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High Volume Down-Hole Progressing Cavity Pumps with Electric Submersible Motors

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Abstract

The submersible motor driven progressing cavity (PC) pumps are becoming more popular in horizontal and deviated wells. In these applications, bottom-driven pumps eliminate rod break problems and significantly reduce tubing wear. In addition, the ability to handle abrasives and viscous fluids gives a special niche to the electric submersible PC pumps.

The existing PC pumps are designed to be driven by sucker rods. These pumps are limited in their flow and depth capabilities due to torque limitations of the sucker rods. The Electric submersible motors can provide higher torque and speed to the PC pumps. Therefore, there is a need to design new PC pumps with higher flow rate and speed capabilities.

This paper presents an overview of issues related to using progressing cavity pumps for pumping high speed and high fluid volume using electric submersible motors.

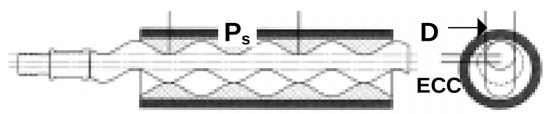
Background

A PC pump consists of a helical steel rotor which turns within a stationary tube with a helical elastomeric lining (stator). As the rotor turns inside the stator, fluid moves through the pump from cavity to cavity. As one cavity diminishes, the opposing cavity increases at exactly the same rate which results in a pulsationless positive displacement flow through the pump. The cavities are separated from each other by a series of seal lines which are created between the rotor and stator.

Figure 1 shows the cross section of a PC pump with a single lobe rotor. Other rotor/stator lobe configurations (multi-lobes) can also be used as a PC pump. Figure 2 shows different multi-lobe cross sections. Detail discussions of the comparison between the single lobe and multi-lobe pump elements are beyond the scope of this paper. The topics discussed in this paper are generally applicable to both single lobe and multi-lobe pumps.

Definitions:
P_s = Stator Pitch

Figure 1 Single Lobe PC Pump Cross Section



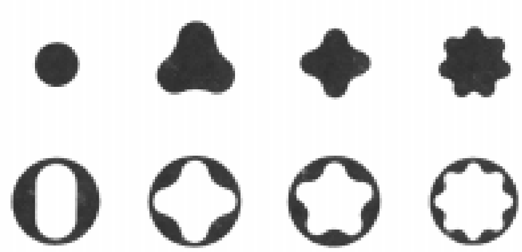
D = Rotor Minor Diameter
Ecc = Pump Eccentricity
Pump flow rate can be calculated as follows:

Equation 1. $Q = K^* P_s{}^*4^*Ecc^*D^*N$
where:
Q = flow rate
N = number of revolutions per unit time
k = conversion factor

Pressure. Pressure capability of a PC pump is a function of the number of times the progressing seal lines are repeated. If cavity pressure increases beyond the seal limits, the seal lines will open, and fluid will “slip” from one cavity to the other at a very high speed. The PC pump slippage is generally a function of pressure differential across the pump, fluid viscosity, and the compression fit between the rotor and stator.

Viscosity and Cavitation. The fluid viscosity affect pump performance by increasing fluid losses through the pump and by changing the

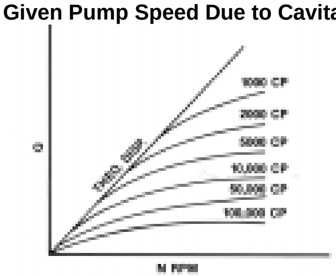
Figure 2 Various Rotor (solid) and Stator Lobe Configurations



pump slippage. In most cases, production fluid exhibit non-Newtonian behavior and their viscosity changes as a function of pump speed and shear rate. The viscosity at the pump speed must be calculated (apparent viscosity) to estimate the impact of viscosity on the pump performance.

