A Study on the Solid-liquid Rotating Flow for Cuttings Transportation in Inclined Annulus

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ABSTRACT

An experimental and numerical study was carried out to study solid-liquid mixture upward hydraulic transport of solid particles in vertical and inclined annuli with rotating inner cylinder. Lift forces acting on a fluidized particle plays a central role in many importance applications, such as the removal of drill cuttings in horizontal drill holes, sand transport in fractured reservoirs, sediment transport and cleaning of particles from surfaces. Effect of annulus inclination and drill pipe rotation on the carrying capacity of drilling mud and pressure drop in a slim hole annulus have been measured for fully developed flows of water and of aqueous solutions of sodium carboxymethyl cellulose (CMC), respectively. For water and CMC solution the higher the concentration of the solid particles is, the larger the pressure gradients become.

KEY WORDS: Solid-liquid mixture flow, Slim hole annulus, Particle concentration, Pressure drop

INTRODUCTION

Among the 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 mixture flows in technology, the available knowledge about particle flows is not complete due to the difficulties encountered in analyzing these complex systems.

Due to the variety of the variables related to the solid-fluid two phase flow, there may be various conditions to be included in considering the influence of the variables related to the transportation of drilling remnants. The study of transportation drilling remnants is a case of engineering that is classified as multi-flow accompanying solid particle, fluid and gas.

The study of drilling remnant transportation ability can be divided into the dynamics of the particles within the fluid largely and can be divided into the specialty and action of the drilling irrigation.

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.

When an oil well is drilled, it is necessary to transport the cuttings up to the surface. To this end, fluid is pumped through the center of drill pipe and back up to the surface through the annular gap between the drill pipe and the drilled hole. The fluid is viscous, non-Newtonian, and will typically have gel strength. The flow up to the annulus might be laminar or it might be turbulent, depending on the situation.

With the increase in use of deviated, highly deviated and long reach drilling, greater consideration must be given to the fluid mechanics of transportation in situation where none, or only a small component, of the bulk flow acts against the tendency for cuttings to drop out of suspension and form a bed on the low side of the annulus. This is even more important in slim hole drilling.

Therefore, numerous mathematical and empirical models for the prediction of cuttings transport in horizontal and directional wells have been developed by several researchers. A detailed reveals that the cuttings transport characteristics change with an increase in wellbore angle. Tomren(1979) and Ford et al.(1991) carried out experimental study on cuttings transport in inclined annulus and observed the existence of different layers that might occur during the mud flow and cuttings in an annulus. They noted that rotation of the drill pipe had little effect unless the annulus is eccentric and the drill pipe is on the low side of a horizontal geometry. In this condition, rotation helped to prevent a bed of cuttings being formed.

Interest has been growing in the interaction between particle and local flow structure in particular 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 and suggested 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%.

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

For inclined annulus, it is interesting to note that steady state conditions, as are known to be prevalent in most drilling operation, commence after the bed has already formed. Due to the constant