FILTECH 2009
CONFERENCE PROCEEDINGS
VOLUME II

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Conference Dates:
October 13 – 15, 2009

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Regions and Countries listed.

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16.45 – 18.00	**S3** Survey Lecture 3	**L3** Sedimentation and Flotation for Sorting	**M3** Combined Processes	**G3** Surface Filtration

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Tuesday – October 13, 2009

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Plenary Lecture	10:30 - 11:30

Introduction to the characterisation of products prior to formulating a solid-liquid separation problem, Dr. Christophe Peuchot, IFTS - Institute for Filtration and Separation, France — I-19

S1	Survey Lecture	13:15 - 14:30

Advances in Pore Structure Evaluation by Porometry, Dr. Krishna Gupta, Porous Materials, Inc - USA — I-21

L1	Sedimentation Analysis in the Gravity Field	13:15 - 14:30

Evaluation of consolidation-sedimentation properties in batch gravity sedimentation of concentrated suspension, N. Katagiri*, T. Hashimoto, E. Iritani, Nagoya University, Japan — I-95

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Laboratory scale evaluation of inclined settling, T. Sobisch*, D. Lerche, LUM GmbH, Germany — I-112

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Improved treatment of secondary effluent with ultrafiltration, T. Peters*, Dr.-Ing. Peters consulting for membrane technology and environmental engineering, Germany — II-477

Processing and characterization of ceramic membranes for efficient removal of lignin from bleaching effluents, M. Ebrahimi*, S. Kerker, A. Wienold, University of Applied Sciences Giessen-Friedberg; H. Neul, A. Ante, Bamag GmbH; M. Hilpert, Sappi Fine Paper Europe; P. Mund, Atech Innovations GmbH, Germany; P. Czermak, Kansas State University, USA — II-485

Electro-ultrafiltration of liposomal dispersions for the removal of trace micropollutants, H. Saveyn*, M. Hakimhashemi, B. De Bock, P. Saveyn, P. Van der Meeren, Ghent University, Belgium — II-491

G1	Air Filter I	13:15 - 14:30

The effect of pleat count and air velocity on the initial pressure drop and fractional efficiency of HEPA filters, I. S. Al-Attar*, E. S. Tarleton, Loughborough University; R. J. Wakeman*, Consultant Chemical Engineer, UK; A. Husain, Kuwait Institute for Scientific Research KISR, Kuwait — II-19

Interaction of fluid with porous structure in filtration processes: Modelling and simulation of pleats deflection, H. Andrä, O. Iliev, M. Kabel*, Z. Lakdawala, K. Steiner, Fraunhofer Institute for Industrial Mathematics ITWM, Germany; V. Starikovicius, Vilnius Gediminas Technical University, Lithuania — II-27

Importance of mechanical filtration in HVAC bags and panel air filter applications, A. Boni*, Hollingsworth & Vose Europe, Germany; J. Manns, D. Healey, S. Cox, Hollingsworth & Vose, USA — II-32

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Characterization of sedimentation and consolidation behaviour of kaolin suspensions in presence of dispersant, C. Le Coeur*, O. Larue, E. Vorobiev, University of Compiègne, France; T. Detloff, T. Sobisch, A. Zierau, D. Lerche, LUM GmbH, Germany I-131

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Treatment of hypersaline oilfield produced water in a membrane sequencing batch reactor, A. Fakhru'l-Razi*, A. R. Pendashteh, D. R. A. Biak, C. A. Luqman, Z. A. Zurina, University Putra Malaysia, Malaysia; S. S. Madaeni, Razi University, Iran; W. M. Zahid, King Saud University, Saudi Arabia II-504

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The Eurovent certification program of air filters, I. Bodenstaff*, AAF International, Netherlands II-53

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M1 - Waste Water Treatment **13:15-14:30 h**
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G1 - Air Filter I **13:15-14:30 h**
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G2 - Air Filter II **15:00-16:15 h**
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S3 - Towards predicting filtration and separation - Progress and challenges **16:45-18:00 h**
Chairman: Siegfried Ripperger

