Multiphase Pumping to Enhance Oil Recovery

Saurabh Goswami

Project Quality Manager, Chevron Corporation, Houston, TX, USA

***Abstract*— Recently, interest in the subsea deployment of multiphase pumps has grown as operators search for methods to improve production and economics for subsea completed wells. Multiphase pumping improves the production and economics by increasing flow rates and optimizing the production cycle of oil and gas reservoirs.**

Subsea pumping is one of the most important methods to enhance oil recovery from oil well. Crude oil exists in various forms such as seawater, sand and gas, as well as oil in an oil well. Therefore, a phase separator is needed at the front of a single-phase pump for pressurization and transfer of crude oil. The application of a multiphase pump can provide such advantages as simplification of the equipment structure and cost savings, because there is no need for a phase separation process. Therefore, the crude oil transfer method using a multiphase pump is being applied to recently developed oil wells.

This study summarizes the research work with reference to the Multiphase Pump in terms of its types, Working principles, Applications and its advantages in oil production.

***Keywords*— Multiphase pump, Oil & Gas Production, Offshore, Sub-sea, Enhance Oil Recovery.**

I. Introduction

Even though subsea completed wells enable development of deep water resources as well as marginal fields in normal water depths, without some form of subsea processing, these wells are expected to experience poor ultimate recoveries due to the high backpressures. Study of researchers' shows that operating on continual high backpressure has direct impact on production decline behaviour that wastes reservoir energy. Energy that could be used to move reservoir fluids to the wellbore and out of the well is instead lost to flow through a choke or a long flow line. It is expected that some form of subsea boosting and/or processing of produced fluids will be necessary to improve efficiencies, allowing longer production from these wells and better recovery factors. Subsea processing covers a wide spectrum of subsea separation and boosting scenarios. Subsea multiphase pumping technology provides many advantages in terms of intervention when compared with single phase artificial lift methods.

And also, an increasingly large number of producing wells are maturing so operators must resolve a number of new problems which will impact the total economics of their production. The most common development for maturing gas wells is reduced bottom hole pressure and increased production of liquids, predominantly water.

Abandoning a mature well was once an option but now regulatory bodies are appearing more and more unreceptive toward abandoning producing wells too early so operators are looking at new technologies such as multiphase boosting as options to enhance oil recovery and maintain economical late-life production.

II. Multiphase Pumping

Conventional methods for producing oil and gas can now be replaced by a simple and economical technology known as MULTIPHASE PUMPING. It does not require separation of oil, gas, water so production from the oil wells can be gathered and pumped to a central processing facility without requiring separate flow lines, separators, intermediate storage tanks, gas flares, compressors, and separate pumping facilities. Elimination of these equipment means a smaller platform and a much more economical installation can be used to boost the production so it can move downstream for processing. Multiphase pumping can handle low inlet pressures, which makes it ideal for lowering the backpressure against the well. In many wells, particularly those on artificial lift, substantial gains and an accelerated production rate can be achieved with even a modest drop in pressure which is enough to payout the additional costs.

By definition a multiphase pump is a Pump that is also able to transport gas. It is an isothermal machine in which the heat generated by compressing gas is carried away by the flow stream through the pump, contrary to a compressor, which is an adiabatic machine and requires additional cooling.

Multiphase pumping is essentially a means of adding energy to the unprocessed effluent which enables the liquid/gas mixture to be transported over long distances without the need for prior separation. Typically the liquid/gas is transported to an existing processing centre for onward long distance transportation. Interest for multiphase production, which leads to simpler and smaller in-field installations, is primarily dictated by the need of a more cost effective production system.

III. TYPES OF MULTIPHASE PUMPS

Figure 1 shows multiphase pumps available in the market and which are divided in two groups based on their principle of operations.

