Downhole hydrocyclone design and optimisation

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The separation of water from hydrocarbons in high water-oil ratio wells (e.g. mature fields) is commonly done in surface processing stations, with produced water discharged into the environment after separation. The lifting of downhole fluids to the surface is, however, costly and not energy efficient. Alternatively, downhole separation technologies, such as hydrocyclones, can be used to carry out the separation in the well bore, so that water can be reinjected into formation wells without lifting it to the surface. Although the use of downhole hydrocyclones is well established, the separation efficiency of a single unit is not high and hydrocyclones arranged in series are often required. This poses a limitation, as there is a space restriction imposed by the casing well diameter.

The objective of this PhD project is to design novel downhole hydrocyclones to enhance the separation of oil and water mixtures, for both single units and compact hydrocyclone arrays. The student will first investigate what type of modifications to the geometry of a hydrocyclone can promote a better separation of the two fluid phases. The height of the hydrocyclone, the curvature of its walls and the diameter of the outflows are variables that are known to have an effect on separation performance but have not been rigorously studied for liquid-liquid hydrocyclones. The project will apply a proven methodology for mini-hydrocyclone design and optimisation that combines rapid manufacturing and computer modelling.

3D printing will be used to manufacture very small hydrocyclones (5-10 mm in diameter) to test the effect of key design variables at the laboratory scale. The student will implement models in a Computational Fluid Dynamics (CFD) software to predict the separation process. This is not a trivial task and will require rigorous validation of base case designs from experimental data obtained at the start of the project. Once validated, the CFD model will be used to simulate a range of hydrocyclone designs at operating conditions that are not limited to those that can be achieved in the lab, but instead at typical downhole conditions obtained from field data. A 'Design of Experiments' approach for the modelling work will allow optimised design parameters to be obtained. At the end of the project, the student will have developed a deep scientific understanding of the effect of design variables on downhole hydrocyclones, a validated simulator and an optimised novel downhole hydrocyclone design. Such an apparatus has the potential to improve water management in mature production wells, not only increasing the value of the asset but also reducing environmental impact.

This project is available for students who apply for Imperial College scholarships or other international scholarship schemes.

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