MOYNO SUBSURFACE PROGRESSING CAVITY PUMPS

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ABSTRACT

An increasingly energy conscious world is seeking not only alternate energy sources but also more efficient methods of production. The drive for energy independence has created an atmosphere conductive to innovations in oil recovery. Enhanced oil recovery methods, such as water flooding, chemical treatment, and steam injection are being used to increase the production of low yield wells, which were considered non-profitable years ago.

Along with new enhanced oil recovery methods is a new and innovative artificial lift method. The Moyno Downhole progressing cavity pump has been sucessfully applied to downhole pumping applications. The pump has only one moving part, the rotor, which attaches to and is driven by the sucker rod string, while the mating stationary part, the stator, is attached to the production tubing string. The rotor is a single threaded helical gear with a circular cross section and an off set or eccentricity. The stator is a double threaded internal helical gear which has a diameter equal to the rotor, but an eccentricity and pitch twice of the rotor. When the rotor and stator are meshed together, a series of sealed cavities, 180° apart, are formed, that progress from suction to discharge as the single helix rotates. The result is a pulsationless positive displacement flow. This unique progressing cavity feature enables the pump to handle high gas-oil ratio crudes without gas locking. Due to inherent low internal velocities heavy crudes of high viscosity can be easily handled. An abrasion resistant elastomer stator and plated rotor offer long life in sand laden crudes. The rotary design lends itself to low profile surface equipment allowing better utilization of the land for agriculture. These futures give the production engineer another alternative method for artificial lift.

INTRODUCTION

All rotary positive displacement pumps operate by trapping a defined quantity of fluid between one or more moving elements such as gears, screws, lobes, vanes, or helical rotors. In case of positive displacement rotary pumps, for a given element size, as the helical rotor turns (rotates) within the stationary (stator) element, the quantity of fluid delivered (BPD) will become a function of pumping depth or discharge pressure, fluid viscosity, and pump speed (rpm). Even though the design and configuration of the rotating and stationary helical elements are complex, the operation of the pump is rather uncomplicated.

Another advantage of this pumping principle is the use of elastomers as the outer gear (stator) in all applications. Through the use of a compression fit between the rotor and the stator (much like an "O" ring seal), the clearance required between the elements is eliminated, thus making the pump capable of pumping low and high viscosity crudes as well as gaseous and sandy fluids.

PUMP DESIGN & OPERATION

The progressing cavity or single screw rotary pump consists of a single threaded helical rotor rolling eccentrically in a double threaded helix of twice the pitch length (Figures 1. & 2.). As the single helix rotates inside the double helix stator a series of sealed cavities, 180° apart, are formed, that progress from suction to discharge. As one cavity diminishes, the opposing cavity increases at the same rate; thus, providing a pulsationless positive displacement flow. The displacement is directly proportional to three design constants: the cross-sectional diameter of the rotor (D), the radius of helix or eccentricity of rotor (E), and the pitch of the stator helix (P_s).

THEORETICAL DISPLACEMENT (at Ø Discharge Pressure) $= D \times 4E \times P_s \times rpm$

Pressure capabilities are a function of the number of times the seal lines are repeated (Figure 3). For example for a given size pump, a three stage pump will have three times as many seal lines as a single stage unit. The flow path through the elements is not far removed from the straightest distance between the suction and discharge. The result is a low internal velocity and subsequent shear. A particle of sand, scale or even gas will be gently moved along in each cavity without disturbing the flow. The pump can virtually move anything that can fit or flow into the cavity.

For best abrasion resistance the rotor or inner gear (single helix) is fabricated from 4150 carbon (tool) steel, 200-240 Brinell Hardness, with a heavy layer of hard chrome plate. This represents one of the best abrasion resistance material available. Over the years, various coatings, including tungsten and silicone carbide, stellites, aluminum, titanium and chromium oxides, and many others have been studied. A coating has yet to be found for the rotor that will match a hard chrome plate for abrasion resistance, when properly applied. Doing so also provides a relatively inexpensive method of resurfacing the rotor for repair.

