IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	Modelling elastomer's thermo-mechano-oxidative ageing by means of coupled chemo-thermo-mechanical constitutive equations.	
Project Number	**IMURA0983**	
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Research Clusters: **Research Themes:**

Highlight which of the Academy's CLUSTERS this project will address?

*(Please nominate JUST **one.** 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)

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Material Science/Engineering (including Nano, Metallurgy)

Energy, Green Chem, Chemistry, Catalysis, Reaction Eng

Math, CFD, Modelling, Manufacturing

CSE, IT, Optimisation, Data, Sensors, Systems, Signal Processing, Control

Earth Sciences and Civil Engineering (Geo, Water, Climate)

Bio, Stem Cells, Bio Chem, Pharma, Food

Semi-Conductors, Optics, Photonics, Networks, Telecomm, Power Eng

HSS, Design, Management

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Advanced computational engineering, simulation and manufacture

Infrastructure Engineering

Clean Energy

Water

Nanotechnology

Biotechnology and Stem Cell Research

Humanities and social sciences

Design

The research problem

With ageing, changes in structure of the polymer chains of an elastomer occur due to cumulative action of mechanical and environmental conditions (oxidation, high temperatures) over time. Under mechanical loads and temperature, there is polymeric chain breakage (scission in the strained network) and chain reformation (network formation in the deformed state) leading to the modification of the elastomer properties.
For a complete lifecycle analysis of an elastomeric component in an industrial application, one should be able to model changes in mechanical behaviour of elastomers (rigidity, hysteresis, fatigue characteristics etc) as a function of temperature, mechanical loading during ageing and oxidation. To achieve this, one must model the constitutive behaviour of elastomer by the help of chemo-thermo-mechanical constitutive equations.
There have been several approaches proposed in the past which can help in accounting for the effect of chemical reactions with mechanical loadings in elastomer continuum, based on the coupling of thermodynamics of irreversible processes & continuum mechanics, but these models at best cater to uniaxial loadings.

In this research problem, one is required to:

1. Develop a robust and scalable chemo-thermo-mechanically coupled constitutive model for elastomers that would work well at complicated loadings (static & dynamic) an elastomer can encounter in industrial applications, for e.g. multiaxial loadings at different temperatures and different level of oxygen penetration inside a tire - Using internal simulations tools, Michelin will be able to give the range of multiaxiality, strain amplitude, oxygen concentration, temperature relevant for the ageing of the materials in a given tyre.
2. One should be able to account for the change in mechanical properties like rigidity, hysteresis, fatigue characteristics etc. of an elastomer as a function of state variables such as partial pressure of oxygen, Temperature, Pressure, stress and strains. Moreover, such a material model can be imagined to be a function of material dependent coefficients which change for different elastomers due to changes in internal material parameters like crosslinks density, reactivity to oxygen, type of polymer matrix, etc.
3. Development of such a material model will require characterizations of elastomers with different internal parameters (crosslinks density, polymer matrix) at different (constant) stresses or (constant) strains and ageing conditions (temperature and concentration of oxygen) to fit the constitutive model to the stress-strain curves in order to determine material dependent coefficients in the model.

Project aims

1. Develop experimental tests to age samples under constant loads (stress or strain controlled) in regulated temperature and oxygen partial pressure.
2. Develop mechanical tests to fit a constitutive material model
3. Develop a constitutive material model for elastomers accounting for thermo-mechano-oxidative ageing as a function of state variables and material internal parameters.
4. Test and validate the material model
5. *Michelin will implement the model in its FEA code and achieve a finite element simulation with this material model for a given tyre to assess the reliability of the model to account for ageing effects.*

Expected outcomes

1. Insights into thermo-mechano-oxidative ageing impacts on materials properties.
2. Feasibility of a finite element simulation coupled with such a material model.
3. Complete lifecycle analysis of an elastomeric component.

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

This project will address the goal of the theme ‘Advanced computational engineering, simulation and manufacture’ by adding to the knowledge of modelling of complex thermodynamical irreversible processes. This project will help in developing the knowledge for modelling of chemical-mechanical-thermal processes and multiphase continuum mechanics

Capabilities and Degrees Required

List the ideal set of capabilities that a student should have for this project. Feel free to be as specific or as general as you like. These capabilities will be input into the online application form and students who opt for this project will be required to show that they can demonstrate these capabilities.

1. Knowledge on continuum mechanics
2. Knowledge on simulation of deformable solids
3. Good level of Mathematics
4. Good knowledge of Thermodynamics
5. Good knowledge to design experiments of mechanical testing of rubbers