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Oseen's correction to Stokes drag on axially symmetric particle in micropolar fluid

Research Article

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Abstract: In this paper, the expressions of Oseen's correction to Stokes drag on small axially symmetric particle placed under slow uniform stream parallel to axis of symmetry(longitudinal flow) and perpendicular to axis of symmetry(transverse flow) are calculated in micropolar fluid with small micropolarity parameter $'k'$. DS-conjecture for writing Stokes drag on axially symmetric particle given by Datta and Srivastava [1] is utilized first combining with the fact concluded by Datta and Rathore [2] that for any free stream direction(axial or transverse), the drag for the polar case can be deduced from the non-polar(i.e. $k = 0$) case simply through multiplication by the factor $1 + k/\mu$ or $\mu \to \mu + k$ to provide general expression of Stokes drag on small axially symmetric particle in micropolar fluid. The formula given by Brenner [3] is then applied to calculate the Oseen's correction to Stokes drag on small axially symmetric particle placed under axial flow for micropolar fluid which is further extended to the expression of Oseen's correction to Stokes drag on small axially symmetric particle placed under transverse flow for micropolar fluid by utilizing the linear relationship between axial and transverse drag. These expressions of Oseen's drag are written up to the first order of Reynolds number Re. These expressions are applied over sphere, spheroids, deformed sphere for validation and comparison purposes. Numerical values of Oseen's drag are calculated and displayed via graphs with respect to small Reynolds number Re. Some practical applications are also highlighted.

MSC: 76A02 • 76D07

Keywords: Oseen's correction • Stokes drag • Axially symmetric particle • Micropolar fluid

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1. Introduction

The theory of micropolar fluids is first advanced by Eringen [4] who used the field approach to describe the macroscopic manifestations of microscopic events. In this widely used theory, a continuum is regarded as consisting of structured particles, which not only contain mass and velocity but also a substructure, and which can support couple stresses and body couples. Rheological complex fluids such as polymeric suspensions, animal blood, liquid crystals(with dumbbell type molecules), lubricant fluid, colloidal expansions are the examples of micropolar fluids where the micropolar fluid theory is applicable. In micropolar fluid, individual particles can rotate independently from the rotation and movement of fluid as a whole. The slow motion of small particles in a fluid is common in bio-engineering, chemical engineering and naval engineering. Because of their growing importance, slow flow problems have started engaging considerable attention in recent years. It is worth noting that the most sought after quantity in such flow problems is the drag force rather than a detailed description of the flow field. These flow problems are governed by the so called Stokes equations obtained by eliminating convective inertia or non-linear terms in Navier-Stokes equations. In other words, zero Reynolds number flow is also called Stokes flow. The solution of this equation and the drag force on a sphere placed in a slow uniform stream of viscous fluid was first determined by Stokes [5]

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and is commonly known as Stokes law. Oseen [6] tackled this type of problem involving the correction to Stokes drag extensively. Oseen provided solutions for the flow past various bodies at small Reynolds number 'R' and calculated the force to the first order in $'R'$, one term more than would be given by the Stokes approximation. By the inclusion of the inertia terms, Oseen improved the flow picture far from the body where the Stokes approximation is inadequate, but near the body the difference between the two solutions is of an order of smallness which is outside the accuracy of either approximation. Oseen's calculation for the force thus requires some further justification, for flow past a sphere, by the work of Kaplun [7] , Kaplun and Lagerstrom [8] and Proudman and Pearson [9]. Oseen failed to calculate correctly the velocity field, his result for the drag on the sphere, namely

$$D = D_0\,[1 + (3/8)\,R]\,, \tag{1}$$

where D_0 is the Stokes drag, is in fact valid because the correction to the velocity field makes no contribution to the total force on the sphere.

Almost similar problem has been considered by Chang [10] for the axially symmetric Stokes flow of a conducting fluid past a body of revolution in the presence of a uniform magnetic field. An equation identical to that cited above, except that the dimensionless Hartmann number, M, appears in place of the Reynolds number, R. It is interesting to note here that Chang [10] result is restricted to axially symmetric flows because of the requirement that there be sufficient symmetry to preclude the existence of an electric field. While, on the other hand, Brenner [4] result is limited only by the requirement that the Stokes drag on the particle(and thus the Oseen drag) be parallel to its direction of motion. Payne and Pell [11] provided a general formula for calculating Stokes drag on axially symmetric body in terms of stream function representing the flow around the body and at infinity. Rao and Rao [12] tackled the problem of slow stationary flow of a micropolar incompressible fluid past a sphere. Adopting Stokesian approach, they found the drag on the sphere and concluded that drag value in the present case is more than that in the case of non-polar classical fluids.Erdogan [13] extended the concept of slow motion to the case of polar fluid motion. He established a convenient expression for the force exerted by the fluid on a body and obtained the expression of force by the fluid on a rigid sphere in uniform translation.Ariman et al. [14] reviewed complete survey developments in microcontinuum fluid mechanics. Ramkissoon and Majumdar [15] derived the expression of drag on an axially symmetric body in the Stokes flow of micropolar fluid. Ramkissoon and O'Neill [16] investigated the force experienced by a rigid particle in the Stokes flow of micropolar fluid and found that the force is to be a linear functional of the free stream velocity. Olmstead and Majumdar [17] considered the steady, incompressible flow of a micropolar fluid in 2 dimensions. They introduced the Oseen linearization of the convective operator and formulated the associated problem for the fundamental solution. Datta and Rathore [2] studied the slow uniform motion of an incompressible viscous micropolar fluid past a prolate spheroid by singularity distribution method developed by Chwang and Wu [18] . Ramkissoon [19] calculated the drag force experienced by Newtonian fluid sphere in micropolar fluid. Iyengar and Charya [20] evaluated the drag experienced by the approximate sphereplaced in an incompressible micropolar fluid and studied its variation with respect to the material parameters. Datta and Srivastava [1] advanced a new approach to evaluate the drag force in a simple way on a restricted axially symmetric body placed in a uniform stream parallel to its axis and perpendicular to its axis, when the flow is governed by Stokes equations. Hayakawa [21] presented a systematic calculation of micropolar fluid flows around a sphere and a cylinder and obtained the explicit velocity fields and the drag forces exerted by the fluid flow in both two and three dimensions. Shu and Chwang [22] developed a number of closed-form fundamental solutions for generalized unsteady Oseen and Stokes flows associated with arbitrary time-dependent translational and rotational motions. In a short note, Palaniappan and Ramkissoon [23] rederived the elegant formula of Stokes drag on axially symmetric particle in micropolar fluid derived earlier by Ramkissoon and Majumdar [15]. Faltas and Saad [24] investigated the motion of a solid spherical particle in an incompressible axi-symmetric micropolar Stokes flow by using Basset type linear slip boundary conditions. They calculated the expressions of drag force and terminal velocity in terms of the parameter characterizing the slip friction. Murthy et al. [25] studied the flow generated by the slow steady rotation of a permeable sphere about its axis of symmetry in an incompressible micropolar fluid which is at rest otherwise.Hoffmann et al. [26] extended the Stokes formula for the resistance force exerted on a sphere moving with constant velocity in a fluid to the case of micropolar fluids by using nonhomogeneous boundary condition for the microrotation vector.Faltas and Saad [27] presented explicit velocity and microrotation components and systematic calculation of hydrodynamic quasistatic drag and couple in terms of nondimensional coefficients for the flow problem of an incompressible asymmetrical steady semi-infinite micropolar fluid arising from the motion of a sphere bisected by a free surface bounding a semi-infinite micropolar fluid. Shu and Lee [28] derived new fundamental solutions for micropolar fluids in explicit form for two and three dimensional steady unbounded Stokes and Oseen flows due to a point couple, including the two dimensional micropolar Stokeslet, the two and three dimensional micropolar Stokes couplet, the three dimensional micropolar Oseenlet, and the three dimensional micropolar Oseen couplet. They also concluded that the drag coefficients in a micropolar fluid are greater than those in a Newtonian fluid.Sherief et al. [29] investigated the translational motion of an arbitrary body of revolution in a micropolar fluid by a combined analytical-numerical method. They evaluated the drag force exerted on a prolate spheroid for various values of aspect ratio and for different values of micropolarity parameters. They concluded that the drag force on the prolate spheroid increases monotonically with an increase of the aspect ratio of the spheroid and also with an increase of the micropolarity parameters. Iyengar and Radhika [30] considered the problem of Stokes flow of an incompressible micropolar fluid past a porous spheroidal shell. Deo and Shukla [31] considered the problem of creeping flow of an incompressible micropolar fluid past a fluid sphere with non-homogeneous boundary condition for micro rotation vector. Srivastava et al. [32] provided an analytic approach to study the steady Oseen's flow past deformed sphere.

1.1. Applications

Krasovitskaya et al. [33] proposed a formula based on Oseen's correction for calculating the settling of solid particles of powdered materials with enhanced accuracy in carrying out sedimentation analysis. Dyer and Ohkawa [34] have used the Oseen drag in acoustic levitation. These two works are the main practical applications of Oseen's correction which was not possible with the Stokes drag. In biology Fung [35] blood flow in small vessels, such as capillaries, is characterized by small Reynolds numbers. A vessel of diameter of 10 Âţm with a flow of 1 milimetre/second, viscosity of 0.02 poise for blood, density of 1 g/cm^3 and a heart rate of 2 Hz, will have a Reynolds number of 0.005. At these small Reynolds numbers, the viscous effects of the fluid become predominant. Oseen's method is better in Understanding of the movement of these particles for drug delivery and studying metastasis movements of cancers.

2. Method

Let us consider the axially symmetric body of characteristic length L placed along its axis (x-axis, say) in a slow uniform stream $U = U_x = U_y$ of micropolar viscous fluid of density ρ and kinematic viscosity ν and small micropolarity k. When Reynolds number UL/ν or $UL\rho/(\mu+k)$ is small, the steady flow of slow incompressible viscous micropolar fluid around this small axially symmetric body in the absence of body forces and body couplesare governed by Stokes equations Ramkissoon and Majumdar [15] ,

$$-\left(\mu+k\right)\nabla\times\nabla\times\boldsymbol{u}+k\,\nabla\times\boldsymbol{\omega}-\nabla p\;=0, \tag{2}$$

$$(\alpha_1+\alpha_2+\alpha_3)\,\nabla\,(\nabla\cdot\boldsymbol{\omega})-\alpha_3\nabla\times\nabla\times\boldsymbol{\omega}+k\,(\nabla\times\mathbf{u})-2k\boldsymbol{\omega}=0, \tag{3}$$

$$\nabla\cdot\mathbf{u}=\mathbf{0} \tag{4}$$

subject to the no-slip and no spin boundary condition. In the above equations, $\mathbf{u}$ is the velocity vector, μ the micro-rotation or spin vector, ρ the viscosity coefficient, p the pressure, 'k' the coupling constant or micropolarity of fluid, $\mathbf{F}$ the external force per unit mass and $\alpha_1, \alpha_2, \alpha_3$ are characteristics constants of the particular fluid under consideration.It should be noted here that the general expression for Stokes drag on small axially symmetric particle placed under slow incompressible viscous micropolar fluid with small micropolarity experiencing no external body forces is proposed with the restriction of no-slip and no spin boundary conditions.

We have taken up the class of those axially symmetric bodies which possesses continuously turning tangent, placed in a uniform stream U along the axis of symmetry (which is x-axis), as well as constant radius 'b' of maximum circular cross-section at the mid of the body. This axi-symmetric body is obtained by the revolution of meridional plane curve (depicted in Fig. 1) about axis of symmetry which obeys the following limitations:

i. Tangents at the points A, on the x-axis, must be vertical,

ii Tangents at the points B, on the y-axis, must be horizontal,

iii. The semi-transverse axis length 'b' must be fixed.

The point P on the curve is may be represented by the Cartesian coordinates (x, y) or polar coordinates (r,θ) respectively , PN and PM are the length of tangent and normal at the point P. The symbol R stands for the intercepting length of normal between the point on the curve and point on axis of symmetry and symbol a is the slope of normal PM which can be vary from 0 to π.

2.1. Axial flow

The expression of Stokes drag on such type of small axially symmetric body placed in axial flow(uniform flow parallel to the axis of symmetry) of micropolar fluid with small micropolarity 'k' is given by Datta and Srivastava [1]

$$F_x\;=\frac{1}{2}\frac{\lambda b^2}{h_x},\quad\text{where}\quad\lambda=6\pi\left(\mu+k\,\right)U_x \tag{5}$$

and

$$h_x=\left(\frac{3}{8}\right)\int_0^{\pi}R\sin^3\alpha\;d\alpha\;. \tag{6}$$

where the suffix 'x' has been introduced to assert that the force is in the axial direction.

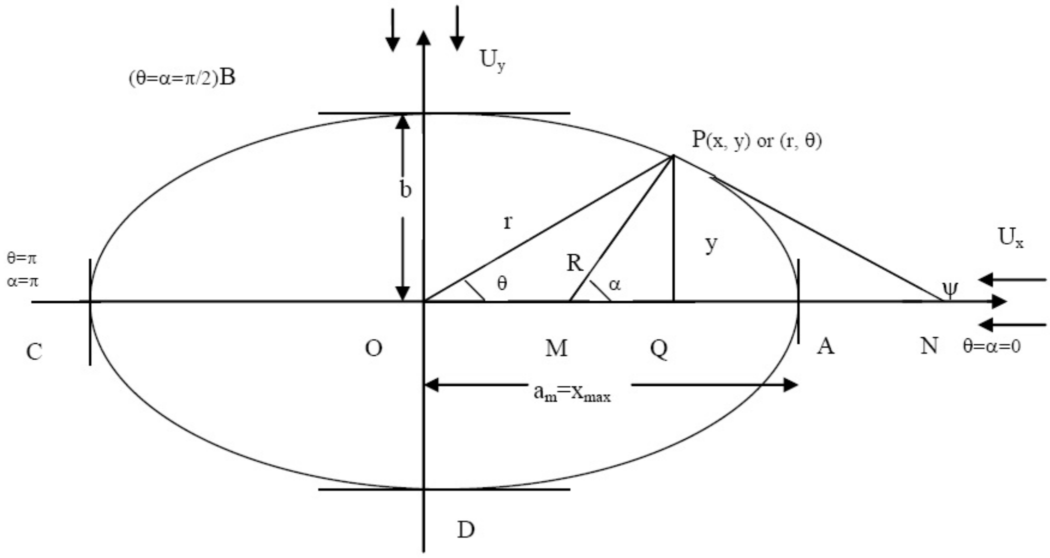

Fig. 1. Geometry of axially symmetric body

2.2. Transverse flow

The expression of Stokes drag on small axially symmetric body placed in transverse flow(uniform flow perpendicular to the axis of symmetry) of micropolar fluid with small micropolarity 'k' is given by Datta and Srivastava [1]

$$F_y = \left(\frac{1}{2}\right)\frac{\lambda b^2}{h_y}, \quad \text{where} \quad \lambda = 6\,\pi\,(\mu + k\,)\,U_y, \tag{7}$$

and

$$h_y = \left(\frac{3}{16}\right)\int_0^{\pi} R\left(2\,\sin\,\alpha - \,\sin^3\,\alpha\right)\,d\alpha\,. \tag{8}$$

where the suffix 'y' has been introduced to assert that the force is in the transverse direction.

The expressions of drag given in (5) and (7) requires the knowledge of geometrical parameters related to body geometry like 'R', 'α' etc. (see Fig. 1) without having the information regarding velocity field and stream function around the body and at infinity in order to calculate drag experienced by body placed in uniform stream. While the expression of drag provided by Payne and Pell [11] requires the knowledge of stream functions around the body and at infinity. Datta and Rathore [2] concluded that for any free stream direction(axial or transverse), the drag for the micropolar case can be deduced from the non-polar (i.e. $k = 0$, the case of Newtonian fluid) case simply through multiplication by the factor $(1 + k/\mu)$ or replacing $\mu \to (\mu + k)$. In other words, micropolar coefficients are independent of body's shape parameters which permit us to do so.

Now, the general expression of drag on small axially symmetric particle placed under uniform stream parallel to axis of symmetry with small micropolarity 'k' is [by using (5)]

$$F_x = \frac{3\,\pi\,\mu\left(1+\frac{k}{\mu}\right)U_x b^2}{h_x} = \frac{8\,\pi\,\mu\left(1+\frac{k}{\mu}\right)U_x b^2}{\int_0^{\pi} R\,\sin^3\,\alpha\;d\alpha}, \quad \frac{k}{\mu} > 0 \tag{9}$$

Similarly, the general expression of drag on same small axially symmetric particle placed under uniform stream perpendicular to axis of symmetry with small micropolarity 'k' is [by using (7)]

$$F_y = \frac{3\,\pi\,\mu\left(1+\frac{k}{\mu}\right)U_y b^2}{h_y} = \frac{16\,\pi\,\mu\left(1+\frac{k}{\mu}\right)U_y b^2}{\int_0^{\pi} R\left(2\,\sin\,\alpha - \,\sin^3\,\alpha\right)\,d\alpha}, \quad \frac{k}{\mu} > 0 \tag{10}$$

Now, by taking $U = U_x = U_y$, on dividing (9) and (10), we get

$$\frac{F_x}{F_y} = \frac{h_y}{h_x} = \frac{1}{2}\,\frac{\int_0^{\pi}\,R\left(2\sin\alpha - \sin^3\alpha\right)d\alpha}{\int_0^{\pi}\,R\sin^3\alpha\;d\alpha} = K(say), \tag{11}$$

which provides,

$$F_x = \,K\,F_y \tag{12}$$

By applying Brenner's formula Brenner [3] which is applicable only for Newtonian fluid but may be extended to micropolar fluid by replacing μ with $\mu + k$, Oseen's correction to Stokes drag on a body placed in axial uniform flow in micropolar fluid, in general, may be written as

$$\frac{F}{F_x} = 1 + \frac{F_x}{16\,\pi\,(\mu + k\,)\,LU} Re + O(Re^2). \tag{13}$$

By using linear relationship between axial and transverse Stokes drag (12), Eq. (13) provide Oseen's correction to Stokes drag on a body placed in transverse uniform stream of micropolar fluid with small micropolarity 'k'

$$\frac{F}{F_y} = K\frac{F}{F_x} = K\left[1 + \frac{F_x}{16\,\pi\,(\mu + k)\,L\,U} Re + O(Re^2)\right]. \tag{14}$$

where K is a real factor defined in (11) and $Re = \rho_1 UL/(\mu + k)$, the particle Reynolds number.

3. Formulation of problem

We consider the small axially symmetric arbitrary particle of characteristic length L placed along its axis (x-axis, say) in a slow uniform stream U of incompressible viscous micropolar fluid of density ρ_1, kinematic viscosity ν or $(k + \mu)/\rho_1$ and small micropolarity 'k'. When particle Reynolds number $UL\rho_1/(\mu + k)$ is small, the steady motion of incompressible viscous micropolar fluid around this small axially symmetric body is governed by Stokes equations Ramkissoon and Majumdar [15],

$$-\left(\frac{\mu + k}{\rho_1}\right)\nabla\times\nabla\times\mathbf{u} + 2\left(\frac{k}{\rho_1}\right)\,(\nabla\times\boldsymbol{\omega}) - \frac{1}{\rho_1}\nabla p\; = \mathbf{0}, \tag{15}$$

$$(\alpha_1 + \alpha_2 + \alpha_3)\,\nabla\,(\nabla\cdot\omega) - \alpha_3\nabla\times\nabla\times\omega + k\,(\nabla\times\mathbf{u}) - 2k\boldsymbol{\omega} = \mathbf{0}, \tag{16}$$

$$\nabla\cdot\mathbf{u} = \mathbf{0} \tag{17}$$

subject to the no-slip and no-spin boundary conditions

$$\mathbf{u} = \mathbf{0}, \quad \boldsymbol{\omega} = \mathbf{0} \tag{18}$$

This equation is the reduced form of complete Navier-Stokes equations in the absence of body forces and body couples and neglecting inertia term $(\mathbf{u}\cdot grad)\mathbf{u}$ which is unimportant in the vicinity of body where viscous term dominates(Stokes approximation). Solution of this equation (15), called Stokes law, $6\pi(\mu+k)Ua$, for a slowly moving sphere having radius 'a', is valid only in the vicinity of the body which breaks down at distance far away from the body. This breaks down of Stokes solution at far distance from the body is known as Whitehead's paradox. It was Oseen in 1910, who pointed out the origin of Whitehead's paradox and suggest a scheme for its resolution Oseen [6]. In order to rectify the difficulty, Oseen went on to make the following additional observations.

In the limit where the particle Reynolds number $Re = \rho_1 Ua/(\mu + k) \to 0$, Stokes approximation becomes invalid only when $r/a \to \infty$. But at such enormous distances, the local velocity $\mathbf{u}$ differs only imperceptibly from a uniform stream of velocity $\mathbf{U}$. Thus, Oseen was inspired to suggest that the inertial term $(\mathbf{u}\cdot grad)\mathbf{u}$ could be uniformly approximated by the term $(\mathbf{U}\cdot grad)\mathbf{u}$. By such arguments, Oseen proposed that uniformly valid solutions of the problem of steady streaming flow past a body at small particle Reynolds numbers could be obtained by solving the linear equations of micropolar fluid

$$\rho_1\,(\mathbf{U}\cdot\nabla\mathbf{u}) = -\left(\mu + k\right)\nabla\times\nabla\times\mathbf{u} + k\,\nabla\times\boldsymbol{\omega} - \nabla p, \tag{19}$$

$$\rho_1\mathbf{I}_r\,(\mathbf{U}\cdot\nabla\mathbf{u}) = (\alpha_1 + \alpha_2 + \alpha_3)\,\nabla\,(\nabla\cdot\boldsymbol{\omega}) - \alpha_3\nabla\times\nabla\times\boldsymbol{\omega} + k\,(\nabla\times\mathbf{u}) - 2k\boldsymbol{\omega}, \tag{20}$$

$$\nabla\cdot\mathbf{u} = \mathbf{0} \tag{21}$$

known as Oseen's equation. In Eq. (16), Ir is micro-inertia.Oseen obtained an approximated solution of his equations for flow past a sphere, from which he obtained the Stokes drag formula

$$F = 6\pi\left(\mu + k\right)\,aU\left[1 + \frac{3}{8}Re + O\left(Re^2\right)\right], \tag{22}$$

where $Re = \rho_1 Ua/(\mu + k)$ is particle Reynolds number.

We find the solution of these Eqs. (19)-(20) as an correction to Stokes drag for various axially symmetric particles like sphere, spheroid(prolate and oblate), deformed sphere by using no-slip and no-spin boundary conditions by utilizing D-S conjecture (5), and (7), followed by linear relationship (10) between axial and transverse Stokes drag (12) and Brenner's formula (13) valid for axial flow and its extension (14) for transverse flow of micropolar fluid with small micropolarity 'k'.