L3 - Sedimenation and Flotation for Sorting **16:45-18:00 h**
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G4 - Poster Session I **8:30-9:45 h**
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L7 - Cake Filtration Analysis I **11:00-12:15 h**
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M5 - Deposition Control **11:00-12:15 h**
Chairman: Kuo-Lun Tung

G5 - Industrial Gas Cleaning **11:00-12:15 h**
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M6 - Membrane Fouling **13:15-14:30 h**
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G6 - Filter Test Systems I **13:15-14:30 h**
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L9 - Cake Filtration Processes I 15:00-16:15 h
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M7 - Modelling and Simulation 15:00-16:15 h
Chairman: Thomas Peters

G7 - Filter Test Systems II 15:00-16:15 h
Chairman: Gerhard Kasper

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L11 - Cake Filtration Processes II 16:45-18:00 h
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M8 - Special Membranes 16:45-18:00 h
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M9 - Poster Session II 8:30-9:45 h
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G9 - Poster Session II 8:30-9:45 h
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L14 - Separation Enhancement by Magnetic Forces 11:00-12:15 h
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L15 - Depth Filtration Analysis II 11:00-12:15 h
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G10 - Monitoring and Control 11:00-12:15 h
Chairman: Hans-Joachim Schmid

G11 - Filter Media Clogging 11:00-12:15 h
Chairman: Markus Lehner

L16 - Separation Enhancement by Physical and Chemical Slurry Treatment Chairman: Eiji Iritani 13:15-14:30 h

S5 - Membrane bioreactors in waste water treatment - Status and trends Chairman: Eberhard Schmidt 13:15-14:30 h

G12 - Ab- and Adsorption 13:15-14:30 h
Chairman: Markus Lehner

G13 - Nanofibre Filter Media 13:15-14:30 h
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L18 - Backwashing Filtration Processes 15:00-16:15 h
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L19 - Precoat Filtration 15:00-16:15 h
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G14 - Modelling and Simulation I 15:00-16:15 h
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G15 - Special Filter Media 15:00-16:15 h
Chairman: Wallace Leung

L20 - Filter Media Development and Application 16:45-18:00 h
Chairman: Reinhard Bott

L21 - Selective Separation and Classification 16:45-18:00 h
Chairman: Harald Anlauf

G16 - Modelling and Simulation II 16:45-18:00 h
Chairman: Martin Lehmann

G17 - Mist and Droplet Separation 16:45-18:00 h
Chairman: Gerd Mauschitz

EFFECT OF SLIP FLOW ON THE PRESSURE DROP IN FIBROUS FILTERS

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ABSTRACT

Slip occurs when the gas velocity at flow boundaries is not zero. As a step toward deriving the effects of slip flow on the pressure drop in fibrous filters, we examine slip flow solutions for relatively simple geometries (sphere, cylinder, parallel plates and circular tube). Whilst the analytical approach is available for the sphere, parallel plate and tube geometries, a CFD solution is necessary for the cylindrical geometry. The results show that slip flow causes a pressure drop reduction in comparison to the no-slip case for all these cases. Since fibrous filters are essentially combinations of these geometric elements, the inclusion of slip conditions in fibrous filter flow analyses will predict lower filter media pressure drops, and improve prediction agreement with measured pressure drops.

KEYWORDS

Fibrous Filter, Pressure Drop, Slip Flow, CFD-Simulation, Incompressible flow

1. Introduction

Fibrous filters are widely used in air cleaning and HVAC applications because they ensure high filtration efficiencies and lower pressure drops in comparison with of other types of filter. However, the random distribution of the fibers determines extremely complex paths for the fluid flow, so that currently the design of fibrous filters is essentially based on empirical criteria.

A major issue that makes modeling fibrous filters difficult is the occurrence of slip flow within narrow gaps among fibers, which affects both semi-empirical models and the implementation of numerical algorithms [1, 2]. This happens whenever the gap size or fiber diameter, L, becomes of the same order as the mean free path of fluid elements, λ_f (i.e., when $Kn = \lambda_f / L \leq 1$). Thus, understanding the characteristics of slip flow at low Reynolds numbers is essential to describe the fluid dynamic behavior of fibrous filters, hence to estimate pressure drops. A full characterization of slip flow around fibers would bring a significant advantage to the numerical solution of the flow field: in fact, if one can calculate a priori the thickness of the fluid layer around fibers which is affected by slip flow, then the computational domain can be divided accordingly, with obvious advantages in terms of time and accuracy of the results.