- Positive Displacement Pumps
- Rotodynamic Pumps

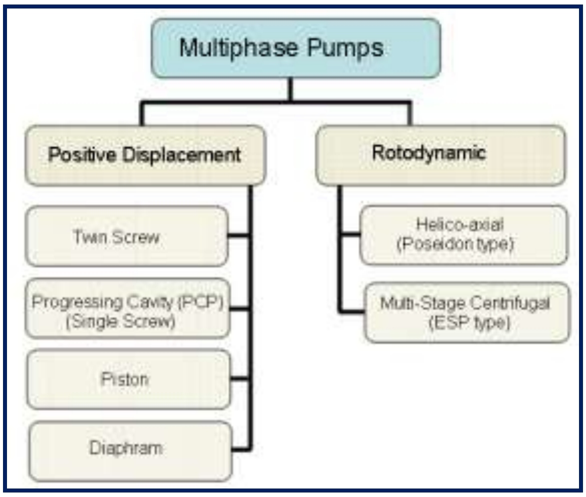

Fig. 1 Types of Multiphase pumps

A. *Positive Displacement Pumps*

Positive displacement pumps operate on the principle that a definite amount of fluid is transferred through the pump based on the volume created by the pumping chamber and the speed at which this volume is moved. The amount of differential pressure that develops in the pump is a function of the resistance to flow downstream of the pump that incurs the pressure losses which must be overcome to deliver the fluid to a set pressure downstream of the pump. For any positive or near positive displacement pump, the interaction between the pump and the adjacent pipeline segments determines pump performance.

1) *Twin Screw Pumps:*

Twin-screw multiphase pumps, which are the most common, work with fixed displacement where each pumping chamber formed when the two meshing screws rotate, delivers a constant volume from inlet to outlet. The liquid part of the multiphase flow becomes very important in compressing gas.

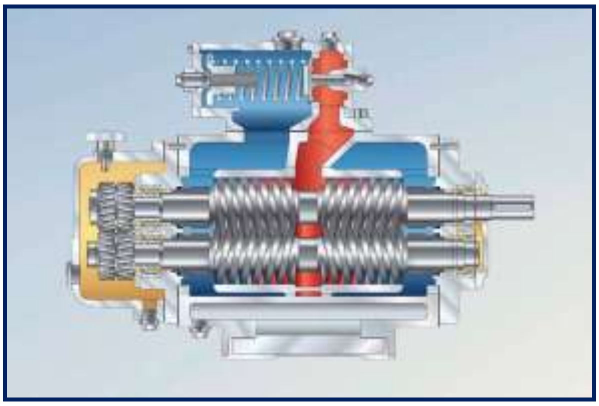

Fig. 2 Twin Screw Multiphase Pump

As shown in Figure 2, the twin-screw pump uses two opposing sets of screw profiles to move inlet flow from opposite ends of the screw sets toward the middle, where it connects to the pump outlet. When the screws turn, the centrifugal forces cause the liquid phase to separate from the gas phase. The liquids concentrate in the perimeter of the screw set in the annulus between the liner and the screw tips, and between the screw tips and the root of the profile. As the flow moves from the inlet toward the outlet, the liquid phase becomes more defined and a laminar stream of liquid travels in the opposite direction of the main flow stream. The reverse flow of liquids is a result of the pressure build-up from downstream lines or the separator pressure control. When the back-flow of liquid which as a result of pressure is practically dead reaches and fills the next upstream pumping chamber, the liquid will compress the gas in the chamber. Overflow liquid will continue to fill preceding upstream chambers, and the gas compression will occur as the liquid continuously fills the chambers. Somewhere there will be equilibrium between gas and liquid pressures, and the combined liquid/gas flow will reach the discharge port of the pump and continue downstream. As shown in Figure 2, the pressure build-up is progressive from chamber to chamber. However, compared to liquid, it is in the last chamber before the outlet where most of the gas compression takes place. Although a typical twin-screw multiphase pump is a constant displacement machine, the back-flow of liquid makes it a virtual variable-displacement machine, thereby allowing it to compress gas. It is still a classic pump, which enables it to transport 100 percent liquid at any time, which is not possible in a variable- displacement machine such as a compressor or a pump with variable displacement in order to operate with solid liquid.