4. Solution

4.1. Flow past a sphere

Let us consider the parametric equation of sphere having radius as

$$x = a\cos t, \quad y = a\sin t, \quad 0 \leqslant t \leqslant \pi. \tag{23}$$

After careful calculation, the values of h_x and h_y are [from (6) and (8)]

$$h_x = h_y = a/2. \tag{24}$$

The expressions of axial and transverse Stokes drag on this sphere placed in micropolar fluid, by using (9) and (10) with fact $b = a$, comes out to be

$$F_x = F_y = 6\pi\mu\left(1+\frac{k}{\mu}\right)Ua, \tag{25}$$

where 'k' is small micropolarity coefficient. This expression matches with the expression of drag on sphere of radius 'a' placed under micropolar fluid given by Ramkissoon [19], Datta and Rathore [2], Shu and Lee [28] which immediately reduces to classical Stokes drag, $6\pi\mu Ua$, on sphere having radius 'a', as $k \to 0$. The non-dimensional Stokes drag coefficient may be obtained by dividing equation (25) with $(\rho_1 U^2\pi a^2)/2$

$$(C_{F_x})_{Stokes} = \frac{F_x}{\frac{1}{2}\rho_1 U^2\pi a^2} = \frac{F_y}{\frac{1}{2}\rho_1 U^2\pi a^2} = \frac{6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)\,U\,a}{\frac{1}{2}\rho_1 U^2\pi a^2} = \frac{12}{Re}\left(1+\frac{k}{\mu}\right), \tag{26}$$

where $Re = \rho_1 Ua/(\mu+k)$ is particle Reynolds number. This matches with fundamental solution given by Shu and Lee [28] for the same Reynolds number.

Now, the value of real constant 'K' comes out to be

$$K = \frac{F_x}{F_y} = 1. \tag{27}$$

The Oseen's correction to axial Stokes drag (26), with the use of (13), comes out to be

$$\frac{F}{F_x} = 1 + \frac{6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)\,U\,a,}{16\,\pi\,\mu\,a\,U} Re + O\left(Re^2\right) = 1 + \frac{3}{8}\left(1+\frac{k}{\mu}\right)\,Re + O(Re^2), \tag{28}$$

where $Re = \rho_1 Ua/\mu$ is particle Reynolds number and F is Oseen's drag in axial flow. The value of F may be re-written as [from Eq. (28)]

$$F = F_x\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\,Re + O(Re^2)\right]$$

The non-dimensional Oseen's drag coefficient may be obtained by dividing with $(\rho_1 U^2\pi a^2)/2$

$$(C_{F_x})_{Oseen's} = \frac{F}{\frac{1}{2}\rho_1 U^2\pi a^2} = \frac{F_x\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\,Re + O(Re^2)\right]}{\frac{1}{2}\rho_1 U^2\pi a^2},$$

By utilizing Eq. (26), this non-dimensional Oseen's drag coefficient comes out as

$$(C_{F_x})_{Oseen's} = \frac{12}{R}\left(1+\frac{k}{\mu}\right)\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\,Re + O(Re^2)\right], \tag{29}$$

where $Re = \rho_1 Ua/\mu$ is particle Reynolds number. This value reduces to $(12/Re)[1+(3/8)Re]$ as $k \to 0$ (i.e. the case of non-polar fluid).

The Oseen's correction to transverse Stokes drag (26), with the use of (14) and (27), comes out to be

$$\frac{F}{F_y} = K\frac{F}{F_x} = 1 + \frac{6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)\,U\,a}{16\,\pi\,\mu\,a\,U} Re + O(Re^2) = 1 + \frac{3}{8}\left(1+\frac{k}{\mu}\right)\,Re + O(Re^2), \tag{30}$$

where $R = \rho_1 Ua/(\mu+k)$ is particle Reynolds numberand F is Oseen's drag in transverse flow. The value of F may be re-written as [from Eq. (30)]

$$F = F_y\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\,Re + O(Re^2)\right]$$

The non-dimensional Oseen's drag coefficient may be obtained by dividing with $(\rho_1 U^2\pi a^2)/2$

$$\left(C_{F_\rho}\right)_{Oseen's} = \frac{F}{\frac{1}{2}\rho_1 U^2\pi a^2} = \frac{F_y\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\,Re + O(Re^2)\right]}{\frac{1}{2}\rho_1 U^2\pi a^2},$$

By utilizing Eq. (26), this non-dimensional Oseen's drag coefficient comes out as

$$\left(C_{F_\rho}\right)_{Oseen's} = \frac{12}{Re}\left(1+\frac{k}{\mu}\right)\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\,Re + O(Re^2)\right], \tag{31}$$

where $Re = \rho_1 Ua/(\mu+k)$ is particle Reynolds number. This value reduces to (12/Re)[1+(3/8)Re] as $k \to 0$ (i.e. the case of non-polar fluid). It is clear (28)-(29) and (30)-(31), the Oseen'1s correction to Stokes drag on sphere having radius 'a' in axial and transverse uniform streams in micropolar fluid is same.

4.2. Flow past spheroid

4.2.1. Prolate spheroid

Suppose a prolate spheroid is generated by the rotation of an ellipse about the x-axis. The parametric equation of the ellipse may be taken as

$$x = a\cos t, \quad y = b\sin t, \quad 0 \leqslant t \leqslant \pi. \tag{32}$$

After careful calculation, the values of h_x and h_y are [from (6) and (8)]

$$h_x = \frac{3b^2}{16ae^3}\left[-2e+\left(1+e^2\right)\log\left(\frac{1+e}{1-e}\right)\right] \tag{33}$$

$$h_y = \frac{3b^2}{32ae^3}\left[2e+\left(3e^2-1\right)\log\left(\frac{1+e}{1-e}\right)\right] \tag{34}$$

The expressions of axial Stokes drag on this prolate spheroid placed in micropolar fluid, by using (9) and (33), comes out to be

$$F_x = 16\,\pi\,\mu\left(1+\frac{k}{\mu}\right)\,U\,a\,e^3\left[-2e+\left(1+e^2\right)\log\left(\frac{1+e}{1-e}\right)\right]^{-1}, \tag{35}$$

$$= 6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)\,U\,a\left[1-\frac{2}{5}e^2-\frac{17}{175}e^4......\right] \tag{36}$$

This expression matches with axial Stokes drag calculated by Datta and Rathore [2] with the help of singularity distribution method which further reduces to the classical expression of drag on prolate spheroid Datta and Srivastava [1], as micropolarity coefficient tends to zero i.e. $k \to 0$.

The expressions of transverse Stokes drag on this prolate spheroid placed in micropolar fluid, by using (10) and (34), comes out to be

$$F_y = 32\,\pi\,\mu\left(1+\frac{k}{\mu}\right)\,U\,a\,e^3\left[2e+\left(3e^2-1\right)\log\left(\frac{1+e}{1-e}\right)\right]^{-1}, \tag{37}$$

$$= 6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)\,U\,a\left[1-\frac{3}{10}e^2-\frac{57}{700}e^4......\right] \tag{38}$$

This expression matches with transverse Stokes drag calculated by Datta and Rathore [2] with the help of singularity distribution method which further reduces to the classical expression of drag on prolate spheroid Datta and Srivastava [1], as micropolarity coefficient tends to zero i.e. $k \to 0$.

Now, the value of real constant 'K' for prolate body comes out to be

$$K = \frac{F_x}{F_y} = \frac{1}{2}\left[2e+\left(3e^2-1\right)\log\left(\frac{1+e}{1-e}\right)\right]\left[-2e+\left(1+e^2\right)\log\left(\frac{1+e}{1-e}\right)\right]^{-1}. \tag{39}$$

$$= 1-\frac{1}{10}e^2-\frac{8}{175}e^4..... \tag{40}$$

The Oseen's correction to axial Stokes drag (35), with the use of (13), comes out to be

$$\frac{F}{F_x} = 1+\frac{16\,\pi\,\mu\left(1+\frac{k}{\mu}\right)\,U\,a\,e^3\left[-2e+\left(1+e^2\right)\log\left(\frac{1+e}{1-e}\right)\right]^{-1}}{16\,\pi\,\mu\,a\,U}Re+O(Re^2) \tag{41}$$

$$= 1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left(1-\frac{2}{5}e^2-\frac{17}{175}e^4.....\right)\,Re+O(Re^2), \tag{42}$$

where $R = \rho_1 Ua/(\mu+k)$ is particle Reynolds number.

The Oseen's correction to transverse Stokes drag (37), with the use of (14) and (39), comes out to be

$$\begin{aligned}\frac{F}{F_y} &= K\frac{F}{F_x} = \left[1-\frac{1}{10}e^2-\frac{8}{175}e^4.....\right]\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left(1-\frac{2}{5}e^2-\frac{17}{175}e^4.....\right)\,Re+O(Re^2)\right]\\ &= \left(1-\frac{1}{10}e^2-\frac{8}{175}e^4....\right)+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left(1-\frac{1}{2}e^2-\frac{18}{175}e^4....\right)\,Re+O(Re^2),\end{aligned} \tag{43}$$

where $Re = \rho_1 Ua/(\mu+k)$ is particle Reynolds number. This Oseen's correction immediately reduces to the nonpolar case obtained by Srivastava and Srivastava [36].

4.2.2. Oblate spheroid

Suppose a oblate spheroid is generated by the rotation of an ellipse about the x-axis. The parametric equation of the ellipse may be taken as

$$x = b\cos t, \quad y = a\sin t, \quad 0 \leqslant t \leqslant \pi. \tag{44}$$

After careful calculation, the values of h_x and h_y are [from (6) and (8)]

$$h_x = \frac{3a}{8e^3}\left[e\sqrt{1-e^2} - \left(1-2e^2\right)\sin^{-1}e\right] \tag{45}$$

$$h_y = \frac{3a}{16e^3}\left[-e\sqrt{1-e^2} + \left(1+2e^2\right)\sin^{-1}e\right] \tag{46}$$

The expressions of axial Stokes drag on this prolate spheroid placed in micropolar fluid, by using (9) and (45), comes out to be

$$F_x = 8\,\pi\,\mu\left(1+\frac{k}{\mu}\right)U\,a\,e^3\left[e\sqrt{1-e^2} - \left(1-2e^2\right)\sin^{-1}e\right]^{-1}, \tag{47}$$

$$= 6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)U\,a\left[1-\frac{1}{10}e^2-\frac{31}{1400}e^4+\frac{9}{1400}e^6......\right] \tag{48}$$

This expression matches with axial Stokes drag calculated by Datta and Rathore [2] with the help of singularity distribution method which further reduces to the classical expression of drag on prolate spheroid Datta and Srivastava [1], as micropolarity coefficient tends to zero i.e. $k \to 0$.

The expressions of transverse Stokes drag on this oblate spheroid placed in micropolar fluid, by using (10) and (46), comes out to be

$$F_y = 16\,\pi\,\mu\left(1+\frac{k}{\mu}\right)U\,a\,e^3\left[-e\sqrt{1-e^2} + \left(1+2e^2\right)\sin^{-1}e\right]^{-1}, \tag{49}$$

$$= 6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)U\,a\left[1-\frac{1}{5}e^2-\frac{79}{1400}e^4......\right] \tag{50}$$

This expression matches with transverse Stokes drag calculated by Datta and Rathore [2] with the help of singularity distribution method which further reduces to the classical expression of drag on prolate spheroid Datta and Srivastava [1], as micropolarity coefficient tends to zero i.e. $k \to 0$. Now, the value of real constant 'K' for prolate body comes out to be

$$K = \frac{F_x}{F_y} = \frac{1}{2}\left[-e\sqrt{1-e^2} + \left(1+2e^2\right)\sin^{-1}e\right]\left[e\sqrt{1-e^2} - \left(1-2e^2\right)\sin^{-1}e\right]^{-1}. \tag{51}$$

$$= 1+\frac{1}{10}e^2+\frac{19}{350}e^4..... \tag{52}$$

The Oseen's correction to axial Stokes drag (36), with the use of (13), comes out to be

$$\frac{F}{F_x} = 1+\frac{8\,\pi\,\mu\left(1+\frac{k}{\mu}\right)U\,a\,e^3\left[e\sqrt{1-e^2} - \left(1-2e^2\right)\sin^{-1}e\right]^{-1}}{16\,\pi\,\mu\,a\,U}Re+O(Re^2) \tag{53}$$

$$= 1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left\{1-\frac{1}{10}e^2-\frac{31}{1400}e^4.....\right\}Re+O\left(Re^2\right) \tag{54}$$

where $R = \rho_1 Ua/\mu$ is particle Reynolds number.

The Oseen's correction to transverse Stokes drag (49), with the use of (14), (51), (54) comes out to be

$$\begin{aligned}\frac{F}{F_y} = K\frac{F}{F_x} &= \left[1+\frac{1}{10}e^2+\frac{19}{350}e^4.....\right]\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left\{1-\frac{1}{10}e^2-\frac{31}{1400}e^4.....\right\}Re+O\left(Re^2\right)\right]\\ &= \left[1+\frac{1}{10}e^2+\frac{19}{350}e^4.....\right]+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left\{1+\frac{31}{1400}e^4......\right\}Re+O\left(Re^2\right),\end{aligned} \tag{55}$$

where $R = \rho Ua/\mu$ is particle Reynolds number. This Oseen's correction immediately reduces to the nonpolar case obtained by Srivastava et al. [32].

4.3. Deformed sphere

We consider the polar equation of deformed sphere as

$$r = a\left[1+\varepsilon\sum_{k=0}^{\infty} d_k P_k(\mu)\right], \quad \mu = \cos\theta \tag{56}$$

where 'ε' is deformation parameter and (r,θ) are polar coordinates.

After careful calculation, the values of h_x and h_y are [from (6) and (8)]

$$h_x = \frac{a}{2}\left[1+\varepsilon\left(d_0-\frac{4}{5}d_2\right)\right], \tag{57}$$

$$h_y = \frac{a}{2}\left[1+\varepsilon\left(d_0-\frac{11}{10}d_2\right)\right]. \tag{58}$$

The Stokes drag experienced by this deformed sphere placed in axial and transverse uniform stream is given by use of by D-S formulae (9) and (10) Datta and Srivastava [1] only up to first order of 'ε', with the use of (57) and (58), as

$$F_x = 6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)\,Ua\left[1+\varepsilon\left(d_0-\frac{1}{5}d_2\right)\right], \frac{\Delta y}{\Delta x} \tag{59}$$

$$F_y = 6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)\,Ua\left[1+\varepsilon\left(d_0+\frac{1}{10}d_2\right)\right] \tag{60}$$

By using (59) and (60) in (10), the value of real factor 'K' comes out to be

$$\begin{aligned} K = \frac{F_x}{F_y} &= \left[1+\varepsilon\left(d_0-\frac{1}{5}d_2\right)\right]\left[1+\varepsilon\left(d_0+\frac{1}{10}d_2\right)\right]^{-1} \\ &= \left[1+\varepsilon\left(d_0-\frac{1}{5}d_2\right)\right]\left[1-\varepsilon\left(d_0+\frac{1}{10}d_2\right)\right] \\ &= 1-\frac{3}{10}d_2\varepsilon+O\left(\varepsilon^2\right) \end{aligned} \tag{61}$$

The Oseen,s correction to axial Stokes drag (59), with the use of (13), comes out to be

$$\frac{F}{F_x} = 1+\frac{6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)\,Ua\left[1+\varepsilon\left(d_0-\frac{1}{5}d_2\right)\right]}{16\,\pi\,\mu\,a\,U}Re+O(Re^2) \tag{62}$$

$$= \left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left\{1+\varepsilon\left(d_0-\frac{1}{5}d_2\right)+O\left(\varepsilon^2\right)\right\}Re+O\left(Re^2\right)\right] \tag{63}$$

where $R = \rho_1 Ua/\mu$ is particle Reynolds number.

The Oseen's correction to transverse Stokes drag (60), with the use of (14), (61), (63) comes out to be

$$\begin{aligned} \frac{F}{F_y} = K\frac{F}{F_x} &= \left[1-\frac{3}{10}d_2\varepsilon+O\left(\varepsilon^2\right)\right]\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left\{1+\varepsilon\left(d_0-\frac{1}{5}d_2\right)+O\left(\varepsilon^2\right)\right\}Re+O\left(Re^2\right)\right] \\ &= 1-\frac{3}{10}d_2\varepsilon+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left\{1+\varepsilon\left(d_0-\frac{1}{2}d_2\right)+O\left(\varepsilon^2\right)\right\}Re+O\left(Re^2\right), \end{aligned} \tag{64}$$

where $Re = \rho_1 Ua/(\mu+k)$ is particle Reynolds number. This Oseen's correction immediately reduces to the non-polar case obtained by Srivastava and Srivastava [36].

The general expressions of Stokes drag on axially symmetric deformed sphere (56) in axial and transverse uniform micropolar flow can be obtained from direct use of DS-conjecture [Eqs. (9) and (10)]

$$F_x = 6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)\,U\,a\left[\begin{array}{l} 1+\varepsilon\left\{d_0-\frac{1}{5}d_2+\frac{3}{8}d_4.....\right\} \\ +\varepsilon^2\left\{2{d_0}^2+\frac{89}{100}{d_2}^2+\frac{9}{64}{d_4}^2-\frac{21}{5}d_0d_2+\frac{3}{4}d_0d_4+\frac{3}{4}d_2d_4+...\right\}+O\left(\varepsilon^3\right) \end{array}\right], \tag{65}$$

$$F_y = 6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)U\,a\left[\begin{array}{l} 1+\varepsilon\left\{d_0+\frac{1}{10}d_2+\frac{9}{4}d_4.....\right\} \\ +\varepsilon^2\left\{\frac{9}{25}{d_2}^2+\frac{225}{64}{d_4}^2-d_0d_2+\frac{3}{4}d_0d_4+\frac{51}{20}d_2d_4+....\right\}+O\left(\varepsilon^3\right)\end{array}\right] \tag{66}$$

which matches with those obtained by author Srivastava et al. [32] in the case of non-polar fluid i.e. for $k=0$. Oseen's correction in Stokes drag Eq. (65) on small axially symmetric body placed in uniform flow of micropolar fluid with small micropolarity 'k' is given by applying Brenner's formula Brenner [3], Eq. (13),

$$\frac{F}{F_x} = 1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left[\begin{array}{l} 1+\varepsilon\left\{d_0-\frac{1}{5}d_2+\frac{3}{8}d_4.....\right\} \\ +\varepsilon^2\left\{2{d_0}^2+\frac{89}{100}{d_2}^2+\frac{9}{64}{d_4}^2-\frac{21}{5}d_0d_2+\frac{3}{4}d_0d_4+\frac{3}{4}d_2d_4+\right\}+O\left(\varepsilon^3\right)\end{array}\right]Re+O\left(Re^2\right) \tag{67}$$

where $Re=\rho_1 U\,a/\left(\mu+k\right)$ is particle Reynolds number. This expression reduces to that obtained by author Srivastava et al. [32] for non-polar fluid i.e. for $k=0$. The general value of real factor 'K', defined in Eq. (11), for deformed sphere (56) comes out to be

$$K = 1+\varepsilon\left\{-\frac{3}{10}d_2-\frac{15}{8}d_4.....\right\}+\varepsilon^2\left\{2{d_0}^2+\frac{14}{25}{d_2}^2+\frac{27}{32}{d_4}^2-\frac{29}{10}d_0d_2+\frac{15}{8}d_0d_4-\frac{15}{16}d_2d_4+.....\right\}+O\left(\varepsilon^3\right). \tag{68}$$

Now, the general value of Oseen's correction in steady transverse micropolar uniform fluid may be obtained from Eqs. (30)-(31) by substituting the value of 'K' Eq. (68)

$$\begin{aligned}\frac{F}{F_y} = &\left[\begin{array}{l} 1+\varepsilon\left(-\frac{3}{10}d_2-\frac{15}{8}d_4....\right) \\ +\varepsilon^2\left(2{d_0}^2+\frac{14}{25}{d_2}^2+\frac{27}{32}{d_4}^2-\frac{29}{10}d_0d_2+\frac{15}{8}d_0d_4-\frac{15}{16}d_2d_4....\right)+O\left(\varepsilon^3\right)\end{array}\right] \\ &+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left\{\begin{array}{l} 1+\varepsilon\left(d_0-\frac{1}{2}d_2-\frac{3}{2}d_4.....\right) \\ +\varepsilon^2\left(4{d_0}^2+\frac{151}{100}{d_2}^2+\frac{9}{32}{d_4}^2-\frac{37}{5}d_0d_2+\frac{3}{4}d_0d_4+\frac{3}{40}d_2d_4...\right)+O\left(\varepsilon^3\right)\end{array}\right\}Re+\ O\left(Re^2\right),\end{aligned} \tag{69}$$

5. Flow past deformed prolate spheroid

We consider the prolate spheroid, as it belongs to the class of axi-symmetric deformed sphere, whose Cartesian equation is

$$\frac{x^2+y^2}{a^2(1-\varepsilon)^2}+\frac{z^2}{a^2}=1 \tag{70}$$

where equatorial radius is $a(1-\varepsilon)$ and polar radius is a, in which deformation parameter ε is positive and sufficiently small that squares and higher powers of it may be neglected. Its polar equation [up to the order of $O(\varepsilon)$], by using the transformation,

$$z = r\cos\theta,\quad \rho = r\sin\theta \tag{71}$$

or

$$r = a\left(1-\varepsilon\sin^2\theta\right) \tag{72}$$

It can be written in linear combination of Legendre functions of first kind Happel and Brenner [37], Senchenko and Keh [38]

$$r = a\left[1+\varepsilon\left\{-\frac{2}{3}P_0\left(\mu\right)+\frac{2}{3}P_2\left(\mu\right)\right\}\right],\quad \mu=\cos\,\theta\,, \tag{73}$$

On comparing this equation with the polar equation of deformed sphere (23), the appropriate design factors for this prolate spheroid are

$$d_0=-\frac{2}{3},\quad d_1=0,\quad d_2=\frac{2}{3},\quad d_k=0\quad \text{for}\quad k\geqslant 3 \tag{74}$$

with

$$P_0(\mu) = 1\ ,\ P_1(\mu) = \mu \text{ and } P_2(\mu) = \frac{3\mu^2 - 1}{2}\ ,\ \mu = \cos\theta \tag{75}$$

With general drag values Eqs. (65) and (66), the expression of axial and transverse Stokes drag on deformed prolate spheroid [(72) and (73)] can be written as

$$F_z = 6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)\,U\,a\left\{1-\frac{4}{5}\varepsilon+\frac{709}{225}\varepsilon^2+....\right\} \tag{76}$$

$$F_\rho = 6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)\,U\,a\left\{1-\frac{3}{5}\varepsilon+\frac{136}{225}\varepsilon^2+....\right\}, \tag{77}$$

This matches with that given in the paper of Datta and Srivastava [1] only up to the first order for non-polar case (i.e. for $k = 0$). By using (67) together with (74), Oseen's correction may be obtained for axial flow as

$$\frac{F}{F_z} = 1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left[1-\frac{4}{5}\varepsilon+\frac{709}{225}\varepsilon^2+...\right]Re+O\left(Re^2\right), \tag{78}$$

By using Eq. (68), the general value of 'K' is

$$K = 1-\frac{1}{5}\varepsilon+\frac{182}{75}\varepsilon^2....... \tag{79}$$

and by using (69) together with 74, Oseen's correction in transverse flow may be obtained as

$$\frac{F}{F_\rho} = \left(1-\frac{1}{5}\varepsilon+\frac{182}{75}\varepsilon^2...\right)+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left[1-\varepsilon+\frac{1291}{225}\varepsilon^2+...\right]Re+O\left(Re^2\right), \tag{80}$$

where $R = \rho_1 Ua/(\mu+k)$ is particle Reynolds number.

