IMPROVING SUBSEA PUMPING

Sven Olson, Leistritz, USA, explains why multiphase twin-screw subsea pumps are an efficient technology for boosting ageing, low energy reservoirs and long tie-backs.

Twin-screw multiphase pumps have now been in service for over 20 years, primarily in offshore topside and onshore applications, with installations all over the world. The primary objectives, such as reducing facility costs, boosting low pressure wells, reducing flaring and venting, and acting as a flow assurance tool, have all been met. Operators have seen their production costs – especially for mature reservoirs – drop and at the same time improved revenue streams from increased production and higher total recovery rate. The twin-screw technology with its special features and advantages is attracting more and more interest from the market.

Increased recovery from mature assets

Changes in deepwater oil and production strategies in recent years have driven operators away from massive billion dollar investments in topside and subsea infrastructure and towards a more balanced strategy, focusing on mid and late life assets. These assets, referred to as brownfields, have increased the emphasis on utilising existing structures and facilities more efficiently to create acceptable financial returns despite low oil prices. Investments in large offshore production facilities at current (and foreseeable) oil prices do not seem to be the way the market will go. Most existing process facilities are oversized and could benefit from more production. With excess available process capacity, many operators are well equipped to go after reservoir life extension and longer tieback projects. An often-used example is the present low recovery rate in the Gulf of Mexico, which often sees operators leave 60% of recoverable hydrocarbons still in place at abandonment. The rate for the North Sea is much better, with some operators now striving to leave no more than 20 - 30% of hydrocarbons in place at the end of production.

Oil prices, which are forecasted to stay depressed for the near future, have driven operators and asset holders to

maintain and even increase the production from subsea reservoirs in their mid and late life. However, traditional technologies for enhanced production are not always sufficient to reach these goals. The brownfield production strategy will require new boosting technologies to be successful and subsea twin-screw pumps offer distinct advantages both over other subsea pump technologies and over conventional ways to produce oil and gas.

The objective of maximising the utilisation of large existing topside capital intense process facilities and delaying decommissioning and abandonment has to be combined with a comprehensive plan to increase production through pressure boosting. As the reservoir pressure decreases with age, added boosting is needed to overcome the static lift through the production riser, first stage separator arrival pressure in addition to flow line losses. Changing reservoir conditions can result in higher water and gas production, which are adding to the challenges. Water flooding and gas lift are traditional methods, but are often inadequate for getting hydrocarbons to surface efficiently.

