Centrifugal pumps in a nutshell

Nutshell filters are used to separate oil from water, but without a properly engineered pump the process will not be optimal

One of the challenges faced by the offshore oil and gas industry is cleaning water contaminated with oil produced by the drilling operations so that it can be disposed of in accordance with environmental regulations. This is achieved on a platform or a floating production, storage, and offloading (FPSO) vessel using a separation package. The final cleaning phase in these packages, just before the water is returned to the sea or re-injected into the well, can use nutshell filters to capture any last remaining oil.

For nutshell filters to work efficiently, it is crucial that the mixing of oil and water must be minimised, preventing restructuring and emulsification during the transfer of the fluid through the separation system. Amarinth, a UK-based pump manufacturer, has worked closely with a number of separator package providers, including Larsen & Toubro, Axsia Serk Baker, and most recently Al Energy Solutions, designing centrifugal pumps that exhibit low shear properties to minimise emulsification of the produced water being presented to the nutshell filters.

Oil is trapped by the nutshells

During the extraction of oil and gas, quantities of water are also produced during the process. This water is contaminated with oil, which must be removed before the water is returned to the sea. A water treatment plant on the platform removes the oil from the water and the final stage of this process uses nutshell filters, which are very effective at removing the suspended oil from the water.

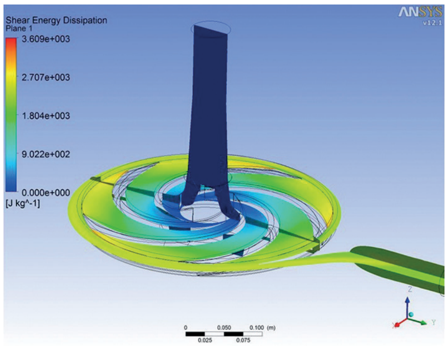
Oily water is introduced into the vessel and distributed to ensure even flow throughout the vessel. As the water flows through the vessel, the nutshell media, which usually consists of walnut or pecan shells, absorbs the oil allowing cleaned water to exit the vessel. Nutshell filters typically clean oil to less than 5mg/l, easily exceeding, for example, the European OSPAR regulations of 30mg/l oil concentration for produced water that is to be returned to the sea. Over time, the oil accumulates on the media and so, to regenerate the filter media, a backflow of produced water is established and the nutshell media is agitated, releasing the filtered oil, which is pumped safely away.

The effects of shear

Generally speaking, centrifugal pumps shear liquids and the higher the speed of the pump, the more shearing will occur. When pumping produced water into nutshell filters, the emulsification of the oil and water produced by this shearing would render the nutshell filters ineffective.

Shearing occurs along a boundary layer when the velocity of the fluid is changed, creating a velocity gradient across the fluid. This causes shear stress between the slower and faster moving flows in the liquid. In a centrifugal pump, the shearing effect is highest at the impeller and it is the resulting turbulence in a fluid of oil suspended in water, which causes the oil and water to emulsify.

Traditionally, low speed progressive cavity (PC) pumps have been used in low shear applications as they emulsify the oil and water much less than centrifugal pumps. However, as operators pump more oil, the amount of produced water increases too. To handle larger volumes of fluids, PC pumps have to increase in length to perhaps 3 or 4m, and so there is a finite limit to their workable capacity, which is comparatively small. On an offshore platform or FPSO there is simply not enough space available for the size of PC pumps that would be required to handle the larger volumes of produced water that need processing.



Modelling shear energy

Visualising the flow

The oil and gas industry has therefore been at the forefront of the need for compact, highly-efficient pumps for separation systems that will not shear the produced water. Unfortunately, there is no international standard or definition defining "low shear". The end-user specification for a pump will usually only include, for example, the flow rate and an estimation of the parts per million of oil in the water, and it is down to the manufacturer to design a pump that exhibits the necessary characteristics to perform the required duty.

