TWI Seminar

Keeping Plant and Structures Operating Safely

Jidosha Kaikan, Ichigaya, Kudan Minami 4-8-13, Chiyoda-ku, Tokyo, 102-0074
Tel: 03-3264-4719

17 November 2014

09:30 – 09:45	Coffee/Registration	
09:45 – 10:00	Introduction	Taka Kakuhari, UKD and Fred Delany
10:00 – 10:30	Fracture and Structural Testing at TWI	Isabel Hadley
10:30 – 11:00	Overview of Non Destructive Testing at TWI	Fred Delany
11:00 – 11:15	Coffee break	
11:15 – 11:45	Fatigue Testing at TWI	Yan-Hui Zhang
11:45 – 12:15	The Structural Integrity Research Foundation	Fred Delany
12:15 – 12:30	Discussion	
12:30 – 13:30	Lunch (provided)	

Speakers will be:

Dr Isabel Hadley

Dr Hadley's higher education was at Cambridge and Sheffield universities. She joined TWI in 1992 after working in several fields including nuclear engineering and offshore technology, and was promoted to Technology Fellow in 2012.

Dr Hadley's technical work focuses on the development of analytical flaw assessment techniques, and their application to safety-critical structures and pressure equipment. Chairing the committee that develops and maintains BS7910 (UK flaw assessment procedure), Dr Hadley is a member of the R6 (UK nuclear assessment procedure) panel. She is also co-author of the European FITNET fitness-for-service procedure.

Dr Yanhui Zhang

Dr Zhang's background is in metallurgy, but since graduation in 1982, he has mainly worked on fatigue. His PhD thesis was about fatigue of high strength aluminium alloys. He has also worked on fatigue of silicon nitride ceramics at ambient and high temperatures, fatigue, creep and thermo-mechanical fatigue of Ni-based superalloys. Since he joined TWI in 2001, he has been working in the Fatigue Section, covering fatigue life assessment based on BS 7910, fatigue testing in different environments (eg, seawater, sour, sweet etc), fatigue design according to standards (eg, BS 7608, DNV C203, etc), and failure investigations.

Fred Delany

Fred joined the NDT research department of TWI in 1986, after obtaining a degree in mechanical engineering and an MSc in offshore structures.

Fred has held a number of senior business development and commercial roles, and contributed to the development of TWI outside the UK. He is currently managing the development of TWI R&D activities in Asia, and visits Japan 4 times per annum.

Fracture and Structural Testing at TWI

Isabel Hadley, TWI seminars, Japan, November 2014

Materials Joining and Engineering Technologies

Outline

- Distinction between small-, medium- and full-scale fracture tests
- Role of each in production, consultancy and research
- Examples of tests carried out in TWI's laboratories
- Current research themes in fracture technology

Range of fracture testing

Small

- Charpy
- Pellini (DWT)
- Tensile
- Hardness

Medium

- Fracture mechanics (CTOD/J/K_{Ic}
- Battelle (DWTT)
- Segment test
- Compact crack arrest

Large

- Wide plate
- Double tension crack arrest

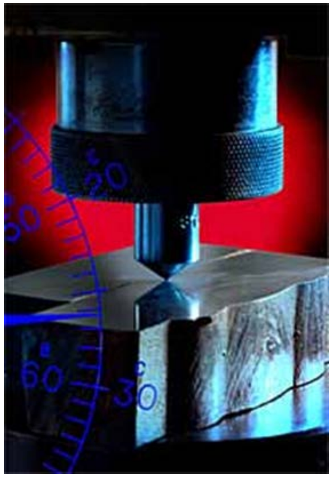
Full

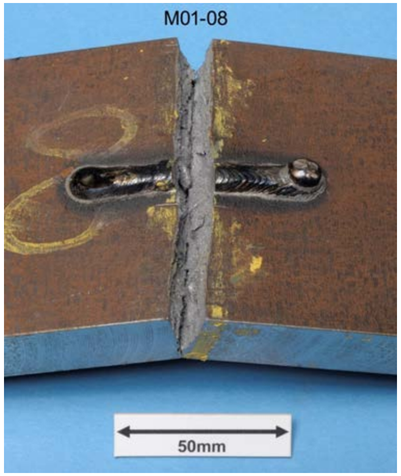
- Pressure test
- Structural test

Most tests can also be carried out in an 'environment' eg H_2, H_2S, CP....

