MATHEMATICAL MODELING AND COMPUTING, Vol. 10, No. 1, pp. 30–36 (2023)

A mathematical model to study the wall roughness effects on the migration of inertial particles in a shear flow

Assoudi R.[1,2], Lamzoud K.[2], Ahmedou A.[3], Chaoui M.[2]

[1] *Laboratory of Materials, Signals, Systems and Physical Modelling, Ibn Zohr University, Agadir, Morocco*
[2] *OPTIMEE Laboratory, Department of Physics, Moulay Ismail University, Meknes, Morocco*
[3] *FST, Nouakchott Al-Aasriya University, Nouakchott, Mauritania*

(Received 16 June 2022; Accepted 31 October 2022)

Separation of particles in a fluid domain is relevant in various industrial applications. The effect due to the roughness is preponderant compared with that due to fluid inertia so that the Reynolds number is low and the creeping flow equations apply. The wall roughness is assumed to be rigid and periodic, varied in one direction. The trajectories of freely moving particles in a shear flow are calculated.

Keywords: *creeping flow; particle migration; rough wall; particle inertia; fluid inertia.*
2010 MSC: 42Axx, 42A10, 42A15, 65Dxx, 74Axx **DOI:** 10.23939/mmc2023.01.030

1. Introduction

Small particle migration in a fluid domain occurs in various applications, e.g., field-flow fractionation separation technique (FFF) [1] in analytical chemistry, cell-sorting in microfluidic devices, and migration of blood cells [2] in biological flows. Understanding the dynamics of particles transport in a fluid flow would help engineers in industrial processes and biological applications.

Many recent studies have been focused on particle migration in the last decades, showing that the appearance of this phenomenon is linked to the nature of the suspending flow, particle size, particle-wall interactions, and inertial effects. On the experimental side, the first study on particle migration was achieved by Segre and Silberberg [3,4]. The authors observed that in a dilute suspension flow through a pipe at a low Reynolds number, the particles migrate across streamlines to specific positions in the channel. This phenomenal effect has been verified by various experimental studies. On the same kind of problem, [5,6] showed that this lateral displacement is due to fluid inertia. From a theoretical point of view, the first enlightening study on particle migration was performed by Safman [7], where analytical expression of the lift force exerted by the fluid on the sphere is given. Additionally, Asmolov [8] and McLaughlin [9] generalized the theory of Saffman, discarding some constraints on the flow parameters.

The motion of a rigid sphere entrained in a linear shear flow in the vicinity of a smooth wall was investigated in a large number of studies by using the asymptotic methods. Leighton and Acrivos [10], Cherukat and McLaughlin [11], and Krishnan and Leighton [12], have calculated the lift force induced by the fluid inertia in the vicinity of a smooth wall. Other theoretical that are interested in the lift force on drops and bubbles in shear flow [13].

In earlier studies, we have studied the problems of influence of wall roughness on a shear flow [14] and its influence on a freely moving spherical particle near a rough wall in a shear flow [15], and the problem of a particle settling towards a rough wall in a fluid at rest [16]. Based on these results, we will evaluate the effect of wall roughness on the separation of spherical particles entrained by a simple linear shear flow. The rough wall assumed here is periodic and changes in one direction. The particles are considered here rigid, spherical, the same density but have a different radius.

2. Creeping flow equations

We consider a rigid, inertial, spherical particle of a radius a translating and rotating along a rough wall in a linear shear flow of velocity $\tilde{\mathbf{V}}^{\infty}$, with negligible fluid inertia. The model is schematized in Fig. 1. We use a right-hand Cartesian coordinates system $(\tilde{x}, \tilde{y}, \tilde{z})$, with unit vectors $(\mathbf{i}_x, \mathbf{i}_y, \mathbf{i}_z)$, linked to the fictitious plane wall located below the roughness. The wall roughness is chosen to be periodic and expanded in a Fourier series as following:

$$\tilde{z}_p = a\,\varepsilon \left[c_0 + \sum_{n=1}^{p} \big(c_n \cos(n\omega\tilde{x}) + s_n \sin(n\omega\tilde{x}) \big) \right], \tag{1}$$

where ε is the dimensionless amplitude, assumed to be small compared of the particle radius ($\varepsilon \ll 1$), and $\omega = 2\pi/\tilde{L}$ is a positive constant, $\tilde{L}$ is the period of roughness, and