The outer gear or stator is molded from a grade of 65 durometer Buna N, a medium high acrylonitrile - butadiene rubber with excellent resistance to grease, oil, and majority of chemicals. Unfortunately, the rubber industry has yet to come up with an elastomer resistant to all chemicals, treating agents, and solvents. The Buna N compound is second in abrasion resistance to high grade of natural rubber; however, first in over all compatibility due to natural rubber lack of resistance to oils, and many hydrocarbons. High temperature applications (200°F +) will require different elastomers (either EPDM or fluoroelastomer) construction. Thermal expansion is common when the elastomeric component (stator) is subjected to increased temperatures even within their limitation. Extensive research is being conducted to develop new and more resistant elastomers for high temperatures and highly aromatic (below 60°C aniline point) down hole environments.

Associated with the relatively simple pumping arrangement is the uncomplicated surface equipment. Since the pump is rotary motion, the surface equipment need only to consist of a set of bearings capable of sustaining the weight of the sucker rod string and the hydraulic thrust plus a packing gland (stuffing box) to seal off flow line pressures. The prime mover can be a standard electric motor, gas or hydraulic engine.

VISCOSITY

As noted earlier in the paper, one of the three factors (for a given pump size) effecting pump performance is viscosity. In a positive displacement pump, until the rotor, piston, lobe, vane, or gear 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 (much like any orifice) will depend on the fluid viscosity, differential pressure across the opening and an entrance loss (k factor) that reduces the theoretical displacement due to turbulence and friction. Assuming negligible fluid vapor pressure, negligible fluid levels & friction losses at the pump suction, as shown in Figure 4, the maximum differential pressure the pump can create by opening a void would be approximately 14.7 PSi at sea level. Under these conditions then, as long as the pressure drop between the suction port and the pumping element entrance does not exceed 14.7 PSi, fluid will fill the void and pump flow will be 100% displacement. Cavitation occurs when the fluid pressure drops below the vapor pressure, therefore, requiring a greater pressure than the 14.7 PSi available for full displacement flow to enter the cavity (element). A portion of the void is filled with fluid vapor which is condensed in the pump after the rotor applies positive pressure. The result is a pulsating, noisy, erratic flow which deviates from a straight line. Obviously as fluid viscosity increases the flow rate (BFPD) decreases due to the higher pressure drop across the opening (orifice). It is then possible for a given pump model (size) using Newtonian fluids of various viscosities at various net positive suction heads to develop curves which would indicate the maximum speed the pump should operate at a given NPSH available (Figure 5., capacity vs RPM). Rearranging Figure 5, we can then, graphically show the optimum pump RPM for a given Newtonian fluid to achieve better volumetric efficiencies (Figure 6.). It should be noted that all rotary positive displacement pumps experience some slip or "blow by" due to the pressure being greater on the discharge than on the suction. Fluid is forced by this differential pressure back through the sealing lines created between the rotating element and the stationary element. The amount of slip is not only dependent on the differential pressure, but also on the number of sealing lines within the pump (as previously shown in Figure 3.) and the viscosity of the material. Figure 7 shows the effect of increased viscosity on pump performance (discharge) when plotted against differential pressure. This is only true as long as the pump is operating in a viscosity and speed range which allows it to operate at 100% volumetric efficiency. On one hand, we have higher viscosity increasing the capacity of the pump because of reduced slip, and on the other, we have higher viscosity reducing capacity because of increased entrance losses resulting in lower volumetric efficiency.