On considering the polar equation of prolate spheroid as a deformed sphere beyond the Eq. (23) with same eccentricity defined as $e = \left(2\varepsilon-\varepsilon^2\right)^{1/2}$ and related with deformation parameter 'ε' containing terms up to second order of 'ε' as

$$r = a\left[1-\varepsilon\sin^2\theta-\frac{3}{2}\varepsilon^2\,\sin^2\theta\,\cos^2\theta\right] \tag{81}$$

The expression of axial and transverse Stokes drag containing the second order terms in 'e' and 'ε' can be achieved by independent application of DS conjecture Datta and Srivastava [1], Eqs. (9) and (10)] as

$$F_z = 6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)Ua\left[1-\frac{2}{5}e^2-\frac{17}{175}e^4.....\right] \tag{82}$$

$$= 6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)Ua\left[1-\frac{4}{5}\varepsilon+\frac{2}{175}\varepsilon^2.....\right], \tag{83}$$

$$F_\rho = 6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)Ua\left[1-\frac{3}{10}e^2-\frac{285}{3500}e^4.....\right] \tag{84}$$

$$= 6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)Ua\left[1-\frac{3}{5}\varepsilon-\frac{9}{350}\varepsilon^2.....\right], \tag{85}$$

On applying Brenner [3] formula (13) to Stokes drag (83), Oseen's correction in axial flow comes out to be

$$\frac{F}{F_z} = 1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left[1-\frac{2}{5}e^2-\frac{17}{175}e^4.....\right]Re+O\left(Re^2\right), \tag{86}$$

$$= 1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left[1-\frac{4}{5}\varepsilon+\frac{2}{175}\varepsilon^2+...\right]Re+O\left(Re^2\right). \tag{87}$$

Now, the value of real factor 'K', defined in (11), with the aid of Eqs. (83) and (85), can be written as

$$K = \frac{F_z}{F_\rho} = 1 - \frac{1}{10}e^2 - \frac{8}{175}e^4 \ldots\ldots \tag{88}$$

$$= 1 - \frac{1}{5}\varepsilon - \frac{29}{350}\varepsilon^2 + \frac{32}{175}\varepsilon^3 \ldots\ldots \tag{89}$$

On substituting the value of 'K' in (14) and with the aid of (88)-(89), the Oseen's correction to transverse Stokes drag comes out to be

$$\frac{F}{F_\rho} = K\frac{F}{F_z} = \left(1 - \frac{1}{10}e^2 - \frac{8}{175}e^4 + \ldots\ldots\right) + \frac{3}{8}\left(1 + \frac{k}{\mu}\right)\left\{1 - \frac{1}{2}e^2 - \frac{18}{175}e^4 + \ldots\ldots\right\} Re + O(Re^2) \tag{90}$$

$$= \left(1 - \frac{1}{5}\varepsilon - \frac{29}{350}\varepsilon^2 \ldots\right) + \frac{3}{8}\left(1 + \frac{k}{\mu}\right)\left\{1 - \varepsilon + \frac{31}{350}\varepsilon^2 \ldots\ldots\right\} Re + O\left(Re^2\right). \tag{91}$$

which reduces to $1 + (3/8)[1 + (k/\mu)]Re$ (leaving second order terms in Re), the case of Oseen's correction [Eq. (31)] to Stokes drag on sphere in transverse flow, as deformation parameter $\varepsilon \to 0$. For Reynolds number $Re = 0$, Oseen's drag F reduces directly to F_ρ, as it should be. Also, this limiting case reduces further to classical Oseen's drag $1 + (3/8)Re$ for non-polar case (i.e. $k = 0$). Author claims that this is the necessary extension of Brenner's formula (13) for Oseen's correction to Stokes drag on deformed prolate spheroid from axial flow to transverse flow.

It is interesting to note that there is discrepancy in the second order term of ε^2 in expressions of Oseen's correction given for axial flow in (78) and (87) and transverse flow in (80) and (91). The reason behind this discrepancy is due to the fact that the polar Eq. (23) contains terms only up to first order while polar Eq. (81) contains terms up to second order in deformation parameter 'ε'.

5.1. Particular Case

5.1.1. Slender elongated spheroid or needle shaped body

The expression (87) and (91) is true not only for small deformation parameter (near zero value) 'ε' but surprisingly provides good agreement in the limiting situation for $e = \varepsilon = 1$, which is the cased of needle shaped body.

On substituting $\varepsilon = 1$ in Eq. (87), the Oseen's correction in axial flow comes out to be

$$\frac{F}{F_z} = 1 + 0.0792857\left(1 + \frac{k}{\mu}\right) Re + O\left(Re^2\right), \tag{92}$$

which reduces to $1 + 0.0792857 \times Re$ as $k \to 0$ (non-polar case) mentioned in Srivastava et al. [36] which further reduces to $F = F_z$, as Reynolds number $Re \to 0$ (the case of Stokes drag).

On substituting $\varepsilon = 1$ in Eq. (91), the Oseen's correction in transverse flow comes out to be

$$\frac{F}{F_\rho} = 0.717142858 + 0.0332143\left(1 + \frac{k}{\mu}\right) Re + O\left(Re^2\right), \tag{93}$$

which reduces to $0.717142858 + 0.0332143 \times Re$ as $k \to 0$ (non-polar case mentioned in Srivastava et al. [36] which further reduces to $F = 0.717142858 F_\rho$, as Reynolds number $R \to 0$ (Stokes drag).

5.1.2. Non-dimensional drag values

The non-dimensional Stokes drag for deformed prolate spheroid may be obtained in axial and transverse flow by dividing Eqs. (82)-(83) and (84)-(85) with factor $(\rho_1 U^2 \pi a^2)/2$

$$\left(C_{F_z}\right)_{Stokes} = \frac{F_z}{\frac{1}{2}\rho_1 U^2 \pi a^2} = \frac{12}{R}\left(1 + \frac{k}{\mu}\right)\left[1 - \frac{2}{5}e^2 - \frac{17}{175}e^4 \ldots\ldots\right], \tag{94}$$

$$= \frac{12}{R}\left(1 + \frac{k}{\mu}\right)\left[1 - \frac{4}{5}\varepsilon - \frac{2}{175}\varepsilon^2 \ldots\ldots\right], \tag{95}$$

$$\left(C_{F_\rho}\right)_{Stokes} = \frac{F_\rho}{\frac{1}{2}\rho_1 U^2 \pi a^2}$$

$$= \frac{12}{R}\left(1 + \frac{k}{\mu}\right)\left[1 - \frac{3}{10}e^2 - \frac{57}{700}e^4 \ldots\ldots\right], \tag{96}$$

$$= \frac{12}{R}\left(1+\frac{k}{\mu}\right)\left[1-\frac{3}{5}\varepsilon-\frac{9}{350}\varepsilon^2.....\right], \tag{97}$$

where $Re=\rho_1 Ua/(\mu+k)$ is particle Reynolds number. These values (94)-(95) and (96)-(97) reduces to classical values $(12/Re)[1+(k/\mu)]$ for sphere given in (96)-(97) as $e\to 0$ and $\varepsilon\to 0$.

The value of Oseen's drag F may be re-written as [from Eqs. (87, 88)]

$$F = F_z\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\ \left[1-\frac{2}{5}e^2-\frac{17}{175}e^4.....\right]Re+O(Re^2)\right],$$

$$= F_z\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\ \left[1-\frac{4}{5}\varepsilon+\frac{2}{175}\varepsilon^2.....\right]Re+O(Re^2)\right].$$

The non-dimensional Oseen's drag coefficient may be obtained by dividing with $(\rho_1 U^2\pi a^2)/2$

$$(C_{F_z})_{Oseen's} = \frac{F}{\frac{1}{2}\rho_1 U^2\pi a^2} = \frac{F_z\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\ [1-\frac{2}{5}e^2-\frac{17}{175}e^4.....]\,Re+O(Re^2)\right]}{\frac{1}{2}\rho_1 U^2\pi a^2},$$

$$= \frac{F_z\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\ [1-\frac{4}{5}\varepsilon+\frac{2}{175}\varepsilon^2.....]\,Re+O(Re^2)\right]}{\frac{1}{2}\rho_1 U^2\pi a^2},$$

By utilizing the value of F_z from Eqs. (82)-(83), this non-dimensional Oseen's drag coefficient comes out as

$$(C_{F_z})_{Oseen's} = \frac{12}{R}\left(1+\frac{k}{\mu}\right)\left[\left(1-\frac{2}{5}e^2-\frac{17}{175}e^4....\right)+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\ \left(1-\frac{4}{5}e^2-\frac{6}{175}e^4....\right)Re+O(Re^2)\right], \tag{98}$$

$$= \frac{12}{R}\left(1+\frac{k}{\mu}\right)\left[\left(1-\frac{4}{5}\varepsilon+\frac{2}{175}\varepsilon^2....\right)+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\ \left(1-\frac{8}{5}\varepsilon+\frac{116}{175}\varepsilon^2....\right)Re+O(Re^2)\right] \tag{99}$$

where $Re=\rho_1 Ua/(\mu+k)$ is particle Reynolds number. This value reduces to $(12/Re)[1+(k/\mu)][1+(3/8)\{1+(k/\mu)\}Re]$ as 'e' and 'ε' approaches to 0 i.e. the classical expression of non-dimensional Oseen's drag coefficient for sphere in micropolar fluid.This value further reduces to classical value $(12/R)[1+(3/8)Re]$ as $k\to 0$ (i.e. the case of non-polar fluid) for sphere.

5.1.3. Transverse case

The value of Oseen's drag F may be re-written as [from Eqs. (90)-(91)]

$$F = F_\rho\left[\left(1-\frac{1}{10}e^2-\frac{8}{175}e^4+.....\right)+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left\{1-\frac{1}{2}e^2-\frac{18}{175}e^4+.....\right\}Re+O(Re^2)\right],$$

$$= F_\rho\left[\left(1-\frac{1}{5}\varepsilon-\frac{29}{350}\varepsilon^2\right)+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left\{1-\varepsilon+\frac{31}{350}\varepsilon^2\right\}Re+O\left(Re^2\right)\right].$$

The non-dimensional Oseen's drag coefficient may be obtained by dividing with $(\rho_1 U^2\pi a^2)/2$

$$\left(C_{F_\rho}\right)_{Oseen's} = \frac{F}{\frac{1}{2}\rho_1 U^2\pi a^2} = \frac{F_\rho\left[(1-\frac{1}{10}e^2-\frac{8}{175}e^4+.....)+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\{1-\frac{1}{2}e^2-\frac{18}{175}e^4+.....\}\,Re+O(Re^2)\right]}{\frac{1}{2}\rho_1 U^2\pi a^2},$$

$$= \frac{F_\rho\left[(1-\frac{1}{5}\varepsilon-\frac{29}{350}\varepsilon^2)+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\{1-\varepsilon+\frac{31}{350}\varepsilon^2+....\}\,Re+O(Re^2)\right]}{\frac{1}{2}\rho_1 U^2\pi a^2}$$

By utilizing the value of F_ρ from Eqs. (84)-(85), this non-dimensional Oseen's drag coefficient comes out as

$$\left(C_{F_\rho}\right)_{Oseen's} = \frac{12}{R}\left(1+\frac{k}{\mu}\right)\left[\left(1-\frac{2}{5}e^2-\frac{17}{175}e^4....\right)+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\ \left(1-\frac{4}{5}e^2-\frac{6}{175}e^4...\right)Re+O(Re^2)\right], \tag{100}$$

$$= \frac{12}{R}\left(1+\frac{k}{\mu}\right)\left[\left(1-\frac{4}{5}\varepsilon+\frac{2}{175}\varepsilon^2....\right)+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\ \left(1-\frac{8}{5}\varepsilon+\frac{116}{175}\varepsilon^2....\right)Re+O(Re^2)\right], \tag{101}$$

where $Re=\rho_1 Ua/(\mu+k)$ is particle Reynolds number. This value reduces to $(12/Re)[1+(k/\mu)][1+(3/8)\{1+(k/\mu)\}Re]$ as 'e' and 'ε' approaches to 0 i.e. the classical expression of non-dimensional Oseen's drag coefficient for sphere in micropolar fluid.This value further reduces to classical value $(12/R)[1+(3/8)Re]$ as $k\to 0$ (i.e. the case of non-polar fluid) for sphere. It is interesting to note here that non-dimensional Oseen's drag (98), (100) and (99), (101) are same. This is due to the fact that F is treated as Oseen's drag for axially symmetric body placed in both axial and transverse flow. So, $F/F_\rho$is the correction due to Oseen in transverse Stokes drag F_ρ with respect to Oseen's drag F on same prolate body placed in axial flow.

6. Flow past deformed oblate spheroid

We consider the oblate spheroid, as it belongs to the class of axi-symmetric deformed sphere whose Cartesian equation is

$$\frac{x^2+y^2}{a^2}+\frac{z^2}{a^2(1-\varepsilon')^2}=1 \tag{102}$$

where equatorial radius is a and polar radius is $a(1-\varepsilon$âĂŹ), in which deformation parameter ε is positive and sufficiently small that squares and higher powers of it may be neglected. Its polar equation,up to the order of $O(\varepsilon)$, by using the transformation

$$z = r\cos\theta,\quad \rho = r\sin\theta,\quad r=\left(x^2+y^2\right)^{1/2} \tag{103}$$

or

$$r=\left(1-\varepsilon'\cos^2\theta\right) \tag{104}$$

It can be written in linear combination of Legendre functions of first kind Happel and Brenner [37], Senchenko and Keh [38]

$$r=a\left[1+\varepsilon'\left\{-\frac{1}{3}P_0(\mu)-\frac{2}{3}P_2(\mu)\right\}\right],\quad \mu=\cos\theta, \tag{105}$$

On comparing this equation with the polar equation of deformed sphere (23), the appropriate design factors for this oblate spheroid are

$$d_0=-\frac{1}{3},\ d_1=0,\ d_2=-\frac{2}{3},\ d_k=0 \text{ for } k\geqslant 3 \tag{106}$$

with

$$P_0(\mu)=1\ ,\ P_1(\mu)=\mu \text{ and } P_2(\mu)=\frac{3\mu^2-1}{2}\ ,\ \mu=\cos\theta \tag{107}$$

With general drag values Eqs. (65) and (66), the expression of axial and transverse Stokes drag on deformed prolate spheroid [(104) and (105)] can be written as

$$F_z=6\pi\mu\left(1+\frac{k}{\mu}\right)U\,a\left\{1-\frac{1}{5}\varepsilon'-\frac{71}{225}\varepsilon'^2+....\right\} \tag{108}$$

$$F_z=6\pi\mu\left(1+\frac{k}{\mu}\right)U\,a\left\{1-\frac{2}{5}\varepsilon'-\frac{14}{225}\varepsilon'^2+....\right\} \tag{109}$$

This matches with that given in the paper of Datta and Srivastava [1] only up to the first order for non-polar case(i.e. for $k=0$). By using (67) together with (106), Oseen's correction may be obtained for axial flow as

$$\frac{F}{F_z}=1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left[1-\frac{1}{5}\varepsilon'-\frac{71}{225}\varepsilon'^2+...\right]Re+O\left(Re^2\right), \tag{110}$$

and by using (69) together with (106), Oseen's correction in transverse flow may be obtained as

$$\frac{F}{F_\rho}=\left(1+\frac{1}{5}\varepsilon'-\frac{39}{225}\varepsilon'^2...\right)+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left[1-\frac{119}{225}\varepsilon^2+...\right]Re+O\left(Re^2\right), \tag{111}$$

where $R=\rho_1 Ua/\mu$ is particle Reynolds number.

On considering the polar equation of oblate spheroid as a deformed sphere beyond the Eq. (111) with same eccentricity defined as $e=\left(2\varepsilon'-\varepsilon'^2\right)^{1/2}$ above and related with deformation parameter ε' as

$$r=a\left[1-\varepsilon'\cos^2\theta-\frac{3}{2}\varepsilon'^2\sin^2\theta\cos^2\theta\right], \tag{112}$$

The expressions of axial and transverse Stokes drag containing the second order terms in e and ε' can be achieved by independent application of D-S conjecture Datta and Srivastava [1] as

$$F_z=6\pi\mu\left(1+\frac{k}{\mu}\right)Ua\left[1-\frac{1}{10}e^2-\frac{31}{1400}e^4+\frac{9}{1400}e^6.....\right] \tag{113}$$

$$= 6\,\pi\,\mu\,\left(1+\frac{k}{\mu}\right)U\,a\left[1-\frac{1}{5}\varepsilon'+\frac{2}{175}\varepsilon'^2.....\right], \tag{114}$$

$$F_\rho = 6\,\pi\,\mu\left(1+\frac{k}{\mu}\right)Ua\left[1-\frac{1}{5}e^2-\frac{711}{12600}e^4.....\right] \tag{115}$$

$$= 6\,\pi\,\mu\,\left(1+\frac{k}{\mu}\right)U\,a\left[1-\frac{2}{5}\varepsilon'-\frac{9}{350}\varepsilon'^2.....\right], \tag{116}$$

On applying Brenner's formula (13) to Stokes drag (114), Oseen's correction in axial flow comes out to be

$$\frac{F}{F_z} = 1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left[1-\frac{1}{10}e^2-\frac{31}{1400}e^4+\frac{9}{1400}e^6.....\right]Re+O\left(Re^2\right), \tag{117}$$

$$= 1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left[1-\frac{1}{5}\varepsilon'+\frac{2}{175}\varepsilon'^2.....\right]Re+O\left(Re^2\right), \tag{118}$$

Now, the real factor K, defined in (11), with the aid of Eqs. (114) and (116), can be written as

$$K = \frac{F_z}{F_\rho} = 1+\frac{1}{10}e^2+\frac{19}{350}e^4...... \tag{119}$$

$$= 1+\frac{1}{5}\varepsilon'+\frac{41}{350}\varepsilon'^2-\frac{38}{175}\varepsilon'^3..... \tag{120}$$

On substituting the value of K (119) in (14)and with the aid of Eq. (120), the Oseen's correction to transverse Stokes drag comes out to be

$$\frac{F}{F_\rho} = K\frac{F}{F_z}$$

$$= \left(1+\frac{1}{10}e^2+\frac{19}{350}e^4....\right)+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left\{1+\frac{31}{1400}e^4.....\right\}Re+O\left(Re^2\right) \tag{121}$$

$$= \left(1+\frac{1}{5}\varepsilon'+\frac{41}{350}\varepsilon'^2.....\right)+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left\{1+\frac{31}{350}\varepsilon'^2.....\right\}Re+O\left(Re^2\right), \tag{122}$$

which reduces to $1+(3/8)[1+(k/\mu)]Re$ (leaving second order terms in Re), the case of Oseen's correction [Eq. (31)] to Stokes drag on sphere in transverse flow, as deformation parameter $\varepsilon \to 0$. For Reynolds number $R = 0$, Oseen's drag F reduces directly to F_ρ, as it should be. Also, this limiting case reduces further to classical Oseen's drag $1+(3/8)Re$ for non-polar case(i.e. $k = 0$). Author claims that this is the necessary extension of Brenner's formula (13) for Oseen's correction to Stokes drag on deformed oblate spheroid from axial flow to transverse flow.

It is interesting to note that there is discrepancy in the second order term of ε^2 in expressions of Oseen's correction given for axial flow in (110) and (118) and transverse flow in (111) and (122). The reason behind this discrepancy is due to the fact that the polar Eq. (23) contains terms only up to first order while polar Eq. (112) contains terms up to second order in deformation parameter ε.

6.1. Particular Case

6.1.1. Flat circular disk

The expression (118) is true not only for small deformation parameter(near zero value) ε' but surprisingly provides good agreement in the limiting situation for $e = \varepsilon' = 1$, which is the case of flat circular disk(edge on case). On substituting $\varepsilon' = 1$ in Eq. (118), the Oseen's correction in axial flow comes out to be

$$\frac{F}{F_z} = 1+0.304285714\left(1+\frac{k}{\mu}\right)Re+O\left(Re^2\right), \tag{123}$$

which reduces to $1+0.304285714\times Re$ as $k\to 0$ (non-polar case) mentioned in Srivastava et al. [36] which further reduces to $F = F_z$, as Reynolds number $Re \to 0$ (the case of Stokes drag).

On substituting $\varepsilon' = 1$ in Eq. (120), the Oseen's correction reduces to the form

$$\frac{F}{F_\rho} = 1.317142857+0.408214285\left(1+\frac{k}{\mu}\right)\times Re+O\left(Re^2\right), \tag{124}$$

which reduces to $1.317142857+0.408214285Re$ as $k\to 0$ (i.e. non-polar case) and immediately further reduces to $F = 1.317142857F_\rho$, as Reynolds number $Re \to 0$ (Stokes drag).

6.1.2. Non-dimensional drag values

The non-dimensional Stokes drag for deformed prolate spheroid may be obtained in axial and transverse flow by dividing Eqs. (113)-(114) and (115)-(116) with factor $(\rho_1 U^2 \pi a^2)/2$

$$(C_{F_z})_{Stokes} = \frac{F_z}{\frac{1}{2}\rho_1 U^2 \pi a^2}$$

$$= \frac{12}{R}\left(1+\frac{k}{\mu}\right)\left[1-\frac{1}{10}e^2-\frac{31}{1400}e^4.....\right], \tag{125}$$

$$= \frac{12}{R}\left(1+\frac{k}{\mu}\right)\left[1-\frac{1}{5}\varepsilon'+\frac{2}{175}\varepsilon'^2.....\right], \tag{126}$$

$$\left(C_{F_\rho}\right)_{Stokes} = \frac{F_\rho}{\frac{1}{2}\rho_1 U^2 \pi a^2}$$

$$= \frac{12}{R}\left(1+\frac{k}{\mu}\right)\left[1-\frac{1}{5}e^2-\frac{711}{12600}e^4.....\right], \tag{127}$$

$$= \frac{12}{R}\left(1+\frac{k}{\mu}\right)\left[1-\frac{2}{5}\varepsilon'-\frac{9}{350}\varepsilon'^2.....\right], \tag{128}$$

where $Re = \rho_1 Ua/(ïĄŋ + \mu)$ is particle Reynolds number. These values (125)-(126) and (127)-(128) reduces to classical values $(12/Re)[1+(k/\mu)]$ for sphere given in (25)-(26) as $e \to 0$ and $\varepsilon \to 0$.

