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A Simplified Method for Prediction of ECD Increase with Drillpipe Rotation

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Abstract

The ability to accurately predict the effect of drillpipe rotation on Equivalent Circulating Density (ECD) remains a challenge for those involved in engineering today's complex wells. In many of these challenging wells (extended-reach drilling, deepwater, HPHT, etc.), the safe drilling window between hole collapse and fracturing is often narrow. Accurate prediction of the effect of drillpipe rotational speed could allow better optimization of operational parameters in the drilling process, and hopefully reduce the incidence of violation of the safe drilling window.

Recently ECD results measured at different circulation rates and drillpipe rotational speeds were modeled and presented to the industry. The calculation methods involved several complex factors including estimated drillpipe eccentricity, nonlinear shear rate modeling coefficients, drillpipe geometry correction factors, etc. The presented results constituted the best-available correlation with direct downhole pressure measurements, but still showed improvement was needed.

Further development work has been done in this same area to reduce the complexity of the calculations and yet improve modeling accuracy. It was noticed that the effect of increasing drillpipe rotational speed at a constant annular velocity produced a near-linear increase in ECD. In addition the ratio of the internal diameter of the hole or casing and the outer diameter of the drillpipe (Di/Do) was found to be a meaningful modeling parameter that could transcend explicit values of estimated drillpipe eccentricity. Data from the earlier work and some additional field results were then reworked using the new calculation scheme, which is presented in the paper. The results presented in this paper show that this calculation technique can produce better prediction of field measurements of downhole pressure changes while rotating and is much simpler to use. Not only can it help in navigating through the safe drilling window, but it also can be used to separate pure rotation effects from other coupled wellbore events, such as hole cleaning and barite sag.

Previous Work

In recent years, the study of the hydraulics effects of drillpipe rotation on annular pressure drop and ECD has been receiving a great deal of attention. Studies have ranged from field measurements to purely theoretical treatments of the problem. In separate studies conducted at drilling sites in the North Sea (Charlez 1998; Isambourg 1999), the effects of drillpipe rotation were studied while circulating and rotating at various rates inside casing (without cuttings), and the results were analyzed in terms of changes in ECD as calculated from downhole pressure tool data. In an early study of slimhole applications, the effects of drillpipe rotation on changes in ECD on narrow-annuli wells in Gabon (Delwiche 1992) were measured. In all of these early studies, no attempt was made to model the results into a coherent calculation scheme.

Several years later, the subject began receiving renewed attention with the goal of contruction of a workable hydraulic model to predict changes in pressure drop and ECD as functions of drillpipe rotational speed and axial velocity. In the first work (Hemphill 2005), a model for calculation of pressure drop and ECD changes in concentric annuli was presented. Shortly thereafter, after correction, a more comprehensive model for calculation of pressure drop and ECD changes in concentric and eccentric annuli (Hemphill 2006) was presented. The calculation of the hydraulic effects of drillpipe rotation on annular pressure drop is quite complicated, as the axial velocities must be coupled with the tangential velocities produced by drillpipe rotation. From the resulting velocity modeling, shear rates at the conduit walls are calculated in order to obtain the changes in pressure drop as a function of azimuth around the annulus and drilling fluid rheological properties. Further complicating the calculations is the necessity of incorporating drillpipe eccentricity in the calculations.

The combined effects of drillpipe eccentricity and drillpipe rotational speed on the local velocities (in concentric and eccentric annuli) are shown in **Figs. 1 and 2**. The fluid rheological properties and other input parameters for the calculations