High fluid viscosity may result in the loss of pump efficiency due to cavitation. In a PC pump, until the rotor closes behind the fluid and applies positive pressure to it, the pump can only create a void. The amount of fluid to flow into the void will depend on the fluid viscosity, entrance losses, and pressure at the pump intake. If the fluid losses are greater than the available head, the void will not fill and pump's efficiency is reduced. This problem rarely occurs in the down-hole applications where several feet of fluid column exists above the pump intake. However, the cavitation problem can be more serious when high volume pumps are laid in the horizontal sections with only a few feet of head available at the pump intake.

Figure 3 Deviation From Theoretical Displacement at a Given Pump Speed Due to Cavitation



Flow Rate and Pump Speed. Theoretical pump flow rate is a function of pump speed and design parameters such as stator lead, rotor diameter, and pump eccentricity. PC pump flow rate increases linearly with the pump speed. Parameters such as fluid viscosity, as discussed earlier, introduce non-linearity to the flow curves. Figure x shows the impact of the viscosity on the PC pump theoretical. displacement.

Abrasives and Pump Wear. PC pumps are known for their ability to handle abrasive applications. The feature that gives the PC pumps its advantage for handling abrasives is the use of elastomers in the pump stators. The parameters that are most relevant to wear in PC pumps are the pump speed, amount and size of particles, and pump internal velocity. Selecting a PC pump for an abrasive application involves selection of a pump which can produce the desired volume at lowest fluid internal velocity and pump rotational speed. Once these criteria are considered, the materials of construction must be selected for maximum wear life. Design of the PC pumps for abrasive applications is discussed in detail in Reference 1.

High Volume ESPCP

The ESPs are traditionally used in high volume, deep, deviated, or horizontal wells. However, the conventional centrifugal ESPs are not very popular in sandy and high viscous applications. This is due to centrifugal pump's short wear life and high shear rate which is not efficient in viscous applications. The impact of sand contribution to ESP failures are documented in many technical papers such as the one listed in Reference 2. It is in viscous and sandy applications where PC pumps are more superior than the centrifugal ESP pumps.

The surface driven PC pumps have depth and volume flow rate limitations. These limitations are primarily due to torque capabilities of the rod string and flow line losses due to rod, couplings, and centralizers. On the other hand, the conventional ESPs can produce more than 35000 BFPD with pressure capabilities in excess of 8000 psi. The electric submersible motors can produce much higher torque compared to what rod strings can handle. Therefore, the marriage between the progressing cavity pumps and electric submersible motors can provide a better solution to high volume and viscous applications than either the conventional ESPs or rod-driven PC pumps.

Tubing Losses. In a rod driven PC pump, the produced fluid travels through an annulus formed between the tubing and the rod string. In an electric submersible PC pump, flow losses are smaller due to elimination of the couplings, centralizers, and rod strings. Flow loss calculations are very difficult due to non-Newtonian behavior of most production fluids.

Fundamental fluid mechanics equations for pipe fluid losses are well documented in many sources and can be used to estimate tubing flow losses. Figure 4 shows a comparison between the tubing flow losses for an electric submersible pump compared to a rod driven pump.

High Volume PC Pumps

There are several methods of increasing PC pump volumetric flow rate. From equation 1, pump flow rate can be increased by increasing pump diameter or stator pitch length. Increasing the stator pitch length will increase the pump's internal velocity as well as reduce its pressure per length capabilities. A special high volume PC pump is designed and optimized. Figure 5 compares this new pump with other standard pumps. Figure 5 shows that in this new design, while the volumetric flow rate has increased, the pump internal velocity and shear rate is reduced. Lower internal velocities and shear rates will reduce pump flow losses in viscous applications and will minimize pump wear due to abrasion.

Models	Max Lift (ft)	Max Flow (BFPD)	Outside Diameter (in)	Pump Length (in)	Internal Velocity (ft/sec)	Shear Rate (1/sec)
ESPCP	2000	2050	5.375	205	5.8	168
20-H-685	2000	1750	4.5	393	11.2	506
20-H-950	2000	2400	4.5	416	12.5	458

* Theoritica data based on 300 rpm pump speed

Figure 5 High Volume PC Pump Design for ESP Applications

Case Analysis

Figure 4 Tubing Losses Comparison