Dynamics and clogging of colloidal monolayers magnetically driven through a heterogeneous landscape

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Typically, clogging is usually characterised through its average velocity in all sort of systems: Pedestrian evacuation, silo discharge of granular media, a collectivity of particles driven through an obstacle landscape, among others. When the average speed decreases to zero, the system is considered to be clogged. However, this approach is partial, as it only allows to characterise a fully clogged state where there is no flow of particles, or unclogged state where there is a flow of particles. Recent works [1] show that a more detailed study of the flow distribution of particles through a bottleneck reveals an intermediate regime of abnormal flow. Such abnormal flow has a certain probability of being occluded for a indefinite period of time. The abnormal flow regime can be characterised by the complementary cumulative distribution function (CCDF) of the difference of passing times (t_p) of particles through a constriction, which exhibits a power law distribution that decays as $t_p^{-\alpha}$, with α the characteristic decay exponent.

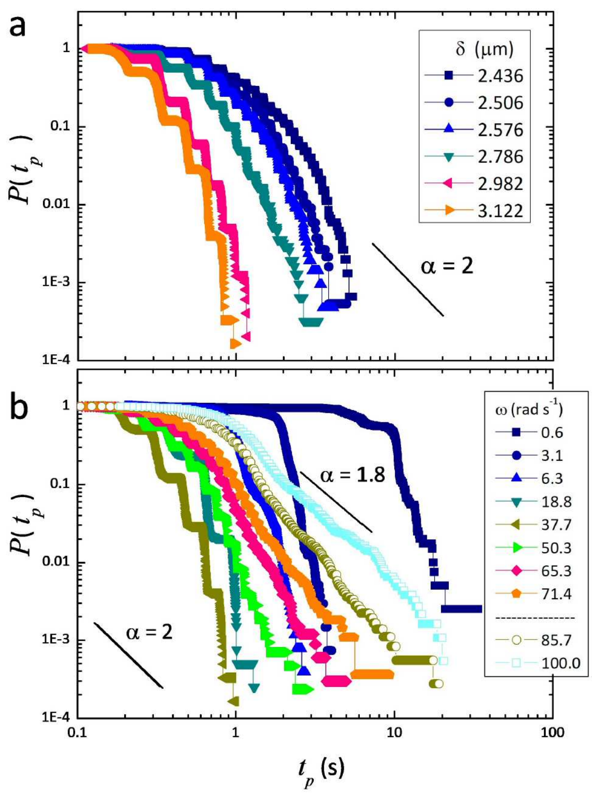

Fig. 1. Cumulative distribution function (CDF) of passing particles trough a constriction. Different colors show a) varying the constriction width and b) varying the frequency.

In this work, we use this approach to characterise a colloidal, microscale system. We combine experiments and numerical simulations to investigate the emergence of clogging in a system of interacting paramagnetic colloidal particles driven against a disordered landscape of larger obstacles. We consider a single aperture in a landscape of immobile silica particles which are irreversibly attached to the substrate. We use an external rotating magnetic field to generate a traveling wave potential which drives the magnetic particles against these obstacles at a constant and frequency tunable speed. Experimentally we find that the particles display an intermittent dynamics with power law distributions at high frequencies. We reproduce these results by using numerical simulations and show that clogging in our system arises at large frequency, when the particles desynchronize with the moving landscape. Further, we use the model to explore the hidden role of flexibility in the obstacle displacements and the effect of hydrodynamic interactions between the particles. We also consider numerically the situation of a straight wall and investigate the range of parameters where clogging emerges in such case. Our work provides a robust method to identify clogging in generical, soft-matter driven systems. [2].

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[1] I. Zuriguel *et al.*, *Clogging transition of many-particle systems flowing through bottlenecks*, Sci. Reports **4**, 7324 (2014)

[2] Sergi G. Leyva, Ralph L. Stoop, P. Tierno, I. Pagonabarraga *Dynamics and clogging of colloidal monolayers magnetically driven through a heterogeneous landscape* , Soft Matter, 2020, **16**, 6985-6992

[3] A. V. Straube, and P. Tierno Europhys. Lett., **103**, 28001, (2013)