Modelling of gas-solid turbulent channel flow with non-spherical particles with large Stokes numbers

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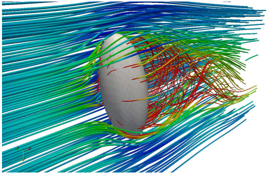
George Mallouppas, Fan Zhao, Marian Zastawny



Cost Action FP1005
October 13 2011

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Summary

- "True" DNS for non-spherical particles to generate a database with lift, drag, torque, torque.
- LES of turbulent channel flow (Kussin & Sommerfeld, 2002) with point particles using the database.
- New large-scale Quaternion integration framework to update to particle positions, taking into account collisions and orientation.
- Conclusion: Rough walls have a big effect for spheres, even bigger for non-spherical particles.
- Conclusion: Disc-shaped particles flow more "steady" then fibre-shaped particles.

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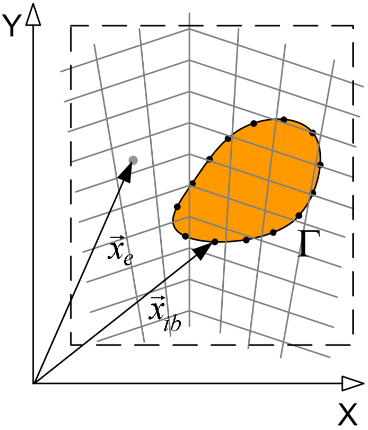
DNS - Immersed Boundary Method



- Fluid domain is represented by an Eulerian grid.
- A Lagrangian grid represents the solid-fluid interface
- Non-distributed force method, Mark and van Wachem (2008), van Wachem and Oliveira (2010).
- Implicit and 2nd order accurate.
- Geometric restriction: closed and solid bodies.

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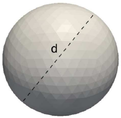
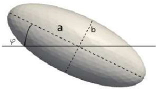
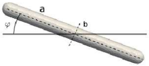
shape	sphericity	proportions	size
sphere	1		$d = 200\,\mu m$
			
ellipsoid 1	0.88	$\frac{a}{b} = \frac{5}{2}$	$a = 368\,\mu m$ $b = 147\,\mu m$
			
fiber 1	0.70	$\frac{a}{b} = 5$	$a = 510\,\mu m$ $b = 102\,\mu m$
			

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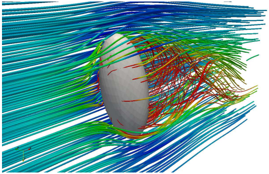
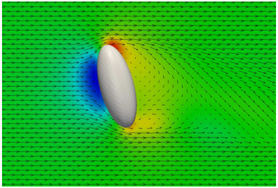
Results: DNS Simulations





$$C_D(\varphi) = C_{D,\varphi=0^o} + (C_{D,\varphi=90^o} - C_{D,\varphi=0^o}) sin^{a_0} \varphi$$

$$C_{D,\varphi=0^o} = \frac{a_1}{Re^{a_2}} + \frac{a_3}{Re^{a_4}}$$

$$C_{D,\varphi=90^o} = \frac{a_5}{Re^{a_6}} + \frac{a_7}{Re^{a_8}}$$

$$C_L = \left(\frac{b_1}{Re^{b_2}} + \frac{b_3}{Re^{b_4}}\right) sin(\varphi)^{b_5 + b_6 Re^{b_7}} cos(\varphi)^{b_8 + b_9 Re^{b_{10}}}$$

$$C_T = \left(\frac{c_1}{Re^{c_2}} + \frac{c_3}{Re^{c_4}}\right) sin(\varphi)^{c_5 + c_6 Re^{c_7}} cos(\varphi)^{c_8 + c_9 Re^{c_{10}}}$$

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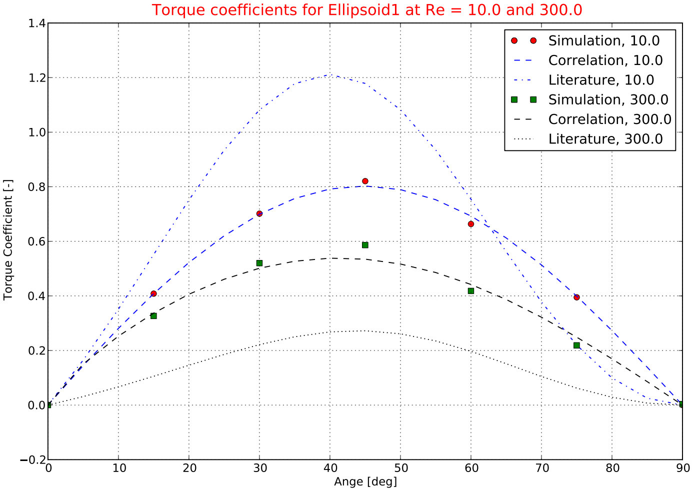
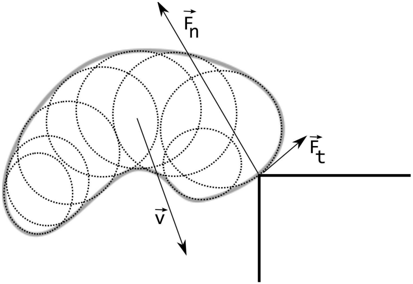
Zastawny, Mallouppas, Fan, van Wachem, Int. J. Multiphase Flow, accepted for publication

