My Introduction

Supratik Roychowdhury, Mumbai, India

- **PhD – Department of Metallurgical Engineering and Materials Science, Indian Institute of Technology Bombay (IIT Bombay), Mumbai, India, 2011.**

- Working in Corrosion Science Section, MSD, **Bhabha Atomic Research Centre, Mumbai, since 1998. Presently on two year leave from BARC for pursuing post-doctoral research in PSI.**

- **Joined PSI on 1st February, 2013, First batch of the "PSI Fellow/COFUND" programme**

- **Experience: Research on correlating microstructure of materials to corrosion/cracking behaviour (Environmental assisted cracking), flow accelerated corrosion, metallurgical support to nuclear power plants and utilities, teaching**

- **Motivation: To work in a research group actively involved in world class materials research on topics related to my fields of interest. LNM in PSI fulfills both these criteria!**

PAUL SCHERRER INSTITUT

PSI

Wir schaffen Wissen – heute für morgen

Paul Scherrer Institut

Roychowdhury Supratik

Environmental effects on fracture of reactor pressure vessel steel

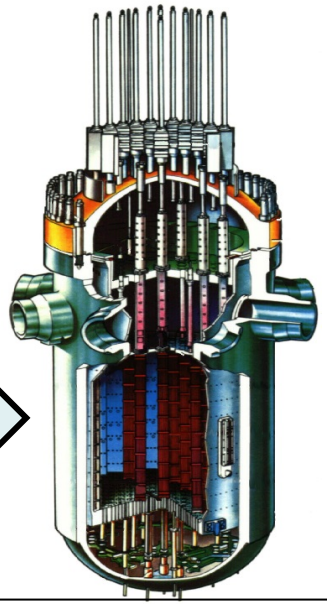
Scientific background

•Integrity of pressure boundary components in an operating nuclear power plant is of utmost importance –safety and useful life of a reactor.

High temperature

Irradiation

Environment
(pure water, 288-320 C, high pressure)



Reactor pressure vessel *(low alloy steel)*

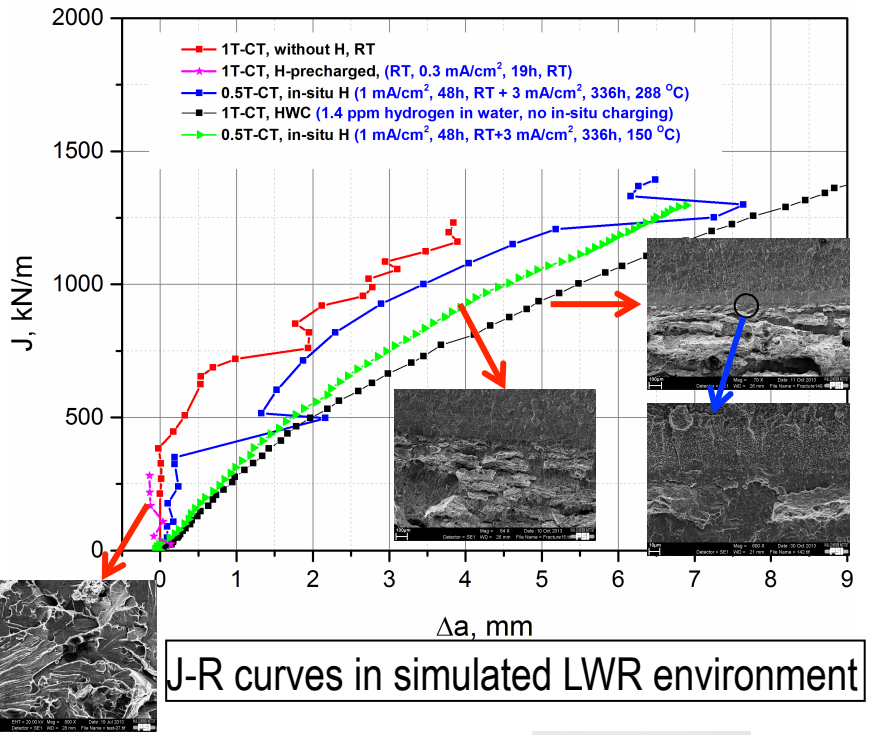
- Thermal aging
- Irradiation embrittlement
- Environmental effects

Loss in fracture toughness and tearing resistance

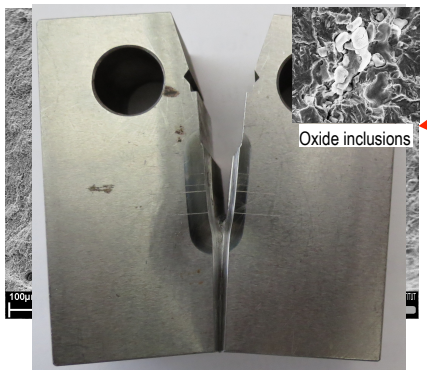
Resistance to brittle fracture reduces!!
Sudden fracture!

