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Nano-scale electro-kinetics in one and two-phase flows: Instabilities, bifurcations, and pattern formation

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The advent of micro, nano and biotechnologies in the last decade has spurred numerous new and active research areas, in particular, in problems of electro-kinetics. Other than the practical importance of these effects is a theoretical interest to these problems: study of the space charge in the electric double-ion layer is a fundamental problem of modern physics, first addressed by Helmholtz. We shall focus on an often-ignored phenomenon: the underlying very rich hydro-mechanics. The relevant hydrodynamics involves micro-scale vortices, vortex instabilities and even turbulences like eddy fluctuations whose vortex pairing dynamics create a range of vortex sizes, all at miniscule Reynolds numbers. Singularities, instabilities, turbulence, continuum of length scales, self-similar solution, vortex pairing etc., are among the investigated phenomena. Despite their micro and nano-length scales, these instabilities and bifurcations exhibit all the hall marks of other classical hydrodynamic instabilities – a sub-harmonic cascade, wide-band fluctuation spectrum and coherent-structure dominated spatio-temporal dynamics. We shall present our results for the one-phase electro-kinetic instability near charge-selective surfaces, influence of this instability on the surface profile, the effect of a coupling between electro-kinetic phenomena and the surface hydrophobicity, Joule heating, geometric confinement, etc. Unstable two-phase liquid-gas flows with a mobile surface charge finalize our investigation. The problems are studied from the view-point of hydrodynamic stability and bifurcation theory using sophisticated asymptotic methods and direct numerical simulations.

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Alternative aviation fuels fire safety

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Recent advancements in bio-energy production allowed increased use of liquid biofuels, introducing the advantages of reduced fossil fuel dependence, lower exhaust emissions and renewable feedstock options. These “drop-in” fuels, however also brought operational challenges for aviation as multiple novel chemicals come into contact with numerous airframe and power plant materials. One set of such challenges involve the fire safety of alternative fuels. The traditional firefighting foams may not be as effective on alternative aviation fuels; impacting the safety of the public and first responders. Purdue research team collaborated with Federal Aviation Administration (FAA) Aircraft Rescue and Fire Fighting (ARFF) division to investigate the “alternative aviation fuels-firefighting foams compatibility”. The fuels studied are fossil derived jet fuel (Jet-A), Fischer-Tropsch (FT), Hydrogenated Esters and Fatty Acids (HEFA), Renewable Synthetic Iso-Paraffinic (SIP) jet fuels and one unleaded aviation gasoline (AvGas) replacement candidate. Each fuel sample was assigned a chemical identification demonstrating its complex composition determined by a Multidimensional Gas Chromatography and Mass Spectroscopy system (GCxGC/MS). Concurrently, each fuel was tested in a closed stainless steel combustion chamber to determine the burn characteristics which are: flammability limits, minimum ignition energy, and the rate of fire spread. Correlations between the chemical compositions and combustion parameters were developed which were further utilized for implementing the tactical and strategic adaptive methods for fighting the alternative aviation fuel fires. This project also accomplished the valuable fuel composition databank of sustainable aviation fuels which provided a great baseline for developing predictive models between fuel chemical/physical characteristics and performance criteria.

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