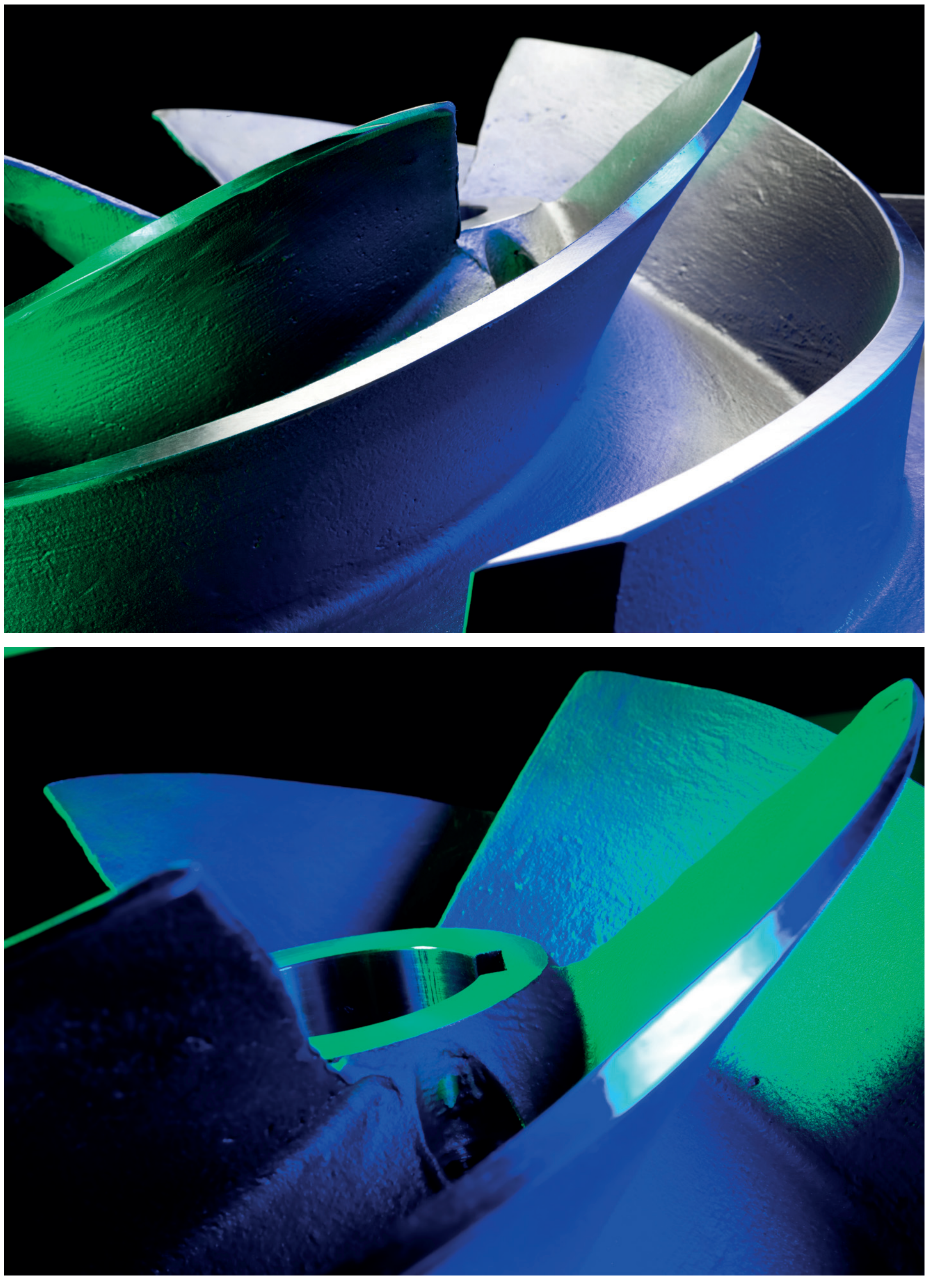
The challenge of using centrifugal pumps for nutshell filters is that to minimise the shearing of the fluid and prevent the emulsification of the oil and water, it is generally accepted that the pump must be run at less than 1800rpm. Additionally, limiting the pressure the pump generates during selection and ensuring the pump efficiency is greater than 75%, all contribute to the fluid flow becoming less disrupted as it passes through the pump and through the impeller vanes. However, running the pump too slowly can increase internal recirculation and result in cavitation, thereby not only causing the unwanted emulsification of the oil and water as the fluid exits but also reducing the pump's life in the long term.

In response to this, Amarinth approached the use of centrifugal pumps in low shear applications afresh. Using the latest in computational fluid dynamic (CFD) modelling, Amarinth's hydraulic design engineers investigated how to reduce the shearing action of impellers in centrifugal pumps at higher flow rates. Using CFD, they were able to visualise the fluid flow through the pump volute and impeller to produce a design that could maintain efficiency and reduce shearing. Experimentation determined that the key ratios to reduce the shearing action on the fluid are the inlet and outlet areas and matching the outlet area to the volute throat area.

Using these techniques, Amarinth's engineers deduced that:

- Turbulence is significantly reduced through controlled changes in fluid velocity and smooth changes in direction
- Optimising the vane tip radius at the impeller inlet can create fluid stagnation at the blade tip, which promotes streamline non-turbulent flow into the impeller channels
- Turbulence and shear can be further reduced by matching the impeller vane profile to the casing volute and cutwater design minimises recirculation and exit wake from the vane trailing edge
- Minimal disruption (eliminating cavitation) of the pumped liquid can be achieved by selecting pumps in the preferred operating range – often pumps in the allowable operating range will work equally well
- Minimal shear at the impeller surface can be achieved through an enhanced surface finish of the impeller

Using this knowledge, combined with computer-aided engineering tools and vane creation software, the engineers were then able to design new impellers and vanes and optimise the geometry of the water passages through the impeller to minimise shear. Stress analysis was also carried out on the new impeller and vanes to ensure that the design was still capable of handling the dynamic loads and mechanical stresses.



Amarinth's custom-designed centrifugal pump impellers

High volume, low shear centrifugal pump

Amarinth has now supplied its API 610 high volume, low shear centrifugal pumps to separation package providers for use on platforms and FPSOs around the world. Manufactured in a variety of materials, usually super-duplex, the low shear pumps can be provided with shrouded or open impellers. The open impeller design, used when the pumped fluid contains high concentrations of solids, creates further demands on the design engineers than a shrouded impeller as shearing can happen more readily on the open impeller vanes.

To minimise the footprint and fit within the confines of the platform or FPSO, Amarinth has also designed the pumps knowing that there will be a need to provide bespoke solutions, including close coupled pumps with horizontal and vertical mounting options and seal support systems, all of which the company can now deliver on the short lead-times often demanded by the industry. State-of-the-art software continues to assist the Amarinth hydraulic design team in modelling fluid behaviour in fine detail and predict with increasingly high degrees of accuracy how mixed fluids such as oil and water will flow through impellers and pumps. This knowledge enables engineers to design more cost-effective solutions to meet the demands of the oil and gas industry, including the use of centrifugal pumps in new applications.

For more information:
This article was written by Andrew Foreman, head of technical engineering at Amarinth. Visit: www.amarinth.com