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The Minimum Required Gas-Injection Rate for Liquid Removal in Air/Gas Drilling

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Abstract

Air/gas drilling is a technology used for increasing rate of penetration in hard formations and reducing fluid damage to low-pressure coal beds for methane production. It has been widely recognized that maintaining adequate air/gas injection rate is vitally important to achieving hole cleaning against both solid and liquid accumulations. However, it is unclear as what constitutes the “adequate” air/gas injection rate for removal of formation liquid influx. It is highly desirable to have a simple and accurate method that can estimate the critical air/gas injection rate required for cleaning formation liquid influx in air/gas drilling.

Based on Guo’s minimum kinetic energy theory for liquid removal in gas production wells, an analytical model has been developed for estimating the minimum required air/gas injection rate to remove formation liquid influx in air/gas drilling. We have expanded Guo’s model to include the effects of Reynolds number and droplet sphericity on the drag coefficient. The theory indicates that the minimum required air/gas injection rate depends mainly on liquid density, liquid-gas interfacial tension, hole size and depth, and rate of penetration. A calculation procedure has been developed for estimating the minimum required air/gas injection rate to remove a given rate of fluid influx from the formation. Engineering charts have also been generated for predicting liquid-carrying capacity of air/gas that is injected into the borehole at various rates. This paper provides drilling engineers the necessary knowledge and a useful tool for minimizing complications in air/gas drilling operations.

Introduction

Compressed air or nitrogen is utilized in air/gas drilling technique as a circulating phase to carry formation cutting and liquid influx to the surface. In the presence of solid particles and liquid influx, fine cuttings and formation liquids form mud and build a ring-shaped restriction at the top of drill collar due to low fluid velocity, this phenomenon is called mud ring. The mud ring restricts fluid flow and increases bottom-hole pressure and fluid density, which in turn reduces fluid velocity and cutting-carrying capacity of the drilling fluid. As a result, cuttings accumulate at the bottom of the hole until the drillstring becomes stuck. Meanwhile, due to insufficient liquid-carrying capacity, liquid accumulation in the bottom can also happen while drilling wet formation which decreases the differential pressure significantly and then will cause decrease in rate of penetration. Therefore, determining the minimum injection rate which can provide the sufficient energy to carry both solid particles and liquids to the surface is desired.

Several methods for determining the minimum gas volume requirement have been presented in literature (Guo and Ghalambor, 2002), but all of these methods are based on the removal of solid particles. But it is believed that in some drilling conditions to continuously carry solid particles and liquids, the minimum injection rate should be more than what it is calculated based on solid-carrying capacity. Therefore, in this study a new method has been presented for determining the capacity of liquid removal in air/gas drilling.

In this study, the minimum kinetic energy of air/gas that is required to carry liquid droplets has been determined. Then this minimum kinetic energy criterion has been applied to a four-phase (gas, oil, water and solid particles) flow model to compare gas kinetic energy with the minimum required kinetic energy. As a result an algorithm for predicting the minimum gas injection rate has been developed.