Wall Slip Phenomenon Assessment of Yield Stress Pseudoplastic Fluids in Couette Geometry

V.C. Kelessidis[1]*, V. Hatzistamou[1], R. Maglione[2]

[1] Technical University of Crete, Mineral Resources Engineering Department, 73100 Chania, Greece
[2] Cascina Europa, 13040 Moncrivello (Vercelli), Italy

* Corresponding author: kelesidi@mred.tuc.gr
Fax: x30.282.1037874

Received: 1.4.2010, Final version: 25.5.2010

Abstract:
Results are presented aiming to determine whether wall slip occurs while performing rheological measurements of Carbopol solutions and bentonite dispersions at different concentrations using a standard oil-field Couette-type viscometer with two gap sizes. Yield stresses using a vane rheometer were also determined and compared to those obtained by extension of the experimentally-derived rheological curves at the Couette viscometer. The results show that, if preparation procedures are followed as suggested for Carbopol solutions and by API standard for drilling fluids, simulating either the pre-shearing in the rig mud pumps or in the bit nozzles during drilling operations, wall slip does not occur, with a good agreement of the rheograms and of the yield stresses determined for both gap sizes of the Couette viscometer and by the vane rheometer. No slip occurs also for CMC solutions which exhibited pseudoplastic power-law behavior.

Zusammenfassung:
Ergebnisse zum Wandgleiten während der Durchführung rheologischer Messungen von Carbopollösungen und Bentonit-Dispersionen in unterschiedlichen Konzentrationen mit Hilfe eines Standard Oelfeld-Couette Visikometers mit zwei Spaltgrößen werden vorgestellt. Fließgrenzwerte wurden durch ein Flügelradrheometer ermittelt und mit denen durch Verlängerung der experimentell gewonnenen Kurven aus dem Couette-Visikometer verglichen. Die Ergebnisse zeigen, dass wenn die Probenvorbereitung so durchgeführt werden wie für Carbopol Lösungen und von API-Standard für Bohrflüssigkeiten vorgeschlagen und die Vorscherung in den Spülpumpen oder in den Bohrdüsen entsprechend simuliert wird, Wandrutschen nicht auftritt. Es tritt auch kein Wandrutschen für CMC Lösungen, die pseudoplastisches Potenz-Gesetz Verhalten zeigen, auf.

Résumé:
Les résultats sont présentés en vue de déterminer si glissement aux parois se produit lors de l'exécution des mesures rhéologiques de solutions et de dispersions Carbopol bentonite à des concentrations différentes en utilisant une huile standard champ viscosimètre Couette-type avec deux tailles écart. Rendement souligne aide d'un rhéomètre à palettes ont également été déterminés et comparés à ceux obtenus par extension des courbes expérimentales dérivés rhéologiques au viscosimètre de Couette. Les résultats montrent que, si les procédures de préparation sont suivies comme l'a suggéré des solutions Carbopol et par les API standard pour les fluides de forage, la simulation soit la pré-cisaillement dans les pompes à boue appareil de forage ou dans les buses de peu lors des opérations de forage, de glissement mur ne se produit pas, avec un bon accord de l'rhéogrammes et du rendement contraintes déterminées pour les deux tailles écart du viscosimètre Couette et par le rhéomètre à palettes. Aucun glissement se produit également des solutions de CMC qui a montré un comportement pseudo-loi de puissance.

Key words: wall slip, rheology, bentonite, Carbopol, Herschel-Bulkley, rheometry

1 INTRODUCTION

Rheological measurements of various suspensions are often flawed by the occurrence of the wall slip effect, evidenced by a reduction of the measured torque (shear stress) at a given shear rate. Wall slip is a phenomenon that develops when the fluid does not adhere perfectly to the smooth surface walls of the viscometer during measurement, being either in the cylinder of the Couette or in the plate of the parallel plate geometry [1, 2]. It may be attributed to a local reduction of the fluid particles concentration at the viscometer smooth walls, so as to form a thin, aqueous- and solvent-rich layer of fluid, 0.1 to 40 microns thick and called the slip layer, characterized by a significantly smaller viscosity and

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org

configurations and both concentrations studied extremely close rheograms and power-law parameters.

REFERENCES

[1] Yoshimura A, Prud'homme RK: Wall slip corrections for Couette and parallel disk viscometers, J. Rheol. 32 (1988) 53 – 67.

