Design optimisation of swellable elastomeric seals using advanced material modelling and FEM simulations

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**Stampede™ Swellable Packers**

Swellable elastomer seal is a type of specifically engineered packer that can expand to contact with wellbore fluids under downhole conditions. The seal is formed by swelling properties of swellable elastomers upon contact with water or brine in a wellbore. The swelling process is influenced by various factors including temperature, pressure, and chemical composition of the fluids present in the wellbore. Understanding these factors is critical to the effective use of such seals in various downhole applications.

**Introduction & Objectives**

Swellable elastomer seal is a type of specifically engineered packer that can expand to contact with wellbore fluids under downhole conditions. The seal is formed by swelling properties of swellable elastomers upon contact with water or brine in a wellbore. The swelling process is influenced by various factors including temperature, pressure, and chemical composition of the fluids present in the wellbore. Understanding these factors is critical to the effective use of such seals in various downhole applications.

**Shape optimisation with Tosca Structure**

Interactive drawing and remeshing can be associated with a localized increase of material strain. This may cause a significant degradation of FE mesh and result in analysis divergence problems. To overcome this, an adaptive remeshing technique particularly useful for CAE plugins is implemented. In this case, ABAQUS is associated with a number of technical challenges specific to the class of multiphysics problems.

**FE-simulation of Pressure penetration & leakage in packer**

Parametric study remains going through a high number of iterations as more parameters are considered. The material properties are subject to different optimization conditions. This means for the optimal geometry through a sensitivity study, which must result in specific design recommendations. In this case, using FE simulation, the analytical approach through a plugin with a commercial UI, which provides access to the parameters of geometry, material, service conditions, etc., is a key component.

**Discussion**

Critical mechanical contact pressure for fluid pressure penetration

- *Maximum principal stress: The maximum principal stress is the highest stress that occurs in the packer, indicating the maximum stress experienced by the material.*
- *Contact pressure: The contact pressure is the pressure at which the fluid penetrates the packer, indicating the pressure required to cause failure by fluid pressure.*
- *Fluid pressure: The fluid pressure is the pressure exerted by the fluid in the wellbore, indicating the pressure that the packer must withstand.*
- *Critical contact pressure: The critical contact pressure is the minimum pressure required to prevent fluid penetration.*

**References**

[6] The development of swellable elastomers is a complex process involving multiple physical and chemical changes. These changes are influenced by various factors including temperature, pressure, and chemical composition of the fluids present in the wellbore.

**Planed Research Outcomes**

- *Design and manufacturing of tools for mechanical testing of swellable elastomeric specimens and mechanical behavior of elastomers under downhole conditions in form of tables and/or mathematical expressions.*
- *Development of an optimisation procedures for available FEA packages (ABAQUS, ANSYS, MSC.Marc etc.) based on three optimisation engines will be used.*
- *Mechanical characterisation of swellable elastomers used by Weir Oil & Gas for packers through experimental studies in Advanced Materials Research Laboratory (AMRL) in the UK, Weir Oil & Gas USA for packers through experimental studies in Advanced Research Centre (ARC)*
- *Linking of moisture swelling with the fluid pressure penetration in order to correlate experimental results with existing, which provides access to the parameters of geometry, material, service conditions, etc.*
- *Contact with fluids.*

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**High-quality elastomers are critical to the life of the packer.**

*Proprietary elastomer compound provides predictable wear when in contact with fluids and reduced remeshing.*

Hyperlacten with swelling

The key component is an advanced material model comprising both hyperelasticity and moisture swelling. It has to consider two-way interaction between mechanical and chemical aspects of swelling. Implementation of such material model requires programming of a semi-empirical swelling law. This swelling law is written as:

\[ \frac{1}{E} - 1 = \frac{1}{E_0} - 1 + \frac{1}{2} \frac{D}{E_0} \]

\[ \frac{D}{E_0} = \frac{1}{2} \left( \frac{1}{E} - 1 - \frac{1}{2} \frac{D}{E_0} \right) \]

where \( E \) is the volume fraction of polymer in the swollen state, \( E_0 \) is the volume fraction of polymer in the original state, and \( D \) is the number of network chains per unit volume of swollen elastomer.

**Benchmark problem for leakage and extrusion**

**Adaptive remeshing**

**Robust Simulation of Swellable Packers**

**Simulation-Based Optimisation**

**FE-simulation of Pressure penetration & leakage in packer**

**Discussion**

**Planed Research Outcomes**

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**References**