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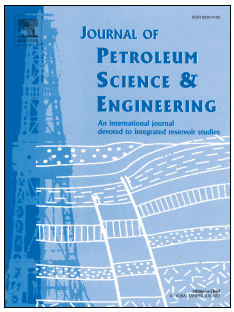

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ACCEPTED MANUSCRIPT

Effect of Capsule Shape on Hydrodynamic Characteristics and Optimal Design of Hydraulic Capsule Pipelines

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Abstract
Hydraulic capsule pipelines (HCPs) are the third generation pipelines transporting hollow containers, known as capsules. These capsules are filled with material/cargo to be transported. The shape of these capsules has a significant effect on the hydrodynamic flow characteristics within HCPs. As the variations in the pressure distribution within HCPs are directly linked to and the flow characteristics within pipelines, it is essential to critically evaluate the effect of capsule shape on the pressure drop across the pipeline. Published literature is severely limited in terms of establishing the effects of the shape of the capsules on the flow characteristics within pipelines. Hence, the present study focuses on using a well-validated Computational Fluid Dynamics tool to numerically simulate the flow of capsules of various shapes quantified in form of a novel shape factor in hydraulic capsule pipelines. Both on-shore and off-shore applications of such pipelines have been investigated in the present study, along-with pipe fittings, such as bends. Variations in flow related parameters within these pipelines have been discussed in detail for a wide range of geometrical parameters associated with the capsules and the pipelines. Pressure drop values have been used to develop novel semi-empirical prediction models as a function of the shape factor and other flow and geometric variables of the capsules. These prediction models have been embedded into a pipeline optimisation methodology, which has been developed based on Least-Cost Principle. The resulting novel optimisation methodology can be used for hydraulic capsule pipeline design. Performance charts for practical applications have been developed for easy implementation of the design methodology for the designers of hydraulic capsule pipelines transporting capsule of different shapes.

Keywords: Hydraulic Capsule Pipeline (HCP), Least-Cost Principle, Optimisation, Shape Factor, Solid-Liquid Flow

1.0 Introduction
Capsule transportation through pipelines is an established mode of bulk solid handing, which is extensively employed in a number of industries i.e. mining industry, process industry, chemical industry etc. In many applications capsules that are being transported do not have any preferential shape. This makes estimation of flow characteristics within transportation pipelines difficult, which in turn affects poor design of such pipelines. Currently the effect of variations in capsule shape is accounted for by defining a shape factor as per the equation given below.

$$\psi = \left(\frac{\text{Volume of Capsule}}{\text{Volume of Circumscribing Sphere}}\right)^{\frac{1}{3}} \quad (1)$$

Ellis et al [1-5] carried out a number of experimental investigations on the flow of both equi-density and heavy-density capsules of shape factors of 1 (spherical) and 0.8094 (cylindrical,

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