Influence of wall slip in dilute suspensions

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At microscales, a slip condition may apply for a viscous liquid on walls with modified surfaces, e.g. hydrophobic ones in water. Such a slip condition, where the tangential velocity is proportional to the shear stress, was proposed by Navier [1]. Experiments [2, 3], which will be recalled here, show that this condition applies and a slip length may be measured. Experimental techniques in this field usually follow the motion of suspended tracer particles; this raises the question of particle-wall interactions.

A slip condition is useful for the flow of suspensions in microchannels, since the pressure head may then be reduced. It may have applications e.g. for separation techniques in analytical chemistry [4]. Particle-wall interactions are also important in these small-scale applications.

We consider a dilute suspension of spherical solid particles near a slip wall. A sphere (on which the no-slip condition applies) is translating and rotating in an ambient parabolic flow. Analytical solutions of Stokes equations for the various flow fields are obtained in bispherical coordinates [5, 6]. The coefficients in the series are solutions of an infinite linear system, which is solved by an extension of Thomas' algorithm for inverting a tridiagonal matrix. This allows to obtained a large number of terms which are necessary to resolve the lubrication situation, when a sphere is close to the slip wall. Accurate results for the force and torque on a sphere, velocity of a freely moving sphere, diffusion tensor are then obtained. The stresslet, that is the symmetric moment of surface stresses on the sphere, is also derived in view of applications to suspension rheology. Expansions of various quantities for a large distance from the wall and for a low slip length are performed on the basis of the analytical solutions, using computer algebra. Padé approximants calculated therefrom provide good approximations.

The Aris-Taylor dispersion of Brownian particles in a shear flow near a slip wall has applications in the measurement of slip [3, 7] and in separation techniques. It is calculated from the advection-diffusion equation, using the expressions for the particle velocity and diffusion tensor [5] near a slip wall.

References

[1] C. L. M. H. Navier. Mémoire sur les lois du mouvement des fluides. *Mémoires de l'Acad. des Sciences de l'Institut de France*, 6:389–416, 1823. *http://gallica.bnf.fr/ark:/12148/bpt6k3221x/f577.pagination*.

[2] D. Lumma, A. Best, A. Gansen, F. Feuillebois, J.O. Rädler, and O.I. Vinogradova. Flow profile near a wall measured by double-focus fluorescence cross correlation. *Phys. Rev. E*, 67(056313):1–10, 2003.

[3] O. I. Vinogradova, K. Koynov, A. Best, and F. Feuillebois. Direct measurements of hydrophobic slippage using double-focus fluorescence cross-correlation. *Phys. Rev. Lett.*, 102(118302), 2009.

[4] M. Martin, Theory of field-flow fractionation. In P.R. Brown and E. Grushka, editors, *Advances in Chromatography*, Marcel Dekker, New York, 1998.

[5] F. Feuillebois, H. Loussaief, and L. Pasol. Particles in creeping flow near a slip wall. In M. D. Todorov and C.I. Christov, editors, *CP1186, Applications of Mathematics in Technical and Natural Sciences*, pages 3–14. American Institute of Physics, 2009.

[6] F. Feuillebois, N. Ghalya, A. Sellier, and L. Elasmi. Motion of particles in a parabolic flow near a slip wall. In M. D. Todorov and C.I. Christov, editors, *Applications of Mathematics in Technical and Natural Sciences*, American Institute of Physics, 2011. Submitted.

[7] R. Sadr, C. Hohenegger, H. Li, P.J. Mucha, and M. Yoda. Diffusion-induced bias in near-wall velocimetry. *J. Fluid Mech.*, 577:443–456, 2007.