The value of Oseen's drag F may be re-written as [from Eqs. (117)-(118)]

$$F = F_z\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left[1-\frac{1}{10}e^2-\frac{31}{1400}e^4.....\right]Re+O(Re^2)\right],$$
$$= F_z\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left[1-\frac{1}{5}\varepsilon'+\frac{2}{175}\varepsilon'^2.....\right]Re+O(Re^2)\right].$$

The non-dimensional Oseen's drag coefficient may be obtained by dividing with $(\rho_1 U^2 \pi a^2)/2$

$$(C_{F_z})_{Oseen's} = \frac{F}{\frac{1}{2}\rho_1 U^2 \pi a^2} = \frac{F_z\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left[1-\frac{1}{10}e^2-\frac{31}{1400}e^4.....\right]Re+O(Re^2)\right]}{\frac{1}{2}\rho_1 U^2 \pi a^2},$$
$$= \frac{F_z\left[1+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left[1-\frac{1}{5}\varepsilon'+\frac{2}{175}\varepsilon'^2.....\right]Re+O(Re^2)\right]}{\frac{1}{2}\rho_1 U^2 \pi a^2},$$

By utilizing the value of F_z from Eqs. (113)-(114), this non-dimensional Oseen's drag coefficient comes out as

$$(C_{F_z})_{Oseen's} = \frac{12}{R}\left(1+\frac{k}{\mu}\right)\left[\left(1-\frac{1}{10}e^2-\frac{31}{1400}e^4....\right)+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left(1-\frac{1}{5}e^2-\frac{6}{175}e^4....\right)Re+O(Re^2)\right], \tag{129}$$

$$= \frac{12}{R}\left(1+\frac{k}{\mu}\right)\left[\left(1-\frac{1}{5}\varepsilon'+\frac{2}{175}\varepsilon'^2....\right)+\frac{3}{8}\left(1+\frac{k}{\mu}\right)\left(1-\frac{2}{5}\varepsilon'+\frac{11}{175}\varepsilon'^2....\right)Re+O(Re^2)\right] \tag{130}$$

where $Re = \rho_1 Ua/(\mu + k)$ is particle Reynolds number. This value reduces to $(12/R)[1+(k/\mu)][1+(3/8)\{1+(k/\mu)\}Re]$ as e and ε approaches to 0 i.e. the classical expression of non-dimensional Oseen's drag coefficient for sphere in micropolar fluid. This value further reduces to classical value $(12/Re)[1+(3/8)Re]$ as $k \to 0$ (i.e. the case of non-polar fluid) for sphere.

6.1.3. Transverse case

The value of Oseen's drag F may be re-written as [from Eqs. (121)-(122)]

$$F = F_\rho \left[\left(1 + \frac{1}{10}e^2 + \frac{19}{350}e^4 + ...\right) + \frac{3}{8}\left(1+\frac{k}{\mu}\right)\left\{1 + \frac{31}{1400}e^4 + ...\right\} Re + O(Re^2) \right],$$
$$= F_\rho \left[\left(1 + \frac{1}{5}\varepsilon' + \frac{41}{350}\varepsilon'^2\right) + \frac{3}{8}\left(1+\frac{k}{\mu}\right)\left\{1 + \frac{31}{350}\varepsilon'^2\right\} Re + O\left(Re^2\right) \right].$$

The non-dimensional Oseen's drag coefficient may be obtained by dividing with $(\rho_1 U^2 \pi a^2)/2$

$$\left(C_{F_\rho}\right)_{Oseen's} = \frac{F}{\frac{1}{2}\rho_1 U^2 \pi a^2}$$
$$= \frac{F_\rho \left[\left(1 + \frac{1}{10}e^2 + \frac{19}{350}e^4 + ...\right) + \frac{3}{8}\left(1+\frac{k}{\mu}\right)\left\{1 + \frac{31}{1400}e^4 + ...\right\} Re + O(Re^2) \right]}{\frac{1}{2}\rho_1 U^2 \pi a^2},$$
$$= \frac{F_\rho \left[\left(1 + \frac{1}{5}\varepsilon' + \frac{41}{350}\varepsilon'^2 + ...\right) + \frac{3}{8}\left(1+\frac{k}{\mu}\right)\left\{1 + \frac{31}{350}\varepsilon'^2 + ...\right\} Re + O(Re^2) \right]}{\frac{1}{2}\rho_1 U^2 \pi a^2}$$

By utilizing the value of F_ρ from Eqs. (115)-(116), this non-dimensional Oseen's drag coefficient comes out as

$$\left(C_{F_\rho}\right)_{Oseen's} = \frac{12}{R}\left(1+\frac{k}{\mu}\right)\left[\left(1 - \frac{1}{10}e^2 - \frac{31}{1400}e^4....\right) + \frac{3}{8}\left(1+\frac{k}{\mu}\right)\left(1 - \frac{1}{5}e^2 - \frac{6}{175}e^4....\right) Re + O(Re^2) \right], \tag{131}$$

$$= \frac{12}{R}\left(1+\frac{k}{\mu}\right)\left[\left(1 - \frac{1}{5}\varepsilon' + \frac{2}{175}\varepsilon'^2....\right) + \frac{3}{8}\left(1+\frac{k}{\mu}\right)\left(1 - \frac{2}{5}\varepsilon' + \frac{11}{175}\varepsilon'^2....\right) Re + O(Re^2) \right] \tag{132}$$

where $Re = \rho_1 U a/(\mu + k)$ is particle Reynolds number. This value reduces to $(12/Re)[1 + (k/\mu)][1 + (3/8)\{1 + (k/\mu)\}Re]$ as e and ε approaches to 0 i.e. the classical expression of non-dimensional Oseen's drag coefficient for sphere in micropolar fluid. This value further reduces to classical value $(12/Re)[1 + (3/8)Re]$ as $k \to 0$ (i.e. the case of non-polar fluid) for sphere.It is interesting to note here that non-dimensional Oseen's drag (129), (131) and (130), (132) are same. This is due to the fact that F is treated as Oseen's drag for axially symmetric body placed in both axial and transverse flow. So, F/F_ρ is the correction due to Oseen in transverse Stokes drag F_ρ with respect to Oseen's drag F on same body placed in axial flow. So, F/F_ρ is the correction due to Oseen in transverse Stokes drag F_ρ with respect to Oseen's drag F on same body placed in axial flow.

7. Numerical discussion

The numerical values of Oseen's drag F/F_z for deformed prolate spheroid placed in axial micropolar flow with respect to deformation parameter ε $(0 \leqslant \varepsilon \leqslant 1)$, eccentricity e $(0 \leqslant e \leqslant 1)$, for various values of Reynolds number $Re(0.1, 0.2, 0.3, 0.4, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0)$ and micropolarity coefficient k/μ (0.0, 2.0, 4.0, 6.0, 8.0, 1.0) are calculated from Eq. (87) and presented in Table 1-6. From these tables, it is found that for a specific value of micropolarity coefficient k/μ, Oseen's drag F/F_z increases on moving from left to right (i.e. for increasing values of Reynolds number, Re) and decreases on moving from top to bottom (i.e. for increasing values of deformation parameter ε and eccentricity e). The corresponding variations are depicted in Figs. 2-7

The numerical values of Oseen's drag F/F_ρ for deformed prolate spheroid placed in transverse micropolar flow with respect to deformation parameter ε $(0 \leqslant \varepsilon \leqslant 1)$, eccentricity e $(0 \leqslant e \leqslant 1)$, for various values of Reynolds number Re (0.1, 0.2, 0.3, 0.4, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0) and micropolarity coefficient k/μ (0.0, 2.0, 4.0, 6.0, 8.0, 1.0) are calculated from Eq. (91) and presented in Table 7-12. These tables also reflect the same trends i.e. for a specific value of micropolarity coefficient k/μ, Oseen's drag F/F_ρ increases on moving from left to right (i.e. for increasing values of Reynolds number, Re) and decreases on moving from top to bottom(i.e. for increasing values of deformation parameter ε and eccentricity e). The corresponding variations are depicted in Figs. 8-13.

The numerical values of Oseen's drag F/F_z for deformed oblate spheroid placed in axial micropolar flow with respect to deformation parameter, ε $(0 \leqslant \varepsilon \leqslant 1)$, eccentricity e $(0 \leqslant e \leqslant 1)$, for various values of Reynolds number Re (0.1, 0.2, 0.3, 0.4, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0) and micropolarity coefficient k/μ (0.0, 2.0, 4.0, 6.0, 8.0, 1.0) are calculated from equation (87) and presented in Table 13-18. From these tables, it is found that for a specific value of micropolarity coefficient k/μ, Oseen's drag F/F_z increases on moving from left to right (i.e. for increasing values of Reynolds number, Re) and decreases on moving from top to bottom (i.e. for increasing values of deformation parameter ε and eccentricity e). The corresponding variations are depicted in Figs. 14-19.

The numerical values of Oseen's drag F/F_rho for deformed oblate spheroid placed in transverse micropolar flow with respect to deformation parameter ε $(0 \leqslant \varepsilon \leqslant 1)$, eccentricity e $(0 \leqslant e \leqslant 1)$, for various values of Reynolds number

Re (0.1, 0.2, 0.3, 0.4, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0) and micropolarity coefficient k/μ (0.0, 2.0, 4.0, 6.0, 8.0, 1.0) are calculated from equation (91) and presented in Table 19-24. From these tables, for a specific value of micropolarity coefficient k/μ, Oseen's drag F/F_ρ increases on moving from left to right(i.e. for increasing values of Reynolds number, Re) and increases on moving from top to bottam (i.e. for increasing values of deformation parameter ε and eccentricity e). The corresponding variations are depicted in Figs. 20-25.

The numerical values of non-dimensional Oseen's drag F/F_z for deformed prolate spheroid placed in axial micropolar flow with respect to deformation parameter ε $(0 \leqslant \varepsilon \leqslant 1)$, eccentricity e $(0 \leqslant e \leqslant 1)$, for various values of Reynolds number Re (0.1, 0.2, 0.3, 0.4, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0) and micropolarity coefficient k/μ (0.0, 2.0, 4.0, 6.0, 8.0, 1.0) are calculated from Eq. (99) and presented in Table 25-30. From these tables, it is found that for a specific value of micropolarity coefficient k/μ, non-dimensional Oseen's drag F/F_z decreases on moving from left to right(i.e. for increasing values of Reynolds number, R) and also decreases on moving from top to bottom(i.e. for increasing values of deformation parameter ε and eccentricity e). The corresponding variations are depicted in Figs. 26-31.

The numerical values of non-dimensional Oseen's drag F/F_z for deformed oblate spheroid placed in axial micropolar flow with respect to deformation parameter ε $(0 \leqslant \varepsilon \leqslant 1)$, eccentricity e $(0 \leqslant e \leqslant 1)$, for various values of Reynolds number Re (0.1, 0.2, 0.3, 0.4, 0.5, 1.0, 2.0, 3.0, 4.0, 5.0) and micropolarity coefficient k/μ (0.0, 2.0, 4.0, 6.0, 8.0, 1.0) are calculated from equation (130) and presented in Table 31-36. From these tables, it is found that for a specific value of micropolarity coefficient k/μ, the non-dimensional Oseen's drag F/F_z decreases on moving from left to right (i.e. for increasing values of Reynolds number, R) and also decreases on moving from top to bottom (i.e. for increasing values of deformation parameter ε and eccentricity e).The corresponding variations are depicted in Figs. 32-37.

Table 1. Numerical values of Oseen's drag F/F_z for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.0$ [calculated from Eq. (87) and depicted in Fig. 2]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.0375	1.075	1.1125	1.15	1.1875	1.375	1.75	2.125	2.5	2.875
0.1	0.19	1.0345	1.069	1.1035	1.138	1.1725	1.345	1.69	2.0351	2.3801	2.7252
0.2	0.36	1.0315	1.063	1.0945	1.126	1.1575	1.3151	1.6303	1.9455	2.2606	2.5758
0.3	0.51	1.0285	1.057	1.0856	1.1141	1.1426	1.2853	1.5707	1.8561	2.1415	2.4269
0.4	0.64	1.0255	1.0511	1.0767	1.1022	1.1278	1.2556	1.5113	1.767	2.0227	2.2784
0.5	0.75	1.0226	1.0452	1.0678	1.0904	1.113	1.226	1.4521	1.6782	1.9042	2.1303
0.6	0.84	1.0196	1.0393	1.0589	1.0786	1.0982	1.1965	1.393	1.5896	1.7861	1.9827
0.7	0.91	1.0167	1.0334	1.0501	1.0668	1.0835	1.1671	1.3342	1.5013	1.6684	1.8355
0.8	0.96	1.0137	1.0275	1.0413	1.0551	1.0688	1.1377	1.2754	1.4132	1.5509	1.6887
0.9	0.99	1.0108	1.0216	1.0325	1.0433	1.0542	1.1084	1.2169	1.3254	1.4338	1.5423
1	1	1.0079	1.0158	1.0237	1.0317	1.0396	1.0792	1.1585	1.2378	1.3171	1.3964

Table 2. Numerical values of Oseen's drag F/F_z for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.2$ [calculated from Eq. (87) and depicted in Fig. 3]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.045	1.09	1.135	1.18	1.225	1.45	1.9	2.35	2.8	3.25
0.1	0.19	1.0414	1.0828	1.1242	1.1656	1.207	1.414	1.8281	2.2421	2.6562	3.0702
0.2	0.36	1.0378	1.0756	1.1134	1.1512	1.1891	1.3782	1.7564	2.1346	2.5128	2.891
0.3	0.51	1.0342	1.0684	1.1027	1.1369	1.1712	1.3424	1.6849	2.0273	2.3698	2.7123
0.4	0.64	1.0306	1.0613	1.092	1.1227	1.1534	1.3068	1.6136	1.9204	2.2272	2.5341
0.5	0.75	1.0271	1.0542	1.0813	1.1085	1.1356	1.2712	1.5425	1.8138	2.0851	2.3564
0.6	0.84	1.0235	1.0471	1.0707	1.0943	1.1179	1.2358	1.4717	1.7075	1.9434	2.1792
0.7	0.91	1.02	1.0401	1.0601	1.0802	1.1002	1.2005	1.401	1.6015	1.802	2.0026
0.8	0.96	1.0165	1.033	1.0495	1.0661	1.0826	1.1652	1.3305	1.4958	1.6611	1.8264
0.9	0.99	1.013	1.026	1.039	1.052	1.065	1.1301	1.2603	1.3905	1.5206	1.6508
1	1	1.0095	1.019	1.0285	1.038	1.0475	1.0951	1.1902	1.2854	1.3805	1.4757

Table 3. Numerical values of Oseen's drag F/F_z for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.4$ [calculated from Eq. (87) and depicted in Fig. 4]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.0525	1.105	1.1575	1.21	1.2625	1.525	2.05	2.575	3.1	3.625
0.1	0.19	1.0483	1.0966	1.1449	1.1932	1.2415	1.483	1.9661	2.4491	2.9322	3.4153
0.2	0.36	1.0441	1.0882	1.1323	1.1765	1.2206	1.4412	1.8824	2.3237	2.7649	3.2062
0.3	0.51	1.0399	1.0799	1.1198	1.1598	1.1997	1.3995	1.799	2.1986	2.5981	2.9977
0.4	0.64	1.0358	1.0715	1.1073	1.1431	1.1789	1.3579	1.7159	2.0738	2.4318	2.7898
0.5	0.75	1.0316	1.0633	1.0949	1.1266	1.1582	1.3165	1.633	1.9495	2.266	2.5825
0.6	0.84	1.0275	1.055	1.0825	1.11	1.1375	1.2751	1.5503	1.8254	2.1006	2.3758
0.7	0.91	1.0233	1.0467	1.0701	1.0935	1.1169	1.2339	1.4678	1.7018	1.9357	2.1697
0.8	0.96	1.0192	1.0385	1.0578	1.0771	1.0964	1.1928	1.3856	1.5785	1.7713	1.9642
0.9	0.99	1.0151	1.0303	1.0455	1.0607	1.0759	1.1518	1.3037	1.4555	1.6074	1.7593
1	1	1.0111	1.0222	1.0333	1.0444	1.0555	1.111	1.222	1.333	1.444	1.555

Table 4. Numerical values of Oseen's drag F/F_z for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.6$ [calculated from Eq. (87) and depicted in Fig. 5]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.06	1.12	1.18	1.24	1.3	1.6	2.2	2.8	3.4	4
0.1	0.19	1.0552	1.1104	1.1656	1.2208	1.276	1.552	2.1041	2.6562	3.2082	3.7603
0.2	0.36	1.0504	1.1008	1.1512	1.2017	1.2521	1.5042	2.0085	2.5128	3.0171	3.5213
0.3	0.51	1.0456	1.0913	1.1369	1.1826	1.2283	1.4566	1.9132	2.3698	2.8264	3.283
0.4	0.64	1.0409	1.0818	1.1227	1.1636	1.2045	1.4091	1.8181	2.2272	2.6363	3.0454
0.5	0.75	1.0361	1.0723	1.1085	1.1446	1.1808	1.3617	1.7234	2.0851	2.4468	2.8085
0.6	0.84	1.0314	1.0628	1.0943	1.1257	1.1572	1.3144	1.6289	1.9434	2.2578	2.5723
0.7	0.91	1.0267	1.0534	1.0802	1.1069	1.1336	1.2673	1.5347	1.802	2.0694	2.3368
0.8	0.96	1.022	1.044	1.0661	1.0881	1.1101	1.2203	1.4407	1.6611	1.8815	2.1019
0.9	0.99	1.0173	1.0347	1.052	1.0694	1.0867	1.1735	1.3471	1.5206	1.6942	1.8677
1	1	1.0126	1.0253	1.038	1.0507	1.0634	1.1268	1.25371	1.3805	1.5074	1.6342

Table 5. Numerical values of Oseen's drag F/F_z for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.8$ [calculated from Eq. (87) and depicted in Fig. 6]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.0675	1.135	1.2025	1.27	1.3375	1.675	2.35	3.025	3.7	4.375
0.1	0.19	1.0621	1.1242	1.1863	1.2484	1.3105	1.621	2.2421	2.8632	3.4843	4.1053
0.2	0.36	1.0567	1.1134	1.1701	1.2269	1.2836	1.5673	2.1346	2.7019	3.2692	3.8365
0.3	0.51	1.0513	1.1027	1.1541	1.2054	1.2568	1.5136	2.0273	2.541	3.0547	3.5684
0.4	0.64	1.046	1.092	1.138	1.184	1.2301	1.4602	1.9204	2.3807	2.8409	3.3011
0.5	0.75	1.0406	1.0813	1.122	1.1627	1.2034	1.4069	1.8138	2.2207	2.6277	3.0346
0.6	0.84	1.0353	1.0707	1.1061	1.1415	1.1768	1.3537	1.7075	2.0613	2.4151	2.7688
0.7	0.91	1.03	1.0601	1.0902	1.1203	1.1503	1.3007	1.6015	1.9023	2.2031	2.5039
0.8	0.96	1.0247	1.0495	1.0743	1.0991	1.1239	1.2479	1.4958	1.7438	1.9917	2.2396
0.9	0.99	1.0195	1.039	1.0585	1.0781	1.0976	1.1952	1.3905	1.5857	1.7809	1.9762
1	1	1.0142	1.0285	1.0428	1.057	1.0713	1.1427	1.2854	1.4281	1.5708	1.7135

Table 6. Numerical values of Oseen's drag F/F_z for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' ($0 \le \varepsilon \le 1$) for various values of Reynolds number and micropolarity coefficient $k/\mu = 1.0$ [calculated from Eq. (87) and depicted in Fig. 7]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.075	1.15	1.225	1.3	1.375	1.75	2.5	3.25	4	4.75
0.1	0.19	1.069	1.138	1.207	1.276	1.345	1.69	2.3801	3.0702	3.7603	4.4504
0.2	0.36	1.063	1.126	1.1891	1.2521	1.3151	1.6303	2.2606	2.891	3.5213	4.1517
0.3	0.51	1.057	1.1141	1.1712	1.2283	1.2853	1.5707	2.1415	2.7123	3.283	3.8538
0.4	0.64	1.0511	1.1022	1.1534	1.2045	1.2556	1.5113	2.0227	2.5341	3.0454	3.5568
0.5	0.75	1.0452	1.0904	1.1356	1.1808	1.226	1.4521	1.9042	2.3564	2.8085	3.2607
0.6	0.84	1.0393	1.0786	1.1179	1.1572	1.1965	1.393	1.7861	2.1792	2.5723	2.9654
0.7	0.91	1.0334	1.0668	1.1002	1.1336	1.1671	1.3342	1.6684	2.0026	2.3368	2.671
0.8	0.96	1.0275	1.0551	1.0826	1.1101	1.1377	1.2754	1.5509	1.8264	2.1019	2.3774
0.9	0.99	1.0216	1.0433	1.065	1.0867	1.1084	1.2169	1.4338	1.6508	1.8677	2.0847
1	1	1.0158	1.0317	1.0475	1.0634	1.0792	1.1585	1.3171	1.4757	1.6342	1.7928

Table 7. Numerical values of Oseen's drag F/F_ρ for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' ($0 \le \varepsilon \le 1$) for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.0$ [calculated from Eq. (91) and depicted in Fig. 8]

		Oseen's drag F/F_ρ									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.037	1.075	1.1125	1.15	1.1875	1.375	1.75	2.125	2.5	2.875
0.1	0.19	1.0129	1.0467	1.0805	1.1143	1.148	1.317	1.6548	1.9926	2.3305	2.6683
0.2	0.36	0.9868	1.0169	1.047	1.0772	1.1073	1.258	1.5593	1.8606	2.162	2.4633
0.3	0.51	0.959	0.9856	1.0121	1.0387	1.0652	1.198	1.4635	1.729	1.9945	2.2599
0.4	0.64	0.9297	0.9528	0.9758	0.9988	1.0219	1.137	1.3673	1.5976	1.828	2.0583
0.5	0.75	0.8988	0.9184	0.938	0.9576	0.9771	1.075	1.2708	1.4667	1.6625	1.8583
0.6	0.84	0.8663	0.8825	0.8987	0.9149	0.9311	1.0121	1.174	1.336	1.498	1.6599
0.7	0.91	0.8322	0.8451	0.858	0.8709	0.8837	0.9481	1.0769	1.2057	1.3345	1.4632
0.8	0.96	0.7965	0.8062	0.8158	0.8254	0.8351	0.8832	0.9794	1.0757	1.172	1.2682
0.9	0.99	0.7593	0.7657	0.7722	0.7786	0.785	0.8172	0.8816	0.946	1.0105	1.0749
1	1	0.72	0.7237	0.7271	0.7304	0.7337	0.7503	0.7835	0.8167	0.85	0.8832

Table 8. Numerical values of Oseen's drag F/F_ρ for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' ($0 \le \varepsilon \le 1$) for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.2$ [calculated from Eq. (91) and depicted in Fig. 9]

