proposed S.M.A.R.T. approach, an upgraded desanding system based on a continuous cleaning loop which can effectively remove solids without disturbing the established flow patterns of the separator was developed.

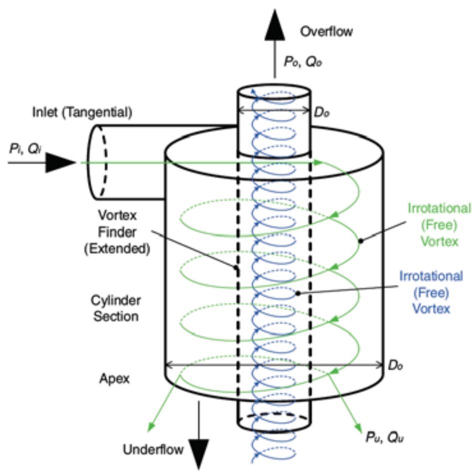
As illustrated in the figure below, the system is focalized to continuously remove the solids from the preferred settlement area to prevent solids accumulation and transport inside the vessel, therefore minimizing its impact on the process. When required, a secondary cleaning area could also be implemented to clean intermittently secondary settlement zones where solids are transported due to separator flow patterns.

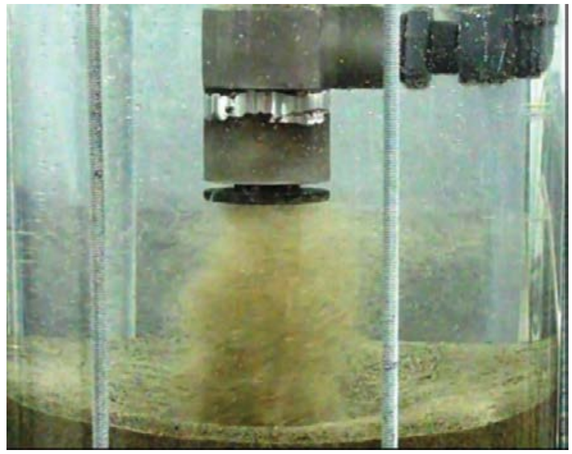


The attached figure shows schematically how the system is composed, illustrating its main features. The loop could be subjected to minor changes to adapt to different process configurations, capacity, performance or space requirements. Moreover, the continuous or intermittent cleaning areas can be modified according to the observed settlement zones or in cases where no high solids loading is expected the whole unit could be cleaned in a batch manner.



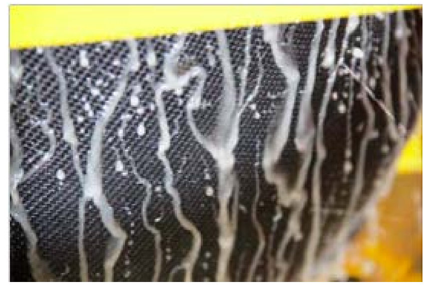
The upgraded desanding loop is based on the use of more efficient cyclonic jetting devices to reclaim the settled solids from the vessels and an external pumped single cone desander operated in a closed loop at a constant flow rate to separate the reclaimed solids and return the clarified water to the vessel (following images courtesy of ***eProcess Technologies LLC***)





The separated solids in the desander are temporarily stored in an accumulator vessel and are intermittently discharged to a filter bag system for dewatering.

The sand removal loop is supplemented by a sand dewatering package to effectively remove the solids from the system, therefore preventing the solids from concentrating in the process due to recycling streams with high content of entrained solids and chemicals. The pictures below illustrate the solids dewatering system (courtesy of ***eProcess Technologies LLC***).



When required for environmental purposes a sand cleaning loop to maximize the hydrocarbons removal from the solids could also be implemented as an addon to the system.

This packaged system presents several advantages which are described below:

- **Proven and standard technology:** the system is based on the use of proven and standard technology, regularly utilized in the industry for similar applications, consequently there is no "learning curve" or qualification processes. The key components conforming the package are: cyclonic jetting heads, progressive cavity pump, single cone desander and filter bags. The main difference relies on how the components are arranged and positioned in the process and the operational mode to continuously remove solids in high solids loading applications, therefore, preventing its accumulation in the separation equipment.

