Lightweight biopolymer drilling fluid for underbalanced drilling: An optimization study

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ABSTRACT

This paper presents an optimization of a lightweight biopolymer drilling fluid for underbalanced drilling (UBD) using Response Surface Methodology (RSM). Concentrations of four raw materials (glass bubbles, clay, xanthan gum and starch) were varied to analyze their effects on three vital responses: density, plastic viscosity (PV) and yield point (YP) of the fluid. Based on the results, the optimum condition was achieved at concentrations of glass bubbles, clay, xanthan gum and starch of 24.46% w/v, 0.63% w/v, 0.21% w/v and 2.41% w/v, respectively. The results showed that it is possible to predict the three response parameters using models generated by RSM since the experimental values were found to be in good agreement with the predicted values (error < 1.0, standard deviation < 0.5 and accuracy > 98.5%).

1. Introduction

Underbalanced drilling (UBD) is a drilling technique where the pressure inside the wellbore is maintained to be lower than reservoir pressure while drilling [Carroux and Lababidi, 2001; Wong and Arco, 2003]. UBD is applied in underpressured or depleted reservoirs to prevent lost circulation and stuck pipe which occurs during conventional overbalanced drilling [Kutlu, 2013; Marbun et al., 2012; Rafique, 2008]. This makes UBD a suitable choice when drilling in formations that are sensitive to rock-fluid or fluid-fluid interactions to prevent permeability damage. UBD is also used in formations with consolidated sands of high permeability. Furthermore, it is also known that UBD could increase the rate of penetration (ROP) by up to 10 times of the conventional drilling process. It plays an important role to reduce formation damage in horizontal drilling as the drilling fluid is prevented from flowing into the target formation [Arco et al., 2000; Marbun et al., 2012; Rafique, 2008]. High pressure losses due to decrease in flow area of the annulus caused by drill cuttings settling out from the drilling fluid by gravitational force could be reduced during UBD in a horizontal well (Kutlu, 2013).

Lightweight fluids may be used in drilling using UBD technique. The density of the drilling fluid is intentionally reduced to ensure the hydrostatic pressure in the wellbore to be lower than the pore pressure of the target formation (Babajan and Qutob, 2010). Hence, drilling fluids with densities below 6.9 lb/gal, which usually contains air or gas including foam, mist and aerated muds, are suitable for UBD [Arco et al., 2000; Medley et al., 1995; Rafique, 2008]. In the past, air drilling was used due to the realization of the advantages in using UBD for drilling a reservoir. These advantages include increased ROP, faster drill cuttings removal from under the drill bit, improved bit life, prevention of lost circulation, reduction of differential sticking and most importantly, formation damage reduction (Caenn and Chillingar, 1996). However, numerous problems arise because air drilling may increase drilling cost, cause drill string corrosion, lead to risk of fires and explosions, cause serious drill string vibrations, excessive drag and torque, require special equipments, post additional works, etc. (Arco et al., 2000; Khalil and Badrul, 2012a, 2012b; Kutlu, 2013; McDonald et al., 1998; Medley et al., 1995; Wong and Arco, 2003).

Moreover, new drilling fluid systems have also been developed to substitute toxic chemicals and non-biodegradable substances due to environmental restrictions (Caenn and Chillingar, 1996). It is reported that the usage of diesel as base fluids in drilling has been reduced because environmental regulations consider diesel as harmful to the environment (Galate and Mitchell, 1986; Khalil and Badrul, 2012a, 2012b). Non-toxic and biodegradable oil based muds from edible vegetable grade oils and plant seed oil are being developed as alternatives. Studies have shown that the use of more water makes the drilling fluid less costly as it reduces the formulation costs