ENERGY-EFFICIENT WIDE-RANGE ESPCP SYSTEM: A NEW APPROACH TO OVERCOME THE MAIN CHALLENGES FOR ARTIFICIAL LIFT SYSTEMS IN THE PERMIAN BASIN

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ABSTRACT

Artificial lift systems are critical for optimizing production in deviated or horizontal oil and gas wells. As these wells face rapid reservoir pressure declines, increased gas and solids production, high deviation in well geometry, and unstable flow regimes, selecting an appropriate artificial lift method becomes paramount. By implementing the right artificial lift system, operators can overcome these challenges, maintain consistent flow rates, and maximize hydrocarbon recovery, thereby achieving sustained and efficient production throughout the life of the well.

Electrical submersible progressive cavity pumps (ESPCP) combine the advantages of an electric submersible pump (ESP) and a progressive cavity pump (PCP).

The main benefits of an ESPCP are the following:

- Eliminates mechanical wear on rods and tubing

- Is suitable for deviated and horizontal wells

- Provides the same advantages as PCPs for solids handling and viscous fluid production

- Allows variation in production rates with the use of a variable speed drive.

However, the ESPCP system with a traditional PCP is commonly used in heavy-oil applications because light oil typically has a high percentage of benzene, toluene, and xylene (BTX). The molecular structure of BTX allows it to attack or adhere to the PCP elastomer, causing aggressive swelling and softening. Light oil is typically found in deeper, warmer reservoirs, causing the BTX to be more active and aggressive while also reducing the mechanical strength of the elastomer. H_2S and CO_2 can also be associated with light oil and have a detrimental effect on the elastomer.

This work describes a new high-efficiency and reliable ESPCP system suitable for light-oil and medium-temperature applications that will overcome the main challenges in Permian operations: gas lock (due to high GVF), solid issues, parted rods (fatigue), hole in tubing (rod/tubing contact), and high power consumption due to low overall system energy efficiency for low-rate applications.

Combining a permanent magnet motor (PMM) and a composite PCP, results in a more efficient pumping system that

- Lowers power consumption and CO_2 emissions reduction
- Increases production by setting the pump deeper, adding more lifting capacity

- Eliminates up to 80% of well failures by elimination of rod string failures
- Improves equipment reliability due to the elimination of a gearbox (the most common type of failure for ESPCP)
- Allows for ESPCP production in light-oil applications (up to 45 API)

INTRODUCTION

The progressing cavity pump (PCP) pump has been utilized for fluid transfer in various industrial applications and surface transfer of oilfield fluids for many years. Recently, it has become a popular choice for the oil and gas industry as an artificial lift method due to its several advantages over other methods. Over the years, extensive research and development have been conducted in the design of PCP. This has expanded their production and lift capabilities, making them suitable for various applications. With the availability of different elastomeric materials, these pumps can efficiently handle multiple well fluids. The PCP is an excellent option for wells that use artificial lift and contain thick, sand-laden crude oil. The pump can handle abrasive fluids, lift up to 6000 ft, and has a capacity of 3000 BOPD. Due to its efficiency, it is quickly gaining popularity as an alternative pumping solution for oil wells.

The PCP system has its advantages but also has some limitations that require special consideration. Some of these considerations include the following:

- The equipment has an upper temperature limit in routine use up to 85°C (185°F).
- The elastomer may swell or deteriorate on exposure to specific fluids, including well-treatment fluids.
- Wells that produce large amounts of gas may experience low volumetric efficiency.
- Sucker rod strings tend to experience fatigue failures.
- Wear and tear on rod strings and tubing can significantly concern directional and horizontal wells.
- Vibration problems may occur in high-speed applications; this factor generates the production rate limitations.

The limitations associated with PCP applications have changed with new products and equipment designs. Over time, PCP technology has evolved into bottom-driven PCPs using an electric submersible motor called an electrical submersible progressing cavity pump (ESPCP). The combination of PCP and ESP technology has eliminated the need for sucker rods, thus expanding the application range to deviated and horizontal wells where traditional rod-driven PCPs have limitations. The use of standard induction motor technology required a speed reduction from the synchronous speed of the ESP motor to that of the PCP (typically in the range of 100 to 500 rpm). To accomplish this, a downhole gear reducer accommodates the speed requirement discrepancy between standard ESP and standard PCP operating speeds. Over time, the downhole ESPCP gear reducer has become an expensive component and one of the most likely failures in the system. However, the introduction of permanent magnet motors (PMMs) has eliminated the need for a gear reducer by providing a direct speed ratio.

The major hurdle for ESPCP technology is the stator component. In the typical PCP application, the stator is an injectable elastomer that the rotor moves against. Over time, the elastomer degrades and/or swells from the downhole environment. Often, PCP applications manage the stator deterioration by swapping rotors at the surface. However, with the ESPCP fully submerged, the stator must survive the harsh conditions for a significantly longer time than current PCP stators can manage to make the system a viable alternative for low-flow unconventional applications.

Existing stator technology limits PCPs to an 85°C (185°F) intake temperature. Also problematic are high concentrations of benzene, toluene, and xylene (BTX), H_2S; and CO_2. Technologies such as metal-to-metal pumps, while they increase the temperature range to 260°C, cannot handle solids, have vibration issues, and are costly. Mechanical bonded pump technology is restricted by manufacturing challenges, mainly due to the difficulty of polymer injection.

We developed a new stator technology, a composite PCP stator, suitable for light-oil and medium-temperature applications to expand the envelope of the ESPCP from heavy- and medium-oil to light-oil applications.

