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

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## Objective

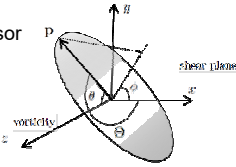
Influence on the particle shape and fluid behavior on the validity of Jeffery' equation

$$\dot{\mathbf{p}} = \mathbf{W} \cdot \mathbf{p} + \xi (\mathbf{D} \cdot \mathbf{p} - [\mathbf{D} : \mathbf{p}\mathbf{p}] \mathbf{p})$$

$\mathbf{W}$  vorticity tensor;  $\mathbf{D}$  deformation rate tensor

$$\xi = \frac{\beta^2 - 1}{\beta^2 + 1} \text{ Shape factor}$$

$$\beta = \frac{L}{D} \text{ Aspect ratio}$$



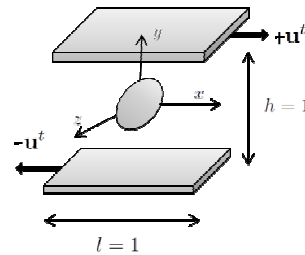
Prolate and oblate ellipsoids; cylinders

## 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

→ velocity and pressure on the whole domain



### Particle position update:

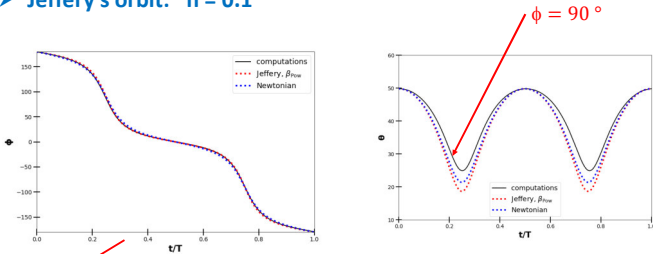
- Velocity of center of mass:  $\mathbf{u}(X_c)$
- Rotation vector:  $\vec{\omega} = \frac{1}{2} \nabla \times \mathbf{u}(X_c)$
- Adams-Bashfort scheme

$$\frac{d\mathbf{X}_c}{dt} = \mathbf{u}(X_c); \frac{d\mathbf{p}}{dt} = \vec{\omega} \times \mathbf{p}$$

## Power Law fluid

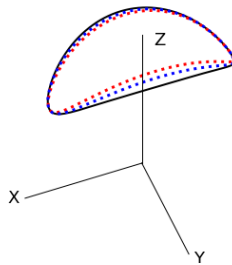
$$\eta = K \dot{\gamma}^{n-1}$$

### Jeffery's orbit: $n = 0.1$



$$T = \frac{2\pi(\beta^2 + 1)}{\dot{\gamma}\beta} \rightarrow \beta_{\text{equivalent}}$$

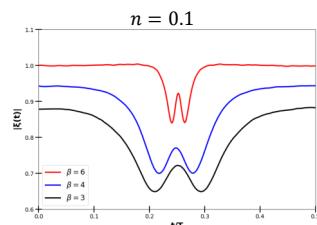
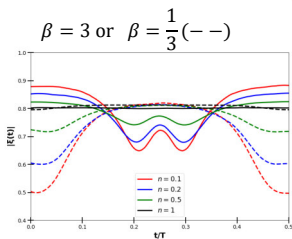
- prolate  $T_{\text{Newt}} < T_{\text{Pow}} \rightarrow \beta_{\text{equivalent}} \nearrow$
- oblate  $T_{\text{Newt}} > T_{\text{Pow}} \rightarrow \beta_{\text{equivalent}} \searrow$



n	$\beta = 3$				$\beta = 1/3$			
	$T_{\text{Pow}}$	$\beta_{\text{Pow}}$	$\xi_{\text{Pow}}$	$\langle \ \Delta \mathbf{p}\  \rangle$	$T_{\text{Pow}}$	$\beta_{\text{Pow}}$	$\xi$	$\langle \ \Delta \mathbf{p}\  \rangle$
1	21.08	3.02	0.8029	0.007	21.94	0.320	0.8139	0.004
0.5	21.85	3.16	0.8181	0.02	21.34	0.326	0.8082	0.04
0.2	22.76	3.32	0.8338	0.04	20.92	0.334	0.7995	0.08
0.1	23.83	3.51	0.8497	0.05	20.83	0.336	0.7975	0.11

$\beta_{\text{equivalent}} = \text{Cte} ?$

$$\|\xi(\mathbf{p})\| = \frac{\sqrt{\omega_x^2 + \omega_y^2 + (\omega_z + \frac{\dot{\gamma}}{2})^2}}{\frac{\dot{\gamma}}{2} \sqrt{(p_x p_z)^2 + (p_y p_z)^2 + (1 - p_y^2 - p_z^2)^2}}$$



## Oldroyd-B fluid

$$\sigma_f = -p\mathbf{I} + 2\eta_f \varepsilon(\mathbf{u}) + \tau ; \quad \tau = \frac{\eta_e}{\lambda} (3\mathbf{s} - \mathbf{I})$$

$$\frac{\partial \mathbf{s}}{\partial t} + \mathbf{u} \cdot \nabla \mathbf{s} - (\nabla \mathbf{u} \cdot \mathbf{s} + \mathbf{s} \cdot \nabla \mathbf{u}^t) + \frac{1}{\lambda} (3\mathbf{s} - \mathbf{I}) = 0$$

$\lambda$  relaxation time from 0.1 to 5 → Main axis // vorticity axis