This work aims to get a deeper understanding of the slip flow in fibrous filters by considering the solutions for three simple geometries (sphere, cylinder and parallel plates), and comparing the resulting drag coefficient, $C_D = \dfrac{2F_D}{\rho U^2 \pi R^2}$, with the value obtained in case of no slip boundary conditions. These geometries are relevant both to the study of the flow field around fibers and to that of aerosol particles

displacement. However, they are extremely appealing also from a fundamental point of view because at such low Reynolds numbers (typically between 10^{-3} and 10^{-1}) [3] one has a purely creeping flow without a wake past the obstacle [4].
The analysis of the stationary Stokes problem shows that the total drag experienced by a sphere in slip-flow regime is equivalent to the Stokes total drag for continuum flow multiplied by a rarefaction coefficient dependent upon the Knudsen number. The rarefaction effects decrease the total drag experienced by a sphere below the continuum model prediction.

2. Flow around a sphere

The creeping flow around a sphere was first investigated by Stokes [5], who derived the well-known formula for the drag coefficient named after him. Whilst inertia is completely neglected in this approach, its effects become significant at large distances, regardless of how small the Reynolds number is. This was taken into account by Oseen, who added a linearized acceleration term to the momentum equation [6], and Goldstein, who derived the exact solution of Oseen's equations [7].

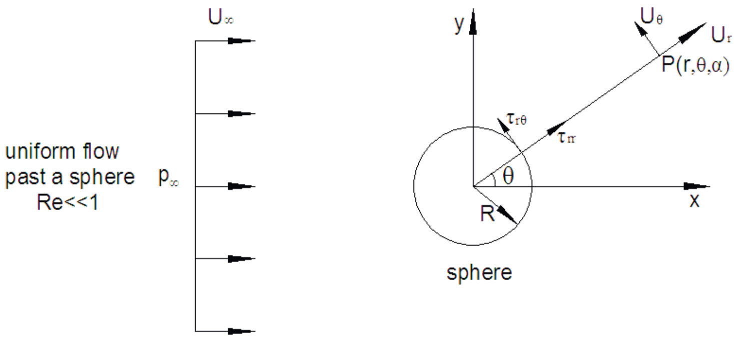

Figure 1 - Problem formulation for the flow around a sphere

An expression for the drag coefficient at small Reynolds numbers can also be obtained by means of the perturbation method [8]. The stream function for creeping flow in a spherical polar coordinate system (sketched in Figure 1) satisfies the biharmonic equation [9, 10]:

$$\nabla^4\psi = \nabla^2(\nabla^2\psi) = 0 \tag{1}$$

The solution of Eq. (1) can be written in the form:

$$\psi(r,\theta) = (\frac{A}{r} + Br + Cr^2 + Dr^4)\sin^2\theta \tag{2}$$

where A, B, C and D are constants. Because the stream function at $r \to \infty$ is

$$\psi(\infty,\theta) = \frac{U_\infty}{2} r^2 \sin^2\theta \tag{3}$$

where U_∞ is the free stream velocity, one can conclude that $D = 0$ and $C = U_\infty/2$. The velocity components resulting from this solution are:

$$u_r = 2\left(\frac{A}{r^3} + \frac{B}{r} + \frac{U_\infty}{2}\right)\cos\theta$$
$$u_\theta = \left(-\frac{A}{r^3} + \frac{B}{r} + U_\infty\right)\sin\theta \quad (4)$$