ABRASION

It is extremely difficult to categorize the abrasive nature of oil field crudes. Abrasion is affected by particle size, shape, hardness, and percent solids in the fluid. Moyno subsurface pumps are required to operate at varying speeds over ranges as low as 40 rpm to 500 rpm. In an effort to reduce maintenance, as the abrasiveness of the pumping fluid increases the operating speed should be reduced. The amount of wear in an abrasive application is more closely proportional to the speed squared than it is to a linear relationship. Fiqure 8 shows one adverse effect that speed reduction may have on pump life. Drawing the effect of a fixed amount of wear on the performance curve for a speed "A" and a speed "B" which is one-half of speed "A". It would take the pump at speed "B" almost four times longer to reach the wear curve. As long as the differential pressure is zero or very low, this equates almost four times the life. Under pressure it is obvious that the same amount of wear has a greater effect on volumetric efficiency at the lower speed than at the higher speed. For example, at 100 PSi the same amount of wear would have caused the flow rate to drop to zero at speed "B", while at the higher speed "A", the flow rate at 100 PSi would still be in excess of 50% of the rate before the wear occurred. Although, it would take almost four times as long to reach the same amount of wear at half the speed, the effect of drop in flow rate under pressure is more apparent at the slower speed as the amount of production decreases with increased slippage. In order to reduce the amount of wear and subsequent slip in abrasive applications, the differential pressure per stage should be reduced by "over - staging". This helps maintaining high volumetric efficiencies under pressure at even lower speeds, therefore, reducing wear and increasing the time between pump replacement.

The unique design of Moyno progressing cavity pump gives this subsurface pump the ability to pump sand and gyp without clogging and locking up. Since there are no internal valves the pump can move anything that can flow or fit into the cavity. The flexibility of the elastomeric stator (outer gear) can help when moving large particles in suspension, also enables the particles to imbed rather than abrade.

CONCLUSION

For the past four years progressing cavity pumps have been used successfully in variety of bottom hole environments. Wells producing highly viscous, abrasive and gaseous fluids. The advantages of this method of artificial lift over conventional rod pumps are: (1) single rotating part (rotor), (2) no valves to clog, gas lock or wear, (3) due to inherent low internal velocities heavy (highly viscous) crudes can be easily handled, (4) an abrasion resistant elastomer stator and chrome plate rotor offer long life in sand laden crudes, and (5) surface equipment maintenance is minimized to packing adjustment and greasing the bearings.

REFERENCES

Bourke, J. D. "Pumping Abrasive Slurries with Progressing Cavity Pumps". Robbins & Myers, Inc., 1982.

Dillon, M. L., Donahue, W., Bourke, J. D. "Factors Affecting Pump Selection for Slurry Type Fuels". Robbins & Myers, Inc., 1975.

