On the vibration-induced propulsion of a rigid body in a viscous liquid

Mher Marc Karakouzian
Department of Mechanical & Material Science, Swanson School of Engineering, University of Pittsburgh. Pittsburgh, USA
m.karakouzian@pitt.edu

Abstract

The physical system comprised of a rigid body propelling in a viscous liquid by means of an internal-acting time-periodic mechanism (vibration-induced motion) appears in many engineering applications, from underwater robotics to the delivery of drugs within the human body. As such, an important question regarding the mechanics of such devices is the following: under what conditions does the time-periodic driving mechanism cause the body to propel (as opposed to simply "oscillate" back and forth)?

Mathematically, this system can be modeled as a coupled fluid-structure interaction problem as follows: consider a rigid body $\mathcal{B}$, contained in a Navier-Stokes liquid occupying the whole space outside of $\mathcal{B}$, which moves freely without constraint (i.e. can both translate *and* rotate) under the action of a zero-average time-periodic force f, with amplitude δ. In this talk, we will provide quantitative sufficient conditions that ensure f *propels* $\mathcal{B}$; namely, the center of mass of $\mathcal{B}$ covers any given distance in a finite time. In particular, using a scaling argument, we prove that propulsion can happen only at an order δ^2 or higher, implying that it occurs only if nonlinear effects are taken into account. This is part of a joint work with Giovanni P. Galdi and Thomas Richter.

Keywords: fluid-structure interaction, vibration-induced motion, time-periodic solutions