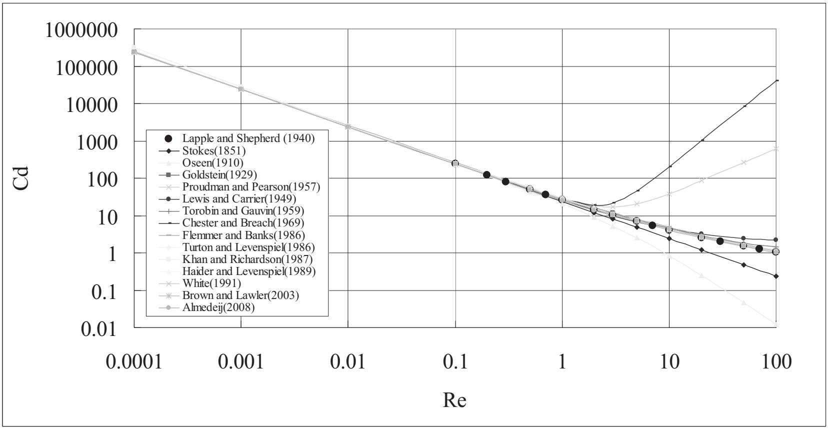

Figure 2 - Drag coefficient on the sphere: comparison between analytical solutions and experimental results available in the literature (case of no slip)

The remaining two arbitrary constants are determined by imposing the conditions on the radial and tangential components of the velocity on the sphere wall. In the case of no slip, $u_r = u_\theta = 0$, and one obtains $A = U_\infty R^3/4$ and $B = -3U_\infty R/4$. Figure 2 shows a comprehensive summary of the results available in the open literature.

In the case of slip flow, the boundary condition for the tangential velocity is proportional to the wall shear stress:

$$u_\theta = \frac{2-\sigma}{\sigma} Kn \frac{R}{\mu} \tau_\theta \;\; (r = R, 0 \le \theta \le \pi) \quad (5)$$

where Kn is the Knudsen number and σ is the tangential momentum accommodation coefficient. The resulting expressions for the arbitrary constants are:

$$A = \frac{1}{4} U_\infty R^3 \frac{1}{1+3Kn^*}$$
$$B = -\frac{3}{4} U_\infty R \frac{1+2Kn^*}{1+3Kn^*} \quad (6)$$

where $Kn^* = Kn(2-\sigma)/\sigma$. The drag force on the sphere is the sum of skin-friction drag, normal stress drag, and pressure drag (or shape drag), which can be calculated by integrating on the sphere surface the tangential stress component $\tau_{r\theta}$, the normal stress component τ_{rr}, and pressure, respectively, where the stress components are given by:

$$\tau_{r\theta} = \mu\left(\frac{1}{r}\frac{\partial u_r}{\partial \theta} - \frac{1}{r}u_\theta + \frac{\partial u_\theta}{\partial r}\right)$$
$$\tau_{rr} = 2\mu\frac{\partial u_r}{\partial r} \tag{7}$$
$$p = p_\infty + 2\mu\cos\theta\frac{B}{r^2}$$

The total drag force resulting from the integration of these stress components is:

$$F_D = 6\pi\mu U_\infty R\frac{1+2Kn^*}{1+3Kn^*} \tag{8}$$

Thus, Eq. (8) shows that the effect of slip flow is to decrease the total drag experienced by the sphere. A non-dimensional drag coefficient can be defined as the ratio between the drag force and the dynamic pressure acting on the projected front area:

$$C_D = \frac{F_D}{\frac{1}{2}\rho U_\infty^2 \pi R^2} \tag{9}$$

In case of no-slip flow, $F_D = 6\pi\mu U_\infty R$, so that $C_D \mathrm{Re}/12 \to 2$. For slip flow, one finds that the drag coefficient is reduced significantly: for example, setting Kn = 0.1 and σ = 1 yields $C_D \mathrm{Re}/12 \to 1.75$, which means a reduction of 12.5%.

3. Flow in circular tubes

The continuum flow momentum equation for the incompressible flow within smooth micro-tubes is:

$$\mu\left(\frac{d^2u}{dr^2} + \frac{1}{r}\frac{du}{dr}\right) = \frac{dp}{dz} \tag{10}$$

where r is the radial coordinate, and z that in the flow direction. The boundary conditions are $u \neq \infty$ when $r = 0$ and:

$$u = -\lambda_f \frac{2-\sigma}{\sigma}\frac{du}{dr} \tag{11}$$

On the tube wall, where λ_f is the mean free path, and σ is the tangential momentum accommodation factor. Introducing the Knudsen number, where the characteristic length is the tube diameter, the velocity distribution is given by:

$$u = -\frac{1}{4\mu}\frac{dp}{dz}\left(R^2 - r^2 + \frac{2-\sigma}{\sigma}\cdot 4Kn\cdot R^2\right) \tag{12}$$

