Repurposing PUMP DESIGN

Sven Olson, Leistritz Advanced Technologies Corp., USA, discusses the flexibility of modern screw pump designs in the industry.

In connection with upstream and midstream oil and gas production, pumps perform a large variety of services, enabling gathering and processing of hydrocarbons and their derivates for the benefit of industrial users and consumers. These pumps are traditionally divided into two categories or principles: hydrodynamic, and positive displacement pumps. The two technologies have both different and sometimes complementary use in oil and gas production and processing.

The hydrodynamic pump – the more commonly used – is the traditional single stage or multistage centrifugal pump. It is applied primarily to handle lighter hydrocarbons and water, typically at higher flow rates, whereas the positive displacement pump services more viscous and gas entrained liquids at higher pressure and often under difficult suction conditions. Special types of positive displacement pumps include high pressure piston pumps used in drilling and hydraulic fraccing operations.

This article will focus on the application of rotary positive displacement pumps and, more precisely, the rotary screw pump. Much of what is to be discussed could also apply to gear pumps, vane pumps, lobe pumps, progressive cavity (PC) pumps, piston and plunger pumps, which are all part of the positive displacement pump family.

As the oil and gas industry is facing increasing demands for operational flexibility, performance and efficiency, screw pumps are now playing a larger role in areas that have traditionally been dominated by centrifugal and reciprocating pumps. This is due in large part to technological innovations and product improvements by screw pump manufacturers.

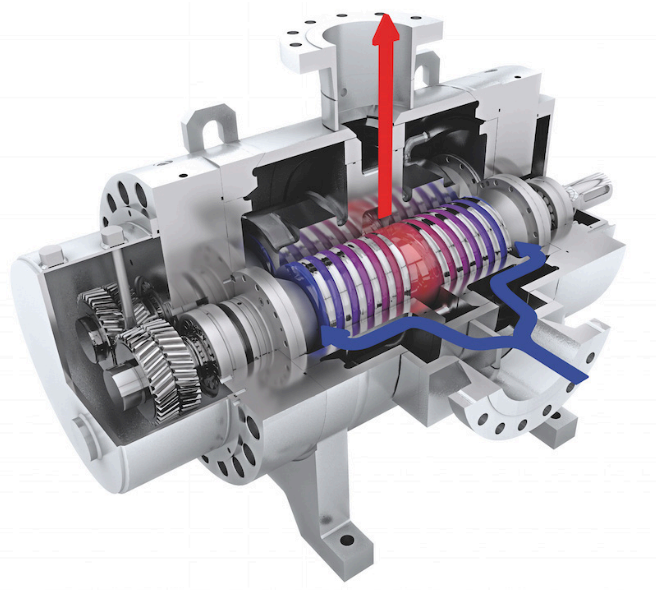

Figure 1. *Twin-screw pump for multiphase service.*

Figure 2. *Multiphase gathering pump station.*

The screw pump has become more commonly used as the industry increasingly moves towards producing more difficult assets with hydrocarbons at higher viscosity and oil/water emulsions and associated gas, making it possible to add late life production and added total recovery.

Presently both twin-screw and three-screw pumps are operating with success in upstream and midstream applications with condensates, multiphase and high gas entrainment fluids as well as with heavy crude and crude oil/water emulsions.

The oil and gas industry is gearing up to produce, transport and refine more non-traditional grades of hydrocarbons. The huge recoverable deposits of heavier and unconventional grades of crude oil from Canada, California, US, Mexico and South America and elsewhere in the world will play an increasingly important role in the future. Typically the crude oil from these areas is highly viscous, often requiring blending with a diluent or heating using steam or other means of treatment just to make the oil flow from the wellsite to the processing facility. On the other side of the spectrum, the production of lighter oils from shale and tight oil demands pumps that can handle oils with low vapour pressure, gas entrainment and flashing problems. The gas tolerant screw pump technology has emerged as a viable alternative to other technologies and is often called upon to meet many of these challenges. The use of screw pumps where liquids with high gas fractions are produced – also known as multiphase production – is a fast growing area.

