Hydraulic Subsurface Pump Numerical Study

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Background

The increase in global energy consumption pushes oil companies to go into more challenging tasks and environments. New inventions, especially in the artificial lift sector are needed to maximize production rate and efficiency under economic conditions.

Standard conventional lift systems as sucker rod pumps use for example steel rods to connect and drive the subsurface pump from the surface. Such solutions for oil production in depths of hundreds or thousands meters and harsh environments are sources of potential equipment failures. Some of these can be avoided by the usage of an innovative hydraulic reciprocating pump.

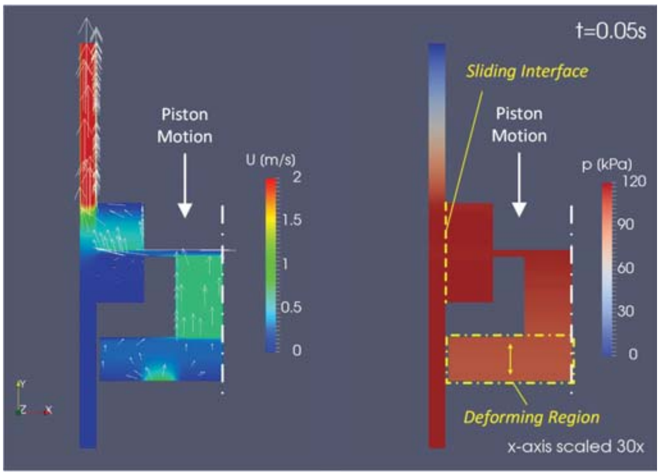

Figure 2: Flow Field in the Subsurface Pump during Downstroke

Pump Design

The working principle of the new hydraulic subsurface pump, whereby the alternate pressurization of the liquid in the tubing respectively in the annulus and the gravitational force of the pump itself a reciprocating piston movement is induced (see Figure 1). The valves, reacting on changes in pressure, will draw new production fluid into the pump and therefore to surface.

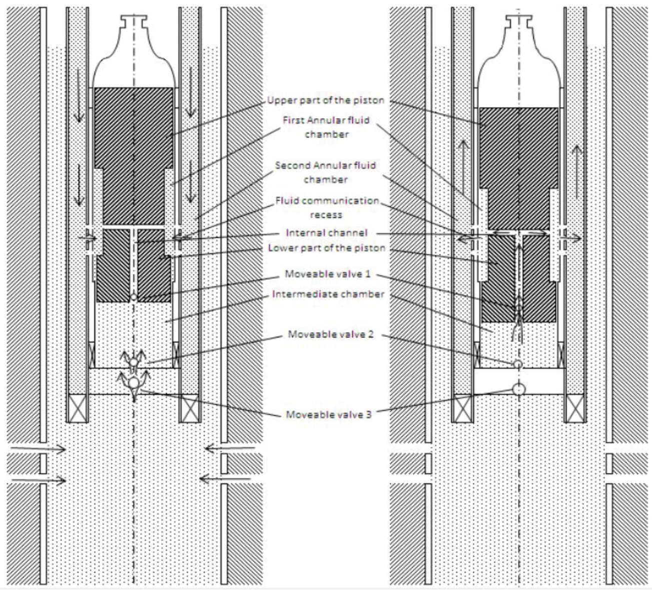

Figure 1: Mechanical principle of the hydraulic pump

Numerical Study

The concept of the hydraulic subsurface pump was validated using the open-source software toolbox OpenFOAM®[2] and its supporting library swak4Foam[3].

The used transient incompressible solver `pimpleDyMFoam` allowed to tackle the challenging task of coupling a dynamic mesh movement with the fluid flow in the well. The dynamic mesh contains a *sliding mesh interface* between the tubing and the moving pump assembly utilizing OpenFOAM's Arbitrary Coupled Mesh Interface (ACMI), and a *deforming mesh region* that models the work chamber volumetric change as the piston moves up and down. The complex mesh movement is driven by fluid pressure forces acting within the pump. The acting forces are evaluated every time step and the analytically calculated *mesh displacement* is then imposed on the dynamic mesh in the next time step. The k-ω Shear Stress Transport[4] turbulence model is used to resolve the turbulent flow at lower Reynolds numbers.

The conducted study provided an insight into the influence of the differential pressure, the piston geometry and its weight, as well as the well geometry on the pump's dynamic behavior. The results will be used in the optimization and further development of the hydraulic subsurface pump concept.

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