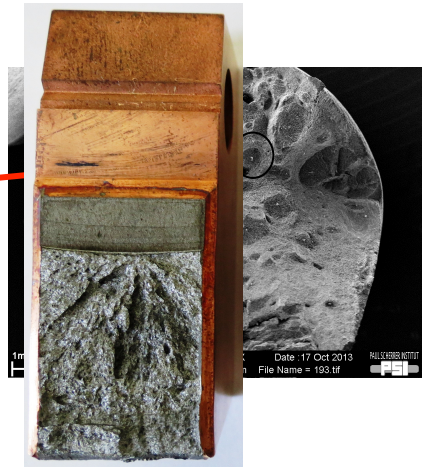
- Sudden fracture in simulated BWR environment during long term SCC experiments is reported
- Presence of hydrogen picked up from aqueous environment can result in such significant loss in toughness
- Aim: Investigate effect of hydrogen pickup, microstructure, loading conditions on fracture toughness at reactor operating conditions

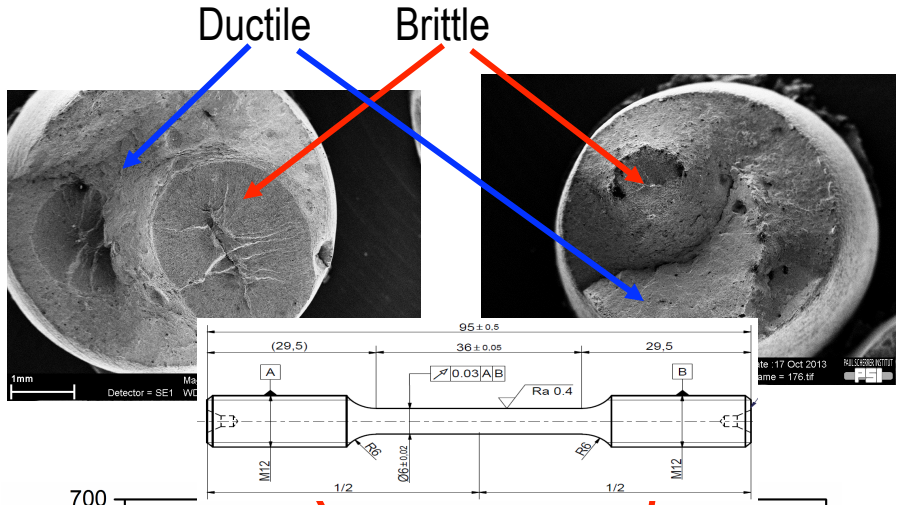
Preliminary results

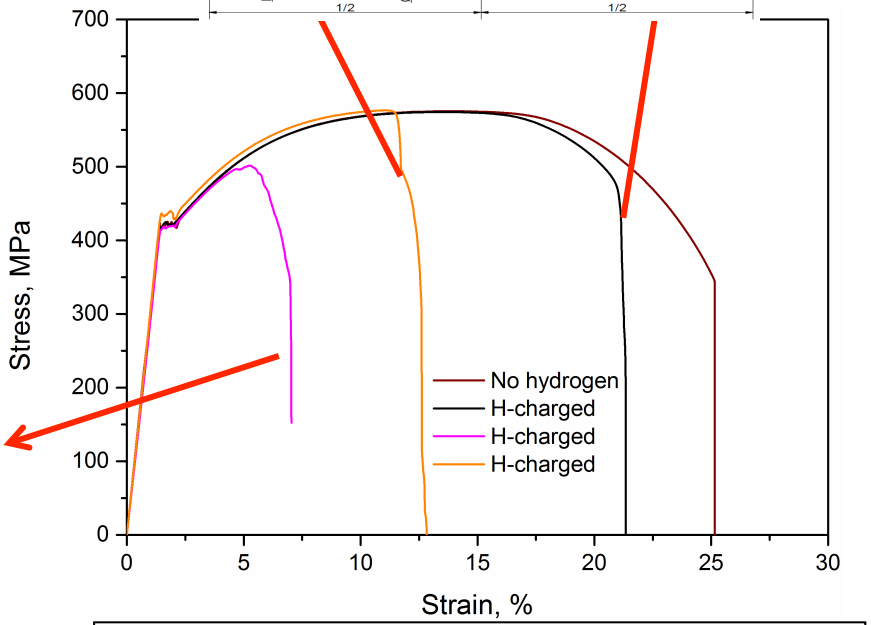


J-R curves in simulated LWR environment









Tensile tests of hydrogen charged specimens in air at room temperature

Publications/Presentations

On the work done…

•Made a presentation on "**Environmental effects on fracture**", in the Half-yearly meeting related to SAFE project with the Swiss Federal Nuclear Safety Inspectorate (ENSI) on 27th June, 2013

