Particle Orientation in a shear flow for power law and viscoelastic Fluids

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Objective

Influence on the particle shape and fluid behavior on the validity of Jeffery’s equation

\[ \dot{p} = W \cdot p + \zeta (D \cdot p - (D \cdot p)p) \]

\[ \zeta = \frac{\beta^2 - 1}{\beta^2 + 1} \] Shape factor

\[ \beta = \frac{D}{L} \] Aspect ratio

Prolate and oblate ellipsoids; cylinders

Direct numerical simulations

- Fictitious domain method:
  - particle defined by a level set
  - Lagrange multiplier for rigidity condition
  - Velocity imposed on upper and lower walls
  - Finite element solution Navier-Stokes + extra-stress

\( \Rightarrow \) velocity and pressure on the whole domain

- Particle position update:
  - Velocity of center of mass: \( u(X_i) \)
  - Rotation vector: \( \vec{\omega} = \frac{1}{2} \nabla \times u(X_i) \)

\[ \frac{dX_i}{dt} = u(X_i) + \frac{dp}{dt} = \vec{\omega} \times p \]

Power Law fluid

\[ \eta = K \dot{\gamma}^{n-1} \]

Jeffery’s orbit: \( n = 0.1 \)

\[ \sigma_f = -p I + 2\eta_f (u + \tau) \]

\[ \tau = \frac{\beta^2 (\beta^2 + 1)}{\beta^2 - 1} \rightarrow \beta_{equivalent} \]

- prolate
  \( T_{kneut} < T_{Pow} \rightarrow \beta_{equivalent} \uparrow \)
- oblate
  \( T_{kneut} > T_{Pow} \rightarrow \beta_{equivalent} \downarrow \)

\( \beta_{equivalent} = \text{Cte?} \)

\[ |(p)| = \sqrt{\frac{\omega_x^2 + \omega_y^2 + (\omega_z + \frac{5}{6})^2}{\frac{1}{3} (p_x p_y)^2 + (p_y p_z)^2 + (1 - p_z^2 - p_y^2)^2}} \]

\[ \beta = \frac{3}{\alpha} \quad \beta = \frac{1}{3} (-\) \]

\[ n = 0.1 \]

Oldroyd-B fluid

\[ \sigma_f = -p I + 2\eta_f (u + \tau) \]

\( \lambda \) relaxation time from 0.1 to 5

\( \rightarrow \) Main axis // vorticity axis

\[ \frac{d}{dt} u \cdot \nabla s - (\nabla u \cdot s + s \cdot \nabla u') + \frac{1}{(3s-1)} (3s-1) = 0 \]

Rotation around vorticity axis \( e_r \) or \( e_z \)