Statement of Research and Teaching Interests

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1 Research Interests

There are many important and industrially significant problems where the understanding of the material behavior and its mathematical representation are yet to be developed. Computer modeling and simulation which has emerged as a powerful tool in a wide variety of engineering applications is often limited and leads to unreliable results due to lack of realistic representation of the material behavior. Among various material types those which exhibit large deformations and time dependent properties have one of the widest range of applications and yet they are the least successfully described mathematically. My primary interest is the development of constitutive models for finitely deforming viscoelastic materials in which I have been involved in the last several years during my doctoral and post-doctoral research.

In my PhD thesis I studied the thermomechanical behavior of solid rocket propellants. These materials are particulate composites with a matrix of lightly cross linked elastomeric binder that is often highly charged with energetic plasticizing constituents. The material typically have a large strain capability, is thermorheologically non-simple, and exhibits marked effects of damage. Using data provided by Thiokol Corp., I have developed a constitutive model and a procedure for the material testing and calibration of the model. The specific propellant considered was that of the redesigned solid rocket motor which is used as the first stage of the US space shuttle. The procedure differs from previous methods in that it requires data from only a small number of relatively easy tests. Verification of the model for various loading conditions was possible since a large amount of data was available. The model has been implemented in a finite element code and is currently being used in the industry.

My post-doctoral research concerned the mechanical behavior of soft tissues which also exhibit nonlinear viscoelastic behavior and undergo large deformations. The particular tissue of interest was bovine pericardium, thin membrane enclosing the heart, which is used as a leaflet tissue in manufacturing bioprosthetic heart valves. Long term durability of bioprostheses is controlled mainly by the mechanical behavior of the leaflet material. Consequently, accurate

description of the mechanical behavior of the tissue leaflet plays an important role in the evaluation of the valve performance.

The particular emphasis of the research was regarding the representation of anisotropy. The project had experimental and computational components. The material testing was carried out at Carbomedics Inc., a heart valve manufacturing company. Computational aspect consisted of implementing various constitutive models in a finite element code. These models represented the material behavior reasonably well for homogeneous deformation states and differed mainly in their treatment of anisotropy. The models were evaluated by comparing the predictions with the experimental data for nonhomogeneous deformation states, in particular a boundary value problem which involved stress concentration.

The study has contributed significantly towards the understanding of the pericardium material and allowed a large deformation, nonlinear, anisotropic behavior of the material to be incorporated into the stress analysis of the heart valve prostheses. This has been a significant effort to establish a linkage between mechanics and materials, which is the main focus of the Institute for Mechanics and Materials where I pursued my post-doctoral research. One of the main objectives of my future plans is to continue to explore this linkage which I believe will significantly contribute to establish interdisciplinary research programs.

My immediate research plan is to continue the project I am currently involved in: the mechanics of soft tissues. During my research on bovine pericardium I extensively surveyed the literature in this area. Even though the general form of the nonlinear load-deformation response of soft tissues is now well established, there is little general agreement on the mathematical descriptions of tissue mechanical properties which are required if any numerical computation or stress analysis is to be carried out. The approach adopted by several investigators to characterise soft biological tissues is the same as that adopted to develop continuum mechanics for rubber-like materials. Such an approach is an important first step in that it accounts for kinematic nonlinearities of tissue behavior. However, much work needs to be done to accurately represent other important features such as viscoelastic effects, anisotropy, compressibility and damage. These are the topics that I would concentrate in my future research.

Recently, new designs of heart valves using polymeric, flexible leaflets have become available. These materials have the advantage of closely simulating the natural leaflet form as biological tissues do, and moreover they do not show intra- and inter-species variability of tissues which is a major concern regarding manufacturing of bioprostheses. Characterization of these materials would be another challeging research area I would like to explore in the future.

My research plans regarding heart valves are not limited to the characterization and mathematical modeling of leaflet materials. I am also interested in studying the mechanical behavior of the entire valve. There are several studies in the literature regarding the analysis of the fluid flowing through the valve or the stress analysis of the structure. Although much still needs to be done in both areas, more important issue is the interaction of the fluid with the structure surrounding it. Computational tools accounting for this interaction have only recently become available and therefore an interest from the industry to employ them has emerged. Exploring the application of these tools will not be only a challenging research topic but also a promising subject in seeking industrial funding.

Industrial collaboration has been an essential part of the projects I have been involved so far. The research problems I worked on came directly from the industry and the results had immediate applications. I would therefore seek research funding primarily from the industry My current focus is on heart valve manufacturers who have needs in the area of material characterisation. In my research I would primarily focus on theoretical and computational aspects and seek industrial and academic collaboration regarding the experimental aspect.

2 Teaching Interests

One of my main motivations for seeking an academic position is my strong interest in teaching. As my vitae indicates my graduate coursework covers various areas of Solid Mechanics. During my graduate study at the University of Texas at Austin I have been a teaching assistant for Statics and Dynamics, and Mechanics of Composite Materials, and lectured and ran tutorial sessions in Mechanics of Solids.

I would readily feel comfortable teaching introductory engineering mechanics courses at undergraduate and graduate level. Statics, Dynamics, Mechanics of Solids, introductory and advanced Strength of Materials, Theory of Elasticity, Theory of Viscoelasticity are some of the topics I would like to be involved in teaching.

During my post-doctoral study I have followed several courses offered by the Bioengineering Department of the University of California San Diego. In a short period of time I would be able to prepare introductory biomechanics courses. In longer term I would like to develop courses in parallel to my research goals, emphasizing the linkage between mechanics and materials in biomedical applications.