$$c_0 = \frac{1}{\tilde{L}} \int_0^{\tilde{L}} \mathcal{R}(\tilde{x}) d\tilde{x}, \quad c_n = \frac{2}{\tilde{L}} \int_0^{\tilde{L}} \mathcal{R}(\tilde{x}) \cos(n\omega\tilde{x}) d\tilde{x}, \quad s_n = \frac{2}{\tilde{L}} \int_0^{\tilde{L}} \mathcal{R}(\tilde{x}) \sin(n\omega\tilde{x}) d\tilde{x},$$

and the function $\mathcal{R}(\widetilde{x})$ is assumed to be periodic. Its expression, in $(\widetilde{x}, \widetilde{y}, \widetilde{z})$ absolute frame of reference a sawtooth profile, is defined in the half region $\widetilde{z} \geqslant 0$ by

$$\begin{cases} 0 \leqslant \widetilde{x} \leqslant \delta\widetilde{L}: & \mathcal{R}(\widetilde{x}) = \dfrac{1}{\delta} \dfrac{\widetilde{x}}{\widetilde{L}}; \\ \delta\widetilde{L} \leqslant \widetilde{x} \leqslant \widetilde{L}: & \mathcal{R}(\widetilde{x}) = \dfrac{1}{\delta - 1} \left(\dfrac{\widetilde{x}}{\widetilde{L}} - 1 \right). \end{cases}$$

Taking $p = 3$ and $\delta = 3/2$ in the Fourier expansion (1) are sufficient to describe the profile as shown in Fig. 1.

The flow around the particle is governed by the Stokes equations. Linearity of this model allows to decompose the problem into three elementary problems:

(1) A spherical particle held fixed in an ambient linear shear flow $\tilde{\mathbf{V}}^{\infty} = k_s \tilde{z}\, \mathbf{i}_x$, in the vicinity of a rough wall.
(2) A spherical particle translating with velocity $\tilde{\mathbf{U}}_p$ along $\tilde{x}$ direction parallel to a rough wall, in a fluid at rest.
(3) A spherical particle rotating with velocity $\tilde{\mathbf{\Omega}}_p$ around $\tilde{y}$ direction parallel to a rough wall, in a fluid at rest.

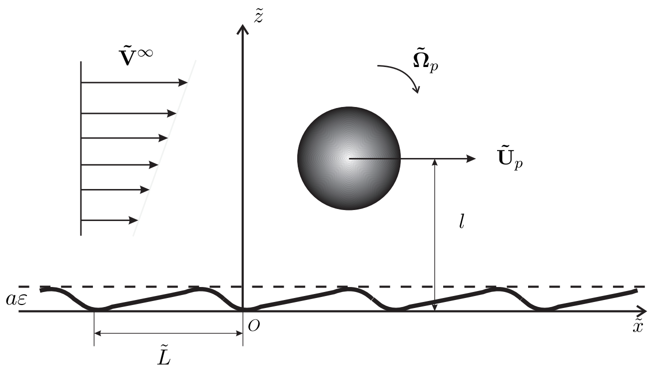


Fig. 1. Spherical particle moving in a linear shear flow near a rough wall.

The resultant force and torque are evaluated by superimposing the forces and torques, exerted on the sphere, due to three elementary flow fields:

$$\tilde{\mathbf{F}} = \tilde{\mathbf{F}}_S + \tilde{\mathbf{F}}_T + \tilde{\mathbf{F}}_R$$
$$\tilde{\mathbf{C}} = \tilde{\mathbf{C}}_S + \tilde{\mathbf{C}}_T + \tilde{\mathbf{C}}_R$$

Where the subscript (S) denotes the problem of sphere fixed in an ambient linear shear flow; (T) and (R) denote the problems of flow fields due to translating and rotating sphere in a fluid at rest, respectively. Let $(\tilde{\mathbf{X}}_p, \tilde{\phi}_p)$ be, respectively, the position vector of the particle center and the angular rotation of a point from particle surface. The translational and rotational velocity of the particle are defined by

$$\tilde{\mathbf{U}}_p = \frac{d\tilde{\mathbf{X}}_p}{d\tilde{t}}; \quad \tilde{\mathbf{\Omega}}_p = \frac{d\tilde{\boldsymbol{\phi}}_p}{d\tilde{t}}.$$