Multiphase pumping

Multiphase pumps are finding added use as a supplement to conventional artificial lift systems and to reduce the production footprint and environmental disturbance by combining oil and gas transport in a single multiphase pipeline to a central process facility. In tight shale production, the typical rapid decline of the natural reservoir pressure and added associated gas production demands solutions justifying increasing drilling, fraccing and completion costs (Figure 1). The desire to extend ultimate recovery and leave minimum hydrocarbons behind requires a flexible multiphase pumping system that can deal with low reservoir pressures. At the same time, legislators in many regions, as well as public opinion, want reduced environmental impact from oil production and reduction of flaring and venting. When all these challenges are facing the operator, applying screw pump technology could be the best way forward.

The benefits of multiphase pumps to oil and gas production

Reducing flowing wellhead pressure

With maturing reservoirs the natural pressure declines, causing production to decrease without being able to overcome the backpressure of the gathering system. Multiphase pumps are able to draw down the flowing wellhead pressure while at the same time boosting the pressure and overcoming the downstream backpressure from flow lines, separators, etc. The lower wellhead pressure transfers into lower bottomhole pressure, which improves the well inflow and the liquid level in the well. Downhole pumps will benefit as intake conditions improve, allowing uninterrupted operation above the bubble point, which adds to downhole pump uptime, total recovery and

Figure 3. *Large twin-screw pump in trunk line service.*

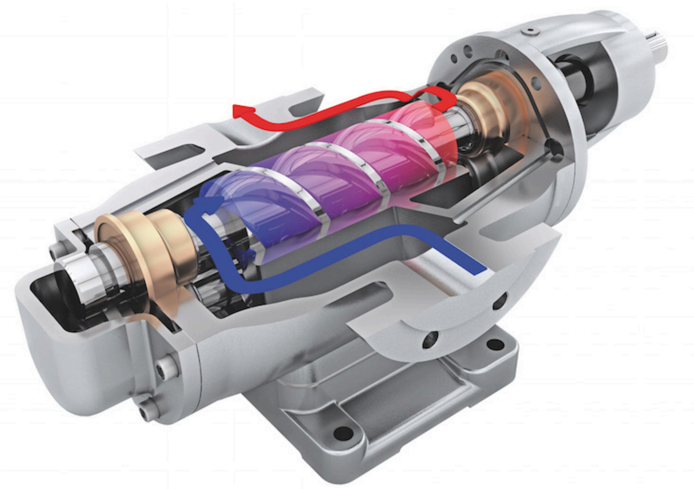

Figure 4. *Single flow two-screw pump.*

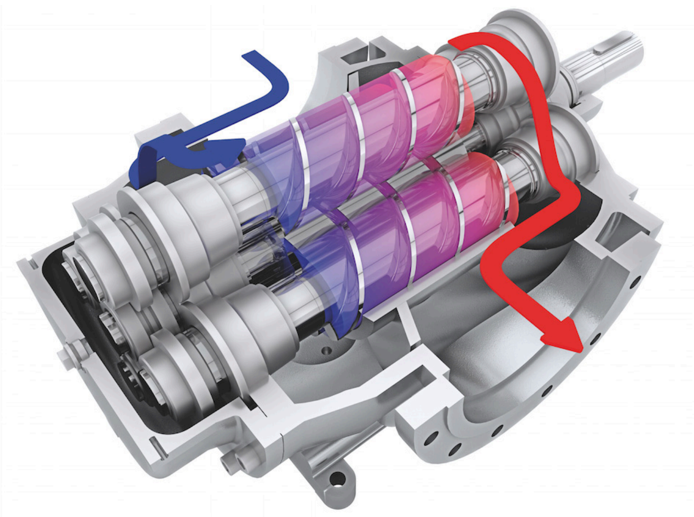

Figure 5. *Five-screw pump.*

shortens the production cycle. It also reduces wear and tear on sucker rod pumps and electric submersible pumps (ESPs).

Facility reduction

Rather than separating the gas from liquids at the production site or pad, treating the liquids and compressing the gas, or storing the liquids in stock tanks and flaring the gas, multiphase pumps can transport the untreated well flow in a single multiphase pipeline back to central processing (Figure 2). Removing separators, heater treaters, flares, stock tanks, conventional pumps and compressors and replacing them with one piece of equipment – a multiphase pump system – will result in significant savings. The economic returns are further improved by reducing truck transport of liquids. Gathering and monetising associated gas production, which is often an undesired byproduct today, significantly improves well cluster development economics when it is possible to use centralised processing.

