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JAMMING MECHANISMS OF DILUTE FIBRE SUSPENSIONS UNDER DEAD-END AND CROSS-FLOW CONDITIONS

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ABSTRACT

The jamming of particles in small constrictions is a critical problem encountered across different systems such as in the dry granular flows and the filtration of colloidal suspensions. While the jamming of suspensions consisting of isotropic particles is well-investigated, we find that the jamming of anisotropic particles such as fibres is less understood. Motivated by the pressure screening process in the pulp and paper industry, we study the fundamental jamming mechanisms of dilute nylon fibre suspensions in a single constriction under dead-end and cross-flow filtration conditions.

We identify three distinct jamming mechanisms for both flow configurations: single fibre bridging, in-situ floc formation (IFF) and upstream floc formation (UFF). The bridging mechanism is a function of fibre to constriction width ratio l/w, position and orientation. With the help of visualization tools and a numerical model, we estimate the range of critical positions and orientations for bridging, which were subject to the flow field as it dictates the trajectories of the fibres. We demonstrate that the number of fibres between bridging events follows an exponential probability distribution and is mostly concentration independent as bridging depends on the probabilities of individual fibres coming from impermissible regions.

The flocculation mechanisms are both functions of l/w and concentration. The IFF mechanism showed a dynamic of intermittent fibre aggregation and shedding over time, which likely arises from the interplay between the hydrodynamic forces and the fibre-fibre and fibre-wall interactions. We show that time intervals between flocculation events follow an exponential probability distribution which is concentration dependent. Moreover, the average time interval between flocculation events is inversely proportional to the square-root of the suspension concentration. Flocculation mechanisms are more likely to result in permanent plugging when the average time interval between events is about half of the total flocculation residence time. Finally, we demonstrate that, unlike isotropic particles, fibres display a wider range of jamming mechanisms with different dynamics that warrant further investigation.