In the case where the fluid inertia effect is negligible, by the assumption $\mathrm{Re} \ll \varepsilon \ll 1$, where Re is the Reynolds number, the equations motion of the spherical particle can be written as follows as

$$m_p \frac{d\tilde{\mathbf{U}}_p}{d\tilde{t}} = \tilde{\mathbf{F}}_S + \tilde{\mathbf{F}}_T + \tilde{\mathbf{F}}_R + \tilde{\mathbf{P}} + \tilde{\mathbf{A}}, \tag{2a}$$

$$J_y \frac{d\tilde{\boldsymbol{\Omega}}_p}{d\tilde{t}} = \tilde{\mathbf{C}}_S + \tilde{\mathbf{C}}_T + \tilde{\mathbf{C}}_R. \tag{2b}$$

Where m_p and J_y are the mass and moment of inertia of the spherical particle, respectively. $\tilde{\mathbf{P}}$ and $\tilde{\mathbf{A}}$ denote the weight and the buoyancy, respectively, which are given by

$$\begin{aligned}
\tilde{\mathbf{P}} &= -\frac{4}{3}\pi a^3 \rho_p g\, \mathbf{i}_z, \\
\tilde{\mathbf{A}} &= \frac{4}{3}\pi a^3 \rho_f g\, \mathbf{i}_z, \\
J_y &= \frac{2}{5} m_p a^2.
\end{aligned}$$

Where, ρ_p and ρ_f are the particle and the fluid densities, respectively, and g is the gravitational acceleration. Based on the assumption of a low roughness amplitude, the expressions of the forces and torques in Eq. (2), in terms of the dimensionless coefficients are expressed as

$$\begin{aligned}
\tilde{\mathbf{F}}_S &= 6\pi\mu_f a \tilde{k}_s l \left[\left(f_{x,S}^{(0)} + \varepsilon f_{x,S}^{(1)}\right)\mathbf{i}_x + \varepsilon f_{z,S}^{(1)} \mathbf{i}_z \right], \\
\tilde{\mathbf{C}}_S &= 4\pi\mu_f a^3 \tilde{k}_s \left(c_{y,S}^{(0)} + \varepsilon c_{y,S}^{(1)}\right)\mathbf{i}_y, \\
\tilde{\mathbf{F}}_T &= -6\pi\mu_f a \tilde{U}_x \left[\left(f_{x,T}^{(0)} + \varepsilon f_{x,T}^{(1)}\right)\mathbf{i}_x + \varepsilon f_{z,T}^{(1)} \mathbf{i}_z \right] - 6\pi\mu_f a \tilde{U}_z f_{z,St} \mathbf{i}_z, \\
\tilde{\mathbf{C}}_T &= 8\pi\mu_f a^2 \tilde{U}_x \left(c_{y,T}^{(0)} + \varepsilon c_{y,T}^{(1)}\right)\mathbf{i}_y, \\
\tilde{\mathbf{F}}_R &= 6\pi\mu_f a^2 \tilde{\Omega}_y \left[\left(f_{x,R}^{(0)} + \varepsilon f_{x,R}^{(1)}\right)\mathbf{i}_x + \varepsilon f_{z,R}^{(1)} \mathbf{i}_z \right], \\
\tilde{\mathbf{C}}_R &= -8\pi\mu_f a^3 \tilde{\Omega}_y \left(c_{y,R}^{(0)} + \varepsilon c_{y,R}^{(1)}\right)\mathbf{i}_y.
\end{aligned}$$

The analytical and numerical results of the friction factors of the forces and torques of the first and second order have been obtained by various authors, see [15,16,18]. In a similar way, the components of translational and rotational velocities of the particle are expanded as

$$\begin{aligned}
\tilde{U}_x &= \tilde{U}_x^{(0)} + \varepsilon \tilde{U}_x^{(1)} + \mathrm{O}(\varepsilon^2), \\
\tilde{\Omega}_y &= \tilde{\Omega}_y^{(0)} + \varepsilon \tilde{\Omega}_y^{(1)} + \mathrm{O}(\varepsilon^2), \\
\tilde{U}_z &= \tilde{U}_z^{(0)} + \varepsilon \tilde{U}_z^{(1)} + \mathrm{O}(\varepsilon^2).
\end{aligned}$$