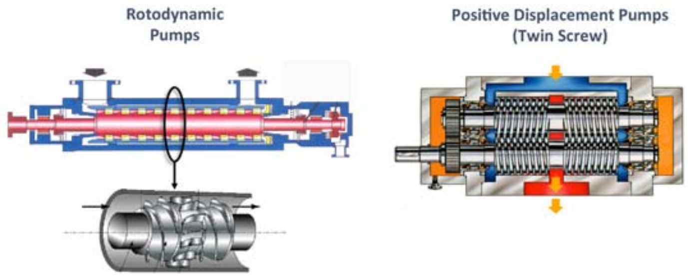


Figure 1. *Subsea boosting technologies.*

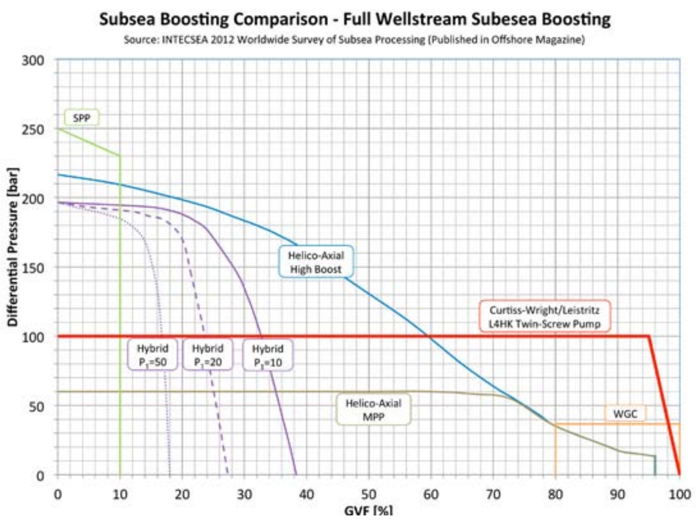


Figure 2. *Subsea boosting comparison.*

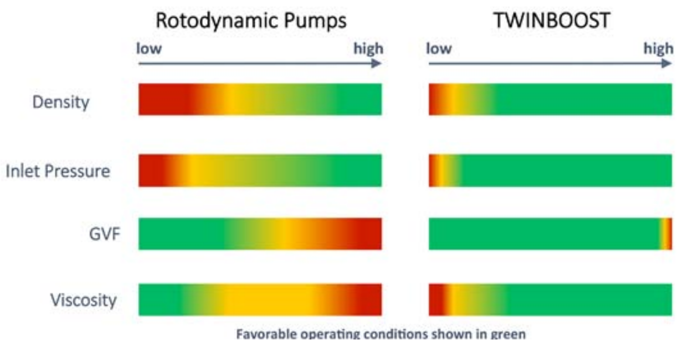


Figure 3. *Operating differences TwinBoost and Roto-dynamic technologies.*

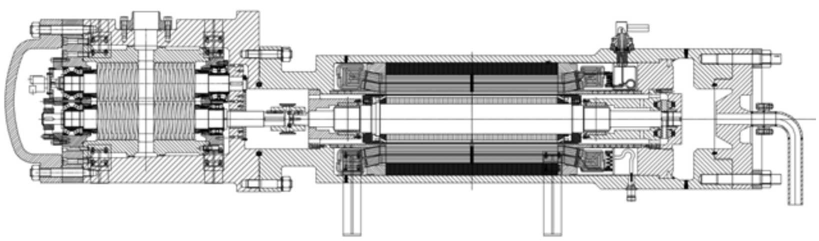


Figure 4. *Subsea canned motor-pump.*

Subsea pressure boosting, alternative technologies

Pressure boosting using subsea multiphase downhole ESPs or mud line pumps is the next step, and can be applied as a complement or as an alternative to the more traditional methods. However, production from a reservoir in mid or late life is very different to initial production and can be a complication for certain style pumps referred to as roto-dynamic pumps. Examples of such pumps are centrifugal, hybrid or helico-axial style pumps, which may work very well in steady state early production. The change in water cut and gas production combined with declining reservoir pressure becomes a challenge to the roto-dynamic pump and can result in unpredictable behaviour and production disturbance.

The multiphase boosting alternative is found in the positive displacement pump family where twin-screw pumps are widely used in oil and gas upstream applications.

The two principles are shown in Figure 1. The different designs result in different operating envelopes or operating windows as can be seen in Figure 2.

Twin-screw and roto-dynamic pumps

The subsea hybrid and helico-axial pump technologies have been around for some time and are installed in several locations around the world. They normally work well during initial production, but suffer from limitations when adapting to changing flow and reservoir conditions. The pump operation is limited to a defined envelope or window in which its hydraulic performance is predictable. However, once outside the limits of the window for which it is designed to operate the flow and pressure may drop off substantially, the pump may vibrate, surge or stall, which can cause production to be severely disturbed. The operator has the option to bring the pump back within its operating window by changing speed or back pressure or recycle. The most difficult sequence of operation is at start up from a shut in well or when added wells are brought on production. As the flowing conditions change over the reservoir life some times the only option is to retrieve the pump from the seafloor to change out the hydraulic parts.

