Morphological transitions of biological filaments under flow

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Under strong flow, the filaments bend over in a tank treading motion but remains aligned with the flow. Credit: *Proceedings of the National Academy of Sciences* (2018). DOI: 10.1073/pnas.1805399115

The study of complex suspensions made of particles suspended in a simple fluid has been growing lately, with many opportunities for industry or lab-on-a-chip technology. The macroscopic flow properties of these suspensions depend on the nature of the suspended micro-particles, such as their size or flexibility, and remain poorly understood. These flow properties directly result from the microscopic interaction between the viscous flow and the particles. Researchers from ESPCI Paris collaborated with a team from the University of California San

Diego to investigate the dynamics of a microscopic flexible filament in a flow. Their results have been published in the *Proceedings of the National Academy of Sciences*.

The scientific team from PMMH-ESPCI Paris led by Anke Lindner and Olivia du Roure developed a model experiment combining microfluidics and fluorescently labeled actin filaments, a biological polymer. In the cell, this protein assembles into filaments, giving the cell its shape, integrity and migration properties. Once purified, marked with fluorescence and reassembled in vitro, these actin filaments represent a perfectly controlled model system of flexible, microscopic and Brownian filaments. The PMMH experiment takes advantage of the precise flow control given in microfluidic devices to track each actin filament during its transport in well-defined conditions.

Scientists from San Diego University realized numerical simulations, including viscous forces as well as elastic restoring forces, and including Brownian fluctuations. Results from simulations and experiments match perfectly.

The study highlighted the existence of three types of morphology in flow depending on the filament length, which determines its flexibility, and on the flow velocity. In each case, the filament is transported by the flow, and its centre of mass follows the stream lines. When the filament is short and the flow slow, the filament remains undeformed and rotates while being advected by the flow. For higher lengths and flow velocity, the filament deforms while rotating and bends to adopt a " C " shape. This transition corresponds to a buckling instability. For even higher values, a third scheme appears in which the filaments bend over in a tank treading motion, but remain aligned with the flow. Transitions between the different regimes are associated with a threshold quantified in terms of a control parameter combining filament flexibility and flow strength. Brownian fluctuations have little influence and mainly participate in blurring the transitions.

The close collaboration between the experimental and numerical teams led to the first complete characterization of the different morphologies and transitions between these regimes. Anke Lindner, co-author of this work, explains that "studying the microscopic behavior of flexible filaments is the first step to understand and explain the properties of a suspension made of flexible fibers at the macroscopic scale."

More information: Yanan Liu et al. Morphological transitions of elastic filaments in shear flow, *Proceedings of the National Academy of Sciences* (2018). DOI: 10.1073/pnas.1805399115

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