

An Indian-Australian research partnership

Project Title:	Fatigue in Actuating Smart Biomedical Materials	
Project Number	IMURA0910	
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IITB Department:	Department of Mechanical Engineering	

Research Clusters:

Research Themes:

1	Material Science/Engineering (including Nano, Metallurgy)	1	Advanced computational engineering, simulation and manufacture
2	Energy, Green Chem, Chemistry, Catalysis, Reaction Eng	2	Infrastructure Engineering
3	Math, CFD, Modelling, Manufacturing	3	Clean Energy
4	CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control	4	Water
5	Earth Sciences and Civil Engineering (Geo, Water, Climate)	5	Nanotechnology
6	Bio, Stem Cells, Bio Chem, Pharma, Food	6	Biotechnology and Stem Cell Research
7	Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng	7	Humanities and social sciences
8	HSS, Design, Management	8	Design

The research problem

Actuating smart materials are of prime importance in the biomedical domain due to their applications in heart valves, stents and drug delivery mechanisms etc. In this project we will focus on fatigue of a shape memory alloy. In shape memory alloys e.g. NiTi, the shape memory and pseudoelasticity is a result of phase-transformation induced by temperature or deformation. The newly evolved phase interfaces with existing matrix and thus causes stiffening of the overall micro-device. In recent publications we modeled pseudoelasticity in NiTi shape memory alloys using a micromechanics based model. In the present work, we would like to modify the constitutive framework with (1) coupled

thermomechanical effects and (2) strong strain gradients at the interfaces of parent and new phase. Thermomechanical effects capture the dissipation due to plasticity and temperature changes in the environment. Strain gradients address the additional stiffening due to interfacial effects of the second phases. In actuating condition, thermomechanical behavior and phase transformations lead to residual strains in the material leading to fatigue. This project focuses on development of a robust higher order strain-gradient model for understanding fatigue in a smart actuating biomaterial.

Project aims

1. Develop constitutive framework for actuation of a shape memory material
2. Numerical algorithms for finite deformation coupled with dissipation and thermal effects and their implementation
3. Validation using test cases available in literature
4. Design use cases that be validated by experiments in subsequent projects

Expected outcomes

1. A constitutive framework for mechanics of a shape memory biomaterial
2. A simulation tool for coupled finite strain thermomechanical behavior

How will the project address the Goals of the above Themes?

The project applies Advanced Computational Engineering for Biomedical applications. It falls in the category (1) and (6).

Capabilities and Degrees Required

An ideal candidate should have a BTech or BE or Masters in Mechanical Engineering, Aerospace Engineering, Civil, Mathematics or Physics, with a strong inclination towards advanced mathematics, numerical methods, continuum mechanics, non-linear elasticity. Experience in at least two of the following three criteria is desired: 1. Background in mechanics of materials; 2. Expertise in numerical methods for PDEs (finite element methods); 3. Expertise in programming (Python, C, C++, Fortran, Julia, etc)

Necessary Courses

Courses on Continuum Mechanics, Elasticity, Numerical Methods, Finite Element Methods, PDEs will be required.
AE639: Continuum Mechanics
AE649: Finite Element Method

Potential Collaborators

Jerome Droniou (expert in numerical methods for PDEs, jerome.droniou@monash.edu)
Ricardo Ruiz-Baier (expert in numerical methods for PDEs, ricardo.ruizbaier@monash.edu)
Raghunath Chellakot (Soft Matter, raghu@phy.iitb.ac.in)
Neela Nataraj (Finite Element Method, neela@math.iitb.ac.in)
We will also look for collaborators in Chemical Engineering or Bio Sciences and Engineering for experimental validations.

Select up to **(4)** keywords from the Academy's approved keyword list (**available at <http://www.iitbmonash.org/becoming-a-research-supervisor/>**) relating to this project to make it easier for the students to apply.

Shape Memory Material, Biomedical Robots, Smart Biomaterials, Computational Fluid Dynamics and Mechanics