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Editorial

Fluid–fluid and fluid–soft matter interaction

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Fluids—whether Newtonian or not—often interact with other bodies, thereby creating a rich tapestry of responses. The classical area of solid–fluid interaction is a very rich research domain that reaches into multifarious applications. These traditional areas have wide-ranging applications such as jet engine design, powder coating technologies, and various manufacturing processes. Two treatises on this topic [1, 2] outline some of the interesting phenomena involving fluid–structure interactions, particularly numerical methods to handle moving boundaries, large deformations, interfaces, and even phase transitions. In addition, some high-fidelity experiments are also outlined in some detail. In the recent past, the growth in interest in the soft matter/complex fluid domain has enabled another niche—the deformation and response of soft materials caused by an interaction with another flowing fluid. Such interactions are very common in biological systems involving flows and transport. This can elicit a dominant physicochemical origin emerging from the complex interplay between various nonlinearities arising out of transport, large deformation, and interfacial behavior. This can lead to the emergence of hitherto-unknown phenomena. Today the area of fluid–fluid and fluid–soft matter interaction is a burgeoning field with a very rich literature informing domains such as environmental and biological flows. However, the papers outlined in this special issue advance the frontier far beyond what is available in textbooks, as will be shown in the following paragraphs. In particular, the topic of fluid–soft matter interactions is hardly covered in any major textbook.

This special issue brings together a diverse group of researchers who are actively contributing to this growing domain. The issue features 4 review articles and 14 regular submissions. Sharma et al. [3] review the breakup and atomization of liquid droplets when subject to a high-speed gas stream. This process, known as aero-breakup, appeals to several applications, specially in the aerospace sector, and many interesting hydrodynamic instabilities can be observed during such an atomization process. Apart from such occurrences in Newtonian fluids, researchers also focus their attention on shock-induced atomization of polymeric and liquid metal droplets.

Panday et al. [4] review the state of the art in the context of surfing of particles and droplets on a fluid interface. “Surfing,” as opposed to “swimming,” motion occurs at an interface such as an air–liquid interface and is induced in particles and drops by a force imbalance. The researchers review the recent advances in the field, and also discuss the mechanics of such propulsion for particles and/or droplets. Understanding of such propulsion is key to several engineering and biomedical applications.

Sudheer et al. [5] discuss issues related to the dynamic wetting of complex fluids and specifically look into literature related to the determination of the apparent contact angle and dynamic contact angle development for complex fluids. They also discuss contact line development in dynamical circumstances through the lens of two types of complex fluids—human blood and polymers. The rod-climbing effect serves to illustrate this latter point, and the researchers discuss issues and applications for the same.

Anuska et al. [6] discuss the fabrication of paper-based microfluidics and detection techniques. In paper-based microfluidics, a fluid wicks through the porous matrix of a suitable paper, where miniature channel walls are delineated by a nonwetting material, often wax. The researchers focus on the issues related to the fabrication of paper microfluidics and delve into the analysis of fluid flow through such porous media and the efficient handling and control of fluids.

One challenge when dealing with complex fluids is that they can belong to several broad classes, including polymeric fluids and viscoplastic fluids. Bhandari et al. [7] use the Bingham plastic fluid model, wherein a fluid has a yield stress yet displays viscous dissipation, to study microscale flows in a membrane-based pumping flow. They report a significantly higher pressure distribution as compared with a Newtonian fluid when

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subject to such flows. Such analysis can help us understand microscale transport phenomena in various natural and artificial contexts, including three-dimensional (3D) printing.

Alif et al. [8] investigate the stability of liquid jets when emerging from an elastic nozzle. Though the topic of hydrodynamic instabilities in the context of liquid jets emerging from nozzles is a well-studied domain, jets issuing from nozzles that can suffer elastic strains are not well studied. The authors introduce a modification of the linear instability theory to accurately describe their experimental results. Such situations involving jets occur in a number of real-life situations including waterjet cutting, combustion processes, etc.

Kumar and Ardekani [9] numerically investigate viscoelastic flows through disordered porous media. They utilize the FENE-P constitutive rule to model their viscoelastic fluid and perform two-dimensional numerical simulations for flow around two cylinders. Through their pore-scale simulations, they provide stimulating insights such as the idea that even small asymmetry in the geometry significantly affects the criterion for viscoelastic flow instability and consequently the flow behavior itself.