- **Water usage:** the system operates in a closed loop, therefore there is no need for an external stream of treated water for the resuspension of the settled solids. Besides flush water is solely required for cleaning and refilling the sand accumulator and / or the interconnecting pipes of the closed loop and also when operated in batch mode for a short period of time for slurry dilution when the cycle initiates. Moreover, flush water usage is minimal as the involved volumes are generally small, depending fundamentally on the sand accumulator capacity which depends on the concentration of solids at the inlet of the separator and the required hold up time between discharges. In any case the flush water could also be supplied from the system itself to reduce the consumption from external sources, with the additional benefit that there are no issues related to chemical compatibilities between different water streams or any added chemicals.

- **Water balance:** in the normal operation mode the system functions in a closed loop, therefore the water fed to the solids dewatering system returns back to the separator vessel through the cyclonic jetting device and is utilized for fluidizing the settled sand on the bottom of the vessel, hence there is no water disbalance in the separator.

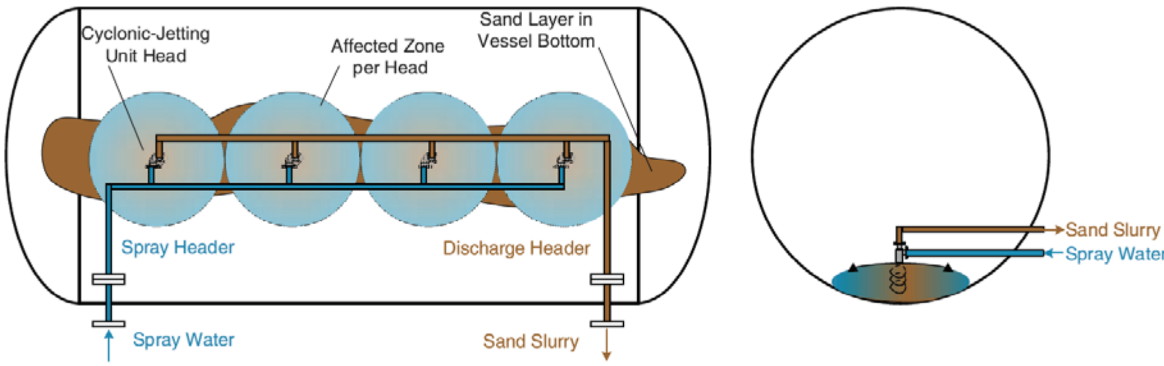
- **Interface disruption:** the cyclonic jetting heads provide a 360° jet pattern with a vertical spray angle greater than 90° that gently fluidify the settled sand, minimizing interface disruptions at the separator. This eases the interface control throughout the operation, even when the batch mode is utilized. The sand settling pattern in each equipment is evaluated to determine how the clusters are positioned and which zone is operated continuously (when required) to minimize flow pattern disruptions, also flow normalizers are positioned accordingly wherever it is required.

- **High solids loading application:** the system is prepared to operate even when submerged under a layer of settled sand, therefore it could be implemented in high solids loading applications or when operated in batch mode even if a thick layer of solids were allowed to settle.

- **High efficiency:** the whole system is designed to perform at the peak efficiency of the cyclonic jetting heads and the desander which also operates at a constant flow rate avoiding fluctuations which could affect its performance. The pump provides the required pressure drop for the desander and the cyclonic jetting system so no additional control loops are required. The spray flow of the cyclonic heads is delivered 0.7 - 1 bar above the operating pressure of the separator and the desander will run from 0.9 - 1.3 bar therefore the pump should supply differential pressure of around 2 - 3 bar approximately.

- **Automation:** the system is easily automated using on - off motorized control valves to initiate - finalize the cleaning cycles of the different zones of the unit and also for the flushing operations.