Where $\tilde{U}_z^{(0)}$ is due only to the force of gravity, because there is no motion of sphere along $\tilde{z}$ for a smooth wall, and the term $\tilde{U}_z^{(1)}$ is due to the presence of the roughness. Taking into account the previous expressions for forces, torques, and velocities, the equation Eq. (2) can be written:

$$\begin{aligned}
\frac{4}{3}\pi a^3 \rho_p \frac{d\tilde{U}_x}{d\tilde{t}} &= -6\pi\mu_f a \tilde{U}_x \left(f_{x,T}^{(0)} + \varepsilon f_{x,T}^{(1)}\right) + 6\pi\mu_f a^2 \tilde{\Omega}_y \left(f_{x,R}^{(0)} + \varepsilon f_{x,R}^{(1)}\right) \\
&\quad + 6\pi\mu_f a \tilde{k}_s l \left(f_{x,S}^{(0)} + \varepsilon f_{x,S}^{(1)}\right),
\end{aligned} \tag{3a}$$

$$\begin{aligned}
\frac{8}{15}\pi a^5 \rho_p \frac{d\tilde{\Omega}_y}{d\tilde{t}} &= 8\pi\mu_f a^2 \tilde{U}_x \left(c_{y,T}^{(0)} + \varepsilon c_{y,T}^{(1)}\right) - 8\pi\mu_f a^3 \tilde{\Omega}_y \left(c_{y,R}^{(0)} + \varepsilon c_{y,R}^{(1)}\right) \\
&\quad + 4\pi\mu_f a^3 \tilde{k}_s \left(c_{y,S}^{(0)} + \varepsilon c_{y,S}^{(1)}\right),
\end{aligned} \tag{3b}$$

$$\begin{aligned}
\frac{4}{3}\pi a^3 \rho_p \frac{d\left(\tilde{U}_z^{(0)} + \varepsilon \tilde{U}_z^{(1)}\right)}{d\tilde{t}} &= -6\pi\mu_f a \tilde{U}_x \varepsilon f_{z,T}^{(1)} + 6\pi\mu_f a^2 \tilde{\Omega}_y \varepsilon f_{z,R}^{(1)} + 6\pi\mu_f a \tilde{k}_s l \varepsilon f_{z,S}^{(1)} \\
&\quad - 6\pi\mu_f a \left(f_{z,St}^{(0)} \tilde{U}_z^{(0)} + \varepsilon f_{z,St}^{(0)} \tilde{U}_z^{(1)}\right) - \frac{4}{3}\pi a^3 (\rho_p - \rho_f) g.
\end{aligned} \tag{3c}$$

In Eq. (3), the equation of the first order (0) due to gravity is easily solved independently. Only the terms of the second order (1) due to roughness will be considered below. In the following, we will make the system dimensionless by using reduced velocities $\tilde{U}_x = \tilde{k}_s a U_x$, $\tilde{U}_z = \tilde{k}_s a U_z$, $\tilde{\Omega}_y = \tilde{k}_s \Omega_y$, and reduced time $t^* = \tilde{k}_s^{-1}$, where $\tilde{k}_s$ is the dimensionless constant. The equations (3) become:

$$\begin{aligned}
\frac{dU_x}{dt} &= \frac{1}{S_{tk}}\left[\frac{l}{a}\left(f_{x,S}^{(0)} + \varepsilon f_{x,S}^{(1)}\right) - U_x\left(f_{x,T}^{(0)} + \varepsilon f_{x,T}^{(1)}\right) + \Omega_y\left(f_{x,R}^{(0)} + \varepsilon f_{x,R}^{(1)}\right)\right],\\
\frac{dU_m}{dt} &= \frac{1}{S_{tk}}\left[\frac{l}{a}\varepsilon f_{z,S}^{(1)} - U_x\varepsilon f_{z,T}^{(1)} + \Omega_y\varepsilon f_{z,R}^{(1)} - f_{z,St}^{(0)}U_m\right],\\
\frac{d\Omega_y}{dt} &= \frac{5}{3S_{tk}}\left[\left(c_{y,S}^{(0)} + \varepsilon c_{y,S}^{(1)}\right) + 2U_x\left(c_{y,T}^{(0)} + \varepsilon c_{y,T}^{(1)}\right) - 2\Omega_y\left(c_{y,R}^{(0)} + \varepsilon c_{y,R}^{(1)}\right)\right],\\
\frac{dx_p}{dt} &= U_x,\\
\frac{dz_p}{dt} &= U_z,\\
\frac{d\phi_y}{dt} &= \Omega_y.
\end{aligned}$$

