Effect of Addition of Carboxymethy Cellulose (CMC) on the Rheology and Flow Properties of Bentonite Suspensions

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Received: 5.6.2012, Final version: 19.10.2012

Abstract:
In this work, bentonite suspension and mixtures containing 5 wt% of bentonite and 0.1 and 0.5 wt% of carboxymethyl cellulose (CMC) were investigated in terms of their rheology and hydrodynamic behaviour in pipe flow. All fluids exhibited non-Newtonian rheological behaviour that can be well described by the three parameters Herschel-Bulkley model. The axial velocity distribution was determined using ultrasonic pulsed Doppler velocimetry technique. In the laminar regime the flow parameters were predicted by integration of the constitutive rheological model used. In the turbulent flow, the Dodge and Metzner model was applied to fit the experimental data. The measurements of the friction factor showed a small amount of drag reduction for the pure bentonite suspension, whereas for the polymer-clay blend the drag reduction was more important.

Zusammenfassung:
In dieser Arbeit wurden Betonitsuspensionen und -mischungen mit 5 % Betonit und 0.1 bis 0.5 % Carboxylmethylcellulose (CMC) hinsichtlich ihres rheologischen und hydrodynamischen Verhaltens in einer Rohrströmung untersucht. Diese Fluide wiesen ein nicht-Newtonsches Verhalten auf, das durch das dreiparametrige Herschel-Bulkley-Modell beschrieben werden kann. Die axiale Geschwindigkeitsverteilung wurde mit Hilfe der gepulsten Ultraschall-Doppler-Methode gemessen. Im laminaren Strömungsbereich wurden die Fließparameter durch Integration der verwendeten rheologischen Konstitutivgleichung vorhergesagt. Im Bereich der turbulenten Strömung wurde das Modell von Dodge und Metzner verwendet, um die experimentellen Daten anzupassen. Die Messungen des Reibungsfaktors zeigten bei den reinen Betonitsuspensioen einen geringen Beitrag zur Strömungswiderstandsreduktion, wohingegen für Suspensionen mit dem Polymeradditiv die Strömungswiderstandsreduktion bedeutender war.

Résumé:
Dans ce travail, une suspension de bentonite à une concentration massique de 5 % et des mélanges de bentonite (5 %) et carboxyméthyl cellulose (CMC) à des concentrations massiques de 0.1 et 0.5 % ont été étudiées en termes de comportements rhéologique et hydrodynamique en écoulement en conduite. Tous les fluides présentent un comportement rhéologique non-Newtonien pouvant être correctement décrit par le modèle à trois paramètres de Herschel-Bulkley. La distribution de vitesse axiale a été déterminée en utilisant la technique ultrasonore à effet Doppler. En régime laminaire, les grandeurs hydrodynamiques ont été déterminées par l'intégration du modèle rhéologique utilisé. En régime turbulent, le modèle de Dodge et Metzner a été appliqué pour corréler les données expérimentales. Les mesures du coefficient de frottement ont mis en évidence une diminution des effets de frottement dans le cas de la suspension de bentonite de base, alors que pour les mélanges polymère-argile, la réduction de frottement était plus importante.

Key words: bentonite, polymer, non-Newtonian, laminar-turbulent, pipe flow.

1 INTRODUCTION

Bentonite suspensions are widely used as widespread thickening agents and as key component in various industrial fluid formulations. Among their uses in civil engineering are soil boring, slurry walls, or nuclear waste barrier, and other industrial applications include cosmetics (creams), chemical (paints), food products (wine), etc. A very important application of bentonite clays is their use as drilling fluids which have numerous roles such as stabilizing the borehole by forming a cake, cleaning the hole by evacuating the cuttings, cooling and lubricating the string and the bit. Given the widespread nature of these applications, numer -

DOI: 10.3933/ApplRheol-23-13475

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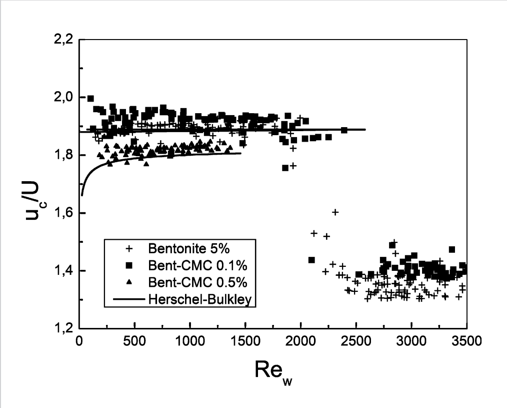

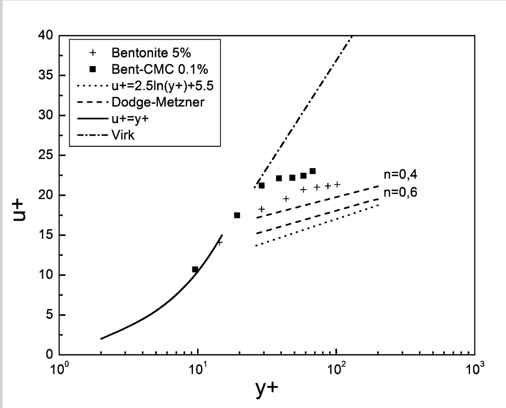

Figure 8 (left): Normalized centerline uc/U versus Re_w.

Figure 9: Mean velocity profiles plots in the wall co-ordinates.

above-mentioned equations established for Newtonian fluids. These results match those shown in Figure 5, where a deviation of experimental data (friction factor vs Reynolds number) from the Blasius equation, also established for Newtonian fluids, was reported. A deviation, but less pronounced, is also observed when the Dodge and Metzner correlation is used to fitting the experimental data for bentonite suspension as well as for bentonite/polymer mixture. The drag reduction obtained by addition of CMC is to be pointed out, as the experimental data tend to approach the Virk MDRA [22], which is given by the following equation:

$$u^+ = 11.7 \ln(y^+) - 17 \qquad (19)$$

4 CONCLUSION

A detailed experimental investigation of laminar, transitional and turbulent pipe flow of a 5 wt% bentonite suspension and bentonite/polymer mixtures (0.1 and 0.5 wt% of CMC added to the base 5 wt% bentonite suspension) was conducted using UPDV measurement techniques. The advantage of this technique is that it is not limited to optically transparent liquids. The rheological measurements have revealed the strong effect of CMC on the rheological properties of the bentonite suspension. All flow curves were satisfactorily fitted using the Herschel-Bulkley model. In the laminar flow, the experimental velocity profiles and friction factors were found to be in satisfactorily agreement with the theoretical equations based upon the Herschel-Bulkley model. In the transition regime, the measurements showed asymmetry in the velocity profiles, as expected for shear-thinning fluids and in accordance with results known in the literature. In the turbulent flow, the friction factors were well described by the Dodge and Metzner correlations. The friction factor measurements and velocity profiles showed drag reduction effect for all fluids. Furthermore, in the case of bentonite suspensions, probably due to their shear-thinning behavior, small drag reduction effects were found whilst the clay-polymer blends exhibited much more pronounced effects. It has been demonstrated that CMC behaves as drag reducer in turbulent flow. However, when fluids are exposed to high shear rate through the pump, polymer chains break down and irreversible degradation occurs, resulting in loss of drag reduction.

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