Results from DNS



Rosendahl (2000)

contacts are found through "spheres":



Hertzian contact model:

$$\boldsymbol{F}_n(t) = K_n(t)\delta_n^{\frac{3}{2}}(t)\boldsymbol{n}(t)$$
$$\boldsymbol{F}_t(t) = min(\mu \boldsymbol{F}_n(t), K_t(t)\delta_t(t))$$

Quaternion update:

$$q'^{n+1} = \tilde{q}'^{n+\frac{1}{2}} q^n$$
$$\tilde{q}'^{n+\frac{1}{2}} = [\cos \frac{\|\omega'^{n+\frac{1}{2}}\| \triangle t}{2}, \sin \frac{\|\omega'^{n+\frac{1}{2}}\| \triangle t}{2} \frac{\omega'^{n+\frac{1}{2}}}{\|\omega'^{n+\frac{1}{2}}\|}]$$
$$\omega'^{n+1} = \bar{\bar{I}}'^{n+1} \times \boldsymbol{L}^{n+1}$$

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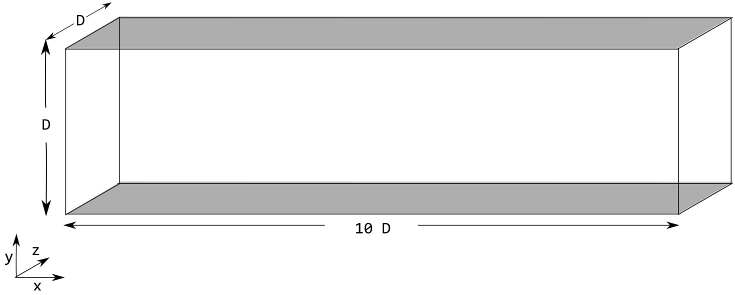
Simulation Domain



D	d_p	m	Re_D	$< U >$	St
$35\,mm$	$200\,\mu m$	1.0	42,000	$19.7\,m/s$	52

Kussin and Sommerfeld (2002)

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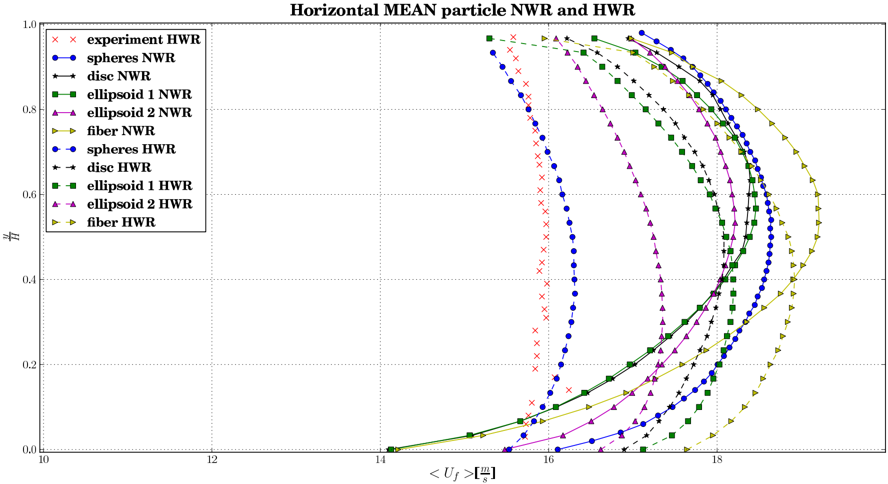
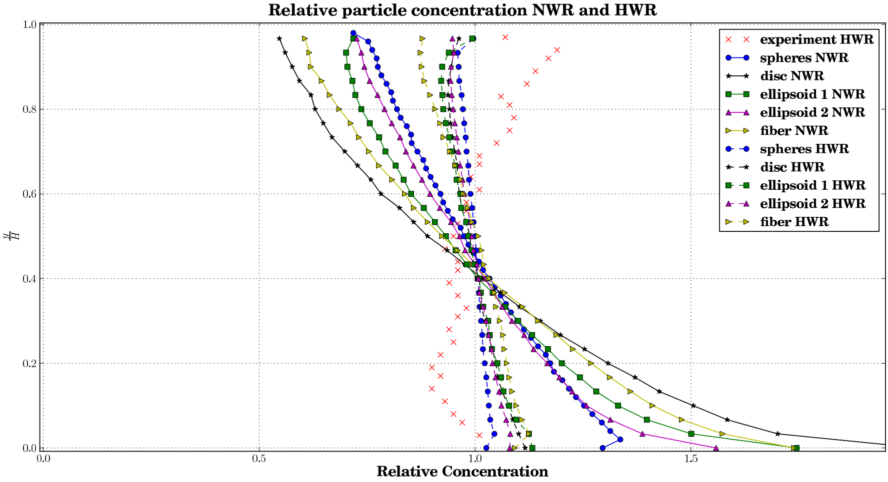