Where $U_m = \varepsilon U_z^{(1)}$ is none other than the migration velocity of the spherical particle due to the roughness. S_{tk} denote the Stokes number; it is dimensionless and represents the ratio between the kinetic energy of the particle and the energy dissipated by friction with the fluid. It is defined by

$$S_{tk} = \frac{2}{9}\frac{\rho_p}{\rho_f}\mathrm{Re}.$$

3. Numerical results and discussion

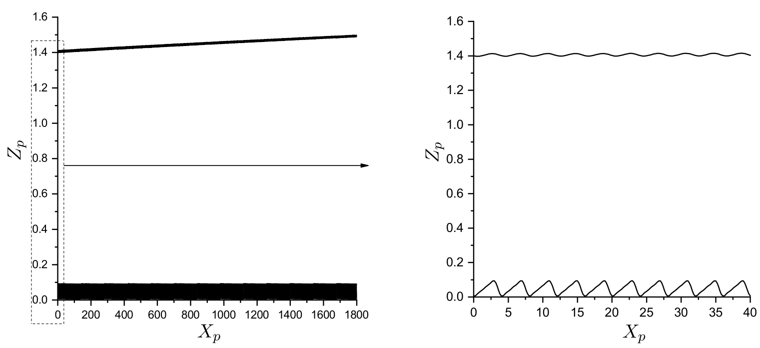
3.1. Trajectories of a freely moving sphere in a linear shear flow near a rough wall

Based on the equations (4) of the sphere motion, and neglecting the effects of inertia of the fluid ($\mathrm{Re} \ll \varepsilon$), we calculate the trajectory of a sphere with inertia near the rough wall defined by $\varepsilon = 0.1$, $L = 4$, and $\delta = 3/4$. The evolution of the position vector of the particle center is obtained by simply integrating its dimensionless velocity:

$$\mathbf{X}(t) = \int_0^t \mathbf{U}_p \, d\tau.$$

Figure 2 presents the trajectory of the inertial particle for the initial position $(l/a)_{(X=0)} = 1.4$ and Stokes number $S_{tk} = 0.5$. The numerical results show that there is an important migration of the sphere during its horizontal displacement $D_x = 400L$, it moves away from the wall by migration by $D_z = 0.0812$.

Figure 3 represents the trajectories of the spheres, of different Stokes numbers (S_{tk}). The results show that the migration of the sphere increases with its inertia, this migration is impor-



a ***b***

Fig. 2. Trajectory of the particle center near a rough wall, for initial values of the position above the base plane $(l/a)_{(X=0)} = 1.4$, with parameters of roughness $\varepsilon = 0.1$, $L = 4$ and $\delta = 3/4$. (***a***) The ordinate Z_p of the sphere center as a function of its abscissa X_p over a distance $d = 400L$. (***b***) The ordinate Z_p of the sphere center as a function of its abscissa X_p over a distance $d = 10L$.

tant when the particle is close to the wall and begins to decay with the increase of the sphere-wall gap, this can be explained that when the sphere near the wall its migration is caused by the coupling between the roughness effect and the inertia effect of the sphere, and as the sphere migrates away from the wall the roughness effect begins to diminish and the inertia of the sphere remains the only source of its migration.

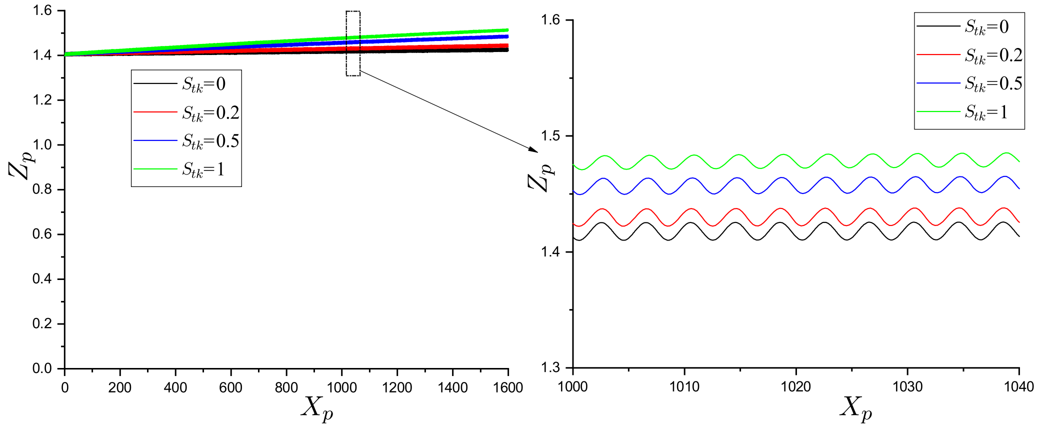


Fig. 3. Migration of spheres, of different Stokes number S_{tk}, near a rough wall, for $\varepsilon = 0.1$, $L = 4$ and $\delta = 3/4$, with the same initial position $(l/a)_{(X=0)} = 1.4$ over a distance $d = 400L$.