- **Covered Area:** the characteristics and flow pattern developed by the cyclonic jetting systems are capable of cleaning wider areas compared to traditional sand jetting systems. Each cyclonic head is capable of cleaning and area below and around the head with a spray angle greater than 90° and an optimal elliptical pattern of around 120 cm, therefore a larger surface is covered in comparison with typical flat spray nozzles commonly utilized in traditional desanding systems.



- **Solids Dewatering:** the provided filter bag system facilitates the solids dewatering, concentrating the discharged slurry from the accumulator, therefore reducing the weight of the reclaimed solids that could be transported to a safe location for final disposal while the drained liquids are collected in a sump and recycled to the process.

- **Easy to Scale:** the size of the package will depend upon the quantity of solids that need to be removed, the dimensions of the vessels where the system has to be deployed, the available space and the requirements for solids storage as a slurry in the accumulator or as dewatered solids in the filter bag cluster. Depending on those parameters, then the question reduces to the number or size of the individual components such as: cyclonic jetting heads clusters, PCP pump, single cone desander, filter bags clusters.

- **Ancillary Services:** the system requires electric power supply for the pump. Motorized valves could be supplied either with pneumatic or electric actuators. The main utility service is flush water which could be supplied from an external source or in certain cases, such as three phase separator applications, managed from the separator water discharge.

- **Packaged:** the system is easily packaged as all the external elements (pump, desander and accumulator, filter bag cluster) are relatively compact. Depending on the required capacity larger units or additional modules in parallel could be utilized.

CONCLUSIONS

It is typically observed in the field that effluents are stored in dedicated vessels and boosted with chemicals as a sufficient treatment prior to recycling the fluids back to the process. However, experience proves that frequently this approach is not enough and many times it ends up generating more complex problem.

As described in the present paper, solids management should be an integral part of the conceptual phase of any strategic project.

Key relevant points to thoroughly engage the new design concept are briefly outlined below.

- **Solids management:** Solids accumulation in process equipment is a normal but frequently overlooked problem until the facilities have to be shut down for cleaning. This is a costly and ineffective procedure; therefore, solids management and disposal are of paramount importance for sustained field operations and should be thoroughly addressed from the initial stages of the engineering designs.

- **Holistic approach:** One of the key aspects for successful solids management is visualizing the whole process as opposed to focalizing in the unit operations. For instance, if the solids extraction devices are properly designed and diligently operated, but no adequate facilities are provisioned for reclaiming and eliminating the solids from the process, then sooner or later a concentration process of the recycled solids will impact on the entire process affecting among other things the treated oil and water quality.

- **"The sooner-the-better"**: Experience demonstrates that, whenever possible, the most effective approach to effluents treatment is reclaiming solids at the earliest possible stage, avoiding its transport along the production facilities with all the derived problems and complexities added up due to the aging and concentration of contaminants, chemicals, etc. It is also generally more simple treating reduced volumes of sludge at the time it is generated as opposed to accumulating large volumes over time and left to rest until the process gets out of hands or the treated fluids quality is severely impacted. Moreover, any smart sand management philosophy should be defined at the early conceptual stages of the projects which is when there are more degrees of freedom and the least impact on the project schedule and economics.

- **Characterize and Classify:** Separate the effluents according to its nature and avoid mixing or collecting streams of diverse nature and composition in a "multipurpose" sump. Due to its apparent simplicity, it is generally a tempting solution to collect the effluents generated in different stages of the process, resulting in a complex mixture of emulsions, chemicals and solids extremely difficult to treat. In general terms, effluents from the water treatment process should be managed separately from the effluents of the oil treatment process. i.e. Direct mixing of the slurry from the desanding process of a FWKO with the skimmed discharge of an induced gas flotation unit could be devastating for any effluent treatment process.

- **Conceptual Hierarchies:** Some times, wishful thinking leads us to believe that effluents could be easily managed in a unique and singular piece of equipment, by adding specialty chemicals or simply by recycling the stream back to the process, nevertheless the rules of physics always prevail. Therefore, any thorough approach should take into consideration the nature of the effluent, a sound process utilizing the proper equipment and the adequate chemicals.

As engineers, we have to adjust to the fluids and not expect the fluids to adjust to us.

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