

An Indian-Australian research partnership

Project Title:	Fracture studies of Mg and Zn based biomedical alloys under dynamic and static loadings in a physiological environment	
Project Number	IMURA1048	
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Research Clusters:

Research Themes:

Highlight which of the Academy's CLUSTERS this project will address? (Please nominate JUST <u>one</u> . For more information, see www.iitbmonash.org)		Highlight which of the Academy's Theme(s) this project will address? (Feel free to nominate more than one. For more information, see www.iitbmonash.org)	
1	Material Science/Engineering (including Nano, Metallurgy)	1	Artificial Intelligence and Advanced Computational Modelling
2	Energy, Green Chem, Chemistry, Catalysis, Reaction Eng	2	Circular Economy
3	Math, CFD, Modelling, Manufacturing	3	Clean Energy
4	CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control	4	Health Sciences
5	Earth Sciences and Civil Engineering (Geo, Water, Climate)	5	Smart Materials
6	Bio, Stem Cells, Bio Chem, Pharma, Food	6	Sustainable Societies
7	Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng	7	Infrastructure
8	HSS, Design, Management		

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The research problem

The traditional implant materials e.g. titanium alloys and stainless steels, demonstrate excellent mechanical properties, resistance to fatigue, wear and corrosion resistance. However, these properties differ from those of human bones, and thus can cause stress shielding. Moreover, in cases where these are used as temporary implants (e.g., plates, wires, screws), a second surgery is typically required to remove the implant after the tissues have healed, which increases the healthcare cost. This further imposes an increased risk of local inflammation as well as the physical irritation due to the rigidity of these traditional implant devices.

Magnesium (Mg) alloys are very attractive as materials for temporary implant devices due to their excellent biocompatibility and mechanical properties being similar to those of natural bone. Recently, magnesium and its alloys have attracted increasing interest as innovative biodegradable materials, particularly for their potential use as temporary orthopaedic implants. Magnesium is not only biocompatible but also essential to human metabolism and the degradation products of magnesium are not toxic to the human physiology.

Despite highly advantageous properties of Mg alloys, they have not been commonly used as body implants because Mg alloys suffer rapid degradation and concurrent generation of undesirable amounts of hydrogen gas even in a mildly corrosive medium such as simulated body fluid (SBF). Zinc (Zn)-based alloys may address such concerns to a great extent. Generally, the corrosion process depends on different factors such as material composition, its processing history, and the environment to which it is exposed. Different pseudo-physiological solutions that mimic the composition of body fluids have been proposed for in-vitro studies.

Simultaneous action of cyclic loadings and aggressive physiological environment may lead to sudden cracking/fracture of implant devices due to corrosion fatigue (CF) and stress corrosion cracking (SCC). Hence, adequate resistance to cracking/fracture in physiological environment is an imperative factor for those materials that are considered for bio-implant applications. CF and SCC of magnesium (Mg) and zinc (Zn) alloys as a potential candidate for temporary implant applications have received very limited attention.

Project aims

1. Experimental investigation of CF and SCC of magnesium and zinc alloys in a simulated physiological environment.
2. Understanding the effect of processing conditions of magnesium and zinc alloy on CF and SCC.
3. Chemo-mechanics based modeling of cracking and fatigue in the prevalent conditions.

How skills/experience of the IITB and the Monash supervisor(s) support the proposed project

1. Prof. Raman Singh has worked extensively in the area of failure of metals due to synergistic action of mechanical loading and corrosive environment, including for bioimplant applications.
2. Prof. Alankar has expertise in the area of computational mechanics of material and has been working on understanding deformation, fracture and fatigue behaviour of metals.

What is expected of the student when at IITB and when at Monash?

At the time of application, the student is expected to have basic understanding of metals, their mechanical behavior and corrosion. The student must be willing to perform experiments and modeling both. Basic understanding of fracture mechanics and finite element modeling is also required. Some programming experience in C / C++ / FORTRAN languages is an asset. At IITB, the student will go through rigorous course work in the above areas. At the

same time he/she will be expected to perform extensive literature review. The major modelling part of the project will be performed at IIT Bombay. The student will perform various fatigue tests and failure analysis at Monash University, including under the synergistic action of mechanical loading and corrosive environment of human body fluid.

Expected outcomes

1. A systematic study of corrosion-fatigue and stress corrosion cracking in simulated physiological condition for various processing conditions of the magnesium alloy.
2. Processing condition-performance map for Mg and Zn alloys as an implant material.
3. A finite element based predictive model for performance of implant materials.

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

This project aims to understand behaviour and life of Mg and Zn alloys in simulated physiological environment. The overarching goal is to establish the feasibility of Mg and Zn-based implants as compared to the existing implants. The project addresses the goals of biomedical cluster. It has components in advanced computational modeling theme and health sciences.

Potential RPCs from IITB and Monash

Associate Professor Tanmay Bhandakkar (expert in Elasticity and fracture mechanics tbhanda@iitb.ac.in)
Associate Professor Wenyi Yan (expert in Mechanical Properties of Alloys, wenyi.yan@monash.edu)

Capabilities and Degrees Required

An ideal candidate should have a BTech or BE or Masters in Mechanical Engineering, Aerospace Engineering, Civil Engineering or Materials Engineering with a strong inclination towards experimental methods and fracture mechanics. Experience in at least two of the following three criteria is desired: 1. Background in experimental methods, 2. Background in mechanics of materials; 3. Expertise in programming (C, C++, Fortran).

Necessary Courses

A few tentative courses are as following:
ME 616: Fracture Mechanics
MM 713 Aqueous Corrosion and its Control
AE639: Continuum Mechanics
AE649: Finite Element Method
ME775: Crystal Plasticity

Potential Collaborators

Hospitals, doctors. We have not contacted yet.

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.

Biomedical implants, Mg alloys, Zn alloys, Corrosion-fatigue, Stress corrosion cracking