The new composite PCP stator reduces the primary degradation mechanisms in the elastomer by a construction designed to mitigate each failure mode mentioned above. The stator provides thermal management to dissipate the heat generated during the pumping process, enhanced elastomer formulation not constrained by standard PCP injection processes, and thin-walled material to eliminate hysteresis effects from dynamic loading.

LABORATORY TESTING

Once the first composite PC-pump prototype was built, its performance needed certification to validate the technology's benefits before installing it in the field.

A high-temperature flow loop testing program was conducted at C-FER Technologies in Edmonton, Alberta, Canada.

PCP Specifications

The pump has the following specifications:

- Nominal displacement: 0.53 m^3/D/RPM
- Maximum torque: 300 Nm
- Rotor connection: 25.4 mm (1.0 in) API
- Stator connection: API 101.6 mm (4.0 in) non-upset (NU) pin threads
- Maximum head capacity: 600 m (1640 ft) of water introduction

Test Fluid

The test fluid was selected to expose the elastomer to aromatic fluid content.

Test Procedure

Two different types of tests were conducted during this test program:

- Pump performance curve tests: The pump performance curve tests tested the PCP performance and operation at varying fluid temperatures, pump speeds, and pump differential pressures. A typical pump performance curve test recorded the volumetric flow rate at five differential pressures with a set pump speed and fluid intake temperature. A test point was captured for the lowest differential pressure when the discharge control valves were open. For the highest differential pressure, the test point was at a maximum differential pressure of 4500 kPa or a minimum target volumetric efficiency of 40%; a lower maximum differential pressure of 3500 kPa was requested during testing. The remaining test points were then equally spaced between the minimum and maximum differential pressures.
- Endurance test: The endurance test tested the PCP system’s performance changes over an extended period. It was conducted 24 hours daily, and the controlled variables were adjusted each workday.

TESTING RESULTS:

Pump performance tests (i.e., pump curves) were conducted throughout the test program to monitor changes in PCP performance or operational behavior that could be related to the varying temperature and/or interaction with the test fluid over time.

All pump performance curve tests were collected using a set of controlled variables:

- Pump speed of 175, 350, or 450 RPM. The speed of 450 RPM was only reached late in the test program when the pump volumetric efficiency had decreased.
- Pump intake pressure of 689.5 kPa (100.0 psi). This stayed steady throughout the entire test program.
- Pump differential pressure (ΔP) ranges. The ΔP ranged from the minimum achievable with open discharge control valves to a maximum of 4500 kPa (653 psi).
- Pump intake fluid temperature (T_{in}.). T_{in} ranged from 90 to 130°C. The intake temperature of 130°C was only reached during the final pump curves after 4 weeks of endurance testing.

General Comments on Testing

The following are general comments regarding testing:

- Endurance testing included approximately 4 days above 350 RPM, and pump performance curves were completed at 350 and 450 RPM. No notable parameter instability or test noise level change was observed at these higher pump speeds. It was noted that 350 and 450 RPM pump speeds are above those typically used when testing conventional PCPs.
- Throughout testing, there was no significant difference in temperature measured at the flow loop casing inlet and at the thermocouple banded to the stator, indicating no stator overheating was observed/captured.

Final Teardown

At the end of the test matrix, a pull of the PCP was completed. No visible elastomer damage or material degradation was visually observed (Figure 1). In addition, no elastomer material was observed in the flow loop.

Upon inspection of the stator, it was observed that the rubber remained bonded, the elastomer surface was unaffected, and the stator cavity profile was not deformed.

CONCLUSIONS

After the stator was inspected at the C-FER facility, it was confirmed that the new elastomer is highly resistant to aromatic compounds such as BTX. The stator cavity shape was not deformed, excess swelling was not present, and the elastomer hardness remained the same.

Additionally, the chemical bond withstood high temperatures without damage.

The results confirm that the new composite PCP stator is suitable for light crude oil and for medium temperatures below 120°C or 250F. Therefore, the ESPCP system envelope will expand from heavy- and medium-oil to light-oil applications.

The energy-efficient wide-range ESPCP system enables a low-flow pumping solution that easily transitions from ESP to a low- or medium-flow system. This solution is more cost-effective and performs better than rod lift/sucker rod pump alternatives. When the efficiency of the ESP drops, migrating to an ESPCP system is a seamless way to maintain efficient production, rather than switching to a sucker rod pump/rod lift system.

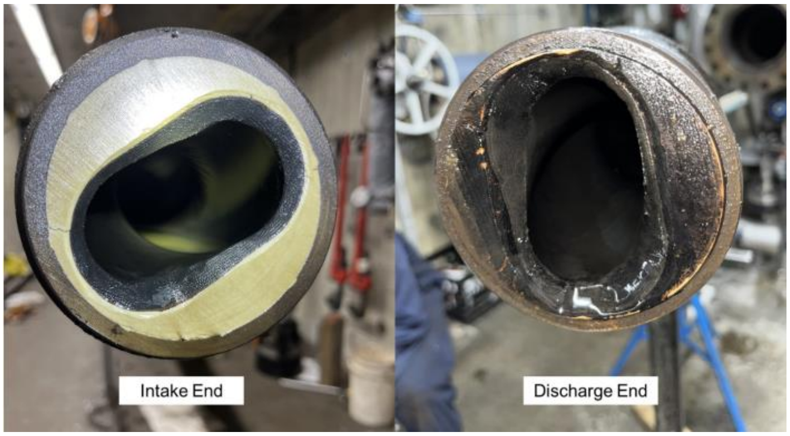

Figure 1. Stator condition after test matrix.

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