2) Progressing Cavity Pumps (Single-Screw):

Widely used in shallow wells as an artificial lift method, the Progressing Cavity Pump has been adapted for surface multiphase pumping. The Progressing Cavity Pump is comprised of a rubber stator and a rotating metal rotor. This pump is effective for low flow rates (less than 30,000 bbl/day total volume of gas, oil and water) and for lower discharge pressures (maximum of 400 psig). This pump has the unique ability to tolerate considerable amounts of solids (sand). However, high sand production rates result in the need to replace the stator on a regular basis.

3) Piston Pumps:

One of the simplest forms of multiphase pumping is the use of a large double-acting piston to compress the multiphase oil, water and gas mixture. This approach is effective in the low and moderate flow rate ranges with a maximum capacity of approximately 110,000 bbl/day (total volume of gas, oil and water) and maximum discharge pressure of approximately 1,400 psig. The first type of piston pump, the “Mass Transfer Pump”, was installed in June 1998 by National Oil Well in Canada. This pump makes use of the same gear box and prime mover that is utilized in conventional sucker rod pumping units. Also, the pumping chamber functions much like a down hole sucker rod pump. It is comprised of two check valve assemblies which operate is the same fashion as the standing valve and traveling valve in a down hole pump

4) Diaphragm Pumps:

The diaphragm pump is a reciprocating pump consisting of two pumping chambers. The piston and motor are immersed in hydraulic oil supplied by a conventional axial-piston hydraulic pump. An elastomeric diaphragm separates the hydraulic oil from the pumped fluids. While these pumps have been primarily associated with the liquid-solids flow associated with deepwater drilling operations, they can be modified to accommodate 100% GVF fluids with high efficiency.

B. *Rotodynamic Pumps*

Rotodynamic pumps operate on the principle that kinetic energy is transferred to fluid which is then converted into pressure. In rotodynamic pumps, this occurs when angular momentum is created as the fluid is subjected to centrifugal forces arising from radial flow through an impeller. This momentum is then converted into pressure when the fluid is slowed down and redirected through a stationary diffuser.

1) *Helico-axial Pumps:*

The Helico-axial pump is a type of rotodynamic pump and fluid flows horizontally through a series of pump stages, each consisting of a rotating helical shaped impeller and a stationary diffuser as shown in Fig 3. This configuration is a kin to a hybrid between a centrifugal pump and an axial compressor. Each impeller delivers a pressure boost with the inter stage diffuser acting to homogenize and redirect flow into the next set of impellers. This inter stage mixing prevents the separation of the gas-oil mixture, enabling stable pressure-flow characteristics and increased overall efficiency. As the gas is compressed though successive stages, the geometry of the impeller/diffuser changes to accommodate the decreased volumetric rate. The impeller clearances are sufficient to allow production of small amounts of sand particles. While helico-axial pumps are more prone to stresses associated with slugging, installation of a buffer tank upstream of the pump is generally sufficient to dampen slugging effects such that they are not a problem.

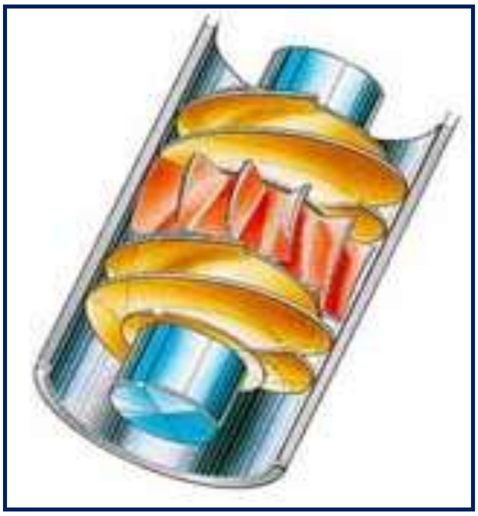

Fig. 3, Helico-axial Pump

Helico-axial pumps has ability to pump any GVF from 0 (100% liquid) to 1.0 (100% gas).

2) *Multistage Centrifugal Pumps:*

Multistage Centrifugal Pumps are rotodynamic pumps and they contain several impellers with in a single casing. Electric Submersible Pumps (ESP's) are basically multistage centrifugal pumps and are used as an artificial method in oil wells.

Recently, these pumps have been adapted for surface pumping applications and their ability to handle gas has been extended.

