Progressive Thinking for Pumps

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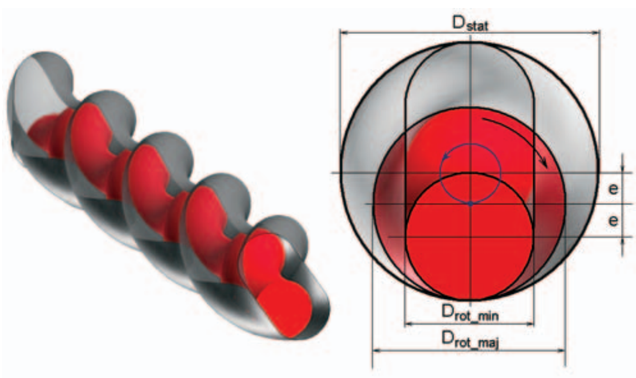
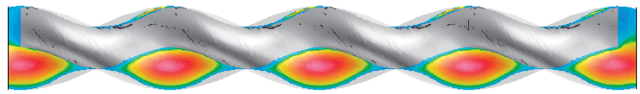
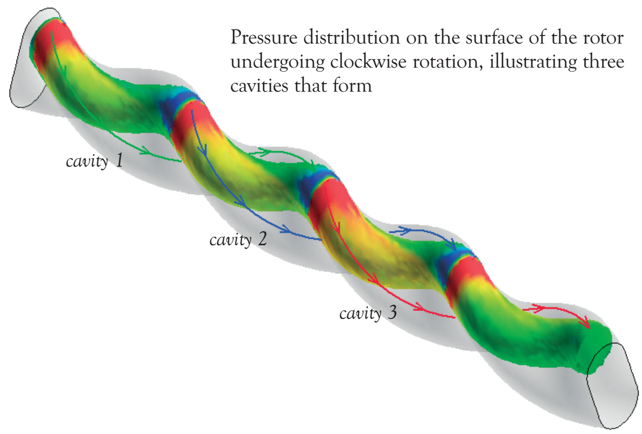


Overall design of a progressive cavity pump (left) and the rotor motion (right); D_{stat} is the stator diameter, D_{rot_min} and D_{rot_maj} are the minor and major rotor diameters, and *e* is the eccentricity



Axial velocity contour plot inside the pump



Pressure distribution on the surface of the rotor undergoing clockwise rotation, illustrating three cavities that form

PROGRESSIVE CAVITY PUMPS (PCPS), first patented by Moineau in the 1930s [1], have become widely used as artificial lift systems in the petroleum industry. Their advantages over other common pumps such as beam or submersible systems include higher overall efficiency, as well as an ability to pump fluids ranging from low (10 cP) to fairly high (100,000 cP) viscosity. These pumps can also tolerate a high percentage of free gas and large concentrations of sand.

PCPs are comprised of two helical elements, one inside the other. The internal element, or gear, is designated as the rotor and the outer element, or barrel, is referred to as the stator. For the pump to work, it is necessary for the rotor gear to have one less thread (or tooth) than the enveloping stator, so that the pitch of the rotor is equal to one-half that of the stator. A pump made up of a two-tooth stator and a single tooth rotor is called a single-lobe pump.

As the rotor turns about its axis, its outermost edge rotates in the opposite direction around the axis of the stator. This coupled motion of helical elements results in the formation of cavities which move axially from pump suction to discharge.

Due to the complexities of the geometry and motion of the rotor, a simulation of the flow inside a PCP poses a challenge. Although simplified 2D and 3D models [2, 3] have been used to simulate PCPs, full 3D transient simulations are only now being attempted. Traditional techniques for transient mesh creation for such a complex geometry can be very time consuming. However, the Mesh Superposition Technique (MST) available in POLYFLOW allows one to skip this procedure by superimposing a mesh for the solid domain (the rotor) onto the mesh for the fluid domain. Although POLYFLOW is traditionally used for simulations of highly viscous materials such as polymers, it is also quite capable of solving flows involving heavy oils, which have relatively lower viscosities.

A transient, isothermal flow for a Newtonian fluid with a viscosity of 20,000 cP is currently being studied for two pitches of progressive cavity pumps. A 3D stator mesh of 62,160 hexahedral elements and a rotor mesh of 6,000 elements are being used for the simulation. The initial results indicate that, at the same flow rate, the torque on the rotor, and therefore the power consumption, varies significantly with the stator design. Although a constant viscosity model is currently being used for the simulations, future work will also include non-isothermal simulations with non-Newtonian viscosity models, such as power law and Carreau-Yasuda. These models will give a better representation of the viscosities of composite crude oil/gas/sand mixtures and therefore will provide insight into the effects of fluid rheology on pump efficiency. Further progress with this work will allow the stator designs currently used by PCP manufacturers to be optimized. ■

References

1 Moineau, R. J. L.: Gear Mechanism. U. S. Patent, 2,085,115, 1935.

2 Gamboa, H. *et al.*: New approach for modeling progressive cavity pump performance. SPE 84137, 2003.

3 Gamboa, H. *et al.*: Understanding the performance of a progressive cavity pump with a metallic stator. 20th Int. Pump Users Symp., 19, 2003.