How Elastic Flow Instabilities Can Induce Motion in Flexible Solid Structures

Jonathan P. Rothstein  
Department Mechanical and Industrial Engineering  
University of Massachusetts Amherst

ABSTRACT:

When a flexible object such as an elastic sheet or cylinder is placed in a flow of a Newtonian fluid, the shedding of separated vortices at high Reynolds number can drive the motion of the structure. This phenomenon is known as Vortex-Induced Vibration (VIV) and has been studied extensively for Newtonian fluids. If the same flexible object is placed in non-Newtonian flows, however, the structure's response is still unknown. Unlike Newtonian fluids, the flow of viscoelastic fluids can become unstable at infinitesimal Reynolds numbers due to a purely elastic flow instability. In this talk, I will investigate the fluid structure interaction between a wormlike micelle solution at high Weissenberg number and a flexible elastic sheet and flexible circular cylinder in cross flow. Elastic flow instabilities have been observed for wormlike micelle solutions in a number of flows including flow into a contraction and flow past a circular cylinder. Here we will present a detailed study of the unstable flow past a cylinder for a series of wormlike micelle solutions whose rheology we have fully characterized. Next we will show that a similar elastic flow instabilities can occur in the vicinity of a thin flexible polymer sheet. We will show that the time varying fluid forces exerted on the flexible sheet can grow large enough to cause a structural motion which can in turn feed back into the flow to modify the flow instability. We will show the same interactions can occur for flexible and flexibly mounted circular cylinders. The static and time varying displacement of the flexible sheets and cylinders, including their oscillation frequency and amplitude, will be presented for varying geometries, for varying fluid flow rates, and for varying fluid compositions and properties. In addition, measurements of flow induced birefringence will be presented in order to quantify the time variation of the flow field and the state of stress in the fluid.

Bio - Jonathan Rothstein is a Professor in the Mechanical and Industrial Engineering Department at the University of Massachusetts Amherst where he has been since 2001. He received his B.Eng. from The Cooper Union in 1996, his M.S. from Harvard University in 1998 and his Ph.D. from MIT in 2001. His research interests include experimental fluid mechanics, micro fluidics, multiphase flows, non-Newtonian flows, rheology, drag reduction, superhydrophobicity and fabrication of micro- and nano-patterned materials. He has won a number of prestigious awards including an NSF CAREER Award, an ONR Young Investigator Award and the Arthur B. Metzner Early Career Award from the Society of Rheology.