Conformational properties of a magnetic filament under flow and an external magnetic field.

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The formation of chain-like structures made of ferromagnetic colloids has been predicted more than four decades ago. Since the pioneering work of Tabata et al.[1] and due to advances in experimental techniques, it is possible to synthesise chains of magnetic colloids with different properties. The formation of these chains has important implications in the behaviour of magnetic fluids and their applications [2].

In this poster we present the results of extensive numerical simulations of a magnetic filament made of ferromagnetic particles, placed in a channel and subjected to a fluid flow and an external magnetic field perpendicular to the latter. We have considered two different flows: Poiseuille and Couette. The simulations combine a hybrid scheme in which fluid particles are coupled to the hydrodynamics via Multiple-Particle Collision dynamics and the interaction between the chain monomers is solved with standard Molecular Dynamics.

We found that, in the presence of a shear flow, the tumbling motion that is characteristic of semiflexible chains at zero field is strongly inhibited by the presence of a perpendicular magnetic field. Beyond a characteristic value, the external magnetic field is able to stabilise the filament with a rather straight conformation and a well defined degree of alignment with the flow. The latter results from the balance between hydrodynamic and magnetic torques. Under these conditions, the orientation of the net magnetic moment of the filament is imposed by the direction of the field. In addition, in the case of a Poiseuille flow, it has been found that the initial position has a long lasting influence on the behaviour of the magnetic filament when the external field is applied [3].

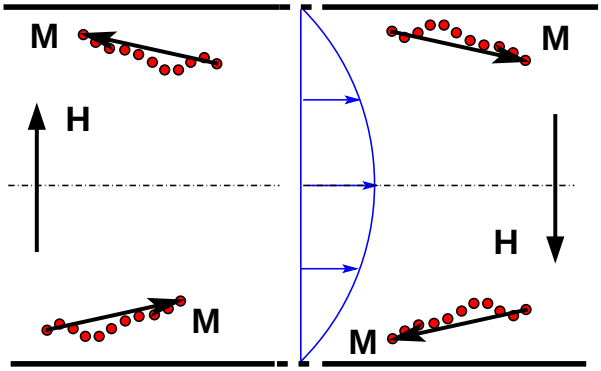

Figure 1: Possible orientations of the filament (chain magnetization M) in a Poiseuille flow and an external magnetic field H.

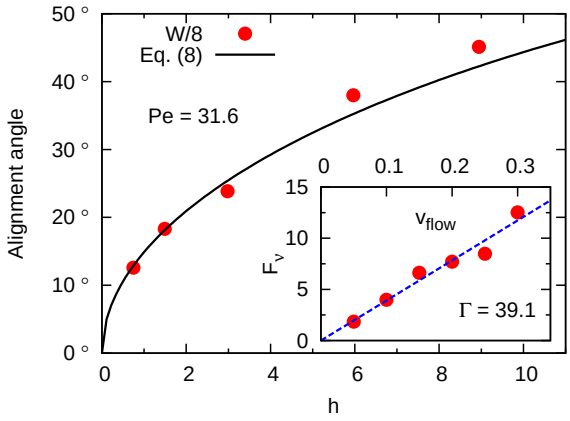

Figure 2: Alignment angle as a function of the strength of the magnetic field in a Poiseuille flow. Flow velocity: 0.3 (Peclet = 31.6). Points correspond to simulation data; black solid line to the theoretical expected behaviour in the linear rod approximation . Inset shows the fit of the friction coefficient, Γ, from simulation data.

[1] O. Tabata, H. Kojima, T. Kasatani, Y. Isono, and R. Yoshida, Chemo-mechanical actuator using self-oscillating gel for artificial cilia, in Proceedings IEEE Sixteenth Annual International Conference on Micro Electro Mechanical Systems, pages 12-15, (2003).

[2] For a review see: H. Wang, Y. Yu, Y. Sun, and Q. Chen, Nano, 6, 1 (2011).

[3] D. Lüsebrink, et al. The Journal of Chemical Physics, 145, 234902 (2016).