average velocity of particles vs channel height

Non-spherical particles



Concentration of particles vs channel height

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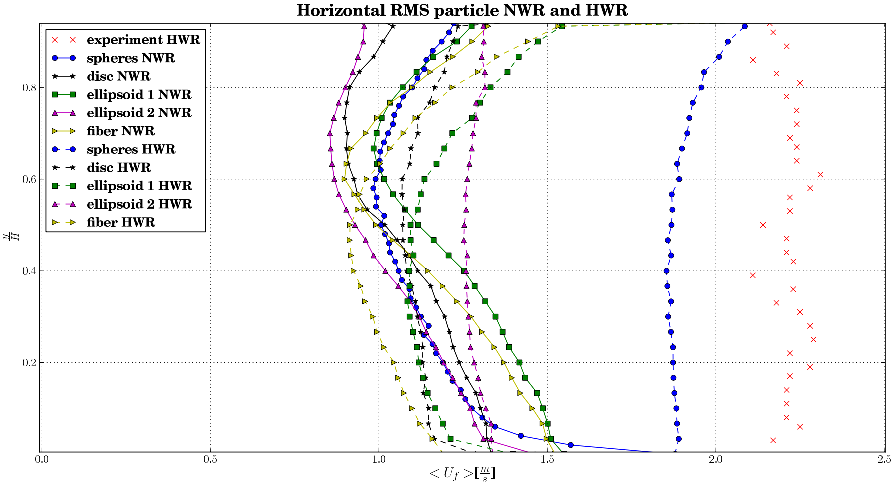
Non-spherical particles



RMS velocity of particles vs channel height

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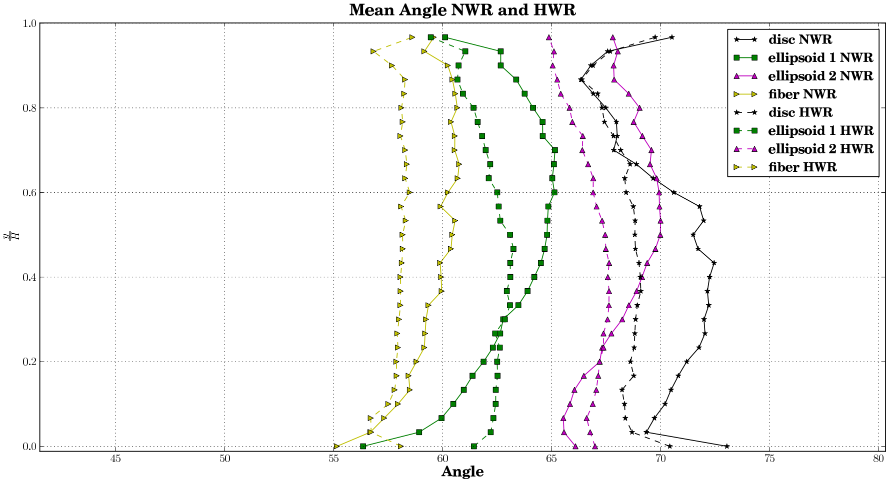
NON-SPHERICAL PARTICLES



Angle of particles vs channel height

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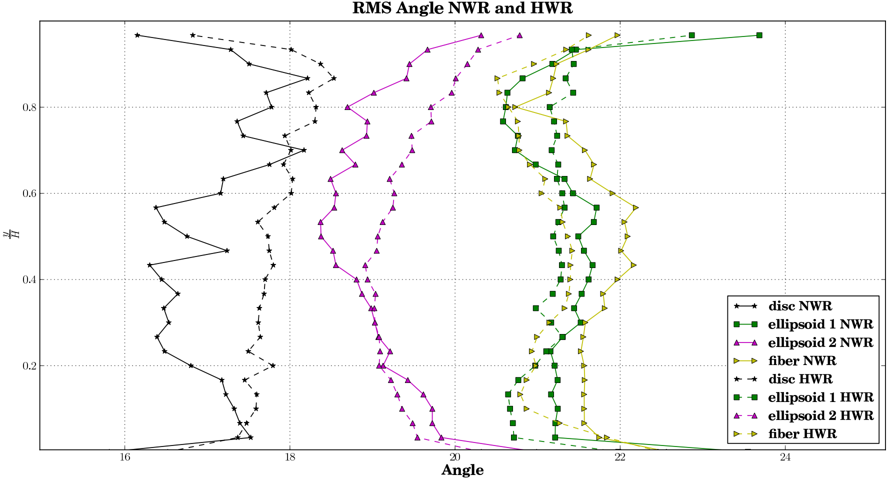

RMS of angle of particles vs channel height

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