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Automatic model-based control scheme for stabilizing pressure during dual-gradient drilling

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ABSTRACT

In this paper, we develop a methodology to maintain the bottom hole pressure with desired bounds and attenuate a kick while drilling into reservoir sections in dual-gradient drilling. An automatic switch control algorithm is developed for feedback control of sub sea pump. A kick is detected by estimation of the flow rates through the drill bit and annuls, which are obtained by new adaptive observers. When a kick is detected, the controller automatically switches to the attenuation mode, which ensures the bottom hole pressure will not go below reservoir pressure with respect to attenuating the kick. The proposed methodology is evaluated on high fidelity drilling simulator. The results show that the proposed methods are effective to stabilize the bottom hole pressure, and control the kick rapidly and safely.

1. Introduction

1.1. Dual-gradient drilling

Managed pressure drilling (MPD) is relatively a new drilling process that allows greater, more precise control of the bottom hole pressure (BHP) in a well bore. The definition is given in ref. [1]. This is typically achieved through a closed, pressurized fluid system in which flow rate, mud density, and back pressure on the fluid returns (choke manifold) are used to set and control the BHP under both static and dynamic conditions. MPD provides a means of quickly affecting pressure to counteract disturbances by allowing manipulation of the topside choke and pumps. MPD concepts come in many variants, such as pressurized mud cap drilling, constant bottomhole pressure control, reverse circulation, dual-gradient drilling, etc.

Dual-gradient drilling (DGD) was introduced in the 1990s. DGD refers to offshore drilling operations where the mud returns do not go through a conventional, large-diameter drilling riser. The returns are either dumped at the sea floor or returned back to the rig through one or more small-diameter return lines [2], which have been proposed by Deep Vision [3], SubSea MudLift Drilling Joint Industry Project [4], Shell [5], AGR [6], and Ocean Riser Systems [7]. The basic concept of DGD is to increase the margin between fracture gradient and pore pressures in deep water wells using two fluid gradients in ref. [8]. The objective is accomplished by rerouting the mud return. Drilling mud is pumped down the drill string as usual, but rather than using the marine riser annulus for the mud return, a parasite line is used to circulate the drilling fluid and cuttings from the seabed to the surface. The annulus above the mud line is then filled with seawater to maintain proper hydrostatic pressure at critical depths downhole. Mud will still move through the annulus but in a very limited distance from the bottom of the hole to the pump on the sea floor. This capability would reduce the number of the casings needed to reach total depth. Common for all DGD concepts is that they use mud with higher than normal density.

1.2. Pressure control

Controlling the bottom hole pressure during well drilling can be a challenging task, due to the very complex dynamics of the multiphase flow potentially consisting of drilling mud, oil, gas and cuttings. A lot of effort has been put into developing advanced complicated models that capture all aspects of the drilling fluid hydraulics. However, a main drawback is the resulting complexity of these models, which require expert knowledge to set up and calibrate, making it a high-end solution. The complexity is also increased by the fact that many of the parameters in such models are uncertain/unknown and possibly slowly changing, which implies that they would need to be tuned as operating conditions change. In order to reduce the complexity, attempts at using low order models for control and estimation of the BHP can be found

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