Flow assurance

Twin-screw multiphase pumps deliver practically constant flow at a given speed independent of the gathering system backpressure. By changing the pump speed, the pumps can vary the flow rate and thereby control the pump inlet and the gathering pressure. Lowering the pressure can allow the opening of a pipeline prone to hydrate blockage, or make liquid logged wells flow again. Paraffin build-up and emulsions can be mitigated against and thus reduces the frequency of chemical injection and well treatment. The pump, which has low internal velocity will limit shearing and not aggravate oil/water emulsions, facilitating downstream treating.

Modern onshore and offshore topside multiphase pumps deliver flow rates of 450 000 bpd (total inlet flow of oil water and gas) at pressure boosts of up to 1500 psi. With the current trend moving towards new deepwater development and longer tie-backs, the industry has recently identified the need for subsea multiphase pumps capable of flows of up to 600 000 bpd and differential pressures exceeding 2500 psi. In addition, the longer step out distances require higher voltage power transmission, subsea power distribution, transformers and variable frequency drive (VFD) development. Onshore, the size of the multiphase pump installations increases as operators strive to centralise processing and production for savings in OPEX and to comply with stricter emission control regulations. In shale and tight formation production operators are reviewing options to move oils and gas to the market in pipelines instead of using trucks and rail tankers. Using multiphase flow lines will bring significant savings and will reduce exposure, making the process environmentally friendly. In addition, associated gas, which in some places is considered a nuisance byproduct, can be transported for use with a multiphase flow line.

Pumps in transfer and pipeline service

Twin-screw pumps

Twin-screw or three-screw pumps are often used in crude oil pipeline services. Three-screw pumps can boost pressure from laterals to the main trunk lines, while twin-screw pumps are predominantly used in the main line boosting stations (Figure 3). The primary advantages of screw pumps in pipelines are their ability to handle a wide range of viscosities, where centrifugal pumps will experience significant head and flow rate reductions. These pumps are sometimes installed with significantly oversized motors to overcome efficiency losses due to viscosity.

Screw pumps are increasingly popular in the midstream market, where their ability to handle high viscosities allows operators to pump at lower temperatures or use less diluent (Figures 4 and 5).

The pumps are hydraulically balanced, pulsation free and deliver a given volume from suction to discharge against the system backpressure. The pump has two rotors, one drive and one driven, and is reliant on the pumped fluid to fill and seal the area between the non-contacting rotors themselves and the liner. The pumped fluid seals each individual pumping chamber of the screw profiles, preventing back flow and loss of prime. The rigid rotor design, made from a single piece of bar stock, keeps the rotors from contacting the liner even at a high pressure and temperature.

The rotors are supported by radial bearings and the torque is transmitted from the drive to the driven rotor using a set of synchronising timing gears. The timing gears and bearings are external to the process fluids and are oil lubricated by a lube oil system which could be either internal or external, depending on pump size and motor power.

The twin-screw pump has four shaft penetrations from process to the clean oil side, so at least four shaft seals are required. The seals are mechanical and supplied in either single and double seal configurations, depending upon the actual service, the process fluids and possible hazardous emissions. Single seals are typically used for straight oil/crude oil service, while double mechanical seals with a barrier fluid system are sometimes used. Cartridge type seals are helpful in connection with service and are often used.

Three-screw pumps

When lighter oil is pumped and when diluents are used to reduce viscosity in heavy oils, gas may flash, which can lead to vapour locking in the centrifugal pump. Low viscosity oil, API 40 or lighter, can be economically and reliably pumped with three-screw pumps as an alternative to horizontal ESPs (Figure 6). As seen in Figure 7, a high pressure three-screw pump is significantly smaller and has no thrust bearing or oil system to maintain.

Screw pumps have extremely low fluid pulsation, removing the need for pulsation dampeners or complicated pipeline support systems as required by reciprocating pumps. They are also hydraulically balanced and operate well below any critical speed range, which guarantees low vibrations. Using VFD the speed can be optimised for flow control depending on use, allowing for large savings on energy and service costs.

