*Proceedings of The Seventh (2007) ISOPE Ocean Mining Symposium*
*Lisbon, Portugal, July 1-6, 2007*

*ISBN 978-1-880653-69-2; ISBN 1-880653-69-9*

# A Study on the Solid-Liquid Helical Flow in a slim hole annulus

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## ABSTRACT

An experimental investigation is carried out to study two-phase vertically upward hydraulic transport of solid particles by water and non-Newtonian fluids in a slim hole concentric annulus with rotation of the inner cylinder. Studying the rheology of particulate suspensions in viscoelastic fluids is essential in many applications such as particle removal from surfaces, transport of proppants in fractured reservoir and cleaning of drilling holes, etc. In this study a clear acrylic pipe was used in order to observe the movement of solid particles. Annular fluid velocities varied from 0.2 to 3.0 m/s. Pressure drop, average flow rate, and particle rising velocity are measured. The higher the concentration of the solid particles is, the larger the pressure gradient becomes in both water and 0.2% Carbomethyl Cellulose(CMC) solutions.

KEY WORDS: Wall shear stress; Skin friction coefficient; Two-phase flow; Slim hole annulus

## INTRODUCTION

Among various industrial unit operations involved with multi-phase systems, agitation of solid-liquid systems is quite commonly encountered such as catalytic reactions, drilling operation of oil well, etc. Although there are many industrial applications of solid-liquid flows in technology, available knowledge about particle flows is not complete due to the difficulties encountered in analyzing these complex systems.

Rotating flows in annular passages are important, since they have many engineering applications in bearings, rotating-tube heat exchangers and, especially, annulus flows of mud in case of slim hole drilling of oil well. Shear stresses close to the wall of the borehole can erode it, and cause to cave. This phenomenon can be very dangerous when the rotating rods are not supported anymore by the wall and can break. It strongly depends on the velocity gradients. Delwiche et al. (1992) found that a laminar flow regime induces lower velocity gradients than a turbulent flow and thus lower shear stresses.

Wall shear stress is of great importance in fluid mechanics research, as it represents local tangential force by the fluid on a surface in contact with it. By integrating the wall shear stress along the surface, one can compute its contribution to lift and drag on immersed objects and pressure drop in pipes and other internal flows.

Pressure and shear stress on the wall are related to the flow in the boundary layer above the wall in quite different ways. The wall shear stress is locally determined by the velocity gradient immediately adjacent to the wall. On the other hand, Blake (1986) found that the wall pressure is a weighted integral of the effects of the velocity field over the half space above the wall.

Interests have been growing in the interaction between particle and local flow structure in particulate two-phase flow. Pigot (1941) discussed the application of Stoke's law for laminar flow and Rittinger's formula for turbulent flow to drilled particle settling velocity calculation. He concluded that high fluid viscosity was not necessary, suggesting that laminar flow in the annulus would lead to more efficient cleaning. For trouble-free operation, he also recommended that the volumetric cuttings concentration in the annulus be kept less than 5%.

Sifferman et al. (1974) found that annular velocity and fluid rheological properties are the most important factors influencing the transport ability of a fluid. Other variables such as particle size, drill pipe rotation, drill pipe eccentricity have only moderate effects on carrying capacity in their study.

Sellgren (1982) discussed the two-phase pressure drop and choice of operating velocities in the vertical upward pipe flows of solid-liquid mixtures. He reported that additional turbulence was created due to the relative velocity between the solid and fluid phases. Chung et al. (1999) and Chung and Graebel (1972) carried out experimental study about single and two phase flow of non-Newtonian fluids in pipe.

This paper concerns an experimental and numerical study of fully developed solid-liquid two-phase flows of Newtonian fluid, water and non-Newtonian fluid, CMC solutions through concentric and eccentric annuli with combined bulk axial flow and inner cylinder rotation.

Non-Newtonian fluids are those for which strain rate and stress curve are not linear, i.e., the viscosity of non-Newtonian fluids is not constant at a given temperature and pressure but depends on other factors such as the rate of shear in the fluid, the apparatus in which the fluid is contained or even the previous history of the fluid. Consequently, the