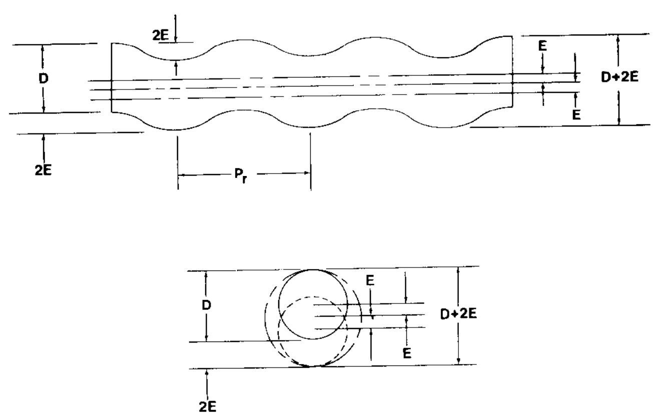

Figure 1 - Progressing cavity down hole pump rotor

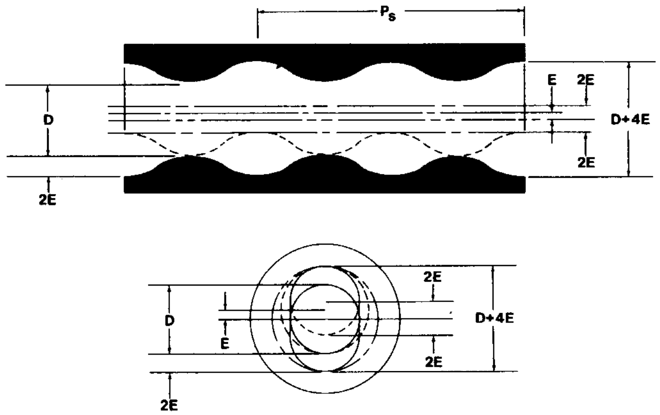

Figure 2 - Progressing cavity down hole pump rotor/stator geometry

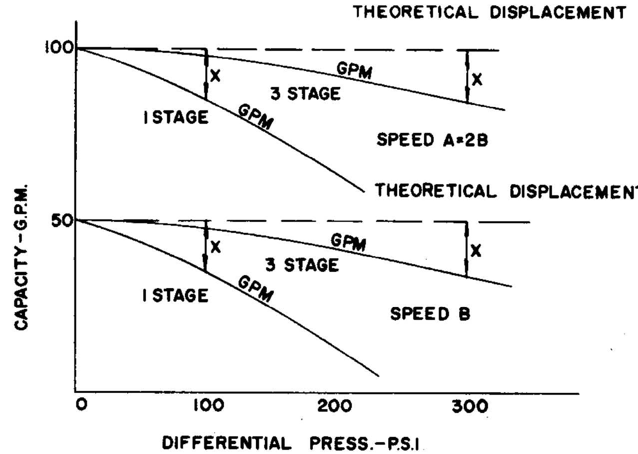

Figure 3 - Effect of increasing internal sealing lines (no. of stages) on slip, pump pressure capabilities.

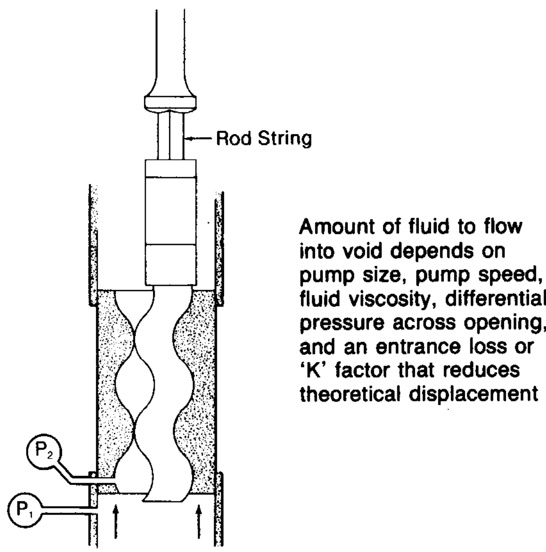

Figure 4 -

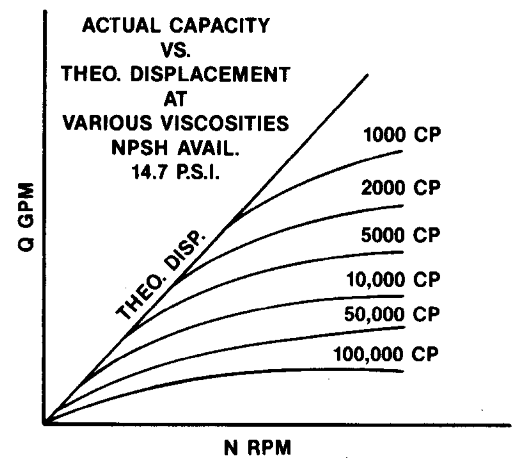

Figure 5 - Curves indicating deviation from theoretical displacement for Newtonian fluids of varying viscosities at a given pump speed and NPSH available

