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Development of a Tool for Fundamental Undersating of Multipahse Non-Newtonain Flow in Annulli

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Abstract

The hydrocarbon reserves of conventional/unconventional sources will remain a major source of the world's energy supply even with the fastest growth of other energy sources including renewable energy. The petroleum and energy industry must be capable of low-energy intensive extraction and transportation of these resources, in an environmentally benign manner. Drilling wellbores is one of the most important part of extracting petroleum resources from the reservoirs. Very complex spatio-temporal flow patterns of multiphase flow, which are often observed in annuli during drilling fluid circulation and wellbore production, are not fully understood. Fundamental understanding of the effects of complex multiphase flow regime on hydrodynamic scaling and geometric scaling is an open challenge. This understanding is essential for substantial economic growth of oil and gas industry. The talk will be based on an experiments and numerical simulations project that helps to understand the multiphase (gas/liquid/solid) flow behavior in annuli under various operating, hydrodynamic and geometric conditions.

The objectives of the project are as follows: 1) to develop a tool or model which will optimize and suggest meaningful surface operating parameters for efficient wellbore cleaning and drill cuttings transmittal to surface, particularly during horizontal drilling wells (cuttings settling in the tangential section), 2) to predict multiphase volume fractions (flow metering) and pressure loss in annuli with a wide range of operating, hydrodynamic and geometric conditions, and 3) early detection of mini-kicks (formation gas invasion to circulating fluids) and provide real-time changes to surface operating parameters before it turns to a well control event and a possible blow-out. Mean velocity and the corresponding Reynolds shear stresses of Newtonian and non-Newtonian fluids have been measured in a fully developed concentric flow with a diameter ratio of 0.5 and at a inner cylinder rotational speed of 300 rpm. With the Newtonian fluid in laminar flow the effects of the inner shaft rotation were a uniform increase in the drag coefficient by about 28 percent, a flatter and less skewed axial mean velocity and a swirl profile with a narrow boundary close to the inner wall with a thickness of about 22 percent of the gap between the pipes. These effects reduced gradually with bulk flow Reynolds number so that, in the turbulent flow region with a Rossby number of 10, the drag coefficient and profiles of axial mean velocity with and without rotation were similar. The intensity of the turbulence quantities was enhanced by rotation particularly close to the inner wall at a Reynolds number of 9,000 and was similar to that of the non rotating flow at the higher Reynolds number.

The effects of the rotation with the 0.2 percent CMC solution were similar to those of the Newtonian fluids but smaller in magnitude since the Ross by number with the CMC solution is considerably higher for a similar Reynolds number. Comparison between the results of the Newtonian and non-Newtonian fluids with rotation at a Reynolds number of 9000 showed similar features to those of non rotating flows with an extension of non-turbulent flow, a drag reduction of up to 67 percent, and suppression of all fluctuation velocities compared with Newtonian values particularly the cross-flow components. The results also showed that the swirl velocity profiles of both fluids were the same at a similar Ross by number. The fluids which do not follow linear relationship between rate of strain and shear stress are termed as non-Newtonian fluid. The non-Newtonian fluids are usually categorized as those in which shear stress depends on the rates of shear only, fluids for which relation between shear stress and rate of shear depends on time and the visco in elastic fluids which possess both elastic and viscous properties.

It is quite difficult to provide a single constitutive relation that can be used to define a non-Newtonian fluid due to a great diversity found in its physical structure. Non-Newtonian fluids can present a complex rheological behaviour involving shear-thinning, visco elastic or thixotropic effects. The rheological characterization of complex fluids is an important issue in many areas. The paper analyses the damping and stiffness characteristics of non-Newtonian fluids (waxy crude oil) used in squeeze film dampers using the available literature for viscosity characterization. Damping and stiffness characteristic will be evaluated as a function of shear strain rate, temperature and percentage wax concentration etc. By using the basic equation of fluid motion (conservation of mass and momentum) the boundary layer parameters for a Non-Newtonian, incompressible and laminar fluid flow, has been evaluated. As a test, the flat plate boundary layer is first analized and afterwards, a case with pressure gradient, allowing separation,

is studied. In the case of curved surfaces, the problem is first developed in general and afterwards particularized to a circular cylinder. Finally suction and slip in the flow interface are examined. The power law model is used to represent the stress strain relationship in Non-Newtonian flow. By varying the fluid exponent one can then, have an idea of how the Non-Newtonian behavior of the flow influences the parameters of the boundary layer. Two equations, in an appropriate coordinate system have been obtained after an order of magnitude analysis of the terms in the equations of motion is performed.