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Experimental investigation of solids transport in horizontal concentric annuli using water and drag reducing polymer-based fluids☆

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ABSTRACT

When drilling long horizontal wells, drilled solids tend to settle down on the low side of the wellbore and form a stationary bed. Presence of stationary cuttings bed causes operational difficulties such as pack-off, excessive torque and drag, slow drilling rate, and in severe cases, stuck pipe, lost circulation, and even loss of the well control. Despite significant progress made in drilling fluids, tools, and field practices, along with more than 50 years of university and industry research, field experience indicates that cuttings transport is still a major problem in most horizontal wells.

There are many variables affecting the efficiency of cuttings transport (e.g. drilling fluid type, density, flow rate and rheological properties, hole inclination angle, drill pipe rotation speed and eccentricity). Among these variables, the drilling fluid flow rate and rheological properties are the most critical ones as they have strong influence on cuttings transport while at the same time, field control of these variables can be managed conveniently. An experimental study was, therefore, designed and conducted to simulate solids transport in the horizontal annuli under controlled conditions of solids feed rate, fluid flow rate and fluid rheological properties.

Cuttings transport experiments were carried out using a 6.5 m long horizontal flow loop with concentric annular geometry (Outer Pipe ID = 0.074 m, Inner Pipe OD = 0.047 m).

Water and high molecular weight partially-hydrolyzed polyacrylamide (PHPA) polymer solutions with various degrees of drag reduction capability were used as carrier fluids. Solids were made out of industrial sand with median (D50) diameter of 0.00275 m.

Effects of drilling rate (i.e. solids feed rate), drilling fluid flow rate and polymer concentration (i.e. drag reduction effect) on the cuttings transport efficiency and pressure losses were investigated.

Maximum drag reduction was observed (i.e., 38% reduction in frictional pressure drop) when optimum polymer concentration of 0.07% W/W was used. The polymer fluid yielding the maximum drag reduction also resulted in the most efficient cuttings transport, which was observed as the lowest cuttings bed deposit height in the annulus.

1. Introduction

The problem of cutting transport in highly inclined and horizontal wellbores has been investigated since 1980's. Comprehensive reviews of the past work could be found in papers written by Pilehvari et al. (1999) and more recently by Li and Luft (2014a, 2014b). Generally, parameters affecting cutting transport could be categorized under three groups (Bilgesu et al., 2007): fluid characteristics, cuttings related factors and operational variables. Effect of fluid rheological properties on transportation of drilled cuttings has been widely studied in the literature.

Williams and Bruce (1950) reported that low viscosity and low gel drilling fluids are better in removing the cuttings. Tomren et al. (1986) reported that effect of viscosity depends on the flow regime; when the flow regime is laminar, it is better to use high viscosity fluids; while in turbulent flow there is no significant effect of viscosity. Azar and Sanchez (1997) reported that high fluid viscosity

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reduces the well cleaning ability in deviated wells. Larsen (1993), on the other hand, found that with increasing the apparent viscosity, equivalent slip velocity of cuttings decreases and, therefore, the efficiency of cuttings transport increases. Cho et al. (2000) indicated that a high viscosity drilling fluid would slightly improve cuttings transport as well as increase the pressure drop when the flow regime is turbulent.

Saasen and Løklingholm (2002) discussed the effect of bed consolidation caused by interaction of polymer based drilling fluids and drilled cuttings and concluded that it is best to use Newtonian fluids. Duan et al. (2009) results suggested polymer solutions are more effective in preventing formation of a bed. Li and Luft (2014a) stated that fluids with higher viscosity and density have better suspension ability, which results in lower cuttings concentration in the annulus.

Generally, increasing the drilling fluid flow rate translates into more effective transport of cuttings. This approach may be applicable in drilling of short horizontal or deviated well sections, however, when drilling a long horizontal section or extended reach wells it may not be feasible to use very high flow rates. High annular frictional pressure losses generally anticipated in long horizontal and extended reach wells could be very prohibitive due to limited pump capacity and increased pump operational costs, as well as other operational problems such as wellbore erosion, lost circulation, etc. In long horizontal wellbore sections, dynamic pressure losses in the annulus may reach to the rock fracture limit and any further increase in flow rate could cause lost circulation problem. In any case, reaching this technical limit puts an end to the drilling capability. Therefore, to enhance the drilling of horizontal and extended reach wells by minimizing the cost and maximizing the length of the horizontal reach, transport of cuttings needs to be improved while keeping the frictional pressure losses as low as possible.

Strategies to minimize the frictional pressure losses are needed as part of an optimization of drilling hydraulics program (Ercan and Ozbayoglu, 2009). Use of drag reducing polymer additives at very low concentration in drilling fluid applications has been proven to be an effective way to reduce frictional pressure losses significantly (Shah et al., 2006). However, using low polymer concentration to reduce the frictional pressure losses may interfere with some other functions of drilling fluid such as cuttings transport performance. Therefore, when analyzing the effect of polymer additives for drag reduction, it is necessary to study the effect of adding the drag reducers on the cuttings removal performance as well.