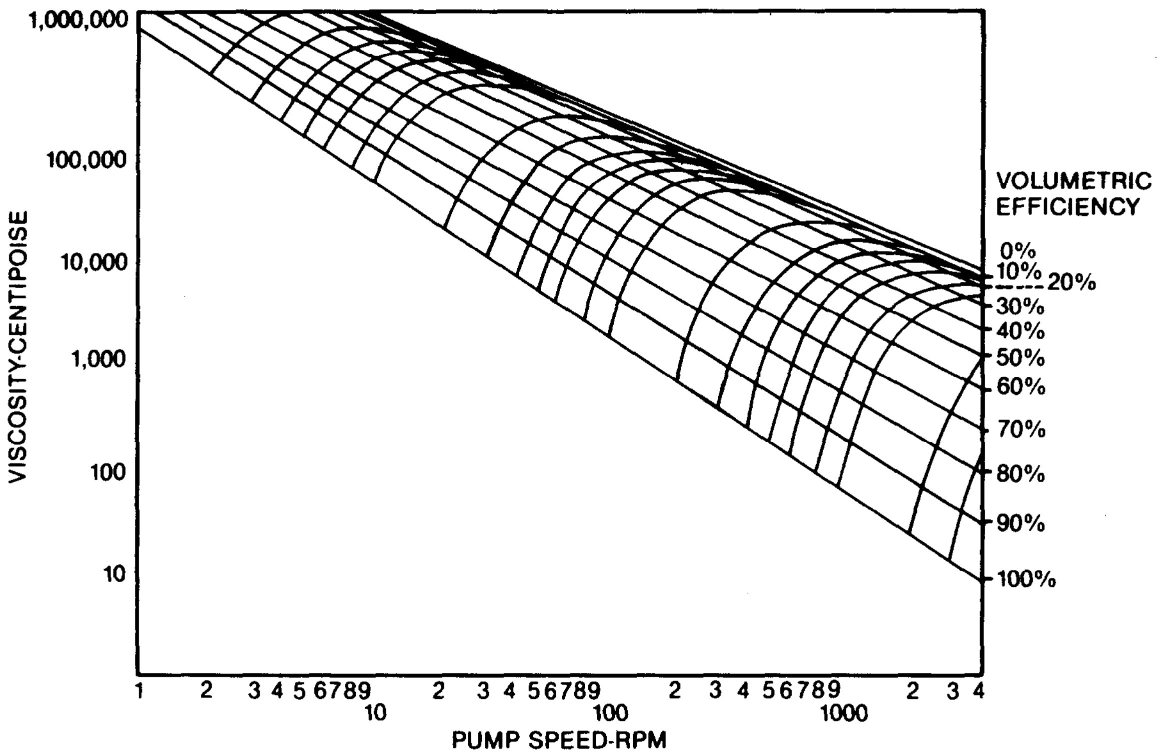

Figure 6 - Viscosity (Newtonian fluids) vs. pump speed

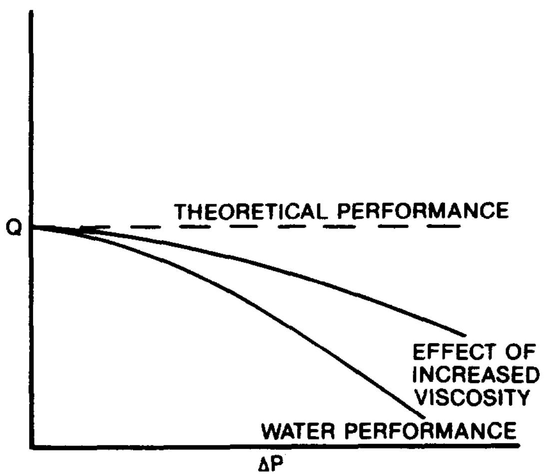

Figure 7 - Effect of increased viscosity on slip

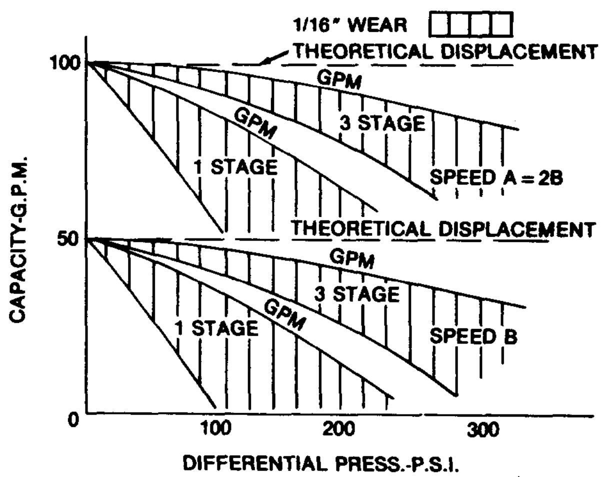

Figure 8 - Wear effect