Fluid-elastic structure interaction with the Navier slip boundary condition

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Student Mentoring, Training and Professional Development

- **Graduate and Undergraduate Students:** 3 graduate students, 1 undergraduate student, and 1 postdoctoral researcher have been involved in Year 1 of this project.
  - Graduate Students:
    - Prajakta Bedekar
    - Deep Gosh
    - Maria Galic (co-superviser with B. Muha)
  - Postdoctoral Researchers:
    - Yifan Wang
  - Undergraduate Students:
    - Acara Turner.

  Prajakta Bedekar is working on her PhD thesis related to the existence proof for FSI with Signorini boundary conditions; Deep Gosh is taking a reading course on the topic of this project; Yifan Wang is working on numerical simulations related to FSI described in this project; Acara Turner was working on the visualization of FSI simulations using Matlab. She graduated this year with a B.S. degree from UH and is continuing her career in Medicine and Mathematics at Baylor College of Medicine.

Research Presentations

- **Year 1:** Canic presented the research related to this NSF project at several meetings and colloquium talks, which include: Plenary Talk at the AIMS meeting Orlando, FL, July 4, 2016; Opening Lecture at the 6th Croatian Mathematical Congress, June 14, 2016; Stanford University's Institute for Computational and Mathematical Engineering, Oct. 3 2016; Stanford University Mathematics Department, Oct 4, 2016; Waseda University, Tokyo, Japan, Nov 11, 2016; RIMS (Research Institute of Math. Sci.), Kyoto University, Japan, Nov. 14, 2016; UC Berkeley LBNL, Jan. 27, 2017; Duke University, Feb 3, 2017; Computational and Mathematical Biomedical Engineering Annual Conference, Pittsburgh, Apr. 11, 2017; Opening lecture at the Undergradaute Student Conference on Applications of Mathematics, Penn State University, May 11, 2017; Opening lecture at EQUADIFF, International Conference on Differential Equations, Bratislava, July 24, 2017.

Research and education related activities

- **Special Courses: Joint effort Canic-Little** taching graduate course Mathematical Hemodynamics in Fall 2017. Topics of this project were mentioned as examples in that course. Dr. Little is schedule to give several class presentations, organized a tour of the Cardiovascular Lab at the Methodist Hospital, and organized the viewing of open heart surgery at the Methodist Hospital.
- **Extended Visits:** Canic spent the Fall semester of 2016 at Stanford University, visiting Alison Marsden as part of ICME.
- **Hosting Visitors at UH:** Canic hosted a collaborator on this proposal, Boris Muha of the University of Zagreb, Croatia from April 26-May 6, 2016. Muha presented a series of lectures at the University of Houston during his visit, reporting on the research related to this project.

Specific Objectives

Specific objectives of this project are:

1. Study existence and well-posedness of FSI problems with the Navier slip condition
2. Study the influence of Navier slip condition in multi-layered structures
3. Design stable loosely-coupled partitioned schemes for FSI with the Navier slip condition
4. Examine stability and convergence of the partitioned schemes
5. Apply the above-mentioned theoretical results to solve real-life problems

Significant Results

- Together with collaborator B. Muha, the PI obtained the first existence result for solutions of FSI problems with the Navier slip condition, involving incompressible, viscous fluids and thin elastic structures modeled by the Koiter shell equations (Published in the Journal of Difrerential Equations)
- Together with collaborators B. Muha and M. Bukac, the PI obtained a first partitioned, loosely-coupled scheme for FSI problems involving the Navier slip condition (preliminary results were submitted for publication in the RIMS conference proceedings, and presented at a talk in Waseda University, Japan)
- Together with collaborator B. Muha a novel compactness result, which is a generalization of the famous Lions-Aubin Lemma, was obtained for problems on moving domains. A manuscript containing this result is near completion.

Key Outcomes and Other Achievents

- A constructive existence proof was designed to show that a weak solution to an FSI problem involving the Navier slip condition exists.
- Based on the main steps in the existence proof, a loosely-coupled partitioned scheme was designed for this class of problems.
- It was found that the main source of difficulties in studying this class of problems comes from the jump in the tangential velocity components across the fluid-structure interface, which is responsible for the loss of smoothing in the structure motion by the fluid viscosity.
- The partitioned, loosely coupled scheme gets around these difficulties by separating the fluid from structure sub-problems using the time-discretization via Lie operator splitting, where the splitting is performed in such a way that: (1) the semi-discretized energy approximates well the continuous energy of the coupled problem, thereby getting around the difficulties associated with the added mass effect, and (2) the viscous dissipation due to slip is cleverly distributed between the fluid and structure sub-problems providing a tight coupling that compensates for the lack of direct smoothing by the fluid viscosity in the no-slip condition.

Plans for the Next Reporting Period

- Complete the manuscript on the generalization of the Lions-Aubin Lemma to problems on moving domains
- Complete the project on the design of the loosely-coupled partitioned scheme
- Prove stability and convergence of the scheme
- Apply the scheme to solve a FSI problem with multi-layered structures coupled via the Navier slip boundary condition arising in composite structure design to minimize acoustic vibrations.