The three-screw pump's main elements are the three rotors (one power and two driven rotors), an externally lubricated bearing capable of handling thrust loads induced by high inlet pressure, a mechanical seal, a separate liner, a outer casing and a bearing/seal housing. The power rotor (coupled to driver) performs the pump work while the idlers act as rotating seals, sealing the individual pumping chambers. The torque is transmitted to the idlers by the driven rotors through rolling contact between the rotors. The pumped fluid creates a barrier between the rotating elements and the surrounding liner, preventing direct metal contact.

The liquid enters the pump and fills the first pumping chamber of the screw set. As the screws rotate, sealed chambers are formed and the liquid is conveyed from suction to discharge. It moves a defined volume from suction to discharge like a piston pump with an infinite piston stroke.

Conclusion

The operational flexibility, higher efficiency and robustness of modern screw pump designs have made them suitable for an increasing number of applications in the upstream and midstream market. A strong driver is the desire by operators to use rapidly shifting trends and monetise available opportunities in the supply and demand of different oil and gas products. Adding flexible screw pump technology to a facility increases the likelihood of taking advantage of such opportunities.

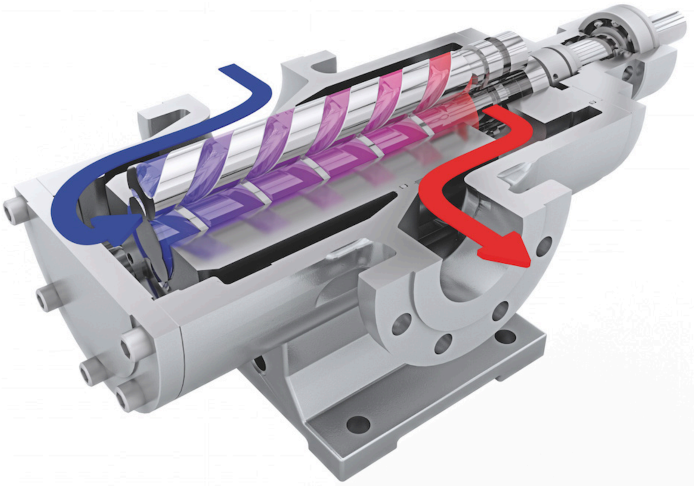

Figure 6. *Three-screw pump.*

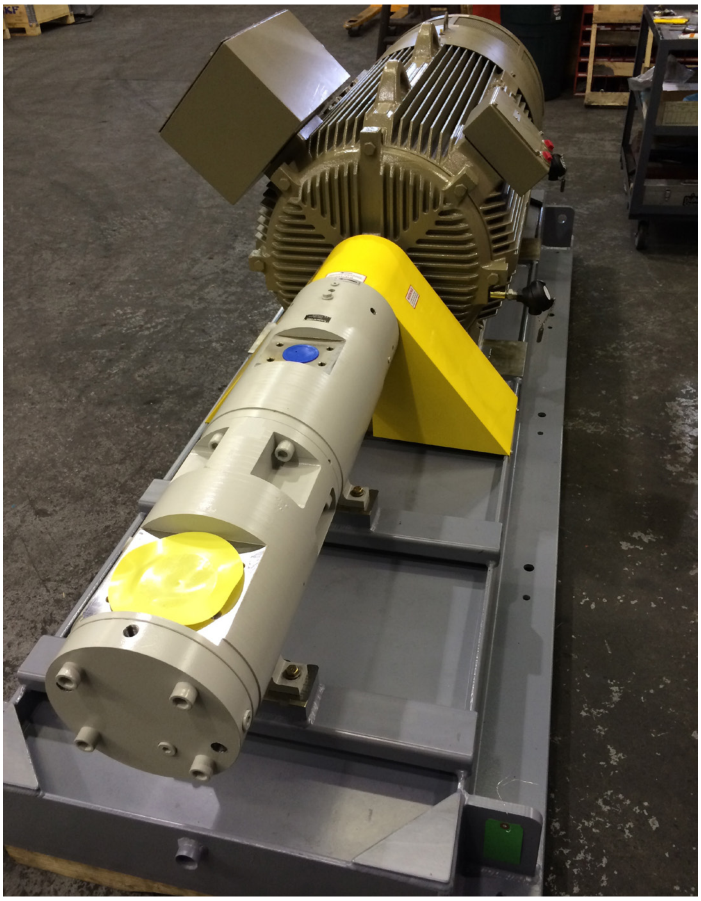

Figure 7. *High pressure three-screw pump for light oil and condensate.*