Project Profile

Project Name:	Displacement Fluid Mechanics in Primary Cemented Annuli
Project Number:	EI-2016-10
Proponent:	Department of Mechanical Engineering, University of British Columbia
Funding Envelope:	Environmental Impacts
Timeframe:	Year 1—October 1, 2015 to September 30, 2016 Year 2—October 1, 2016 to September 30, 2017 Year 3—October 1, 2017 to November 30, 2018

Project objectives

The objective of the project are to develop a process model for annular flows of cementing materials during primary cementing, extending previous work to cover turbulent flow regimes, mixed flow regimes and weakly compressible fluids. Analysis of this model should produce simplified design recommendations for primary cementing operations, including guidance on when turbulent displacement is beneficial.

Project description

In [1-13] the UBC cementing group has developed a consistent method of modelling the complex 3D displacement flows that occur in primary cementing of oil & gas wells. These models however are currently focused exclusively at laminar flows of incompressible fluids. Such flows are important in primary cementing and particularly in longer horizontal sections, where pore-frac envelopes become restrictive to frictional pressures. However, significant numbers of wells are cemented at least partly in turbulent flow regimes or in regimes where some fluids are in laminar regime and some turbulent (according to the fluid properties). Secondly, as well as incompressible fluids, some operators and service companies advocate the use of weakly compressible fluids, such as foamed cement, and some oil-based drilling fluids show weak compressibility at large depths. It would be advantageous to model these scenarios as well.

This project is aimed at extending the scope of the current UBC primary cementing models to cover fully turbulent and mixed flow regimes, as well as relevant weakly compressible fluids. The UBC primary cementing models are the only public domain process models for annular displacement flows during primary cementing. Extending the models in this way will enable a complete range of process scenarios to be modelled in a consistent and reliable way. As well as model extension, this paves the way for development of an engineering design tool for primary cementing, able to predict (and hence prevent) large scale defects in primary cementing.

Project background

A significant % of wells leak, allowing gas and subsurface fluids to migrate to surface. This is despite >80 years of worldwide experience in primary cementing of oil & gas wells, together with significant evolution of industry no-how, equipment and materials. Leakage is common in Western Canada and presents both environmental and health/safety risks, as well as reducing well productivity. One widely acknowledged reason for surface casing vent flows is poor mud removal, on a bulk scale. Commonly, this manifests in a channel of drilling mud that is left behind in the annulus during the cementing process, typically stuck in the narrowest part of the annulus. Such features are routinely picked up at the evaluation stage in CBL readings, snaking upwards in the cemented annulus and providing a porous channel between reservoir zones. This project focuses at development of a computational model of the displacement process in the cemented annulus, following on from an established history of primary cementing model development at UBC [1-13].

Project approach

The project will be carried out using the following approach:

More than 10 dimensionless parameters are involved in modelling the displacement of 2 non-Newtonian fluids with yield stress in a 3D annular geometry. A more serious difficulty in studying these flows is the disparity of scales (annular gap ~10^{-2}m, annular circumference ~0.5m, annular length ~10^{3}m), which means that computations at the smallest (annular gap) scale carried out over the wellbore scale are not feasible in sensible timescales using todays CFD tools. The UBC approach has been to reduce the problem to 2D by averaging across the annular gap. On the gap scale this means representing the hydraulics in a simplified fashion that can be up-scaled into the 2D (azimuthal & length-wise) model. The resulting models are solvable in real time on standard desktop computers and can represent bulk flow features on the scale of the wellbore.

In modelling turbulent flows in this way, the approach is strictly valid only in the narrow annulus limit. It is necessary to find closure expressions for the flow of Herschel-Bulkley fluids in turbulent flow and to use these to model turbulent dispersion, transverse to the flow and Taylor-dispersion in the streamwise direction. The enhanced dispersivity in turbulent flow is what is primarily responsible for variations from the laminar approach in [1-13]. This model development is underway and implementation of a fully turbulent displacement model will be the goal for the first year of the project. To model weakly compressible flows (foamed cements and drilling fluids) is the goal for the second year. Weak compressibility in the wellbore context essentially means that the pressure increase due to depth needs to be accounted for in the density that is included in the conservation laws. In principle this can be achieved by working with a redefined stream-function, based on steady mass (not volume) conservation. In parallel, in the second year we hope to begin development of an engineering design tool for primary cementing. We will engage with BCOGC in order to collect data typical of primary cementing operations conducted in NE British Columbia, so that we may eventually simulate such wells. Finally, we will seek out collaborative possibilities within the industry for validation studies.

Project deliverables

The deliverables from this project include the following:

1. Annual Report.
2. Presentation to the project sponsors.

The other main deliverables will consist of contributions to the open scientific literature in each of the outlined areas, in the form of both scientific journal papers and conference presentations. The results will provide an independent assessment of the rationale for some aspects of current primary cementing operations. The net result of all of these will be a PhD thesis.

In the second and third years we hope to develop a prototype simulator at UBC that can receive field inputs in terms of well geometry, fluid properties and pump schedule, and will output the fluid stages during and after the placement operation. According to robustness and utility, either limited executable versions of this simulator will be made available, or UBC will conduct in-house analysis on their behalf. Analysis of cementing operations, in the form of recommendations on cementing practice backed up by model simulation will be another benefit for the industry in Western Canada.

References

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