IV. Applications

Multiphase Pumps can be used for offshore, onshore or sub-sea applications to provide artificial lift to boost production from low and medium pressure wells.

Multiphase pumps are ideal for a broad range of crude oils and water cuts, and work very well with viscous crudes, gassy and foamy wells.

V. Benefits of a multiphase pump

It reduces back pressure on the well by boosting the untreated well flow, and by allowing the reservoir to accelerate production and the operator to delay abandoning a producing well.

Facility requirements are reduced by eliminating separation and processing equipment such as separators, flares, pumps, compressors, flow lines, etc. With multiphase pumping, process facilities can be centralized and optimized for gathering a large number of producing wells, thereby reducing footprint and limiting environmental impact, as well as drastically reducing operating and capital expenditures.

Flow assurance is an equally important benefit of multiphase pumping. Increased liquid production, slugging–especially terrain-induced liquid slugging, which is very difficult to address–and surging are problems. Multiphase pumps have the advantage of catching and breaking up slugs and allowing first-stage production separation to work without liquid carry-over or other upset conditions. The same problems occur with risers, where slugs effectively can be mitigated by using multiphase pumps.

These pumps can be operated remotely so it is also useful in de-manning of marginal production facilities.

VI. Conclusions

In this review work, I have analysed that Multiphase pumps have emerged as a viable alternative to conventional pumping. Multiphase pumps can reduce significant cost by reduction of conventional equipment such as separators, tanks, flares, separate flow lines, stock pumps and compressors. Multiphase pumps can increase recoverable reserves. Additionally, multiphase pumps can reduce back pressure on the well by boosting the untreated well flow, and by allowing the reservoir to accelerate production and the operator to delay abandoning a producing well.

Disclaimer: This paper does not represent any Chevron Corporation position and it is in no way related to Chevron Corporation.

REFERENCES

[1] Joon-Hyung Kim, Him-Chan Lee, Jin-Hyuk Kim, Yong-Kab Lee and Young-Seok Choi,"Reliability Verification of the Performance Evaluation of Multiphase Pump" International Journal of Mechanical, Aerospace, Industrial and Mechatronics Engineering Vol:8, pp. 1895-1899,Dec.2014.

[2] Gong Hua, Gioia Falcone, Catalin Teodoriu and Gerald L. Morrison "Comparison of MultiphasePumping Technologies for Subsea and Downhole Applications" in SPE Technical Conference and Exibition, 2011 paper SPE 14678.

[3] R. J Wikens, D K Thomas, S. R Glassmeyer, "Surfactant Use for Slug Flow Pattern Suppression and NewFlow Pattern Types in a Horizontal Pipe", Journal of fluids engineering PP 164-169, Vol 128, January 2006.

[4] Mac Shippe, ,Dr. Stuart Scott, "MultiPhase Pumping as an alternative to Coventional Separation, Pumpingand Compression" in pipeline Simulation Interest Group (PSIG) annual meeting,2002 paper PSIG-0210.

[5] (2014) Leistritz website. [Online]. Available: http://www. leistritzcorp.com/screw_pumps_products_mpp.cfm

[6] (2014) Sulzer website. [Online]. Available: http://www.sulzer.com/en/Products-and-Services/Pumps-and-Systems/Multiphase-Pumps

[7] (2014) Flowserv website. [Online]. Available: http://www.flowserve.com/Products/Pumps/Positive-Displacement

[8] Curtiss-Wright Electro-Mechanical Corporation. "OVERVIEW OF SBMS-500 SUBSEA MULTIPHASE PUMPING SYSTEM" 2004

[9] Hans-Juergen Schoener "*Multiphase Pumping – A Successfully Growing Oil FieldProduction Technology" Scandinavian Oil – Gas Magazine no. 9/10, 2004*

[10] Farmo Multiphase Pumps for Offshore and Land applications , Farmo Engineering AS, September 2002

[11] Sven Olson "Multiphase Pumping Meets Challenges" The American Oil & Gas Reporter, Mar. 2014.

[12] Sven Olson "Multiphase Pump Solve Liquid Loading" The American Oil & Gas Reporter, May 2006.