The mean velocity is defined as:

$$< u > = \frac{1}{A}\int u\,dA = \frac{1}{\pi R^2}\int_0^R 2\pi r u\,dr = -\frac{R^2}{8\mu}\frac{dp}{dz}\left(1 + \frac{2-\sigma}{\sigma}\cdot 8Kn\right) \tag{13}$$

so that the volumetric flow rate is:

$$\dot{G} = \pi R^2 < u > = -\frac{\pi R^4}{8\mu}\frac{dp}{dz}\left(1 + \frac{2-\sigma}{\sigma}\cdot 8Kn\right) \tag{14}$$

and one can calculate the pressure drop in a tube of length *L* as:

$$\Delta p = \frac{8\mu L\dot{G}}{\pi R^4}(1+\frac{2-\sigma}{\sigma}\cdot 8Kn)^{-1} \tag{15}$$

For an ideal gas at temperature T, the mass flow rate is given by:

$$\dot{m} = -\frac{\pi R^4}{8\mu K_{gas}T}\frac{dp}{dz}p\left(1+8\frac{2-\sigma}{\sigma}Kn\right) \tag{16}$$

For isothermal flow, the product of pressure and the Knudsen number is constant and one can write $pKn = p_0 Kn_0$. Then, the mass flow rate can be re-written as:

$$\dot{m} = \frac{\pi R^4 p_0^2}{16\mu RT\cdot z}[\frac{p_i^2}{p_0^2}-\frac{p_z^2}{p_0^2}+16\frac{2-\sigma}{\sigma}\cdot Kn_0(\frac{p_i}{p_0}-\frac{p_z}{p_0})] \tag{17}$$

and setting $p_z = p_0$ yields:

$$\dot{m} = \frac{\pi R^4 p_0^2}{16\mu RTL}[\frac{p_i^2}{p_0^2}-1+16\frac{2-\sigma}{\sigma}\cdot Kn_\infty(\frac{p_i}{p_0}-1)] \tag{18}$$

On the other hand, the mass flow rate for the continuum flow, i.e. with no slip, is given by:

$$\dot{m}_* = \frac{\pi R^4 p_0^2}{16\mu RTL}(\frac{p_i^2}{p_0^2}-1) \tag{19}$$

Thus, in case of slip flow the mass flow rate through the tube is larger than in case of no slip, because $\dot{m}/\dot{m}_* > 1$ for the same pressure difference between the two ends of the tube:

$$\frac{\dot{m}}{\dot{m}_*} = 1+\frac{16\frac{2-\sigma}{\sigma}\cdot Kn_0}{\frac{p_i}{p_0}+1} \tag{20}$$

Since the flow rate for the slip case increases over the no-slip case, one can conclude that slip flow induces a reduction of frictional drag on the flow.

4. Flow around a cylinder

The flow around a cylinder is important not only in the context of fibrous filters, but also in many other engineering applications, both from the fluid dynamics and from the heat transfer points of view [11]. Unfortunately, for the uniform viscous flow around a circular cylinder, Stokes proposed that there was no analytic solution, which is known as Stokes' paradox [5, 9]. Technically speaking, this happens because uniform flow around a cylinder does not satisfy a certain consistency condition [12]. More recently, the corresponding necessary condition for the existence of a solution was found assuming that there is a slip on the surface of the cylinder [13].
Several Authors have proposed asymptotic solutions for the creeping flow around a cylinder with no-slip boundary condition [10] and drag coefficient correlations [14-17], including a recent work suggesting a solution for the Stokes paradox [18]. Experimental data are available in the range of Reynolds numbers from 0.06 to 0.5

[19] as well as for higher Reynolds numbers [20]. Figure 3 summarizes different results for the drag coefficient on a cylinder in case of no-slip (both theoretical and experimental) available in the literature.