•PSI report on "**Literature review on environmental effect on fracture toughness – role of hydrogen**", **TM-46-13-05**

•Abstract submitted for presentation in the The International Symposium **Fontevraud 8** on "**Contribution of Materials Investigations and Operating Experience to LWRs' Safety, Performance and Reliability**" will be held in **Avignon** from **14 to 18 September 2014**

• **Paper presented in the 16th International Conference on Environmental Degradation of Materials in Nuclear Power Systems – Water Reactors, August 11-15, 2013, Asheville, NC, USA**

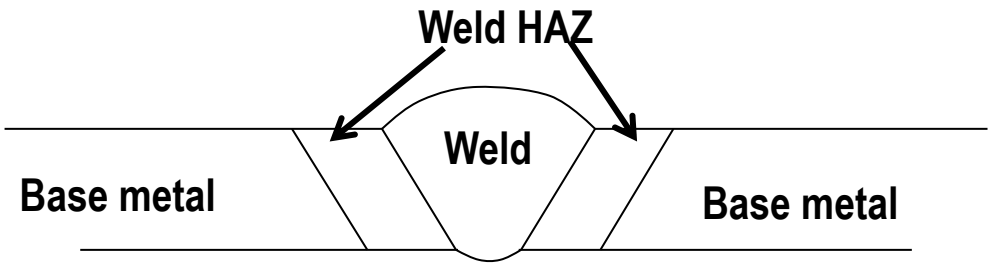
Anticipated…

•1 Journal publication on the work done June 2014
•Presentation and publication in the conference proceedings of **Fontevraud 8**

Further work planned..

Weld HAZ simulation

•Identify the temperature, hold times (simulating welding conditions and PWHT), based on reported literature and trial experiments, to obtain microstructure (grain size, phases) and hardness simulating actual weld HAZ



Schematic of a weld

Tensile tests

•Tensile tests with and without hydrogen at different temperatures (3 temperatures simulating different LWR operating conditions), microstructures (simulating HAZ) and strain rates, followed by characterisation (SEM, TEM)

Fracture toughness tests

•Tests in air at room temperature to generate baseline data

•Tests in simulated LWR environment for different microstructures

Critical steps in the project

Already done..

- Standardising H-charging conditions - ✓
- In-situ hydrogen charging setup for use in LWR conditions - ✓
- Fracture toughness test in LWR conditions and data analysis - ✓

To be done..

- Weld HAZ simulatio… …mes …imulating welding conditions and PWHT… …al experiments, to obtain microstructure (grain s… …tual weld HAZ

- Heat treating cylindrical te… …CT and 0.5T CT specimens to obtain the desired microstructure simulatin… …eld HAZ, without dimensional changes/damage

- Involves high temperature (> 1000˚C)
- Severe oxidation, damage to specimens

- Lower temperature to limit oxidation
- May not be very accurate simulation of weld HAZ
- Can induce microstructural variation typical of HAZ

Contingency Plan

- Choice of heat treatment schedules: Choose heat treatment temperature and duration, to induce different microstructure and hardness without inducing dimensional changes/ damage

Resources for project execution…

Resources		
Material (Steel, Stainless steel, previously characterized)	√	
Resources for H-charging facility	√	
H-analysis facility	√	
Characterization equipment's (LM, SEM, TEM, microhardness)	√	
Mechanical testing equipment	√	
Test systems simulating LWR conditions	√	
Extensometer for high temperature fracture toughness tests (air)	**X**	Procured
Heat treatment facility	√	Limited capability

Future career after PSI fellowship

Short term objectives ….

- **Possibility of continuing in PSI further for another year (subject to grant of approval from BARC)**

Long term objectives / interest ….

- **Pursue a career in academics coupled with research**

PSI-Fellow Programme

The good points…

- **Efficiently managed, right from the initial application stage:** Applicants were well informed at all stages of the selection procedure
- Organization of various events/workshops for PSI fellows
- Opportunity to work in a multi-cultural environment
- Opportunity to attend/present papers in conferences and interact with experts

Scope for improvement…

- Timelines during the application stage were too tight
- Information (or relevant web links) necessary for quick settling-in may be provided prior to arrival

- *Acknowledge the support provided by ENSI and the European Community's Seventh Framework Programme for funding this project!*
- *Acknowledge Hans-Peter Seifert (mentor) and my group for helping me in all matters related to work or otherwise.*

Thank you