3.2. Migration comparison of that due to particle inertia coupled with wall roughness effects and that due to the fluid inertia effect

The migration of a particle can have several sources. Yahiaoui and Feuillebois [17] studied the effect of fluid inertia on the motion of a spherical particle without inertia in a quadratic flow. Their results showed that the fluid inertia causes also the sphere migration. In this paragraph, we will make a comparison between the migration due to the fluid inertia, in the case of a free sphere near a smooth wall limited a simple shear flow, and that due to the coupling between the effects of the particle inertia and the wall roughness, in the case of a free sphere near a rough wall limited a simple shear flow. For this, we took the case of a steel grain of radius $a = 1.5\,\mu$m and density $\rho_p = 7.85010^3\,\mathrm{kg\,m^{-3}}$, in free motion in air of density $\rho_f = 1.293\,\mathrm{kg\,m^{-3}}$ and kinematic viscosity $\nu = 1.510^{-5}\,\mathrm{m^2\,s^{-1}}$, with a shear rate $k_s = 10^3\,\mathrm{s^{-1}}$. These parameters give:

— A Reynolds number around the particle: $\mathrm{Re} = 1.4 \times 10^{-4}$.
— A Stokes number of the particle: $S_{tk} = 0.2$.

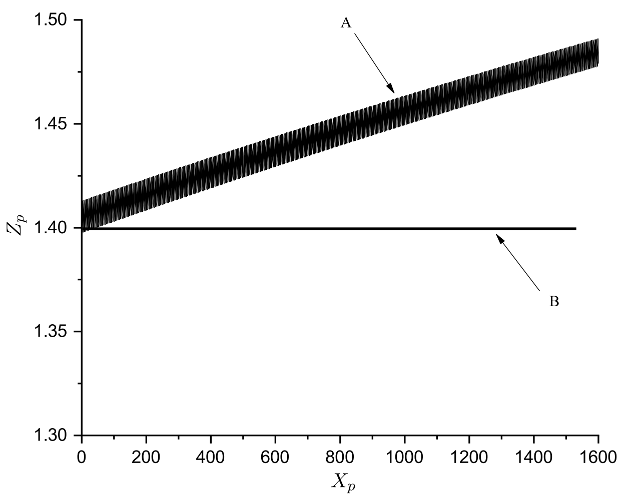


Fig. 4. Trajectory of a sphere with inertia $S_{tk} = 0.2$, near a rough wall, for $\varepsilon = 0.1$, $L = 4$, in a shear linear flow with initial position $(l/a)_{(X=0)} = 1.4$ and $\mathrm{Re} = 1.4 \times 10^{-4}$, and comparison with the results of Yahiaoui and Feuillebois [17] (trajectory B).

The numerical results in Fig. 4, show that during an horizontal displacement $D_x = 400L$ of the sphere center, the particle makes a displacement by migration due to fluid inertia equal to $D_z = 1.03 \times 10^{-4}$ (trajectory B), and during the same displacement, the sphere with inertia near a rough wall makes a displacement by migration $D_z = 3.79 \times 10^{-2}$ (trajectory A), which shows that the migration due to the fluid inertia is negligible compared to that due to the coupling between the roughness effect and sphere inertia effects (under the assumption $\mathrm{Re} \ll \varepsilon$).

4. Conclusion

This paper studied the migration of spherical particle moving freely in a shear flow along a rough wall. Based on the creeping equations, we have calculated the trajectories of spheres without inertia and with inertia, by neglecting the effect of fluid inertia. The results show that in the absence of the particle inertia, the particles will follow a periodic trajectory with low migration, more and more the particle inertia becomes important more its migration increases. The results also show that the migration due to the fluid inertia is negligible compared to that due to the coupling between the roughness effect and the particle inertia.