[2] Kalyon DM: Apparent slip and viscoplasticity of concentrated suspensions, J. Rheol. 49 (2005) 621 – 640.

[3] Barnes HA, Nguyen QD: Rotating vane rheometry – a review, J. Non-Newtonian Fluid Mech. 98 (2001) 1 – 14.

[4] Kelessidis VC, Maglione R: Yield stress of water–bentonite dispersions, Colloids and Surfaces A 318 (2008) 217 – 226.

[5] Bingham EC: Fluidity and plasticity, McGraw-Hill, New York (1922).

[6] Mooney M: Explicit formulas for slip and fluidity, J. Rheol. 2 (1931) 210 – 222.

[7] Reiner M: Slippage in a non-Newtonian liquid. J. Rheology 2 (1931) 337 – 350.

[8] Karnis A, Mason SG: Particle motions in sheared suspensions: XXIII. Wall migration of fluid drops, J Colloid and Interface Science 24 (1967) 164 – 169.

[9] Vinogradov GV, Froishteter GB, Trilisky KK, Smorodinsky EL: The flow of plastic disperse systems in the presence of the wall effect, Rheol. Acta 14 (1975) 765 – 775.

[10] Leighton D, Acrivos A: The shear-induced migration of particles in concentrated suspensions, J. Fluid Mech. 181 (1987) 415 – 439.

[11] Mannheimer RJ: Laminar and turbulent flow of cement slurries in large diameter pipe: A comparison with laboratory viscometers, J. Rheol. 35 (1991) 113 – 133.

[12] Aral BK, Kalyon DM: Effects of temperature and surface roughness on time-dependent development of wall slip in steady torsional flow of concentrated suspensions, J. Rheol. 38 (1994) 957 – 972.

[13] Barnes HA: A review of the slip (wall depletion) of polymer solutions, emulsions and particle suspensions in viscometers: Its cause, character, and cure, J. Non-Newtonian Fluid Mech. 56 (1995) 221 – 251.

[14] Walls HJ, Caines SB, Sanchez AM, Khanb SA: Yield stress and wall slip phenomena in colloidal silica gels, J. Rheol. 47 (2003) 847 – 868

[15] Chryss AG., Bhattacharya SN., Pullum L: Rheology of shear thickening suspensions and the effects of wall slip in torsional flow, Rheol. Acta 45 (2005) 124 – 131

[16] De Kee D, Kim YD, Nguyen QD: Measuring rheological properties using a slotted plate device, Korea-Australia Rheol. J. 19 (2007) 75 – 80.

[17] Sofou S, Muliawan E, Hatzikiriakos S, Mitsoulis E: Rheological characterization and constitutive modeling of bread dough, Rheol. Acta 47 (2008) 369 – 381.

[18] Zahirovic S, Lubansky AS, Yeow YL, Boger DV: Obtaining the steady shear rheological properties and apparent wall slip velocity data of a water-in-oil emulsion from gap-dependent parallel plate viscometry data, Rheol. Acta 48 (2009) 221 – 229.

[19] Kiljanski T: A method for correction of the wall-slip effect in a Couette rheometer, Rheol. Acta 28 (1989) 61 – 64.

[20] Magnin A, Piau JM: Cone and plate rheometry of yield stress fluids. Study of an aqueous gel. J. Non-Newtonian Fluid Mech. 36 (1990) 85 – 108.

[21] Buscall R, Ian McGowan J, Morton-Jones AJ: The rheology of concentrated dispersions of weakly attracting colloidal particles with and without wall slip, J. Rheol. 37 (1993) 621 – 641.

[22] Mallik S, Ekere NN, Durairaj R, Marks AE: An investigation into the rheological properties of different lead-free solder pastes for surface mount applications, Soldering & Surface Mount Technology, 20 (2008) 3 – 10.

[23] Tsenoglou C: Viscoplasticity of agglomerated suspensions, Rheol. Acta 28 (1989) 311–314.

[24] Tabuteau H, Coussot P, de Bruyn JR: Drag force on a sphere in steady motion through a yield-stress fluid, J. Rheol. 51 (2007) 125 – 137.

[25] Saak AW, Jennings HM, Shah SP: The influence of wall slip on yield stress and viscoelastic measurements of cement paste, Cement Concrete Res. 31 (2001) 205 – 212.

