Versão UK

Scientific Work Proposal for Mathematics Phd Thesis

Scientific Domain

Mathematics

Main Area

Mathematics of Fluid Mechanics and its Applications, Analysis Mathematics, Numerical Simulation and Mathematical Modeling with Experimentations

Thesis title (Provisory)

One-dimensional Fluid-Structure Interaction Problems using the Cosserat Theory

Keywords

One-dimensional model, Fluid-structure Interaction Problems, Cosserat Theory, Newtonian Fluids, Non-Newtonian Fluids, Partial Differential Equations, Ordinary Differential Equations, Laboratory Experimentation.

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Scientific Work Proposal:

In recent decades, the study of the phenomena of interaction between fluid and structure have attracted a large number of researchers from different fields such as mechanical engineering, biology, medicine, biomedical engineering, physics and mathematics. In the field of applications in medicine, biology and medical engineering, the phenomena of fluid-structure have received increasing attention in the scientific community because they have application in a wide variety of problems associated with the flow of blood in the vascular system as, for example, in the clinical problem of an arteriosclerosis or aneurysm vein situation, among others. Today, the study of phenomena of fluid-structure is a topic of great interest, with major social and economic implications. The models to be studied are related to the specific problem associated with the arteriosclerosis or aneurysm vein situation, i.e., involving the flow of blood, coupled to structure and/or permeability of the vein. The most recent mathematical models for this fluid-structure interaction problem found in the literature are sophisticated, with its genesis in a wide variety of factors, such as multiple scales and complex interactions between fluid and porous medium. These models usually involve coupled systems of nonlinear, time-dependent partial (or ordinary) differential equations and algebraic equations. Its analytical and numerical treatment is complex and requires the use of sophisticated arguments. In order to overcome this deviation, we use an alternative theory, the theory of Cosserat associated with fluid dynamics, which allow us to approximate the 3D model by simplified 1D models. Based on this approach theory we reduce the nonlinear three-dimensional equations governing the axisymmetric unsteady motion of a non-Newtonian incompressible fluid (or Newtonian fluid) to a one-dimensional system of ordinary (or partial) differential equations depending on time and on a single spatial variable. From this new system we obtain the unsteady equation for the mean pressure gradient and the wall shear stress both depending on the volume flow rate, Womersley number, viscosity and viscoelastic parameters over a finite section of a straight tube with variable circular cross-section. The aim of this project is precisely to study, in terms of mathematical analysis, numerical optimization and laboratory experiences these alternative models resulting from the application of the Cosserat theory to the clinical problem of arteriosclerosis or aneurysm vein situation.

Some General References about Fluid-Structure Interaction Problems:

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Versão PT

Proposta de Trabalho Científico para Tese de Doutoramento em Matemática

Domínio Científico

Matemática

Área

Matemática da Mecânica dos Fluidos e suas Aplicações, Análise Matemática, Simulações Numéricas e Modelação Matemática com Experimentação

Tema Provisório para a Tese

Problemas Unidimensionais de Interação Fluido-Estrutura usando a Teoria de Cosserat

Theory

Palavras Chave

Modelo Unidimensional, Problemas de Interação Fluido-Estrutura, Teoria de Cosserat, Fluidos Newtonianos, Fluidos não-Newtonianos, Equações Diferenciais Parciais, Equações Diferenciais Ordinárias, Experimentação Laboratorial

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Proposta de Trabalho Científico:

Nas últimas décadas, o estudo dos fenômenos de interação entre fluido e estrutura tem atraído um grande número de pesquisadores de diversas áreas como engenharia mecânica, biologia, medicina, engenharia biomédica, física e matemática. No campo das aplicações em medicina, biologia e engenharia médica, os fenômenos de estrutura fluida têm recebido cada vez mais atenção na comunidade científica porque têm aplicação em uma ampla variedade de problemas associados ao fluxo de sangue no sistema vascular como, por exemplo, o problema clínico de uma situação de arteriosclerose ou veia aneurismática, entre outros. Hoje, o estudo dos fenômenos de estrutura e fluido é um tema de grande interesse, com grandes implicações sociais e econômicas. Os modelos a serem estudados estão relacionados ao problema específico associado à situação de arteriosclerose ou veia aneurismática, ou seja, envolvendo o fluxo de sangue, acoplado à estrutura e/ou permeabilidade da veia. Os modelos matemáticos mais recentes para este problema de interação fluido-estrutura encontrados na literatura são sofisticados, tendo sua gênese em uma ampla variedade de fatores, como escalas múltiplas e interações complexas entre fluido e o meio poroso. Esses modelos geralmente envolvem sistemas acoplados de equações diferenciais parciais (ou ordinárias) não lineares dependentes do tempo e equações algébricas. O seu tratamento analítico e numérico é complexo e requer o uso de argumentos sofisticados. Para ultrapassar este desvio, utilizamos uma teoria alternativa, a teoria de Cosserat associada à dinâmica dos fluidos, que nos permite aproximar o modelo 3D por modelos 1D simplificados. Com base nessa teoria de abordagem, reduzimos as equações tridimensionais não lineares que governam o movimento instável axissimétrico de um fluido incompressível não-newtoniano (ou fluido newtoniano) a um sistema unidimensional de equações diferenciais ordinárias (ou parciais) dependendo do tempo e de uma única variável espacial. A partir deste novo sistema, obtemos a equação instável para o gradiente de pressão médio e a tensão de cisalhamento na parede, ambas dependendo da vazão volumétrica, número de Womersley, viscosidade e parâmetros viscoelásticos em uma seção finita de um tubo reto com seção transversal circular variável.

O objetivo deste projeto é justamente estudar, em termos de análise matemática, otimização numérica e experiências laboratoriais, esses modelos alternativos resultantes da aplicação da teoria de Cosserat ao problema clínico da arteriosclerose ou situação de veia aneurismática.

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Algumas Referências Preparatórias Obras do Orientador, Coorientador e do

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