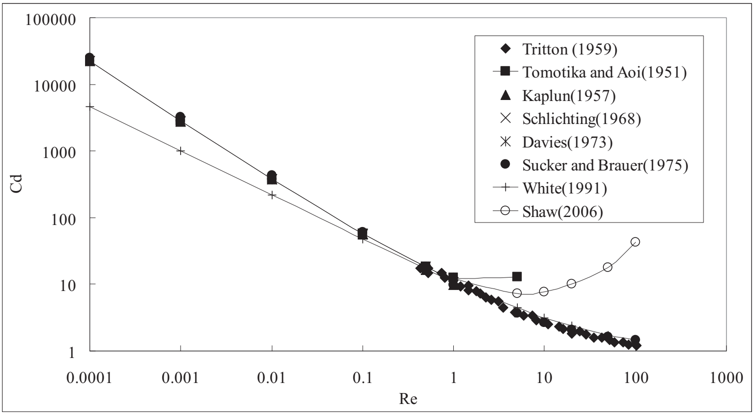

Figure 3 - Drag coefficient on the cylinder: comparison between analytical solutions and experimental results available in the literature (case of no slip)

To investigate the effect of slip flow on a cylinder, we carried out numerical simulations of the flow field using the commercial code Fluent v6.3. From this the drag coefficient could be obtained. The results were then compared with the CFD solution for the no-slip problem. The slip-flow condition is the same used above for the spherical geometry, given by Eq. (5), and was implemented as a user-defined function. To allow updating the boundary condition as the flow field solution converges, the problem is solved as a transient flow instead of a steady-state flow.

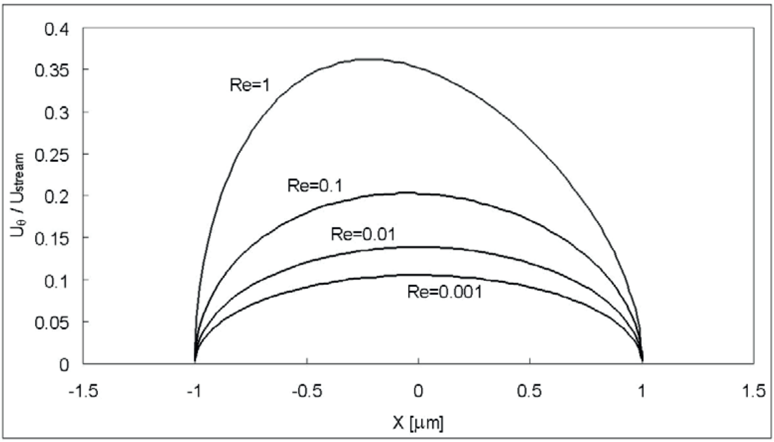

Figure 4 - Tangential velocity on the cylinder wall

Figure 4 shows an example of the tangential velocity on the cylinder wall in case of slip flow, while Figure 5 shows the comparison between the drag coefficients obtained with slip and no-slip boundary conditions, setting Kn = 0.1 and σ = 1. One can observe a clear reduction of the drag coefficient for slip flow of the order of 10%, which is consistent with the value calculated analytically for the spherical geometry above, using the same values for the slip parameters Kn and σ.

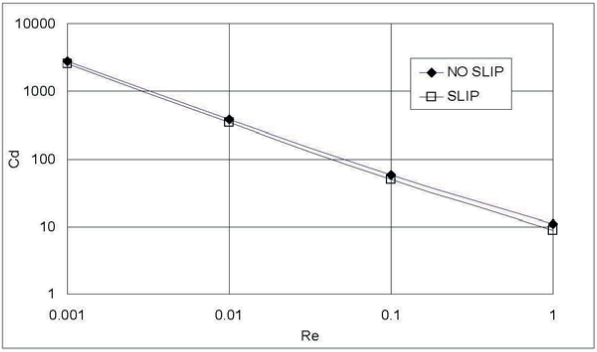

Figure 5 - Drag coefficient on a cylinder in cross-flow: comparison between slip flow and no-slip flow

5. Conclusions

The problem of laminar (creeping) flow with slip flow boundary conditions was studied for both external flow (sphere, cylinder) and internal flow (circular tube), and compared with the solutions obtained in case of no-slip boundary condition. The study of slip flow in these geometries is the first step towards a better understanding of slip flow in fibrous filters: in fact, they are the simplest representation of fibers (the cylinder), of pores within the filter (the tube), and of particles or aerosols (the sphere). In two cases (sphere and tube), the solution for slip flow can be found analytically, while for the cylinder a numerical solution obtained with a commercial CFD code is provided. In all cases, slip flow causes a reduction of the drag exerted by the wall on the flow, which results into a reduction of the drag coefficient (in case of external flow) or of pressure drops (in case of internal flow).
On the basis of these results, one can tackle the investigation of more realistic systems, where several of these basic elements are combined together.