		Oseen's drag F/F_ρ									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.045	1.09	1.135	1.18	1.225	1.45	1.9	2.35	2.8	3.25
0.1	0.19	1.0197	1.0602	1.1007	1.1413	1.1818	1.3845	1.7899	2.1953	2.6007	3.0061
0.2	0.36	0.9928	1.029	1.0651	1.1013	1.1374	1.3182	1.6798	2.0414	2.403	2.7646
0.3	0.51	0.9644	0.9962	1.0281	1.0599	1.0918	1.2511	1.5697	1.8883	2.2068	2.5254
0.4	0.64	0.9343	0.962	0.9896	1.0172	1.0449	1.1831	1.4595	1.7358	2.0122	2.2886
0.5	0.75	0.9027	0.9262	0.9497	0.9732	0.9967	1.1142	1.3492	1.5841	1.8191	2.0541
0.6	0.84	0.8696	0.889	0.9084	0.9279	0.9473	1.0445	1.2388	1.4332	1.6275	1.8219
0.7	0.91	0.8348	0.8503	0.8657	0.8812	0.8966	0.9739	1.1284	1.2829	1.4375	1.592
0.8	0.96	0.7985	0.81	0.8216	0.8331	0.8447	0.9024	1.0179	1.1335	1.249	1.3645
0.9	0.99	0.7606	0.7683	0.776	0.7837	0.7915	0.8301	0.9074	0.9847	1.062	1.1393
1	1	0.7211	0.7251	0.7291	0.733	0.737	0.757	0.7968	0.8367	0.8765	0.9164

Table 9. Numerical values of Oseen's drag F/F_ρ for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.4$ [calculated from Eq. (91) and depicted in Fig. 10]

		Oseen's drag F/F_ρ									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.0525	1.105	1.1575	1.21	1.2625	1.525	2.05	2.575	3.1	3.625
0.1	0.19	1.0264	1.0737	1.121	1.1683	1.2156	1.4521	1.9251	2.398	2.871	3.344
0.2	0.36	0.9988	1.041	1.0832	1.1254	1.1676	1.3785	1.8004	2.2222	2.6441	3.0659
0.3	0.51	0.9697	1.0068	1.044	1.0812	1.1183	1.3042	1.6759	2.0476	2.4192	2.7909
0.4	0.64	0.9389	0.9712	1.0034	1.0357	1.0679	1.2291	1.5516	1.874	2.1965	2.5189
0.5	0.75	0.9066	0.9341	0.9615	0.9889	1.0163	1.1534	1.4275	1.7016	1.9757	2.2499
0.6	0.84	0.8728	0.8955	0.9181	0.9408	0.9635	1.0769	1.3036	1.5303	1.7571	1.9838
0.7	0.91	0.8374	0.8554	0.8734	0.8915	0.9095	0.9996	1.1799	1.3602	1.5405	1.7208
0.8	0.96	0.8004	0.8139	0.8273	0.8408	0.8543	0.9217	1.0564	1.1912	1.326	1.4607
0.9	0.99	0.7619	0.7709	0.7799	0.7889	0.7979	0.843	0.9332	1.0233	1.1135	1.2037
1	1	0.7217	0.7264	0.731	0.7357	0.7403	0.7636	0.8101	0.8566	0.9031	0.9496

Table 10. Numerical values of Oseen's drag F/F_ρ for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.6$ [calculated from Eq. (91) and depicted in Fig. 11]

		Oseen's drag F/F_ρ									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.06	1.12	1.18	1.24	1.3	1.6	2.2	2.8	3.4	4
0.1	0.19	1.0332	1.0872	1.1413	1.1953	1.2494	1.5197	2.0602	2.6007	3.1413	3.6818
0.2	0.36	1.0049	1.0531	1.1013	1.1495	1.1977	1.4388	1.9209	2.403	2.8851	3.3673
0.3	0.51	0.975	1.0175	1.0599	1.1024	1.1449	1.3573	1.7821	2.2068	2.6316	3.0564
0.4	0.64	0.9435	0.9804	1.0172	1.0541	1.0909	1.2752	1.6437	2.0122	2.3807	2.7492
0.5	0.75	0.9106	0.9419	0.9732	1.0046	1.0359	1.1925	1.5058	1.8191	2.1324	2.4457
0.6	0.84	0.876	0.9019	0.9279	0.9538	0.9797	1.1093	1.3684	1.6275	1.8867	2.1458
0.7	0.91	0.84	0.8606	0.8812	0.9018	0.9224	1.0254	1.2314	1.4375	1.6435	1.8496
0.8	0.96	0.8023	0.8177	0.8331	0.8485	0.8639	0.9409	1.0949	1.249	1.403	1.557
0.9	0.99	0.7631	0.7734	0.7837	0.7941	0.8044	0.8559	0.9589	1.062	1.165	1.2681
1	1	0.7224	0.7277	0.733	0.7384	0.7437	0.7702	0.8234	0.8765	0.9297	0.9828

Table 11. Numerical values of Oseen's drag F/F_ρ for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.8$ [calculated from Eq. (91) and depicted in Fig. 12]

		Oseen's drag F/F_ρ									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.0675	1.135	1.2025	1.27	1.3375	1.675	2.35	3.025	3.7	4.375
0.1	0.19	1.0399	1.1007	1.1616	1.2224	1.2832	1.5872	2.1953	2.8034	3.4115	4.0196
0.2	0.36	1.0109	1.0651	1.1194	1.1736	1.2278	1.499	2.0414	2.5838	3.1262	3.6686
0.3	0.51	0.9803	1.0281	1.0759	1.1237	1.1714	1.4104	1.8883	2.3661	2.844	3.3219
0.4	0.64	0.9481	0.9896	1.0311	1.0725	1.114	1.3213	1.7358	2.1504	2.565	2.9795
0.5	0.75	0.9145	0.9497	0.985	1.0202	1.0555	1.2317	1.5841	1.9366	2.289	2.6415
0.6	0.84	0.8793	0.9084	0.9376	0.9667	0.9959	1.1416	1.4332	1.7247	2.0162	2.3077
0.7	0.91	0.8425	0.8657	0.8889	0.9121	0.9352	1.0512	1.2829	1.5147	1.7465	1.9783
0.8	0.96	0.8042	0.8216	0.8389	0.8562	0.8736	0.9602	1.1335	1.3067	1.48	1.6532
0.9	0.99	0.7644	0.776	0.7876	0.7992	0.8108	0.8688	0.9847	1.1006	1.2165	1.3325
1	1	0.7231	0.729	0.7351	0.741	0.747	0.7769	0.8367	0.8965	0.9562	1.0161

Table 12. Numerical values of Oseen's drag F/F_{ρ} for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' ($0 \le \varepsilon \le 1$) for various values of Reynolds number and micropolarity coefficient $k/\mu = 1.0$ [calculated from Eq. (91) and depicted in Fig. 13]

		Oseen's drag F/F_{ρ}									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.075	1.15	1.225	1.3	1.375	1.75	2.5	3.25	4	4.75
0.1	0.19	1.0467	1.1143	1.1818	1.2494	1.317	1.6548	2.3305	3.0061	3.6818	4.3574
0.2	0.36	1.0169	1.0772	1.1374	1.1977	1.258	1.5593	2.162	2.7646	3.3673	3.9699
0.3	0.51	0.9856	1.0387	1.0918	1.1449	1.198	1.4635	1.9945	2.5254	3.0564	3.5874
0.4	0.64	0.9528	0.9988	1.0449	1.0909	1.137	1.3673	1.828	2.2886	2.7492	3.2098
0.5	0.75	0.9184	0.9576	0.9967	1.0359	1.075	1.2708	1.6625	2.0541	2.4457	2.8373
0.6	0.84	0.8825	0.9149	0.9473	0.9797	1.0121	1.174	1.498	1.8219	2.1458	2.4697
0.7	0.91	0.8451	0.8709	0.8966	0.9224	0.9481	1.0769	1.3345	1.592	1.8496	2.1071
0.8	0.96	0.8062	0.8254	0.8447	0.8639	0.8832	0.9794	1.172	1.3645	1.557	1.7495
0.9	0.99	0.7657	0.7786	0.7915	0.8044	0.8172	0.8816	1.0105	1.1393	1.2681	1.3969
1	1	0.7238	0.7304	0.7371	0.7437	0.7503	0.7836	0.85	0.9164	0.9829	1.0493

Table 13. Numerical values of Oseen's drag F/F_z for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' ($0 \le \varepsilon \le 1$) for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.0$ [calculated from Eq. (118) and depicted in Fig. 14]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.0375	1.075	1.1125	1.15	1.1875	1.375	1.75	2.125	2.5	2.875
0.1	0.19	1.0367	1.0735	1.1102	1.147	1.1837	1.3675	1.735	2.1026	2.4701	2.8377
0.2	0.36	1.036	1.072	1.108	1.144	1.18	1.3601	1.7203	2.0805	2.4406	2.8008
0.3	0.51	1.0352	1.0705	1.1058	1.1411	1.1764	1.3528	1.7057	2.0586	2.4115	2.7644
0.4	0.64	1.0345	1.0691	1.1037	1.1382	1.1728	1.3456	1.6913	2.037	2.3827	2.7284
0.5	0.75	1.0338	1.0677	1.1015	1.1354	1.1692	1.3385	1.6771	2.0157	2.3542	2.6928
0.6	0.84	1.0331	1.0663	1.0994	1.1326	1.1657	1.3315	1.663	1.9946	2.3261	2.6577
0.7	0.91	1.0324	1.0649	1.0973	1.1298	1.1623	1.3246	1.6492	1.9738	2.2984	2.623
0.8	0.96	1.0317	1.0635	1.0953	1.1271	1.1588	1.3177	1.6354	1.9532	2.2709	2.5887
0.9	0.99	1.0311	1.0621	1.0932	1.1243	1.1554	1.3109	1.6219	1.9329	2.2438	2.5548
1	1	1.0304	1.0608	1.0912	1.1217	1.1521	1.3042	1.6085	1.9128	2.2171	2.5214

Table 14. Numerical values of Oseen's drag F/F_z for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' ($0 \le \varepsilon \le 1$) for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.2$ [calculated from Eq. (118) and depicted in Fig. 15]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.045	1.09	1.135	1.18	1.225	1.45	1.9	2.35	2.8	3.25
0.1	0.19	1.0441	1.0882	1.1323	1.1764	1.2205	1.441	1.8821	2.3231	2.7642	3.2052
0.2	0.36	1.0432	1.0864	1.1296	1.1728	1.2161	1.4322	1.8644	2.2966	2.7288	3.161
0.3	0.51	1.0423	1.0846	1.127	1.1693	1.2117	1.4234	1.8469	2.2703	2.6938	3.1173
0.4	0.64	1.0414	1.0829	1.1244	1.1659	1.2074	1.4148	1.8296	2.2444	2.6592	3.0741
0.5	0.75	1.0406	1.0812	1.1218	1.1625	1.2031	1.4062	1.8125	2.2188	2.6251	3.0314
0.6	0.84	1.0397	1.0795	1.1193	1.1591	1.1989	1.3978	1.7957	2.1935	2.5914	2.9892
0.7	0.91	1.0389	1.0779	1.1168	1.1558	1.1947	1.3895	1.779	2.1685	2.558	2.9476
0.8	0.96	1.0381	1.0762	1.1143	1.1525	1.1906	1.3812	1.7625	2.1438	2.5251	2.9064
0.9	0.99	1.0373	1.0746	1.1119	1.1492	1.1865	1.3731	1.7463	2.1195	2.4926	2.8658
1	1	1.0365	1.073	1.1095	1.146	1.1825	1.3651	1.7302	2.0954	2.4605	2.8257

Table 15. Numerical values of Oseen's drag F/F_z for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.4$ [calculated from Eq. (118) and depicted in Fig. 16]

					Oseen's drag F/F_z						
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.0525	1.105	1.1575	1.21	1.2625	1.525	2.05	2.575	3.1	3.625
0.1	0.19	1.0514	1.1029	1.1543	1.2058	1.2572	1.5145	2.0291	2.5436	3.0582	3.5728
0.2	0.36	1.0504	1.1008	1.1512	1.2017	1.2521	1.5042	2.0084	2.5127	3.0169	3.5212
0.3	0.51	1.0494	1.0988	1.1482	1.1976	1.247	1.494	1.988	2.4821	2.9761	3.4702
0.4	0.64	1.0484	1.0967	1.1451	1.1935	1.2419	1.4839	1.9679	2.4518	2.9358	3.4198
0.5	0.75	1.0474	1.0948	1.1422	1.1896	1.237	1.474	1.948	2.422	2.896	3.37
0.6	0.84	1.0464	1.0928	1.1392	1.1856	1.232	1.4641	1.9283	2.3924	2.8566	3.3208
0.7	0.91	1.0454	1.0908	1.1363	1.1817	1.2272	1.4544	1.9088	2.3633	2.8177	3.2722
0.8	0.96	1.0444	1.0889	1.1334	1.1779	1.2224	1.4448	1.8896	2.3345	2.7793	3.2242
0.9	0.99	1.0435	1.087	1.1306	1.1741	1.2176	1.4353	1.8707	2.306	2.7414	3.1768
1	1	1.0426	1.0852	1.1278	1.1704	1.213	1.426	1.852	2.278	2.704	3.13

Table 16. Numerical values of Oseen's drag F/F_z for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.6$ [calculated from Eq. (118) and depicted in Fig. 17]

					Oseen's drag F/F_z						
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.06	1.12	1.18	1.24	1.3	1.6	2.2	2.8	3.4	4
0.1	0.19	1.0588	1.1176	1.1764	1.2352	1.294	1.588	2.1761	2.7642	3.3522	3.9403
0.2	0.36	1.0576	1.1152	1.1728	1.2305	1.2881	1.5762	2.1525	2.7288	3.3051	3.8813
0.3	0.51	1.0564	1.1129	1.1693	1.2258	1.2823	1.5646	2.1292	2.6938	3.2584	3.823
0.4	0.64	1.0553	1.1106	1.1659	1.2212	1.2765	1.5531	2.1061	2.6592	3.2123	3.7654
0.5	0.75	1.0541	1.1083	1.1625	1.2166	1.2708	1.5417	2.0834	2.6251	3.1668	3.7085
0.6	0.84	1.053	1.106	1.1591	1.2121	1.2652	1.5304	2.0609	2.5914	3.1218	3.6523
0.7	0.91	1.0519	1.1038	1.1558	1.2077	1.2596	1.5193	2.0387	2.558	3.0774	3.5968
0.8	0.96	1.0508	1.1016	1.1525	1.2033	1.2541	1.5083	2.0167	2.5251	3.0335	3.5419
0.9	0.99	1.0497	1.0995	1.1492	1.199	1.2487	1.4975	1.9951	2.4926	2.9902	3.4877
1	1	1.0486	1.0973	1.146	1.1947	1.2434	1.4868	1.9737	2.4605	2.9474	3.4342

Table 17. Numerical values of Oseen's drag F/F_z for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.8$ [calculated from Eq. (118) and depicted in Fig. 18]

					Oseen's drag F/F_z						
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.0675	1.135	1.2025	1.27	1.3375	1.675	2.35	3.025	3.7	4.375
0.1	0.19	1.0661	1.1323	1.1984	1.2646	1.3307	1.6615	2.3231	2.9847	3.6463	4.3078
0.2	0.36	1.0648	1.1296	1.1944	1.2593	1.3241	1.6483	2.2966	2.9449	3.5932	4.2415
0.3	0.51	1.0635	1.127	1.1905	1.254	1.3176	1.6351	2.2703	2.9055	3.5407	4.1759
0.4	0.64	1.0622	1.1244	1.1866	1.2488	1.3111	1.6222	2.2444	2.8667	3.4889	4.1111
0.5	0.75	1.0609	1.1218	1.1828	1.2437	1.3047	1.6094	2.2188	2.8282	3.4377	4.0471
0.6	0.84	1.0596	1.1193	1.179	1.2387	1.2983	1.5967	2.1935	2.7903	3.3871	3.9838
0.7	0.91	1.0584	1.1168	1.1752	1.2337	1.2921	1.5842	2.1685	2.7528	3.3371	3.9214
0.8	0.96	1.0571	1.1143	1.1715	1.2287	1.2859	1.5719	2.1438	2.7158	3.2877	3.8596
0.9	0.99	1.0559	1.1119	1.1679	1.2239	1.2798	1.5597	2.1195	2.6792	3.2389	3.7987
1	1	1.0547	1.1095	1.1643	1.2191	1.2738	1.5477	2.0954	2.6431	3.1908	3.7385

Table 18. Numerical values of Oseen's drag F/F_z for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 1.0$ [calculated from Eq. (118) and depicted in Fig. 19]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0	0	1.075	1.15	1.225	1.3	1.375	1.75	2.5	3.25	4	4.75
0.1	0.19	1.0735	1.147	1.2205	1.294	1.3675	1.735	2.4701	3.2052	3.9403	4.6754
0.2	0.36	1.072	1.144	1.2161	1.2881	1.3601	1.7203	2.4406	3.161	3.8813	4.6017
0.3	0.51	1.0705	1.1411	1.2117	1.2823	1.3528	1.7057	2.4115	3.1173	3.823	4.5288
0.4	0.64	1.0691	1.1382	1.2074	1.2765	1.3456	1.6913	2.3827	3.0741	3.7654	4.4568
0.5	0.75	1.0677	1.1354	1.2031	1.2708	1.3385	1.6771	2.3542	3.0314	3.7085	4.3857
0.6	0.84	1.0663	1.1326	1.1989	1.2652	1.3315	1.663	2.3261	2.9892	3.6523	4.3154
0.7	0.91	1.0649	1.1298	1.1947	1.2596	1.3246	1.6492	2.2984	2.9476	3.5968	4.246
0.8	0.96	1.0635	1.1271	1.1906	1.2541	1.3177	1.6354	2.2709	2.9064	3.5419	4.1774
0.9	0.99	1.0621	1.1243	1.1865	1.2487	1.3109	1.6219	2.2438	2.8658	3.4877	4.1097
1	1	1.0608	1.1217	1.1825	1.2434	1.3042	1.6085	2.2171	2.8257	3.4342	4.0428

Table 19. Numerical values of Oseen's drag F/F_ρ for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.0$ [calculated from Eq. (122) and depicted in Fig. 20]

		Oseen's drag F/F_ρ									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	1.0375	1.0750	1.1125	1.1500	1.1875	1.3750	1.7500	2.1250	2.5000	2.8750
0.1000	0.1900	1.0587	1.0962	1.1337	1.1713	1.2088	1.3965	1.7718	2.1471	2.5225	2.8978
0.2000	0.3600	1.0823	1.1199	1.1575	1.1952	1.2328	1.4210	1.7973	2.1736	2.5500	2.9263
0.3000	0.5100	1.1083	1.1461	1.1839	1.2217	1.2595	1.4485	1.8265	2.2045	2.5825	2.9604
0.4000	0.6400	1.1367	1.1748	1.2128	1.2508	1.2889	1.4790	1.8593	2.2396	2.6200	3.0003
0.5000	0.7500	1.1676	1.2059	1.2442	1.2826	1.3209	1.5125	1.8958	2.2792	2.6625	3.0458
0.6000	0.8400	1.2008	1.2395	1.2782	1.3169	1.3556	1.5491	1.9360	2.3230	2.7100	3.0969
0.7000	0.9100	1.2365	1.2756	1.3147	1.3539	1.3930	1.5886	1.9799	2.3712	2.7625	3.1537
0.8000	0.9600	1.2746	1.3142	1.3538	1.3934	1.4331	1.6312	2.0274	2.4237	2.8200	3.2162
0.9000	0.9900	1.3150	1.3552	1.3954	1.4356	1.4758	1.6767	2.0786	2.4806	2.8825	3.2844
1.0000	1.0000	1.3579	1.3988	1.4396	1.4804	1.5212	1.7253	2.1335	2.5417	2.9500	3.3582

Table 20. Numerical values of Oseen's drag F/F_ρ for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.2$ [calculated from Eq. (122) and depicted in Fig. 21]

		Oseen's drag F/F_ρ									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	1.0450	1.0900	1.1350	1.1800	1.2250	1.4500	1.9000	2.3500	2.8000	3.2500
0.1000	0.1900	1.0662	1.1112	1.1562	1.2013	1.2463	1.4715	1.9219	2.3723	2.8227	3.2731
0.2000	0.3600	1.0898	1.1350	1.1801	1.2253	1.2704	1.4962	1.9478	2.3994	2.8510	3.3026
0.3000	0.5100	1.1159	1.1612	1.2066	1.2519	1.2973	1.5241	1.9777	2.4313	2.8848	3.3384
0.4000	0.6400	1.1443	1.1900	1.2356	1.2812	1.3269	1.5551	2.0115	2.4678	2.9242	3.3806
0.5000	0.7500	1.1752	1.2212	1.2672	1.3132	1.3592	1.5892	2.0492	2.5091	2.9691	3.4291
0.6000	0.8400	1.2086	1.2550	1.3014	1.3479	1.3943	1.6265	2.0908	2.5552	3.0195	3.4839
0.7000	0.9100	1.2443	1.2913	1.3382	1.3852	1.4321	1.6669	2.1364	2.6059	3.0755	3.5450
0.8000	0.9600	1.2825	1.3300	1.3776	1.4251	1.4727	1.7104	2.1859	2.6615	3.1370	3.6125
0.9000	0.9900	1.3231	1.3713	1.4195	1.4678	1.5160	1.7571	2.2394	2.7217	3.2040	3.6863
1.0000	1.0000	1.3661	1.4151	1.4640	1.5131	1.5621	1.8070	2.2968	2.7867	3.2765	3.7664

Table 21. Numerical values of Oseen's drag F/F_ρ for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.4$ [calculated from Eq. (122) and depicted in Fig. 22]

		Oseen's drag F/F_ρ									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	1.0525	1.1050	1.1575	1.2100	1.2625	1.5250	2.0500	2.5750	3.1000	3.6250
0.1000	0.1900	1.0737	1.1262	1.1788	1.2313	1.2839	1.5466	2.0721	2.5975	3.1230	3.6485
0.2000	0.3600	1.0973	1.1500	1.2027	1.2554	1.3081	1.5715	2.0984	2.6252	3.1521	3.6789
0.3000	0.5100	1.1234	1.1763	1.2293	1.2822	1.3351	1.5997	2.1289	2.6581	3.1872	3.7164
0.4000	0.6400	1.1519	1.2052	1.2584	1.3117	1.3649	1.6311	2.1636	2.6960	3.2285	3.7609
0.5000	0.7500	1.1829	1.2366	1.2902	1.3439	1.3976	1.6659	2.2025	2.7391	3.2757	3.8124
0.6000	0.8400	1.2163	1.2705	1.3246	1.3788	1.4330	1.7039	2.2456	2.7873	3.3291	3.8708
0.7000	0.9100	1.2521	1.3069	1.3617	1.4165	1.4712	1.7451	2.2929	2.8407	3.3885	3.9363
0.8000	0.9600	1.2904	1.3459	1.4014	1.4568	1.5123	1.7897	2.3444	2.8992	3.4540	4.0087
0.9000	0.9900	1.3311	1.3874	1.4436	1.4999	1.5562	1.8375	2.4002	2.9628	3.5255	4.0882
1.0000	1.0000	1.3742	1.4314	1.4885	1.5457	1.6028	1.8886	2.4601	3.0316	3.6031	4.1746