[1] Pasol L., Martin M., Ekiel-Jeżewska M. L., Wajnryb E., Bławzdziewicz J., Feuillebois F. Motion of a sphere parallel to plane walls in a Poiseuille flow. Application to field-flow fractionation and hydrodynamic chromatography. Chemical Engineering Science. **66** (18), 4078–4089 (2011).

[2] Kim Y. W., Yoo J. Y. Three-dimensional focusing of red blood cells in microchannel flows for bio-sensing applications. Biosensors and Bioelectronics. **24** (12), 3677–3682 (2009).

[3] Segré G., Silberberg A. Radial particle displacements in Poiseuille flow of suspensions. Nature. **189**, 209–210 (1961).

[4] Segré G., Silberberg A. Behaviour of macroscopic rigid spheres in Poiseuille flow Part 2. Experimental results and interpretation. Journal of fluid mechanics. **14** (1), 136–157 (1962).

[5] Ho B. P., Leal L. G. Inertial migration of rigid spheres in two-dimensional unidirectional flows. Journal of fluid mechanics. **65** (2), 365–400 (1974).

[6] Leal L. G. Particle motions in a viscous fluid. Annual Review of Fluid Mechanics. **12**, 435–476 (1980).

[7] Saffman P. G. The lift on a small sphere in a slow shear flow. Journal of fluid mechanics. **22** (2), 385–400 (1965).

[8] Asmolov E. S. Dynamics of a spherical particle in a laminar boundary layer. Fluid Dynamics. **25**, 886–890 (1990).

[9] McLaughlin J. B. Inertial migration of a small sphere in linear shear flows. Journal of Fluid Mechanics. **224**, 261–274 (1991).

[10] Leighton D., Acrivos A. The lift on a small sphere touching a plane in the presence of a simple shear flow. Zeitschrift für angewandte Mathematik und Physik ZAMP. **36**, 174–178 (1985).

[11] Cherukat P., McLaughlin J. B. The inertial lift on a rigid sphere in a linear shear flow field near a flat wall. Journal of Fluid Mechanics. **285**, 407 (1995).

[12] Krishnan G. P., Leighton D. T. (Jr.) Inertial lift on a moving sphere in contact with a plane wall in a shear flow. Physics of Fluids. **7** (11), 2538–2545 (1995).

[13] Legendre D., Magnaudet J. The lift force on a spherical bubble in a viscous linear shear flow. Journal of Fluid Mechanics. **368**, 81–126 (1998).

[14] Assoudi R., Lamzoud K., Chaoui M. Influence of the wall roughness on a linear shear flow. FME Transactions. **46** (2), 272–277 (2018).

[15] Lamzoud K., Assoudi R., Bouisfi F., Chaoui M. A spherical particle settling towards a corrugated wall. Russian Journal of Nonlinear Dynamics. **15** (2), 125–134 (2019).

[16] Chaoui M., Feuillebois F. Creeping flow around a sphere in a shear flow close to a wall. The Quarterly Journal of Mechanics and Applied Mathematics. **56** (3), 381–410 (2003).

[17] Yahiaoui S., Feuillebois F. Lift on a sphere moving near a wall in a parabolic flow. Journal of Fluid Mechanics. **662**, 447–474 (2010).

[18] Assoudi R., Chaoui M., Feuillebois F., Allouche H. Motion of a spherical particle along a rough wall in a shear flow. Zeitschrift für angewandte Mathematik und Physik ZAMP. **69**, 112 (2018).

Математична модель для вивчення впливу шорсткості стінки на міграцію інерційних частинок у зсувному потоці

Ассуді Р.[1,2], Ламзуд К.[2], Ахмеду А.[3], Чауї М.[2]

[1] *Лабораторія матеріалів, сигналів, систем та фізичного моделювання,*
Університет Ібн Зохр, Агадір, Марокко
[2] *Лабораторія OPTIMEE, кафедра фізики,*
Університет Мулая Ісмаїла, Мекнес, Марокко
[3] *FST, Університет Нуакшот Аль-Аасрія, Нуакшот, Мавританія*

Розділення частинок у рідинній області актуальне в різних промислових застосуваннях. Вплив шорсткості є більшим, ніж вплив інерції рідини, тому число Рейнольдса є низьким і застосовуються рівняння повзучого потоку. Шорсткість стінки вважається жорсткою і періодичною, змінюваною в одному напрямку. Розраховано траєкторії вільних частинок у зсувному потоці.

Ключові слова: *повзучий потік, міграція частинок, шорстка стінка, інерція частинок, інерція рідини.*