This article discusses an alterative pump technology, which comes from the positive displacement pump family and has quite different hydraulic characteristics. The most widely used multiphase pump used topside and offshore is the twin-screw pump, which operates practically independent of inlet flow gravity and inlet pressure and at a much lower rotational speed. The backpressure and the liquid viscosity determine the pressure boost and power to the pump, not density, pump speed or inlet pressure. Therefore, when installed for subsea boosting it brings substantial advantages, especially for production from mid and late life fields. The twin-screw pump performs normally better under typical late life conditions such as high gas fraction, slug flow, emulsions and high oil viscosity.

Joint project

Four years ago three partners, Leistritz, Curtiss-Wright and Rosetti Marino formed an alliance and a joint project under the name TwinBoost with the objective of producing an integrated subsea boosting system based on the Leistritz twin-screw pump, the Curtiss-Wright canned motor technology and the system integration and controls by Rosetti Marino. This multiphase boosting system offers an alternative to roto-dynamic pump technology.

The Leistritz twin-screw pump is equipped with one-piece solid rotors and has been installed in multiphase production onshore and topside all over the world in high GOR and difficult flow assurance applications.

The canned motor technology from Curtiss-Wright provides reliable and efficient power to the pump. By maintaining the electrical windings in a clean, protected environment for the life of the machine, improved motor reliability is possible. The motor and pump are coupled together, sharing a common lubricating and barrier oil system that cools the motor, lubricating bearings and providing protection for the mechanical seals of the pump. The canned motor technology ensures that both the stator and rotor windings are protected in an inert atmosphere isolated from all liquids by a can designed to withstand the shut-in pressure of the pump. The can protects the windings against water ingress to the barrier oil system, which can be detrimental for a motor with wet windings. The oil has a larger tolerance to particles and does not have to be dielectric, which is a great advantage in the offshore environment.

The first generation of the pump and motor was qualified in Brazil by a local operator. Packaged by a local subsea integrator the unit performed over 1000 hrs submerged in a tank at a test facility using all its topside equipment including the umbilical on a reel for the test. Live crude oil and natural gas direct from offshore production was used for the tests and full power testing was performed under cold start and at severe slug flow up to 100% gas void fraction (GVF). The unit ran at 60 bar differential pressure at 80% GVF for an extended time with variable speed control between 1400 and 2000 RPM.

The operator performed the subsea deployment after qualification at the test facility at a mature single well site about 800 m water depth with an offset of 2.5 km from the host platform.

The deployment went as planned and the unit was installed on the seafloor with flow lines and umbilical connected. Unfortunately, during commissioning unplanned human intervention during the automated start up sequence caused over-pressurisation, which resulted in an internal barrier oil leak and increased oil consumption. The unit was still started up and ran for some time, immediately showing a drawdown of the flowing wellhead pressure and an increase in production. Due to high barrier oil consumption and after proving the subsea operation of the unit it was finally shut in.

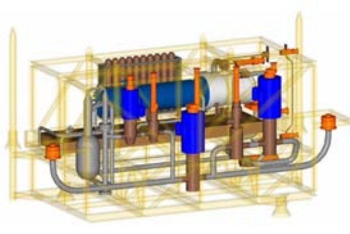
Rosetti Marino has repackaged the current generation of the TwinBoost motor/pump module into a smaller and lighter unit. This company relies on its experience on offshore structures, subsea manifolds, automation and control systems. Its facilities in Ravenna, Italy are well equipped for the final assembly and integration of the both the flow base and the retrievable module. A graving dock in the yard allows the modules to be submerged for system integration and final testing before delivery.

The main data for TwinBoost are shown in Figure 7 together with a picture of the base configuration of the retrievable motor/pump module. Also shown are the weights and mode of retrieval and deployment of the module. Its flow base can be either in suction pile or mud skirt execution and the flow line section of the base is also designed to be retrievable. It is also possible to do round trip pigging according to the flow line configuration.