Recently, Corredor et al. (2014) studied the hole cleaning performance of drag reducing fluids using series of bed erosion tests. Comparing the hole cleaning performance of drag reducing fluid versus water, Corredor et al. (2014) concluded that water removes the particles from bed deposits at lower critical velocity.

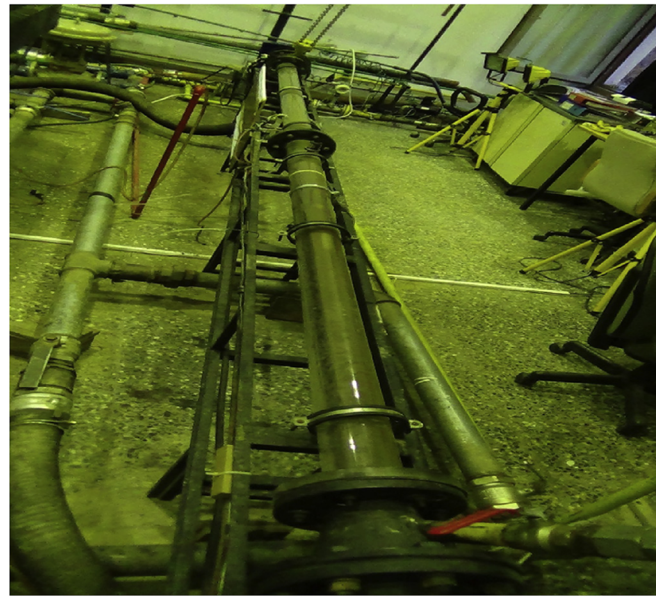

Fig. 2. Experimental set-up used for cuttings transport experiments.

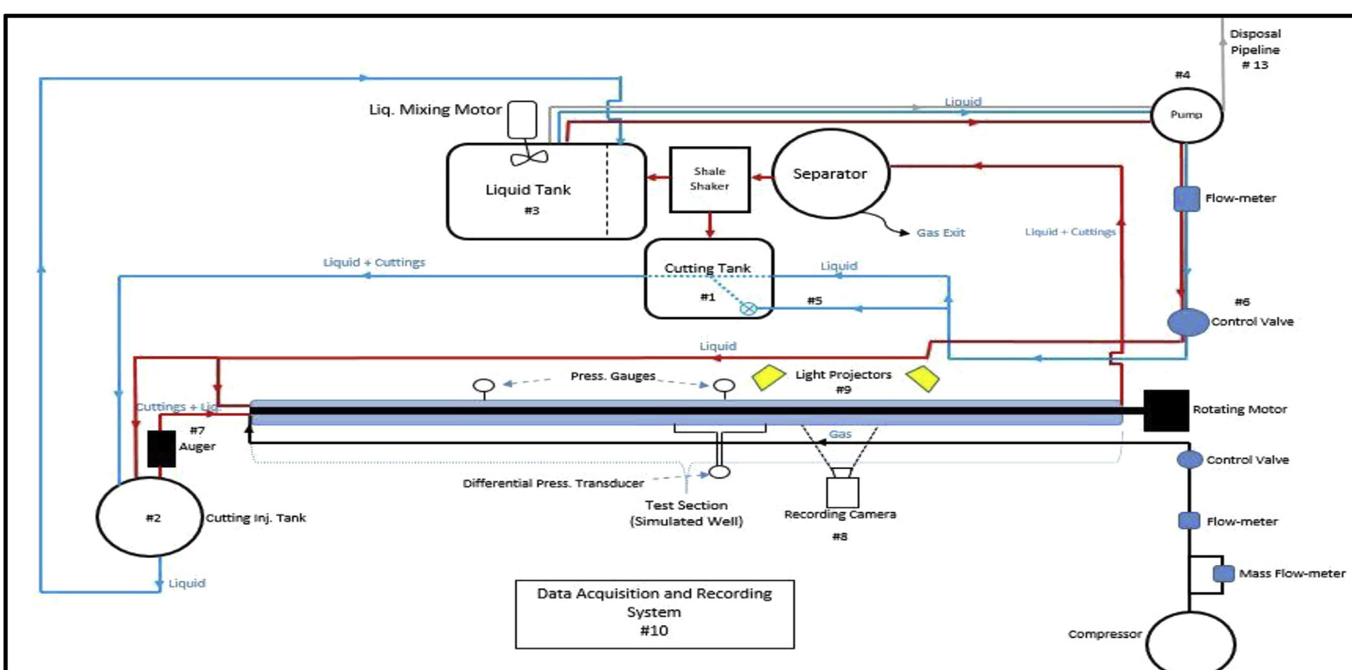

Fig. 1. Schematic of experimental set-up used for cuttings transport experiments.