Table 22. Numerical values of Oseen's drag F/F_ρ for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.6$ [calculated from Eq. (122) and depicted in Fig. 23]

		Oseen's drag $F/F_r ho$									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	1.0600	1.1200	1.1800	1.2400	1.3000	1.6000	2.2000	2.8000	3.4000	4.0000
0.1000	0.1900	1.0812	1.1412	1.2013	1.2613	1.3214	1.6217	2.2222	2.8227	3.4233	4.0238
0.2000	0.3600	1.1049	1.1651	1.2253	1.2855	1.3457	1.6468	2.2489	2.8510	3.4531	4.0553
0.3000	0.5100	1.1310	1.1915	1.2519	1.3124	1.3729	1.6753	2.2801	2.8848	3.4896	4.0944
0.4000	0.6400	1.1595	1.2204	1.2812	1.3421	1.4029	1.7072	2.3157	2.9242	3.5327	4.1412
0.5000	0.7500	1.1906	1.2519	1.3132	1.3746	1.4359	1.7425	2.3558	2.9691	3.5824	4.1957
0.6000	0.8400	1.2240	1.2860	1.3479	1.4098	1.4717	1.7813	2.4004	3.0195	3.6387	4.2578
0.7000	0.9100	1.2600	1.3226	1.3852	1.4478	1.5104	1.8234	2.4494	3.0755	3.7015	4.3276
0.8000	0.9600	1.2983	1.3617	1.4251	1.4885	1.5519	1.8689	2.5029	3.1370	3.7710	4.4050
0.9000	0.9900	1.3391	1.4034	1.4678	1.5321	1.5964	1.9179	2.5609	3.2040	3.8470	4.4901
1.0000	1.0000	1.3824	1.4477	1.5131	1.5784	1.6437	1.9710	2.6234	3.2765	3.9297	4.5828

Table 23. Numerical values of Oseen's drag F/F_ρ for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.8$ [calculated from Eq. (122) and depicted in Fig. 24]

		Oseen's drag F/F_ρ									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	1.0675	1.1350	1.2025	1.2700	1.3375	1.6750	2.3500	3.0250	3.7000	4.3750
0.1000	0.1900	1.0887	1.1562	1.2238	1.2914	1.3589	1.6967	2.3723	3.0479	3.7235	4.3991
0.2000	0.3600	1.1124	1.1801	1.2479	1.3156	1.3833	1.7220	2.3994	3.0768	3.7542	4.4316
0.3000	0.5100	1.1385	1.2066	1.2746	1.3427	1.4107	1.7509	2.4313	3.1116	3.7920	4.4724
0.4000	0.6400	1.1672	1.2356	1.3041	1.3725	1.4410	1.7833	2.4678	3.1524	3.8370	4.5215
0.5000	0.7500	1.1982	1.2672	1.3362	1.4052	1.4742	1.8192	2.5091	3.1991	3.8890	4.5790
0.6000	0.8400	1.2318	1.3014	1.3711	1.4407	1.5104	1.8586	2.5552	3.2517	3.9482	4.6447
0.7000	0.9100	1.2678	1.3382	1.4086	1.4791	1.5495	1.9017	2.6059	3.3102	4.0145	4.7188
0.8000	0.9600	1.3063	1.3776	1.4489	1.5202	1.5916	1.9482	2.6615	3.3747	4.0880	4.8012
0.9000	0.9900	1.3472	1.4195	1.4919	1.5642	1.6366	1.9983	2.7217	3.4451	4.1685	4.8920
1.0000	1.0000	1.3906	1.4641	1.5375	1.6111	1.6845	2.0519	2.7867	3.5210	4.2560	4.9910

Table 24. Numerical values of Oseen's drag F/F_ρ for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' ($0 \le \varepsilon \le 1$) for various values of Reynolds number and micropolarity coefficient $k/\mu = 1.0$ [calculated from Eq. (122) and depicted in Fig. 25]

		Oseen's drag F/F_ρ									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	1.0750	1.1500	1.2250	1.3000	1.3750	1.7500	2.5000	3.2500	4.0000	4.7500
0.1000	0.1900	1.0962	1.1713	1.2463	1.3214	1.3965	1.7718	2.5225	3.2731	4.0238	4.7744
0.2000	0.3600	1.1199	1.1952	1.2704	1.3457	1.4210	1.7973	2.5500	3.3026	4.0553	4.8079
0.3000	0.5100	1.1461	1.2217	1.2973	1.3729	1.4485	1.8265	2.5825	3.3384	4.0944	4.8504
0.4000	0.6400	1.1748	1.2508	1.3269	1.4029	1.4790	1.8593	2.6200	3.3806	4.1412	4.9018
0.5000	0.7500	1.2059	1.2826	1.3592	1.4359	1.5125	1.8958	2.6625	3.4291	4.1957	4.9623
0.6000	0.8400	1.2395	1.3169	1.3943	1.4717	1.5491	1.9360	2.7100	3.4839	4.2578	5.0317
0.7000	0.9100	1.2756	1.3539	1.4321	1.5104	1.5886	1.9799	2.7625	3.5450	4.3276	5.1101
0.8000	0.9600	1.3142	1.3934	1.4727	1.5519	1.6312	2.0274	2.8200	3.6125	4.4050	5.1975
0.9000	0.9900	1.3552	1.4356	1.5160	1.5964	1.6767	2.0786	2.8825	3.6863	4.4901	5.2939
1.0000	1.0000	1.3987	1.4800	1.5620	1.6437	1.7253	2.1335	2.9500	3.7664	4.5828	5.3992

Table 25. Numerical values of Oseen's drag F/F_z for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' ($0 \le \varepsilon \le 1$) for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.0$ [calculated from Eq. (99) and depicted in Fig. 26]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	120.0380	60.0750	40.1125	30.1500	24.1875	12.3750	6.7500	5.1250	4.5000	4.2750
0.1000	0.1900	110.4450	55.2704	36.8998	27.7304	22.2410	11.3589	6.1556	4.6329	4.0302	3.7957
0.2000	0.3600	100.8810	50.4804	33.6978	25.3197	20.3030	10.3504	5.5726	4.1566	3.5811	3.3418
0.3000	0.5100	91.3452	45.7052	30.5064	22.9178	18.3730	9.3497	5.0009	3.6962	3.1525	2.9133
0.4000	0.6400	81.8369	40.9447	27.3256	20.5248	16.4510	8.3567	4.4405	3.2516	2.7445	2.5102
0.5000	0.7500	72.3566	36.1989	24.1554	18.1406	14.5370	7.3714	3.8914	2.8228	2.3571	2.1325
0.6000	0.8400	62.9042	31.4678	20.9959	15.7652	12.6310	6.3938	3.3536	2.4099	1.9902	1.7803
0.7000	0.9100	53.4797	26.7514	17.8470	13.3987	10.7320	5.4240	2.8272	2.0128	1.6440	1.4534
0.8000	0.9600	44.0831	22.0497	14.7088	11.0411	8.8425	4.4618	2.3120	1.6315	1.3182	1.1519
0.9000	0.9900	34.7145	17.3627	11.5812	8.6923	6.9603	3.5074	1.8082	1.2660	1.0131	0.8759
1.0000	1.0000	25.3738	12.6904	8.4642	6.3523	5.0861	2.5607	1.3157	0.9164	0.7285	0.6252

Table 26. Numerical values of Oseen's drag F/F_z for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' ($0 \le \varepsilon \le 1$) for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.2$ [calculated from Eq. (99) and depicted in Fig. 27]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	144.0450	72.0900	48.1350	36.1800	29.0250	14.8500	8.1000	6.1500	5.4000	5.1300
0.1000	0.1900	132.5350	66.3244	44.2798	33.2765	26.6898	13.6300	7.3867	5.5595	4.8363	4.5548
0.2000	0.3600	121.0580	60.5765	40.4373	30.3836	24.3641	12.4200	6.6871	4.9880	4.2973	4.0101
0.3000	0.5100	109.6140	54.8462	36.6076	27.5014	22.0480	11.2190	6.0011	4.4355	3.7830	3.4959
0.4000	0.6400	98.2043	49.1336	32.7907	24.6297	19.7415	10.0280	5.3286	3.9020	3.2934	3.0122
0.5000	0.7500	86.8279	43.4386	28.9865	21.7687	17.4446	8.8457	4.6697	3.3874	2.8285	2.5590
0.6000	0.8400	75.4850	37.7613	25.1951	18.9183	15.1570	7.6726	4.0243	2.8919	2.3883	2.1363
0.7000	0.9100	64.1756	32.1016	21.4164	16.0785	12.8790	6.5088	3.3926	2.4154	1.9728	1.7441
0.8000	0.9600	52.8997	26.4596	17.6506	13.2493	10.6110	5.3542	2.7744	1.9578	1.5819	1.3823
0.9000	0.9900	41.6574	20.8352	13.8974	10.4307	8.3524	4.2089	2.1698	1.5193	1.2157	1.0511
1.0000	1.0000	30.4485	15.2285	10.1571	7.6227	6.1032	3.0728	1.5788	1.0997	0.8743	0.7503

Table 27. Numerical values of Oseen's drag F/F_z for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.4$ [calculated from Eq. (99) and depicted in Fig. 28]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0	168.0530	84.105	56.1575	42.21	33.8625	17.325	9.4500	7.175	6.3000	5.985
0.1000	0.19	154.6240	77.3785	51.6597	38.8226	31.1381	15.9024	8.6179	6.486	5.6424	5.3139
0.2000	0.36	141.2340	70.6726	47.1769	35.4476	28.4248	14.4906	7.8016	5.8193	5.0136	4.6785
0.3000	0.51	127.8830	63.9873	42.7089	32.0849	25.7227	13.0896	7.0012	5.1747	4.4136	4.0786
0.4000	0.64	114.5720	57.3225	38.2558	28.7347	23.0318	11.6994	6.2167	4.5522	3.8424	3.5143
0.5000	0.75	101.2990	50.6784	33.8176	25.3968	20.3520	10.32	5.4480	3.952	3.3000	2.9856
0.6000	0.84	88.0658	44.0549	29.3943	22.0713	17.6834	8.9514	4.6951	3.3738	2.7864	2.4924
0.7000	0.91	74.8716	37.4519	24.9859	18.7582	15.0259	7.5936	3.9580	2.8179	2.3016	2.0348
0.8000	0.96	61.7164	30.8695	20.5923	15.4575	12.3796	6.2466	3.2368	2.2841	1.8456	1.6127
0.9000	0.99	48.6003	24.3078	16.2137	12.1692	9.7445	4.9104	2.5315	1.7724	1.4184	1.2263
1.0000	1	35.5233	17.7666	11.8499	8.8932	7.1205	3.585	1.8420	1.283	1.0200	0.8754

Table 28. Numerical values of Oseen's drag F/F_z for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.6$ [calculated from Eq. (99) and depicted in Fig. 29]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	192.0600	96.1200	64.1800	48.2400	38.7000	19.8000	10.8000	8.2000	7.2000	6.8400
0.1000	0.1900	176.7130	88.4326	59.0397	44.3687	35.5864	18.1742	9.8490	7.4126	6.4484	6.0731
0.2000	0.3600	161.4100	80.7687	53.9164	40.5115	32.4855	16.5607	8.9162	6.6506	5.7298	5.3469
0.3000	0.5100	146.1520	73.1283	48.8102	36.6685	29.3974	14.9595	8.0014	5.9139	5.0441	4.6613
0.4000	0.6400	130.9390	65.5115	43.7209	32.8396	26.3220	13.3707	7.1048	5.2026	4.3913	4.0163
0.5000	0.7500	115.7710	57.9182	38.6487	29.0249	23.2594	11.7943	6.2262	4.5165	3.7714	3.4121
0.6000	0.8400	100.6470	50.3484	33.5935	25.2244	20.2096	10.2302	5.3658	3.8558	3.1844	2.8484
0.7000	0.9100	85.5675	42.8022	28.5553	21.4380	17.1725	8.6784	4.5235	3.2204	2.6304	2.3255
0.8000	0.9600	70.5330	35.2795	23.5341	17.6657	14.1481	7.1389	3.6992	2.6104	2.1092	1.8431
0.9000	0.9900	55.5432	27.7803	18.5299	13.9076	11.1360	5.6118	2.8931	2.0256	1.6210	1.4014
1.0000	1.0000	40.5981	20.3047	13.5427	10.1637	8.1377	4.0971	2.1051	1.4662	1.1657	1.0004

Table 29. Numerical values of Oseen's drag F/F_z for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.8$ [calculated from Eq. (99) and depicted in Fig. 30]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	216.0680	108.1350	72.2025	54.2700	43.5375	22.2750	12.1500	9.2250	8.1000	7.6950
0.1000	0.1900	198.8020	99.4866	66.4197	49.9148	40.0347	20.4459	11.0800	8.3392	7.2545	6.8322
0.2000	0.3600	181.5860	90.8648	60.6560	45.5754	36.5462	18.6308	10.0300	7.4819	6.4460	6.0152
0.3000	0.5100	164.4210	82.2693	54.9114	41.2521	33.0721	16.8295	9.0016	6.6532	5.6746	5.2439
0.4000	0.6400	147.3060	73.7004	49.1860	36.9446	29.6123	15.0421	7.9929	5.8529	4.9402	4.5184
0.5000	0.7500	130.2420	65.1579	43.4798	32.6530	26.1669	13.2686	7.0045	5.0811	4.2428	3.8386
0.6000	0.8400	113.2270	56.6420	37.7927	28.3774	22.7358	11.5089	6.0365	4.3378	3.5825	3.2045
0.7000	0.9100	96.2634	48.1524	32.1247	24.1177	19.3190	9.7632	5.0889	3.6230	2.9590	2.6161
0.8000	0.9600	79.3496	39.6894	26.4758	19.8739	15.9160	8.0313	4.1617	2.9367	2.3729	2.0735
0.9000	0.9900	62.4861	31.2529	20.8461	15.6461	12.5280	6.3133	3.2548	2.2780	1.8236	1.5766
1.0000	1.0000	45.6728	22.8428	15.2356	11.4341	9.1549	4.6092	2.3682	1.6495	1.3114	1.1255

Table 30. Numerical values of Oseen's drag F/F_z for deformed prolate spheroid placed in axial micro-polar flow with respect to deformation parameter 'ε' ($0 \le \varepsilon \le 1$) for various values of Reynolds number and micropolarity coefficient $k/\mu = 1.0$ [calculated from Eq. (99) and depicted in Fig. 31]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	240.0750	120.1500	80.2250	60.3000	48.3750	24.7500	13.5000	10.2500	9.0000	8.5500
0.1000	0.1900	220.8910	110.5410	73.7996	55.4608	44.4830	22.7170	12.3113	9.2658	8.0605	7.5914
0.2000	0.3600	201.7630	100.9610	67.3955	50.6394	40.6069	20.7000	11.1453	8.3133	7.1622	6.6836
0.3000	0.5100	182.6900	91.4104	61.0127	45.8356	36.7467	18.6990	10.0010	7.3924	6.3051	5.8266
0.4000	0.6400	163.6740	81.8893	54.6511	41.0495	32.9025	16.7130	8.8810	6.5032	5.4891	5.0204
0.5000	0.7500	144.7130	72.3977	48.3109	36.2811	29.0743	14.7420	7.7828	5.6457	4.7142	4.2651
0.6000	0.8400	125.8080	62.9355	41.9918	31.5304	25.2620	12.7870	6.7073	4.8198	3.9805	3.5606
0.7000	0.9100	106.9590	53.5027	35.6941	26.7974	21.4656	10.8480	5.6544	4.0256	3.2880	2.9068
0.8000	0.9600	88.1662	44.0993	29.4176	22.0821	17.6852	8.9237	4.6241	3.2630	2.6365	2.3039
0.9000	0.9900	69.4290	34.7254	23.1624	17.3845	13.9207	7.0148	3.6164	2.5321	2.0262	1.7518
1.0000	1.0000	50.7476	25.3809	16.9284	12.7046	10.1721	5.1214	2.6314	1.8328	1.4571	1.2505

Table 31. Numerical values of Oseen's drag F/F_z for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter 'ε' ($0 \le \varepsilon \le 1$) for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.0$ [calculated from Eq. (130) and depicted in Fig. 32]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	120.0380	60.0750	40.1125	30.1500	24.1875	12.3750	6.7500	5.1250	4.5000	4.2750
0.1000	0.1900	117.6500	58.8789	39.3126	29.5475	23.7029	12.1210	6.6011	5.0011	4.3812	4.1534
0.2000	0.3600	115.2890	57.6966	38.5221	28.9521	23.2239	11.8710	6.4546	4.8796	4.2651	4.0348
0.3000	0.5100	112.9570	56.5281	37.7408	28.3637	22.7507	11.6240	6.3104	4.7604	4.1515	3.9190
0.4000	0.6400	110.6510	55.3735	36.9688	27.7824	22.2833	11.3800	6.1685	4.6436	4.0405	3.8062
0.5000	0.7500	108.3730	54.2326	36.2061	27.2081	21.8215	11.1400	6.0289	4.5291	3.9321	3.6963
0.6000	0.8400	106.1230	53.1056	35.4526	26.6408	21.3655	10.9020	5.8916	4.4169	3.8262	3.5893
0.7000	0.9100	103.9000	51.9923	34.7085	26.0806	20.9152	10.6680	5.7567	4.3070	3.7230	3.4851
0.8000	0.9600	101.7050	50.8929	33.9736	25.5275	20.4706	10.4370	5.6240	4.1995	3.6222	3.3839
0.9000	0.9900	99.5368	49.8072	33.2480	24.9814	20.0317	10.2100	5.4937	4.0943	3.5241	3.2856
1.0000	1.0000	97.3963	48.7354	32.5317	24.4423	19.5986	9.9857	5.3657	3.9914	3.4285	3.1902

Table 32. Numerical values of Oseen's drag F/F_z for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter 'ε' ($0 \le \varepsilon \le 1$) for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.2$ [calculated from Eq. (130) and depicted in Fig. 33]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	144.0450	72.0900	48.1350	36.1800	29.0250	14.8500	8.1000	6.1500	5.4000	5.1300
0.1000	0.1900	141.1800	70.6547	47.1752	35.4570	28.4434	14.5459	7.9213	6.0014	5.2575	4.9841
0.2000	0.3600	138.3470	69.2359	46.2265	34.7425	27.8687	14.2457	7.7455	5.8555	5.1181	4.8417
0.3000	0.5100	135.5480	67.8338	45.2889	34.0364	27.3009	13.9494	7.5725	5.7125	4.9818	4.7028
0.4000	0.6400	132.7820	66.4482	44.3625	33.3388	26.7399	13.6569	7.4022	5.5723	4.8486	4.5674
0.5000	0.7500	130.0480	65.0791	43.4473	32.6497	26.1858	13.3682	7.2347	5.4349	4.7185	4.4355
0.6000	0.8400	127.3480	63.7267	42.5431	31.9690	25.6386	13.0834	7.0699	5.3003	4.5915	4.3071
0.7000	0.9100	124.6800	62.3908	41.6502	31.2967	25.0982	12.8025	6.9080	5.1684	4.4676	4.1822
0.8000	0.9600	122.0460	61.0714	40.7683	30.6330	24.5647	12.5254	6.7488	5.0394	4.3467	4.0607
0.9000	0.9900	119.4440	59.7687	39.8976	29.9776	24.0381	12.2522	6.5924	4.9131	4.2289	3.9428
1.0000	1.0000	116.8760	58.4825	39.0381	29.3307	23.5183	11.9829	6.4388	4.7897	4.1142	3.8283

Table 33. Numerical values of Oseen's drag F/F_z for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 040$ [calculated from Eq. (130) and depicted in Fig. 34]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	168.0530	84.1050	56.1575	42.2100	33.8625	17.3250	9.4500	7.1750	6.3000	5.9850
0.1000	0.1900	164.7100	82.4305	55.0377	41.3665	33.1840	16.9702	9.2416	7.0016	6.1338	5.8148
0.2000	0.3600	161.4050	80.7753	53.9309	40.5329	32.5135	16.6200	9.0364	6.8315	5.9712	5.6487
0.3000	0.5100	158.1390	79.1394	52.8371	39.7092	31.8510	16.2742	8.8345	6.6646	5.8122	5.4867
0.4000	0.6400	154.9120	77.5229	51.7563	38.8953	31.1966	15.9330	8.6359	6.5010	5.6568	5.3287
0.5000	0.7500	151.7230	75.9257	50.6885	38.0913	30.5501	15.5963	8.4405	6.3407	5.5050	5.1748
0.6000	0.8400	148.5720	74.3478	49.6337	37.2972	29.9117	15.2640	8.2483	6.1836	5.3568	5.0250
0.7000	0.9100	145.4600	72.7892	48.5919	36.5129	29.2812	14.9363	8.0593	6.0298	5.2122	4.8792
0.8000	0.9600	142.3870	71.2500	47.5630	35.7384	28.6588	14.6130	7.8736	5.8793	5.0712	4.7375
0.9000	0.9900	139.3510	69.7301	46.5472	34.9739	28.0444	14.2942	7.6912	5.7320	4.9338	4.5999
1.0000	1.0000	136.3550	68.2296	45.5444	34.2192	27.4380	13.9800	7.5120	5.5880	4.8000	4.4664

Table 34. Numerical values of Oseen's drag F/F_z for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.6$ [calculated from Eq. (130) and depicted in Fig. 35]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	192.0600	96.1200	64.1800	48.2400	38.7000	19.8000	10.8000	8.2000	7.2000	6.8400
0.1000	0.1900	188.2400	94.2062	62.9002	47.2760	37.9246	19.3940	10.5610	8.0018	7.0100	6.6455
0.2000	0.3600	184.4630	92.3146	61.6353	46.3233	37.1583	18.9940	10.3270	7.8074	6.8242	6.4557
0.3000	0.5100	180.7310	90.4450	60.3852	45.3819	36.4012	18.5990	10.0960	7.6167	6.6425	6.2705
0.4000	0.6400	177.0420	88.5975	59.1500	44.4518	35.6532	18.2090	9.8696	7.4298	6.4649	6.0899
0.5000	0.7500	173.3980	86.7722	57.9297	43.5329	34.9144	17.8240	9.6462	7.2465	6.2914	5.9141
0.6000	0.8400	169.7970	84.9689	56.7242	42.6253	34.1848	17.4440	9.4266	7.0670	6.1220	5.7428
0.7000	0.9100	166.2400	83.1877	55.5335	41.7290	33.4643	17.0700	9.2107	6.8912	5.9568	5.5763
0.8000	0.9600	162.7280	81.4286	54.3578	40.8439	32.7529	16.7000	8.9984	6.7192	5.7956	5.4143
0.9000	0.9900	159.2590	79.6916	53.1968	39.9702	32.0507	16.3360	8.7899	6.5508	5.6386	5.2570
1.0000	1.0000	155.8340	77.9767	52.0507	39.1077	31.3577	15.9770	8.5851	6.3862	5.4857	5.1044