Figure 5. *MPAM, retrievable motor pump module.*

Figure 6. *Subsea deployment using anchor handling vessel.*

Base Configuration



TwinBoost	
Flow	up to 800 m^3/h
differential pressure	100 bar (up to 150 bar)
GVF	0-100%
shut-in pressure	5000 psi (base case) 10000 psi (option)
motor shaft power	1.5 ÷ 2.5 MW (2000 ÷ 3300 HP)
water depth	up to 3000 m
weight ±10%	pump-motor unit: 70 t flowbase: 75 t baseframe: t.b.d.

notes:

- pump-motor unit deployable through moonpool (vertically and horizontally retrievable)
- available in single and twin-module configuration

Figure 7. *Base configuration.*

Incorporated in the overall TwinBoost system located on the motor/pump module is the subsea control module SCM and oil system. The SCM is retrievable and can be configured to communicate with other SCMs on trees and manifolds, even if they are of older legacy generations. Topside equipment includes the HPU providing barrier oil normally via the electric/hydraulic umbilical to a subsea oil inventory, which is activated locally as needed.

The GLCC is part of the liquid management system, which is used to supply the multiphase pump with liquid during heavy slug flow and at start up of shut-in wells.

The topside E-building includes the VFD speed control, high voltage gear and the MCS integrated in the control and automation systems of the host platform.

Many operators prefer subsea boosting stations with two or more pumps to provide redundancy and give flexibility when gathering production from multiple wells. TwinBoost is offered with this in mind where two retrievable motor/pump modules share a common flow base.

Summary

Subsea production from existing and mature assets will play an increasing role for operators around the world. This in turn will necessitate the use of new technologies in addition to the traditional ones. The playing field seems to tilt in favour of adding subsea boosting as a vital tool to maximise recovery and yield from already operating process facilities. Several boosting options are available in the market today where some are better suited for early life production and others will do a better job in low energy reservoirs with high gas and water production.

The twin-screw multiphase pump, based on the positive displacement principle is well suited to produce these reservoirs.

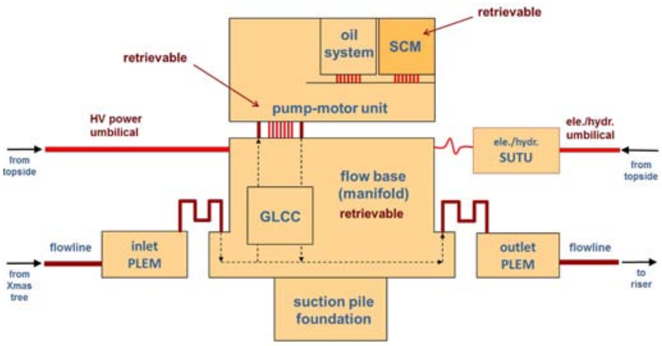


Figure 8. *Subsea system layout.*

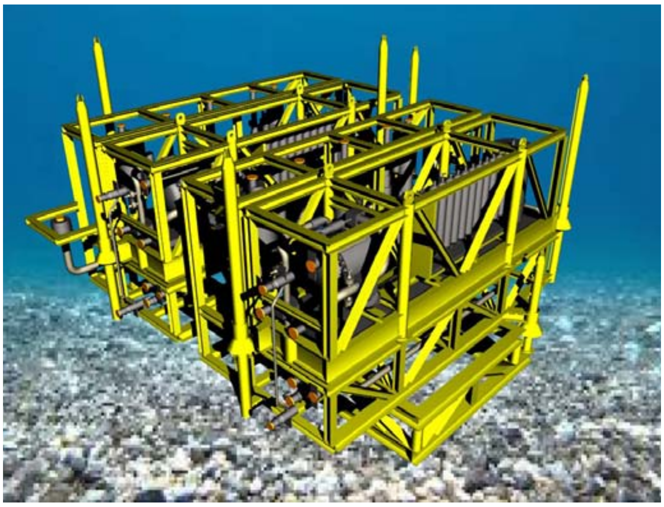


Figure 9. *TwinBoost in dual pump execution.*