MECHANICAL ENGINEERING SEMINAR

Thursday, April 20, 2023, at 13:00, D. Dan and Betty Kahn Building, Auditorium 1

Nonlinear dynamics of elastic and magnetic fluid interfaces

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Hosted by: Asst. Prof. Evgeniy Boyko

In this talk, I will discuss some recent progress from my research group on the nonlinear dynamics of flow-driven interfaces, specifically (i) the elasticity-endowed interface between a fluid and a soft solid, and (ii) the surface-tension-endowed interface between a magnetic fluid and air. In both cases, under specific flow conditions that we identify, the interfaces become unstable and undergo complex, unsteady deformations, which we capture with reduced models. In the case of (i), we seek to understand why laminar flows in compliant microchannels become unstable at a low Reynolds number of 200 to 300. Using a reduced model derived from judicious simplification of the governing equations of fluid and solid mechanics, we perform a global stability analysis that yields a critical Reynolds number ≈ 200, consistent with previous experiments on "ultrafast mixing" induced by this flow–structure instability. Interestingly, the linear operator is non-normal due to the deformed base shape of the channel. In the case of (ii), we seek to understand how a magnetic field can be designed to manipulate the shape of fluid interfaces in a "hands off" manner. Through a reduced Hele-Shaw model, we show that a nonlinear traveling wave can be sustained on the interface of a magnetic fluid droplet. Weakly nonlinear analysis reveals that this wave emerges from a Hopf bifurcation, suggesting strategies for time-dependent control. A new long-wave thin film equation of generalized Kuramoto–Sivashinsky-type is derived to better understand the nonlinear wave dynamics.

Dr. Christov received his Ph.D. in Engineering Sciences & Applied Mathematics from Northwestern University in 2011. Subsequently, he was awarded an NSF Mathematical Sciences Postdoctoral Research Fellowship and spent two years with the Complex Fluids Group at Princeton University. In 2013, Dr. Christov was selected as the Richard P. Feynman Distinguished Postdoctoral Fellow at the Center for Nonlinear Studies at Los Alamos National Laboratory. In 2016, he became an Assistant Professor of Mechanical Engineering at Purdue University, being promoted to Associate Professor (with tenure) in 2022. He was recognized as Fulbright U.S. Scholar for the 2022–2023 academic year. At Purdue, Dr. Christov directs the Transport: Modeling, Numerics & Theory laboratory (TMNT-Lab), where advanced mathematics is combined with state-of-the-art simulations to make progress on fundamental questions at the interface of engineering, mathematics, and physics.

Seminars Coordinator: Assoc. Prof. Matthew Suss.