TECHNICAL BULLETIN

PROGRESSING CAVITY PUMPS | LS-TB-O28

LIFTING SOLUTIONS

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LS-TB-028	PC PUMP CAPACITY VS ACTUAL FLOW RATE	MAY 23, 2022	ENGINEERING

BACKGROUND

Understanding the relationship between progressing cavity (PC) pump volumetric capacity and the actual delivered downhole and surface flow rates is fundamental to proper pump selection and application. This technical bulletin explains the main variables and adjustment factors (and their main causes) that help translate pump capacity into actual flow rates. It also briefly touches on the common approaches to model selection. The bulletin references information from the ISO 15136-1 International Standard: Progressing Cavity Pump Systems for Artificial Lift: Part 1: Pumps.

PUMP CAPACITIES

PC Pump Capacity is a measure of the displacement of the pump expressed in volume per day at a reference rotational speed – most commonly m^3/day/100 RPM or BPD/100 RPM. It is related to the volume of the cavities which in turn are defined by the pump geometry parameters of eccentricity, minor diameter, and pitch. To enable end users to select pumps for their application conditions, as well as compare pump products between different suppliers, the PC pump industry has defined several variations of Pump Capacity as described below.

Theoretical Pump Capacity: Capacity of a pump calculated based on the fundamental geometric design parameters eccentricity, minor diameter, and pitch. Typically, this is done using the stator parameters and is applicable to rotor sizing with zero interference fit (size on size). *Reference ISO 15136-1 Annex G.2 Equation G.1.*

Nominal Pump Capacity: The number obtained after rounding off theoretical pump capacity, which is typically done for convenience and ease of reference. Also referred to as nominal pump capacity, displacement, and designated as model. *Reference ISO 15-136-1 Section 6.5.1.*

Validated Pump Capacity: Actual measured capacity obtained from hydraulic validation test of a pump model conducted during the model validation process. It is the value measured at zero differential pressure, with water as the test fluid and with the test performed at ambient temperature (25-30°C). Its value is typically 2 to 5% below the theoretical pump capacity due to the interference fit of the rotor slightly reducing the cavity volume. *Reference ISO 15136-1 Section 6.5.1 and Annex B.2.3.2 and Annex G.2.*

Actual Pump Capacity: Actual measured capacity obtained from hydraulic validation test of an individual new pump at its associated pump testing conditions (fluid type, fluid temperature and speed). Varies from the validated pump capacity depending on differences in the pump rotor sizing and pump test temperature. Specifically, tighter fit pumps and higher testing temperatures have lower actual pump capacities due to a reduction in the cavity size.

PUMP CAPACITY VS DOWNHOLE PUMP FLOW RATE

Nominal Pump Capacity is the most published and as such widely used capacity although design programs and suppliers' technical literature may include theoretical and validated capacity and some pump test reports include the actual capacity. As described above the main differences between the nominal/theoretical capacity and actual pump capacity is related to differences in the cavity size which in turn are determined by the stator and rotor sizes. For a new pump the stator size is a function of the pump temperature with higher temperatures resulting in smaller sizes due to elastomer thermal expansion shrinking the cavities. While dependent on the specific pump geometry, a 20°C increase in temperature will decrease the cavity size and associated pump capacity by about 2 to 4%. There are also inherent variations in stator size associated with the manufacturing process, but these typically amount to changes in capacity of less than 2%. Rotor dimensions are related to the stator size and desired pump fit with more tightly fit pumps having larger rotor sizes and decreasing the cavity size and associated pump capacity.

PC pumps due to their positive displacement nature have flow rates that are a function of their capacity (displacement) and rotational speed. However, because the pump pressure seal created between the rotor and stator changes as a function of the component fit as well as the fluid conditions, there is backwards fluid slippage which reduces the actual flow rates. The ratio of the actual pump flow rate to that calculated based on the capacity and rotational speed is the volumetric efficiency. Depending on which capacity is used in the calculation the volumetric efficiency values can differ slightly. As previously described because the nominal capacity is most commonly used, it is normally the reference for published volumetric efficiencies. However, some pump test reports may include volumetric efficiencies referenced against validated or actual capacity. Note that when actual capacity is used to calculate volumetric efficiency then the value at zero pressure by definition will be 100%.

Pump slippage is a complex phenomenon dependent on many variables but most importantly the rotor/stator fit and fluid viscosity. While beyond the scope of this bulletin and described separately in Technical Bulletin LSI-TB-007, the tighter the fit and higher the viscosity the lower the pump slippage. When expressed as a rate (volume per time), slippage is independent of rotational speed which results in it having a diminishing effect on reducing volumetric efficiency with increasing pump speed.

In the actual downhole environment, the rotor/stator fit during operation may be different than surface pump test conditions due to differences in temperature that change the stator internal size due to elastomer thermal expansion. These changes occur quickly and are highly predictable. Additionally, the stator internal profile may change size over time due to interaction with liquids and gas resulting most often in elastomer swell and changing the cavity size, associated rotor/stator fit, slippage and volumetric efficiency. Normally the reduction in cavity size and associated capacity due to elastomer swell is more than offset by the increased rotor/stator fit and reduced slippage resulting in higher volumetric efficiencies The internal stator profile (and to a lesser extent rotor outside profile) may also wear over time resulting in slightly larger cavities and increased cavity size but reduced rotor/stator fit and increased slippage resulting in decreasing volumetric efficiencies.

SURFACE FLOW RATES

While the pump behavior is driven by the specific downhole operating conditions typically the ongoing evaluation of its performance is done based on measured surface flow rates which in turn are used to calculate volumetric pump efficiencies.

Depending on the operation this surface flow rate measurement may be done in a variety of different ways with differing implications. In the most representative situation relative to downhole conditions the measured flow rates encompasses all of the liquid including dissolved gas, free gas and solid components. But often the measured flow rate may only capture the liquids and free gas or the liquids and solids or just the liquids. Depending on the portion of free gas and solids in the flow stream at the surface measurement location this can result in the actual flow rates and associated volumetric efficiencies being underestimated.

When evaluating downhole pump performance based on surface flow rate measurements, consideration must also be given to fluid volume changes due to temperature and pressure at various locations in the system. Pressure and temperature at the pump intake govern the inflow of fluids into the pump intake and associated cavity fillage. While the pump discharge temperature is normally similar to the intake, the discharge pressure is substantially higher resulting in reduced pump discharge flow rates. The magnitude of the reduction is dependent on the compressibility of the fluid which is primarily dependent on the oil and/or water composition, gas content and relative pressure. As the fluid flows up the tubing the pressure decreases significantly and for wells with elevated downhole temperatures the fluid temperature may decrease as well. But what is most important is the pressure and temperature at surface where the flow rates are measured especially in the case where these measurements consider the gas component the volume of which is highly sensitive to pressure.

Often for simplicity the pump performance including its flow rate and associated volumetric efficiency is based directly on the measured surface flow rate. However more advanced design programs with multiphase flow models can determine fluid rates at various temperature and pressure conditions. This in turn can be used to adjust the measured surface flow rates to downhole pump intake conditions and more accurately assess downhole pump operation including changes over time. The importance of doing this is a function of the nature of the fluid and the changes in flow rates from downhole to surface conditions along with the granularity with which one is wanting to monitor pump performance.