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References

1. Spielman, L. and S.L. Goren, Model for predicting pressure drop and filtration efficiency in fibrous media. Environmental Science & Technology, vol. 2(4), pp. 279-287, 1968.
2. Tronville, P. and R.D. Rivers, CFD analysis of flow patterns and resistance of air filter media having random fiber diameters, Proc. 19th Annual Conference of the American Filtration Society, Rosemont (USA), 2006.
3. Fuchs, N.A., The Mechanics of Aerosols. 1964, New York: Dover Publications.
4. Schlichting, H., Boundary-layer Theory, Sixth Ed., New York: McGraw-Hill Book Company, 1968.
5. Stokes, G.G., On the effect of the internal friction of fluids on the motion of pendulums. Trans. Cambridge Philosophical Soc., vol. 9, pp. 8-106, 1851.

6. Oseen, C.W., Über die Stokes'sche formel, und über eine verwadte Aufgabe in der Hydrodynamik vi. Arkiv för matematik, astronomi och fysik, vol. 6(29), 1910.
7. Goldstein, S., The steady flow of viscous fluid past a fixed spherical obstacle at small Reynolds numbers. Proc. R. Soc. Lond., vol. 123A, 1929.
8. Proudman, I. and J.R.A. Pearson, Expansions at small Reynolds number flow past a sphere and a circular cylinder. J. Fluid Mech., vol. 2, pp. 237-262, 1957.
9. Happel, I. and H. Brenner, Low Reynolds Number Hydrodynamics: with special applications to particulate media. Prentice-Hall international series in the physical and chemical engineering sciences. Englewood Cliffs, NJ: Prentice-Hall, 1965.
10. Tomotika, S. and T. Aoi, The steady flow of viscous fluid past a sphere and circular cylinder at small Reynolds numbers. Quarterly Journal of Mechanics and Applied Mathematics, vol. 3(2), 1950.
11. Bertola, V. and Cafaro, E., Analytical function theory approach to the heat transfer problem of a cylinder in cross-flow at small Péclet numbers, Int. J. Heat Mass Transf., vol. 49(17-18), pp. 2859-2863, 2006.
12. Avudainayagam, A. and Jothiram, B., A circle theorem for plane Stokes flows, Quart. J. Mech. Appl. Math., vol. 41, pp. 383–393, 1988.
13. Raja Sekhar, G.P., Tejeswara Rao, K., Padmavathi, B.S., and Amaranath, T., Two dimensional Stokes flows with slip-stick boundary conditions. Mechanics Research Communications, 1995, vol. 22(5): pp. 491-501.
14. Kaplun, S., Low Reynolds numbers flow past a circular cylinder. Journal of Mathematics and Mechanics, vol. 6, pp. 595-603, 1957.
15. White, F.M., Viscous Fluid Flow. Second ed., New York: McGraw-Hill, 1991.
16. Sucker, D. and H. Brauer, Fluiddynamik bei der angestromten Zylindern. Warme und Stoffubertragung, vol. 8, pp. 149-158, 1975.
17. Tomotika, S. and T. Aoi, An expansion formula for the drag on a circular cylinder moving through a viscous fluid at small Reynolds numbers. Quarterly Journal of Mechanics and Applied Mathematics, vol. 4(4), pp. 401-406, 1951.
18. Shaw, W.T., A simple resolution of Stokes' paradox? arXiv:0901.3621, January 2009.
19. Finn, R.K., Determination of the Drag on a Cylinder at Low Reynolds Numbers. J. Appl. Phys., vol. 24(6), pp. 771-773, 1953.
20. Tritton, D.J., Experiments on the Flow Around a Circular Cylinder at Low Reynolds Number. Journal of Fluid Mechanics, vol. 6, pp. 547-567, 1959.