Table 35. Numerical values of Oseen's drag F/F_z for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' $(0 \le \varepsilon \le 1)$ for various values of Reynolds number and micropolarity coefficient $k/\mu = 0.8$ [calculated from Eq. (130) and depicted in Fig. 36]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	216.0680	108.1350	72.2025	54.2700	43.5375	22.2750	12.1500	9.2250	8.1000	7.6950
0.1000	0.1900	211.7700	105.9820	70.7628	53.1855	42.6651	21.8189	11.8820	9.0021	7.8863	7.4762
0.2000	0.3600	207.5210	103.8540	69.3397	52.1138	41.8031	21.3686	11.6180	8.7833	7.6772	7.2626
0.3000	0.5100	203.3220	101.7510	67.9334	51.0547	40.9513	20.9240	11.3580	8.5688	7.4728	7.0543
0.4000	0.6400	199.1720	99.6722	66.5438	50.0083	40.1099	20.4853	11.1030	8.3585	7.2730	6.8512
0.5000	0.7500	195.0720	97.6187	65.1709	48.9745	39.2787	20.0523	10.8520	8.1523	7.0778	6.6533
0.6000	0.8400	191.0220	95.5900	63.8147	47.9535	38.4579	19.6251	10.6050	7.9504	6.8873	6.4607
0.7000	0.9100	187.0200	93.5862	62.4752	46.9451	37.6473	19.2038	10.3620	7.7526	6.7014	6.2733
0.8000	0.9600	183.0690	91.6072	61.1525	45.9494	36.8471	18.7881	10.1230	7.5591	6.5201	6.0911
0.9000	0.9900	179.1660	89.6530	59.8464	44.9664	36.0571	18.3783	9.8887	7.3697	6.3434	5.9142
1.0000	1.0000	175.3130	87.7238	58.5571	43.9961	35.2774	17.9743	9.6582	7.1845	6.1714	5.7425

Table 36. Numerical values of Oseen's drag F/F_z for deformed oblate spheroid placed in axial micro-polar flow with respect to deformation parameter ' ε' ($0 \le \varepsilon \le 1$) for various values of Reynolds number and micropolarity coefficient $k/\mu = 1.0$ [calculated from Eq. (130) and depicted in Fig. 37]

		Oseen's drag F/F_z									
ε	e	Re=0.1	Re=0.2	Re=0.3	Re=0.4	Re=0.5	Re=1.0	Re=2.0	Re=3.0	Re=4.0	Re=5.0
0.0000	0.0000	240.0750	120.1500	80.2250	60.3000	48.3750	24.7500	13.5000	10.2500	9.0000	8.5500
0.1000	0.1900	235.2990	117.7580	78.6253	59.0950	47.4057	24.2432	13.2023	10.0020	8.7625	8.3069
0.2000	0.3600	230.5790	115.3930	77.0441	57.9042	46.4479	23.7429	12.9093	9.7593	8.5302	8.0696
0.3000	0.5100	225.9130	113.0560	75.4816	56.7274	45.5015	23.2489	12.6208	9.5209	8.3031	7.8381
0.4000	0.6400	221.3030	110.7470	73.9375	55.5647	44.5665	22.7614	12.3370	9.2872	8.0811	7.6124
0.5000	0.7500	216.7470	108.4650	72.4121	54.4161	43.6430	22.2804	12.0579	9.0582	7.8642	7.3926
0.6000	0.8400	212.2460	106.2110	70.9052	53.2816	42.7310	21.8057	11.7833	8.8338	7.6525	7.1786
0.7000	0.9100	207.8000	103.9850	69.4169	52.1612	41.8304	21.3375	11.5134	8.6141	7.4460	6.9703
0.8000	0.9600	203.4090	101.7860	67.9472	51.0549	40.9412	20.8757	11.2481	8.3990	7.2445	6.7679
0.9000	0.9900	199.0740	99.6145	66.4960	49.9627	40.0634	20.4204	10.9875	8.1886	7.0482	6.5713
1.0000	1.0000	194.7930	97.4709	65.0634	48.8846	39.1971	19.9714	10.7314	7.9828	6.8571	6.3805

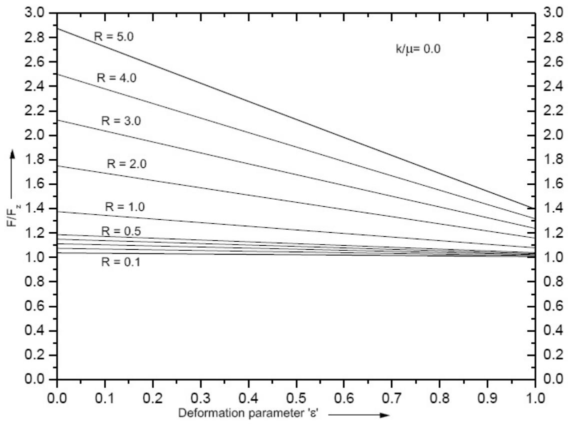

Fig. 2. Variation of Oseen's drag for deformed prolate spheroid in axial micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R'(Using Table 1)

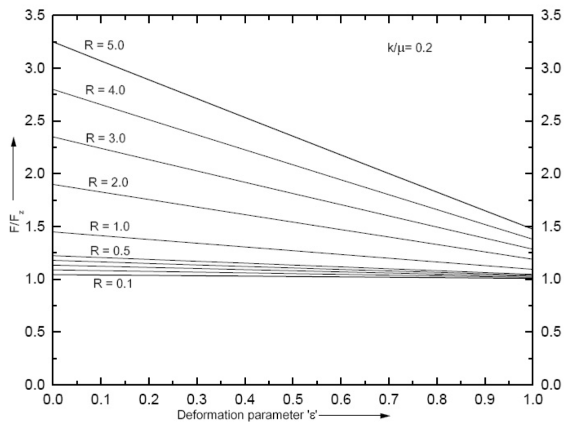

Fig. 3. Variation of Oseen's drag for deformed prolate spheroid in axial micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R'(Using Table 2)

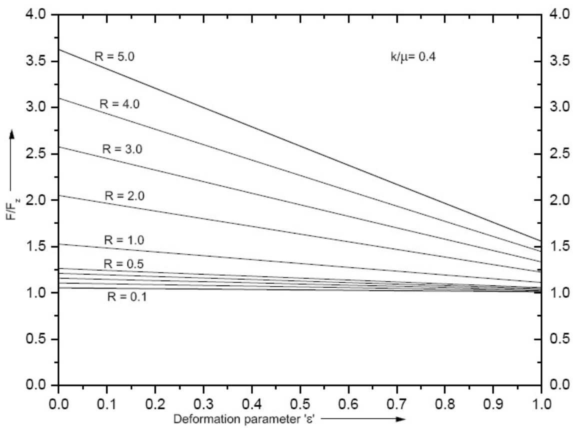

Fig. 4. Variation of Oseen's drag for deformed prolate spheroid in axial micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R'(Using Table 3)

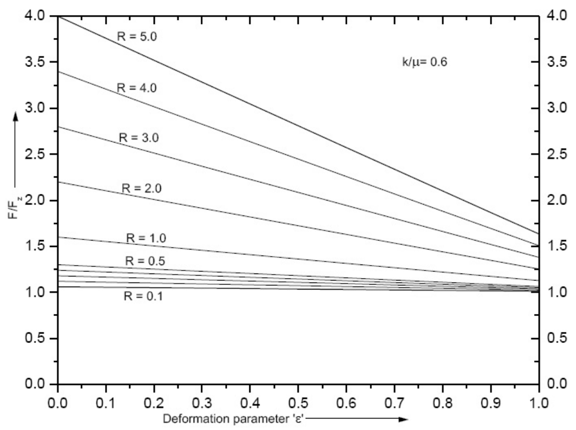

Fig. 5. Variation of Oseen's drag for deformed prolate spheroid in axial micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R'(Using Table 4)

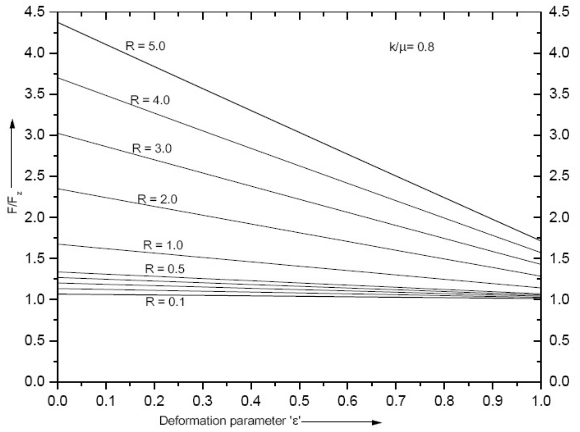

Fig. 6. Variation of Oseen's drag for deformed prolate spheroid in axial micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R'(Using Table 5)

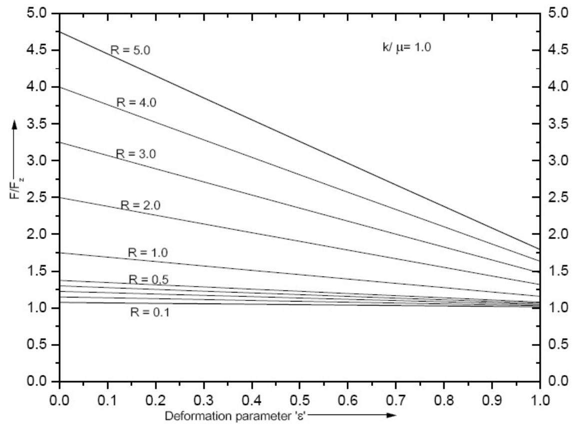

Fig. 7. Variation of Oseen's drag for deformed prolate spheroid in axial micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R'(Using Table 6)

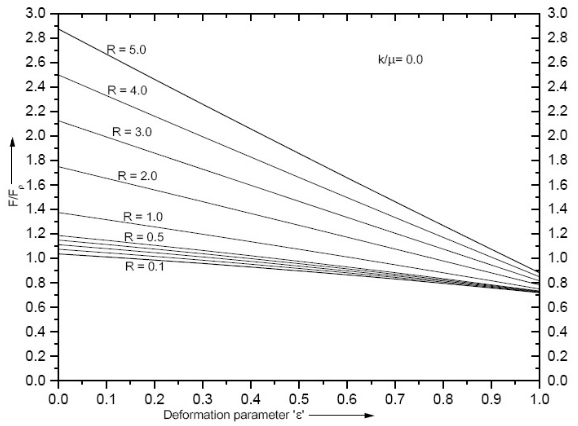

Fig. 8. Variation of Oseen's drag for deformed prolate spheroid in transverse micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 7)

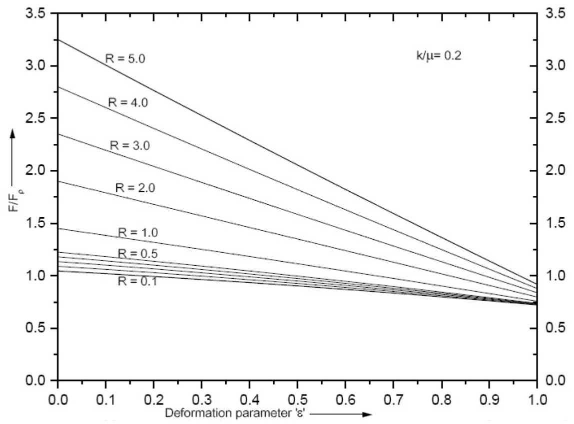

Fig. 9. Variation of Oseen's drag for deformed prolate spheroid in transverse micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 8)

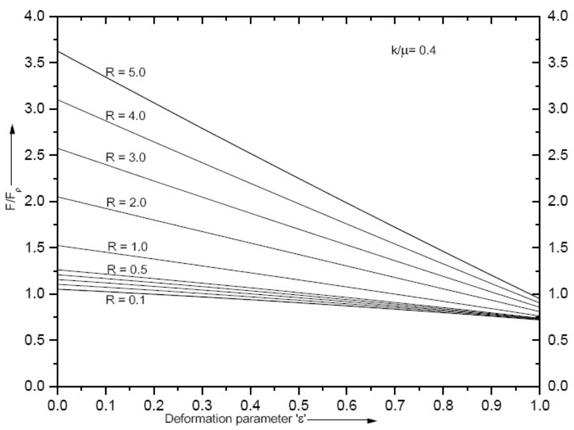

Fig. 10. Variation of Oseen's drag for deformed prolate spheroid in transverse micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 9)

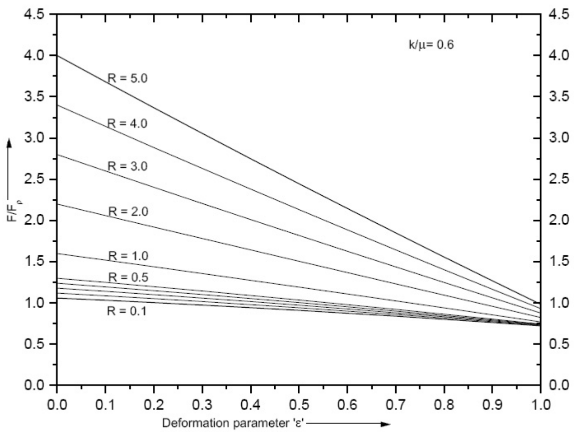

Fig. 11. Variation of Oseen's drag for deformed prolate spheroid in transverse micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 10)

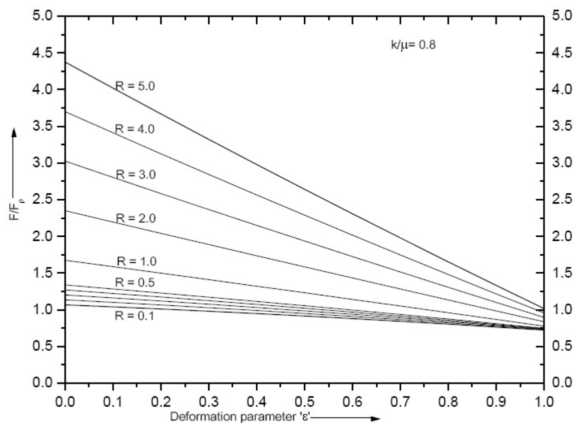

Fig. 12. Variation of Oseen's drag for deformed prolate spheroid in transverse micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 11)

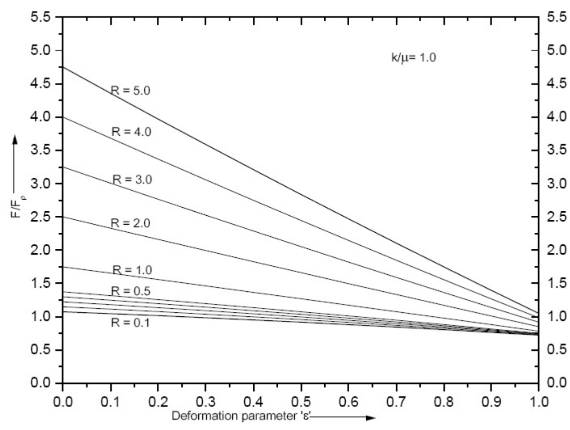

Fig. 13. Variation of Oseen's drag for deformed prolate spheroid in transverse micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 12)

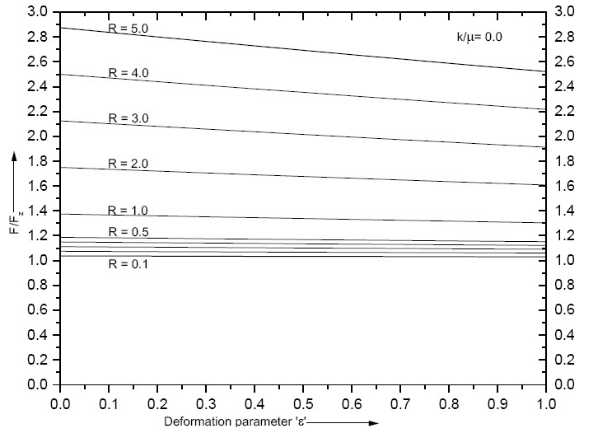

Fig. 14. Variation of Oseen's drag for deformed oblate spheroid in axial micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 13)

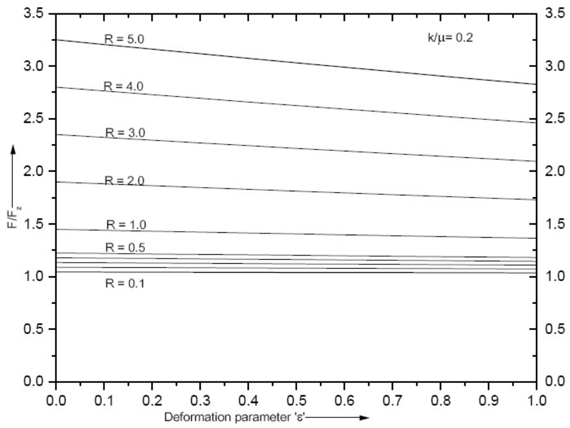

Fig. 15. Variation of Oseen's drag for deformed oblate spheroid in axial micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 14)

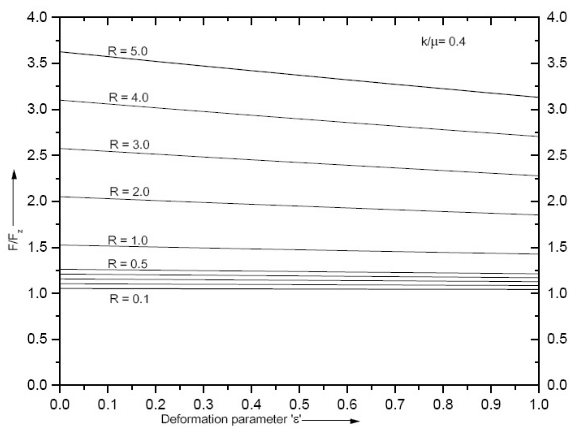

Fig. 16. Variation of Oseen's drag for deformed oblate spheroid in axial micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 15)

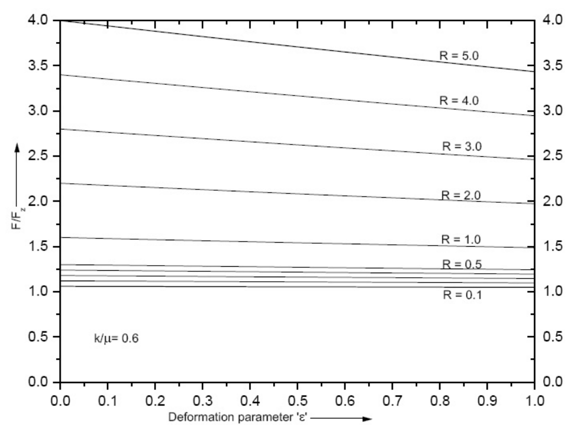

Fig. 17. Variation of Oseen's drag for deformed oblate spheroid in axial micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 16)

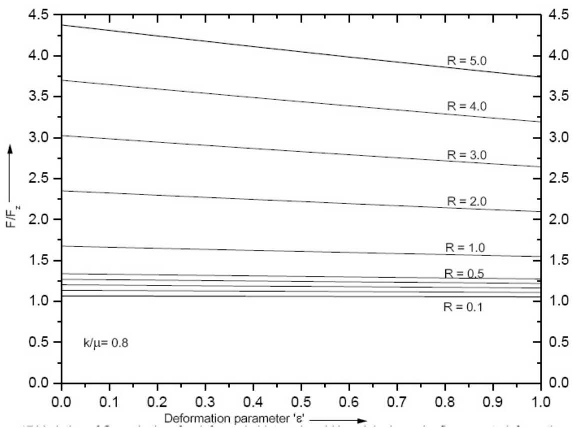

Fig. 18. Variation of Oseen's drag for deformed oblate spheroid in axial micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 17)

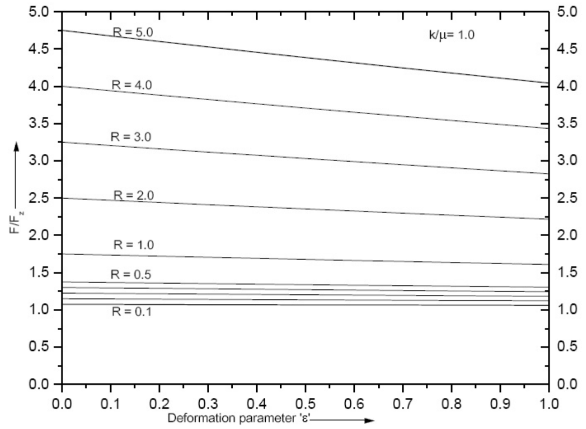

Fig. 19. Variation of Oseen's drag for deformed oblate spheroid in axial micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 18)

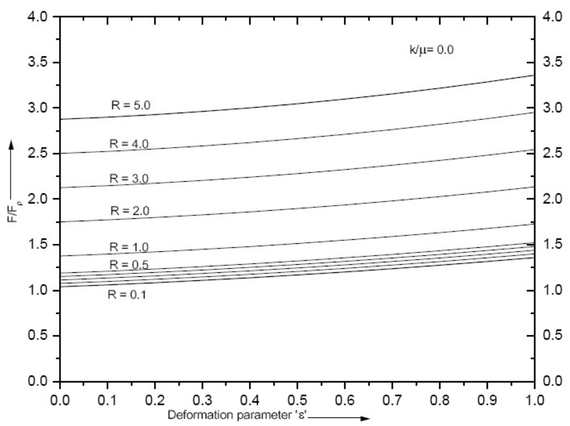

Fig. 20. Variation of Oseen's drag for deformed oblate spheroid in transverse micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 19)

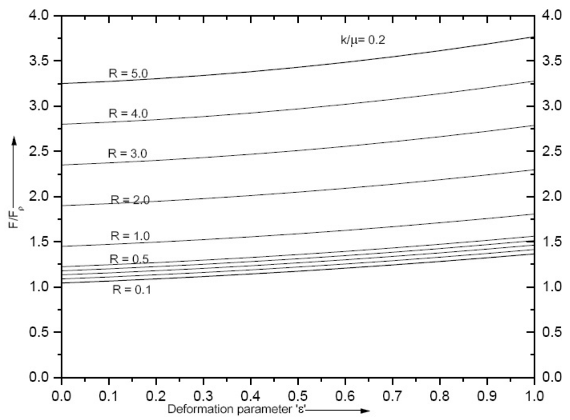

Fig. 21. Variation of Oseen's drag for deformed oblate spheroid in transverse micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 20)