Satheesh and Tomar [10] conduct numerical simulations to study the impact of a spherical capsule on a rigid surface at moderate Weber and Reynolds numbers. The numerical simulations are conducted in three dimensions using the front tracking scheme in a finite volume framework. The researchers show that the dynamics of such an impact can be classified into two regimes—one at low Weber numbers and another at higher Weber numbers—that can be distinguished by their scaling laws.

Lathia et al. [11] experimentally investigate the non-coalescence of droplets in an open-chip electrowetting platform. The platform was designed by employing coplanar interdigitated electrodes and then used to investigate the non-coalescence of water droplets separated by a layer of oil. They report a regime map with the operating parameters, viz. applied voltage and frequency, for the non-coalescence process.

Hasan et al. [12] investigate the response of a geometrically nonlinear flexible structure under a surface gravity wave. They investigate the dynamical response of such a system and find that the system exhibits two saddle-node bifurcations in the frequency response curve. The authors believe that their model will enable designers to choose the proper operational parameters for optimizing such systems.

Samuel et al. [13] investigate the impacts of the Arrhenius activation energy and binary reaction on the heat and mass transfer in a magnetohydrodynamic Jeffrey fluid flow in the presence of nonuniform heat generation, thermal radiation, and velocity slip. Their study illustrates that the temperature distribution escalates as the Biot number grows. The results obtained in this study are relevant to a variety of industrial and engineering processes such as thermal insulation, gas turbines, polymer production, geothermal reservoirs, and many more.

Raj et al. [14] investigate the stability of concentrated emulsions from droplet configuration information. Toward this end, they employ as inputs the droplet packing configuration and a measure of the local probabilistic propagation. They find that the mean size of these avalanches depends on how the droplets are packed together.

Reaching beyond a binary interactions, Jadhav and Ghosh [15] investigate the changing morphology of multicore compound droplets through a two-dimensional numerical simulation. Compound droplets are relevant to several areas including biotechnology, drug delivery, and microfluidics. Jadhav and Ghosh find that the temporal evolution of multicore droplets, unlike single droplets, can exhibit an intriguing time-dependent morphology in unsteady flows.

Asghar et al. [16] investigate the biomechanics of bacterial swimming near an interface with the intermediate fluid being modeled as an Oldroyd-4 constant slime. They utilize numerical simulations to understand bacterial gliding motion, where the microbe is engulfed in a slime mold. Understanding of bacterial gliding is key to many applications, including understanding bacterial pathogenesis.

Another study focusing on swimming investigates scallop-like swimmers in a noisy environment, where the noise is of thermal origin. Patil and Ghosh [17] demonstrate a technique to extract information from the spatially and temporally resolved trajectories of the scallop-like swimmer.

Mahapatra and Bandopadhyay [18] illustrate the existence of a modified electroosmotic slip velocity for viscoelastic fluid flows over walls having spatially varying surface potentials. The proposed electroosmotic slip velocity can be used in computational models of complex fluid flows through microchannels to approximate the motion of the electric double layer without resolving the charge density profiles close to the walls.

Pradhan et al. [19] look at cavitation events in a superfluid liquid helium environment using a cylindrical piezoelectric transducer. The cavitation events are in fact nanometer-sized electron bubbles that are produced as a result of the excitation. Mist formation and cavitation events are experimentally observed and reported, and the experiments were performed in the temperature range of 1.4–1.6 K.

Pawar and Narhe [20] report a numerical investigation of the effect of droplet motion on the temporal growth dynamics during condensation on phase-change materials. Based on their work, they report four growth regimes, which can be identified by their respective power-law signatures.

The papers in this special issue showcase exciting scientific insights and rigorous reviews across a wide gamut of applications ranging from shock–droplet interactions, paper microfluidics, and droplet surfing across interfaces to the biomechanics of bacterial swimming. Essentially, the papers advance the knowledge in the general frontier of interfacial fluid flow in particular fluid–soft matter interactions. The issue contains papers that deal with both theory and experiments. We hope that the interfacial physics community at large will benefit from these works. The intended readership of this special issue includes graduate-level students, postdoctoral fellows, and early-career and advanced faculty members in the area of fluid mechanics and interfacial transport.

Data availability No data is needed for this editorial.

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