[26] Roberts GP, Barnes HA, Carew P: Modeling the flow behavior of very shear thinning liquids, Chem. Eng. Sci. 56 (2001) 5617 – 5623.

[27] Plucinski J, Gupta RK, Chakrabarti S: Wall slip of mayonnaises in viscometers, Rheol. Acta 37 (1998) 256–269.

[28] Jana SC, Kapoor B, Acrivos A: Apparent wall slip velocity coefficients in concentrated suspensions of noncolloidal particles, J. Rheol. 39 (1995) 1123 – 1132.

[29] Kelessidis VC: Investigations on the thixotropy of bentonite suspensions, Energy Sources Part A 30 (2008) 1729 – 1746.

[30] Bonn D, Denn MM: Yield stress fluids slowly yield to analysis, Science 324 (2009) 1401 – 1402.

[31] Kelessidis VC, Tsamantaki C, Dalamarinis P: Effect of pH and electrolyte on the rheology of aqueous Wyoming bentonite-dispersions, Appl. Clay Sci. 38 (2007) 86 – 96.

[32] Grikshtas R, Rao MA: Determination of slip velocities in a concentric cylinder viscometer with Mooney and Kiljanski methods, J. Texture Stud. 24 (1993) 173 – 184.

[33] Speers RA, Tung MA, Williamson DT: Rheological

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org

determination of peptizing agents in bentonite clays, Rheol. Acta 27 (1988) 561 – 564.
[34] Kok MV: Characterization and Development of Drilling Fluid Type for an Oil Field, Energy Sources Part A 32 (2010) 395 – 399
[35] BenAzouz K, Dupuis D, Bekkour K: Rheological characterizations of dispersions of clay particles, Appl. Rheol. 20 (2010) 13041.
[36] Autio K, Houska M: Measurement of flow curves for model liquids and real food systems with two commercial viscometers, J. Food Eng. 13 (1991) 57 – 66.
[37] Kelessidis VC, Hatzistamou V: Preparation methodology and rheological properties of yield pseudoplastic transparent fluids, J. Dispersion Sci. Technol. (2010) accepted.
[38] American Petroleum Institute Specifications 13A: Specification for drilling fluid materials, SPE (2006).
[39] Joye, D.D: Shear rate and viscosity corrections for a Casson fluid in cylindrical (Couette) geometries, J. Colloid Interface Sci. 267 (2003) 204–210.
[40] Hanks RW: Couette viscometry of Casson fluids, J. Rheol. 27 (1983) 1 – 6.
[41] Kelessidis VC, Maglione R: Modeling rheological behavior of bentonite suspensions as Casson and Robertson-Stiff fluids using Newtonian and true shear rates in Couette viscometry, Powder Technol. 168 (2006) 137 – 147.
[42] Kelessidis VC, Maglione R: Shear rate corrections for Herschel-Bulkley fluids in Couette geometry, Appl. Rheol. 18 (2008) 34482.
[43] Kelessidis VC, Maglione R, Tsamantaki C, Aspirtakis Y: Optimal determination of rheological parameters for Herschel-Bulkley drilling fluids and impact on pressure drop, velocity profiles and penetration rates during drilling, J. Petroleum Sci. Eng. 53 (2006) 203 – 224.
[44] Morrison SR, Harper JC: Wall Effect In Couette Flow Of Non-Newtonian Suspensions, Ind. Eng. Chem. Fund. 4 (1965) 176–181.
[45] Tsamantaki C, Kelessidis VC, Dalamarinis P, Mpandelis GE: Static and dynamic yield stress of water-bentonite suspensions, Paper presented at the 2nd International Conference on: "Advances in Mineral Resources Management and Geotechnics", Hania, Greece (2006) 247 – 254.
[46] Haimoni A, Hannant DJ: Development in the shear vane test to measure the gel strength of oil well cement slurries, Adv. Chem. Res. 1 (1988) 221 – 229.
[47] Banfill PFG, Kitching DR: Use of a controlled stress rheometer to study the yield stress of oilwell cement slurries, in Banfill PFG (Ed.), Rheology of Fresh Cement and Concrete, E & FN Spon, London (1991) 125 – 136.
[48] Ulherr PHT, Guo J, Fang TN, Tiu C: Static measurements of yield stress using a cylindrical penetrometer, Korea-Austral. Rheol. J. 14 (2002) 17 – 23.

This is an extract of the complete reprint-pdf, available at the Applied Rheology website
http://www.appliedrheology.org