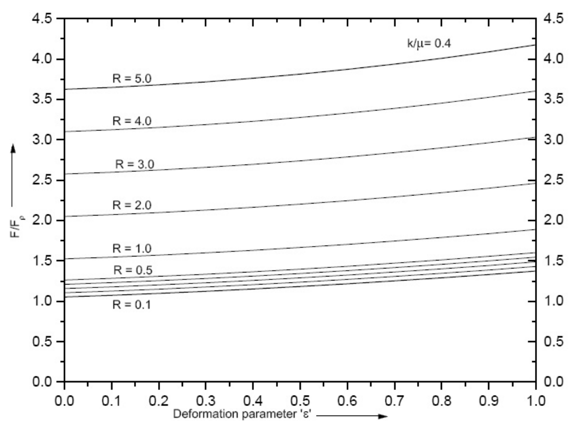

Fig. 22. Variation of Oseen's drag for deformed oblate spheroid in transverse micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 21)

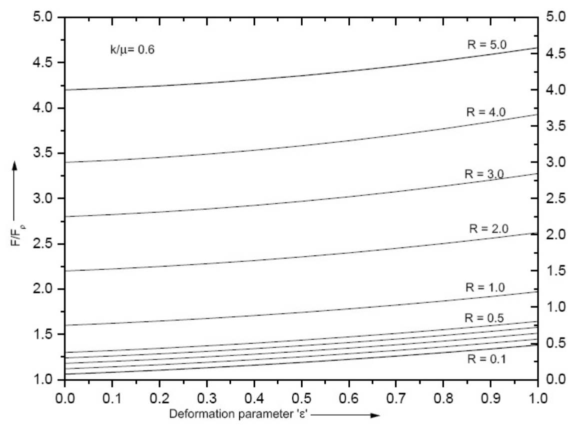

Fig. 23. Variation of Oseen's drag for deformed oblate spheroid in transverse micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 22)

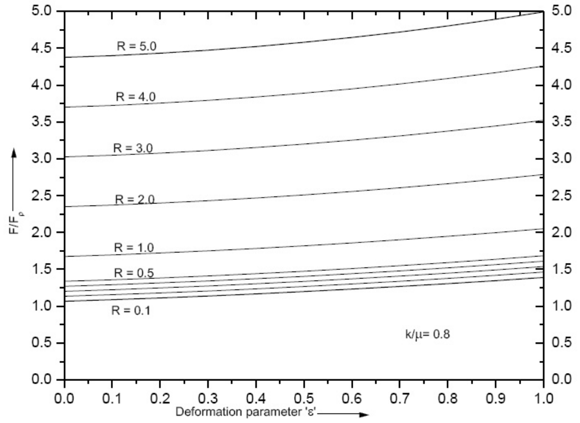

Fig. 24. Variation of Oseen's drag for deformed oblate spheroid in transverse micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 23)

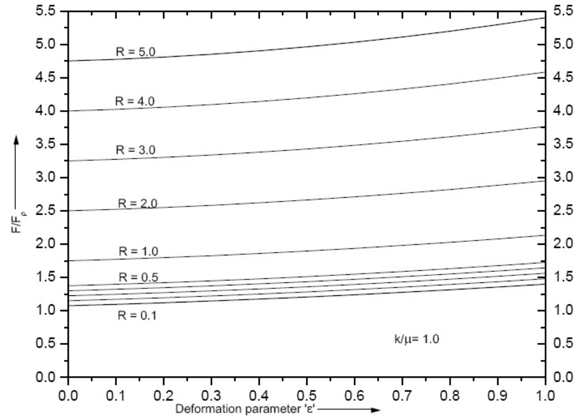

Fig. 25. Variation of Oseen's drag for deformed oblate spheroid in transverse micropolar flow w. r. t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 24)

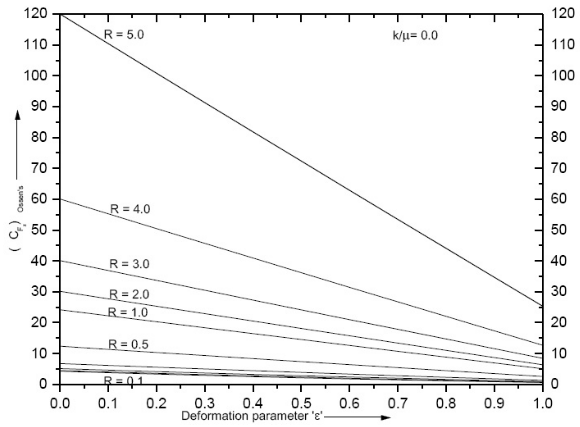

Fig. 26. Variation of non-dimensional Oseen's drag for deformed prolate spheroid in axial micropolar flow w.r.t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 25)

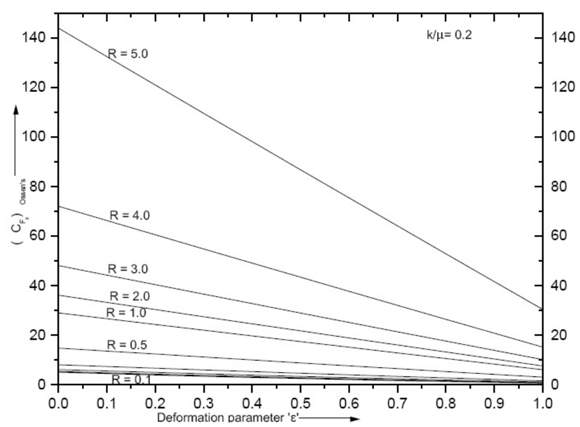

Fig. 27. Variation of non-dimensional Oseen's drag for deformed prolate spheroid in axial micropolar flow w.r.t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 26)

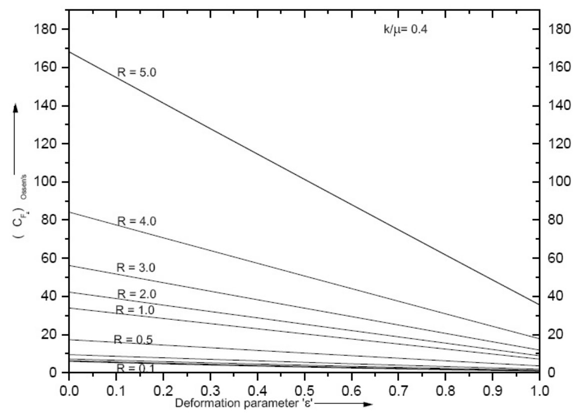

Fig. 28. Variation of non-dimensional Oseen's drag for deformed prolate spheroid in axial micropolar flow w.r.t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 27)

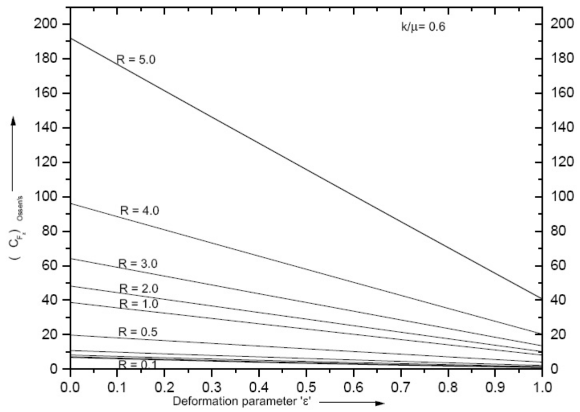

Fig. 29. Variation of non-dimensional Oseen's drag for deformed prolate spheroid in axial micropolar flow w.r.t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 28)

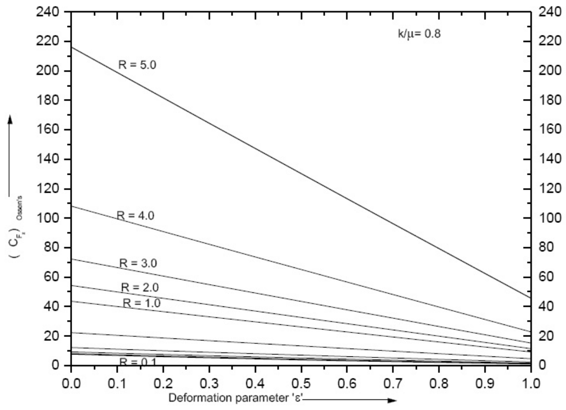

Fig. 30. Variation of non-dimensional Oseen's drag for deformed prolate spheroid in axial micropolar flow w.r.t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 29)

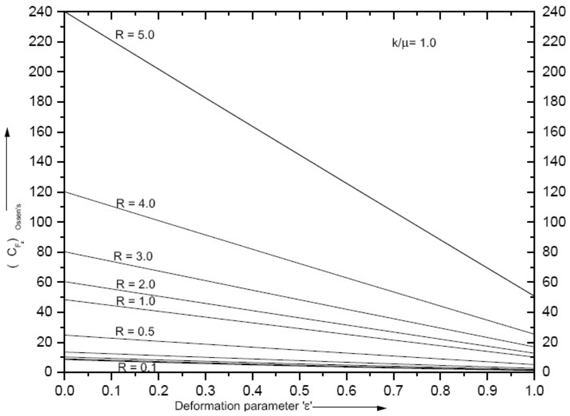

Fig. 31. Variation of non-dimensional Oseen's drag for deformed prolate spheroid in axial micropolar flow w.r.t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 30)

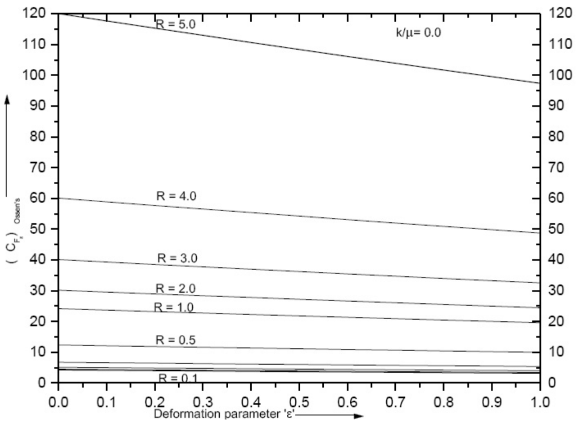

Fig. 32. Variation of non-dimensional Oseen's drag for deformed oblate spheroid in axial micropolar flow w.r.t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 31)

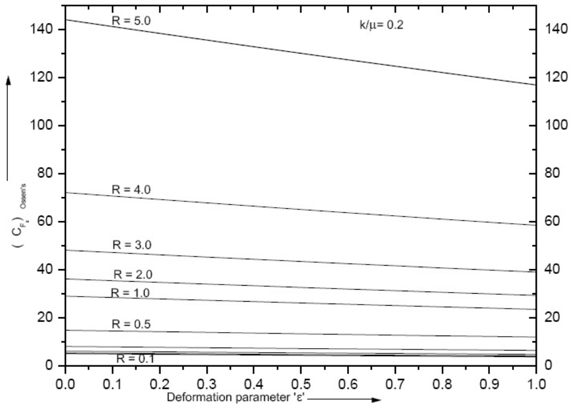

Fig. 33. Variation of non-dimensional Oseen's drag for deformed oblate spheroid in axial micropolar flow w.r.t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 32)

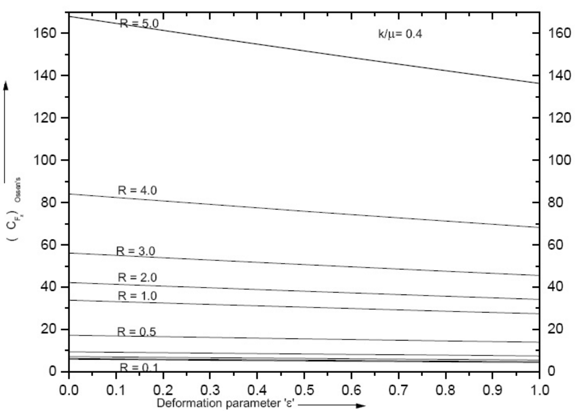

Fig. 34. Variation of non-dimensional Oseen's drag for deformed oblate spheroid in axial micropolar flow w.r.t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 33)

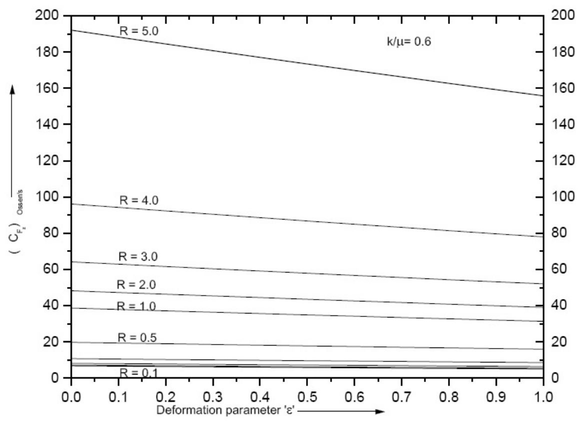

Fig. 35. Variation of non-dimensional Oseen's drag for deformed oblate spheroid in axial micropolar flow w.r.t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 34)

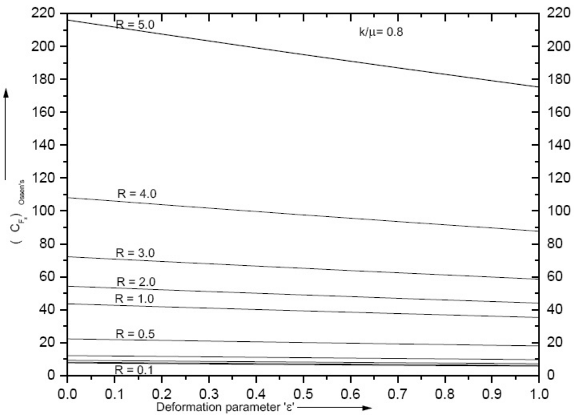

Fig. 36. Variation of non-dimensional Oseen's drag for deformed oblate spheroid in axial micropolar flow w.r.t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 35)

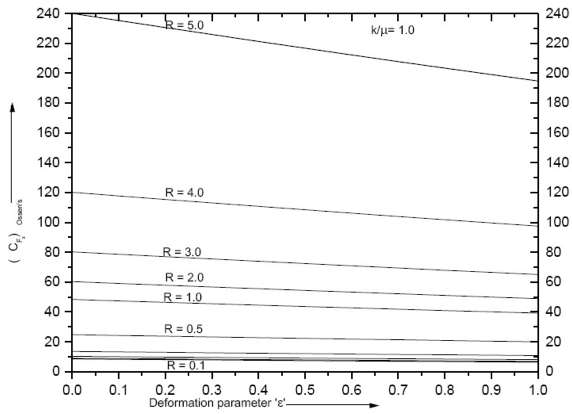

Fig. 37. Variation of non-dimensional Oseen's drag for deformed oblate spheroid in axial micropolar flow w.r.t. deformation parameter 'ε' for various values of micropolarity coefficent k/μ and Reynolds number 'R' (Using Table 36)

8. Conclusion

The new analytic method to evaluate the expressions of Oseen's correction to Stokes drag on small axially symmetric particle placed under uniform stream parallel to axis of symmetry(longitudinal flow) and perpendicular to axis of symmetry(transverse flow) are calculated in micropolar fluid with small micropolarity parameter âĂŸkâĂŹ is advanced. The proposed expressions of drag on axially symmetric particle in both configuration in micropolar fluid need not to solve the Stokes equation under the restriction of no-slip boundary conditions but provide similar solutions as we get on solving the equation. The proof of the proposed method is not provided here as it may directly be achieved by following the proof of DS-conjecture starting from basic integral formula(fundamental solution given inShu and Chwang [22] of drag on sphere in micropolar fluid. It is interesting to be concluded here that the proposed expressions may be written directly for axially symmetric particle by replacing $\mu \to \mu + k$ in DS-conjecture. Then, the Oseen's correction to this Stokes drag on axially symmetric particle placed in axial micropolar fluid has been obtained by applying Brenner's formulae Brenner [3] which further extended to transverse flow. The results have been applied further to deformed prolate and oblate spheroid. Numerical values of drag in various situations and non-dimensional drag values are calculated and presented in tables 1-36. Corresponding variations are depicted in Figs. 2-37. Authors are also trying to exploit the present method to evaluate Oseen's correction to Stokes drag on porous axially symmetric bodies in micropolar fluid and may appear in future work.

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References

[1] S. Datta, D.K. Srivastava, Stokes drag on axially symmetric bodies: a new approach, Proceedings Math. Sci., Ind. Acad. Sci.109(4) (1999) 441-452.

[2] S. Datta, S.K. RathoreSingh, Slow uniform flow of a micropolar fluid past a prolate spheroid, Indian J. Pure Appl. Math. 14(12) (1983) 1474-1483.

[3] H. Brenner, The Oseen resistance of a particle of arbitrary shape, J. Fluid Mech. 11(1961) 604-610.

[4] A.C. Eringen, Theory of micropolar fluids, J. Math. Mech. 16(1966) 1-18.

[5] G.G. Stokes, On the effect of the internal friction of fluids on the motion of pendulums, Trans. Camb. Phil. Soc.9 (1851) 182-187.

[6] C.W. Oseen, NeuereMethoden und Ergebnisse in der Hydrodynamik. Leipzig: AkademischeVerlagsgesellschaft (1927).

[7] S. Kaplun, Low Reynolds number flow past a circular cylinder, J. Math. Mech. 6 (1957) 595-603.

[8] S. Kaplun, P.A. Lagerstrom, Asymptotic expansions of Navier-Stokes solution for small Reynolds numbers, J. Math. Mech. 6 (1957) 585-593.

[9] I. Proudman, J.R.A. Pearson, Expansions at small Reynolds numbers for the flow past a sphere and a circular cylinder, J. Fluid Mech. 2 (1957) 237-262.

[10] I.D. Chang, Stokes flow of a conducting fluid past an axially symmetric body in the presence of a uniform magnetic field, J. Fluid Mech. 9 (1960) 473.

[11] L.E. Payne, W.H. Pell, The Stokes flow problem for a class of axially symmetric bodies, J. Fluid Mech. 7(4) (1960) 529-549.

[12] S.K.L. Rao, P.B. Rao, Slow stationary flow of a micropolar incompressible fluid past a sphere, J. Engg. Mathematics. 4(3) (1970) 209-217.

[13] M.E. Erdogan,Dynamics of polar fluids, ActaMechanica.15 (1972) 233-253.

[14] T. Ariman, M.A. Turk, N.D. Sylvester, Microcontinuum Fluid MechanicsïĂŋa review. 11 (1973) 905-930.

[15] H. Ramkissoon, S.R. Majumdar,Drag on an axially symmetric body in the Stokes flow of micropolar fluid, Physics of Fluids.19(1976) 16-21.

[16] H. Ramkissoon, M.E. O'Neill, Stokes force in microcontinuum fluid mechanics, ActaMechanica. 46 (1983) 255-263.

[17] W.E. Olmstead, S.R. Majumdar, Fundamental Oseen solution for the 2-dimensional flow of a micropolar fluid, Int. J. Eng. Sci.21(5) (1983) 423-430.

[18] A.T. Chwang, T.Y. Wu, Hydromechanics of low Reynolds number flow-part 2: singularity method for Stokes flows, J. Fluid Mech. 67 (1975) 787-815.

[19] H. Ramkissoon, Flow of a Micropolar Fluid Past a Newtonian Fluid Sphere, ZAMM. 65(12) (1985) 635-637.

[20] T.K.V. Iyengar, T.K.V. D. S. Charya, Stokes flow of an incompressible micropolar fluid past an approximate sphere, Int. J. Engng Sci. 31(1)(1993) 115-123.

[21] H. Hayakawa, Slow viscous flows in micropolar fluids, Physical Review E. 61(5)(2000) 5477-5492.

[22] Jian-Jun. Shu, A.T. Chwang, Generalized fundamental solutions for unsteady viscous flows, Physical Review E. 63 (2001) 051201(7 pages).

[23] D. Palaniappan, H. Ramkissoon, A drag formula revisited, Int. J. Engng. Sci. 43(2005) 1498-1501.

[24] M.S. Faltas, E.I.Saad, Stokes flow with slip caused by the axisymmetric motion of a sphere bisected by a free surface bounding a semi-infinite micropolar fluid, Int. J. Engng. Sci. 43 (2005) 953-976.

[25] J.V. MurthyRamana, N.Ch.S.N.Iyengar, P. Aparna, Slow steady rotation of a permeable sphere in an incompressible micropolar fluid, IeJEMTA(Engineering and Mathematics). 2 (2007). 44-60.

[26] Karl-Heinz.Hoffmann, D. Marx, Nikolaid D. Botkin, Drag on spheres in micropolar fluids with nonzero boundary conditions for microrotations, J. Fluid Mech.590, (2007) 319-330.

[27] M.S. Faltas, E.I.Saad, Three-dimensional Stokes flow caused by a translating-rotating sphere bisected by a free surface bounding a semi-infinite micropolar fluid, Mathematical Methods in the Applied Sciences. 31(2008) 1233-1256.

[28] Jian-Jhu.Shu, Jenn Shiun. Lee, Fundamental solutions for micropolar fluids, J. Engng. Math. 61(2008) 69-79.

[29] H.H. Sherief, M.S. Faltas, E.A. Ashmawy, Axi-symmetric translational motion of an arbitrary solid prolate body in a micropolar fluid, Fluid Dynamics. 42 (2010) 065504(18 pages).

[30] T.K.V. Iyengar, T.S.L. Radhika, Stokes flow of an incompressible micropolar fluid past a porous spheroidal shell, Bulletin of The Polish Academy of Sciences Technical Sciences. 59(1) (2011) 63-74.

[31] S. Deo, P. Shukla, Creeping flow of micropolar fluid past a fluid sphere with non zero spin boundary condition, Int. J. Engng. Tech. 1(2)(2012) 67-76.

[32] D.K. Srivastava, R.R. Yadav, S. Yadav, Steady Oseen flow past deformed sphere: an analytic approach, Journal of Theoretical and Applied Mechanics, Polish Society of Theoretical and Applied Mechanics. 51(3)(2013) 661-673.

[33] R.A. Krasovitskaya, M.I. Ermolaev, A.A. Mukhin, R.S. MilâĂŹshenko, Use of Oseen's correction in sedimentation analysis of powders, Chemistry and Materials Science(Refractories and Industrial Ceramics). 11(7-8)(1970) 518-

520.

[34] Thomas W. Dyer, Tihiro. Ohkawa, Acoustic levitation by Oseen drag, J. Acoust. Soc. Am. 92(4) (1992) 2207-2211.

[35] Yuan-cheng. Fung, Biomechanics: Circulation. 2nd ed. New York, NY: Springer-Verlag. (1997)

[36] D.K. Srivastava, R.R. Yadav, Nirmal. Srivastava, Oseen's correction to Stokes drag on axially symmetric arbitrary particle in transverse flow: a new approach, Theoretical and Applied Mechanics(TAM), Belgrade, Serbia. 41(3)(2014) 177-212.

[37] J. Happel, H. Brenner, Low Reynolds Number Hydrodynamics, Nijhoff, Dordrecht, TheNederlands (1964).

[38] S. Senchenko, H.J. Keh, Slipping Stokes flow around a slightly deformed sphere, Physics of Fluids 18 (2006) 088101-04.

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