IITB-Monash Research Academy

Indian Institute of Technology Bombay | MONASH University

An Indian-Australian research partnership

Project Title:	Designing hydrogen-resistant alloys: Mechanistic evaluation of hydrogen-induced corrosion and cracking in martensitic and precipitation hardened stainless steels
Project Number	**IMURA0805**

Monash Main Supervisor (Name, Email Id, Phone)	Prof Sebastian Thomas Sebastian.Thomas@monash.edu	*Full name, Email*
Monash Co-supervisor(s) (Name, Email Id, Phone)		
Monash Head of Dept/Centre (Name,Email)	Prof. Nick Birbilis Nick.Birbilis@monash.edu	*Full name, email*
Monash Department:	Materials Science and Engineering	
Monash ADGR (Name,Email)	Prof. Christopher Hutchinson Christopher.Hutchinson@monash.edu	*Full name, email*
IITB Main Supervisor (Name, Email Id, Phone)	Prof. Indradev Samajdar indra@iitb.ac.in	*Full name, Email*
IITB Co-supervisor(s) (Name, Email Id, Phone)	Prof. Ajay Panwar panwar@iitb.ac.in	*Full name, Email*
IITB Head of Dept (Name, Email, Phone)	Prof. N. Venkatramani Head.met@iitb.ac.in	*Full name, email*
IITB Department:	Metallurgical Engineering and Materials Science	

Research Clusters:

Highlight which of the Academy's CLUSTERS this project will address?
(Please nominate JUST ***one.*** *For more information, see www.iitbmonash.org)*

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

Research Themes:

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	*Advanced computational engineering, simulation and manufacture*
2	*Infrastructure Engineering*
3	*Clean Energy*
4	*Water*
5	*Nanotechnology*
6	*Biotechnology and Stem Cell Research*
7	*Humanities and social sciences*
8	Design

The research problem

Hydrogen (H) induced corrosion and cracking of high strength stainless steels (martensitic and precipitation hardened stainless steels) is a benign problem faced by Oil and Gas (O&G) industries, especially on metallic infrastructure exposed to hydrogen sulphide (H_2S) ("sour") environments. H is absorbed into steels during corrosion in sour environments, with absorbed H scaling with the H_2S concentration of the environment. The quest for fossil fuels today has resulted in deeper O&G exploration (in oil and gas fields), where the H_2S concentration is significantly higher thus, exposing alloys to a higher H concentrations than what they are currently designed to withstand. The development of cost-effective H-resistant alloys is required enable O&G infrastructure to withstand extremely sour conditions in deeper O&G exploration. Similarly, a mechanistic understanding of H-induced corrosion/cracking is essential in the context of material selection, damage prediction and component design for application in sour environments.

It is well-known that the presence of absorbed H causes cracking driven by H embrittlement in steels. The absorbed H either diffuses through the steel (known as diffusible H) or could get trapped at different microstructural features such as vacancies, carbides, dislocations etc in the steel (known as trapped H). The presence of either diffusible or trapped H favours cracking of high strength stainless steels, as recognised by the drop in the stress intensity factor for cracking (K_{ISCC}) with the presence of absorbed H. Past work has correlated the H-induced crack growth rate to the diffusible H concentration within steels, but recent research has identified that H infact intrinsically activates metal dissolution. Therefore, H-induced metal dissolution (or corrosion) could significantly contribute to the overall H-induced crack growth rate and also control H absorption/diffusion in steels. A mechanistic understanding of H-induced corrosion and its influence on H-induced cracking is therefore essential to design cost-effective H-resistant alloys.

Project aims

The project has four principal aims:

(i) To identify the mechanism of H-induced corrosion in a martensitic steel (AISI 410) and a precipitation hardened stainless steel (17-4 PH), using spectro-electrochemical methods including online inductively coupled plasma-atomic emission spectroscopy (ICP-OES) and electron microscopy.

(ii) To study the effect of H-induced corrosion on the overall H-induced crack growth rates, using electrochemical methods, slow strain rate testing and direct current potential drop (DCPD) to categorise the electrochemical crack-growth vs the hydrogen embrittlement driven crack growth.

(iii) Identify the susceptibilities of the different stainless steel microstructures to H-induced cracking/corrosion and relate them to the H-diffusion/trapping characteristics of each microstructure.

(iv) Propose a framework to design H-resistant alloys.

Expected outcomes

(i) Development of a mechanism for H-induced corrosion of martensitic and precipitation hardened stainless steels.

(ii) Identify the influence of H-induced corrosion on HE and vice-versa.

(iii) Identity microstructures or microstructural features which make stainless steels probe to H-induced corrosion/cracking.

(iv) Propose a framework to develop H-resistant alloys for O&G applications.

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

The project will serve to provide critical knowledge to firstly understand (and thus predict) infrastructure damage in sour environments, caused by H interactions with metal components. It will also provide a design framework to develop next-generation H-resistant alloys.

Capabilities and Degrees Required

The candidate must have a Bachelors or Masters Degree in Metallurgical Engineering, Metallurgy or Materials Science.

The candidate must have knowledge of electron characterisation methods and basic electrochemical methods to test corrosion of alloys.

Potential Collaborators

None at this stage

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.

Metallurgy, stainless steel, hydrogen embrittlement, cracking, alloy design