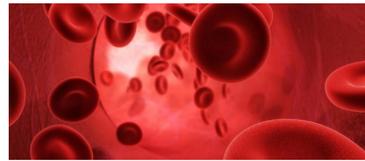


ER1: Prediction of Viscosity of Highly Concentrated Suspensions

Yousef El Hasadi, Martin Crapper and Antonia Larese

Motivation

- Suspensions are mixtures of particles suspended in liquid.
- Important in nature, they are manifested in blood, bacteria, viruses, living cells flows and sediment transport.
- Essential part of process industries such oil, food, paint and pharmaceuticals.
- Very rich and difficult to predict rheology.
- Determining flow properties such as viscosity is very important.



The Franklin Institute



Mawride group

Ferrero

Stokesian dynamics coupled with DEM approach

$$F_H + F_C + F_B = 0$$

$$F_H = -R_{FU}(X) \cdot (U - U_\infty) + R_{FE}(X) : E$$

$$U_i^\infty = \dot{\gamma} y_i n_x, E^\infty = (n_x n_y + n_y n_x) \frac{\dot{\gamma}}{2}$$

$$\langle F_B(t_n) \rangle = K_B T R_{FU}(X(t_n)) \cdot \nabla \cdot R_{FU}^{-1}(X(t_n))$$

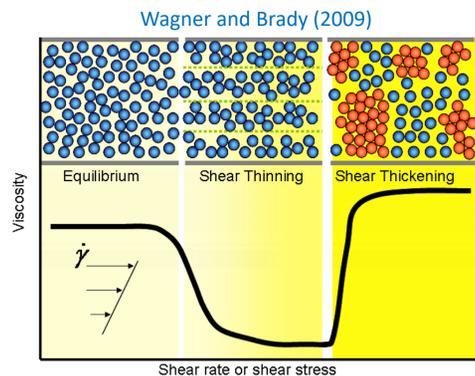
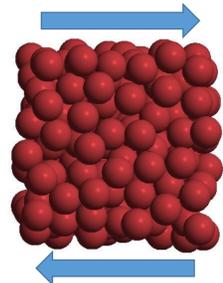
$$|F_{C,tan}| = \mu \leq |F_{C,norm}|$$

$$(U - U_\infty) = R_{FU}^{-1} \cdot (R_{FE}(X) : E^\infty + F_C + F_B)$$

Hydrodynamic Force (Lubrication)

Brownian Force

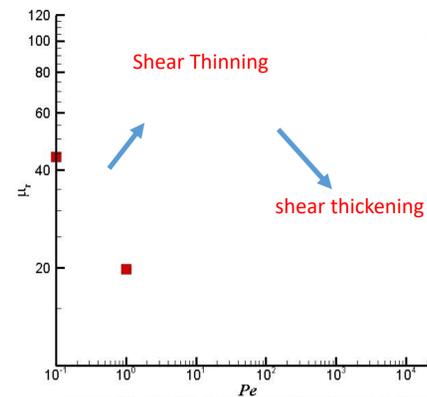
Contact Force



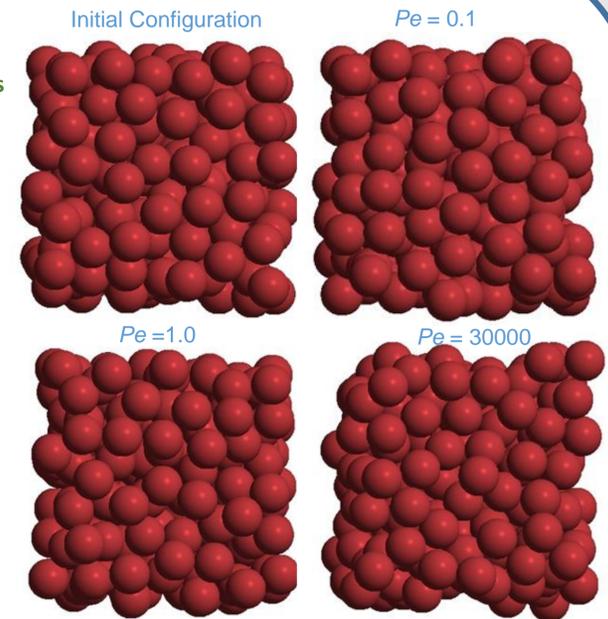
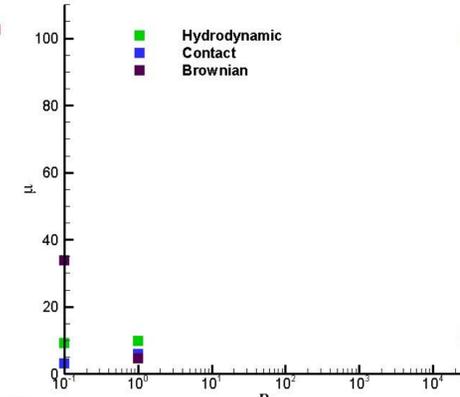
Wagner and Brady (2009)

Results

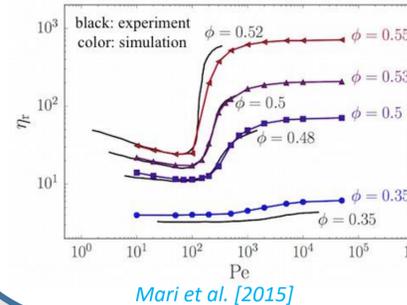
Total relative viscosity at $\phi = 0.5$, and different Pe numbers



Different relative viscosity components at $\phi = 0.5$, and different Pe numbers



Microstructures for the case of $\phi = 0.5$ and different Pe numbers



Mari et al. [2015]

- The Predicted total viscosity shows the expected trend of thinning and thickening at low, and high Pe respectively.
- A good comparison with the experimental results is achieved.

Conclusions & Future work

- A Stokesian dynamics coupled with DEM approach tested successfully for predicting the viscosity of highly dense suspensions.
- The approach is working in both Brownian and non-Brownian regimes.
- Can we make a zero viscosity suspensions?

References

- Mari, Romain, Ryohei Seto, Jeffrey F. Morris, and Morton M. Denn. "Discontinuous shear thickening in Brownian suspensions by dynamic simulation." *Proceedings of the National Academy of Sciences* 112, no. 50 (2015): 15326-15330.
- Wagner, Norman J., and John F. Brady. "Shear thickening in colloidal dispersions." *Physics Today* 62, no. 10 (2009): 27-32.

This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no ITN 607453