Why use small-scale tests?

- Quick, cheap, easy test to demonstrate quality of product/component
  - Tensile, Charpy, hardness tests
  - Sometimes no other tests required

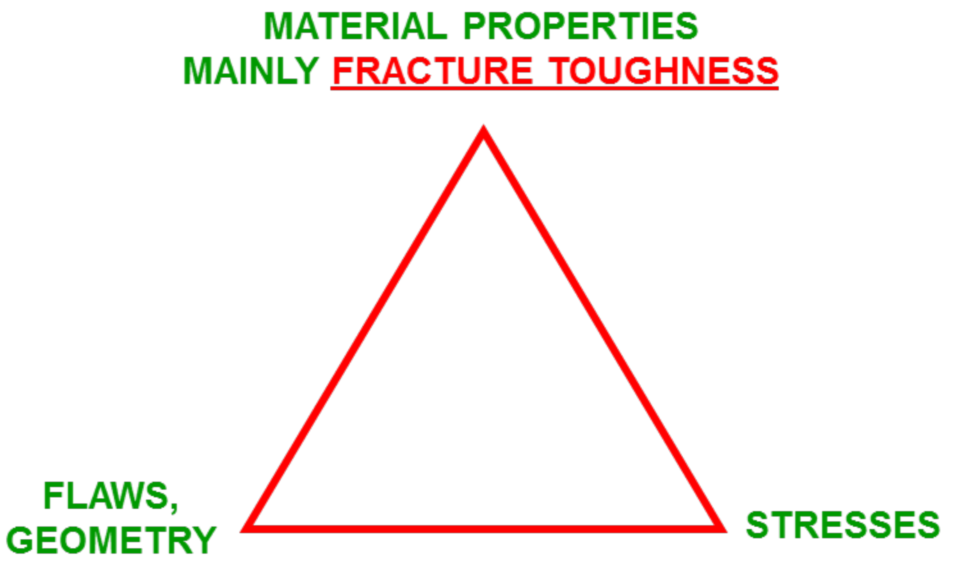


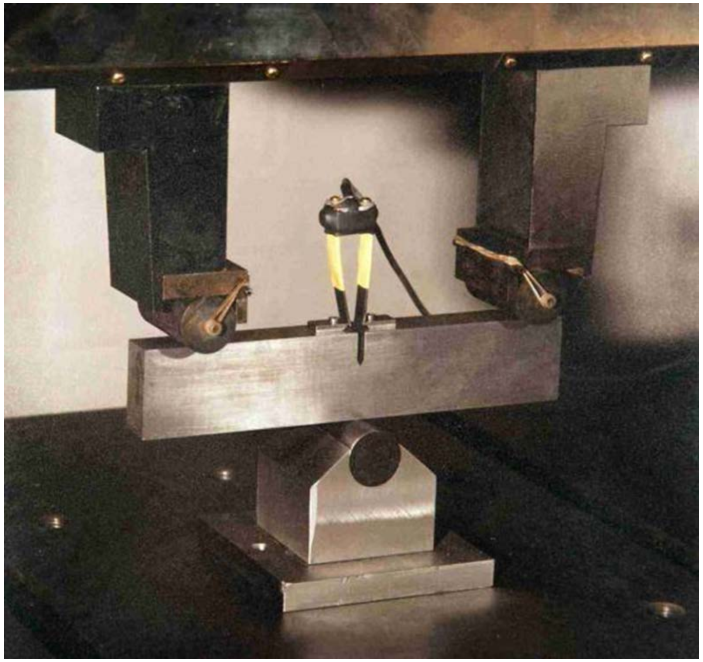


- May be needed to help plan other tests, eg if Charpy results are poor, investigate further with fracture mechanics tests

Why use medium-scale tests?

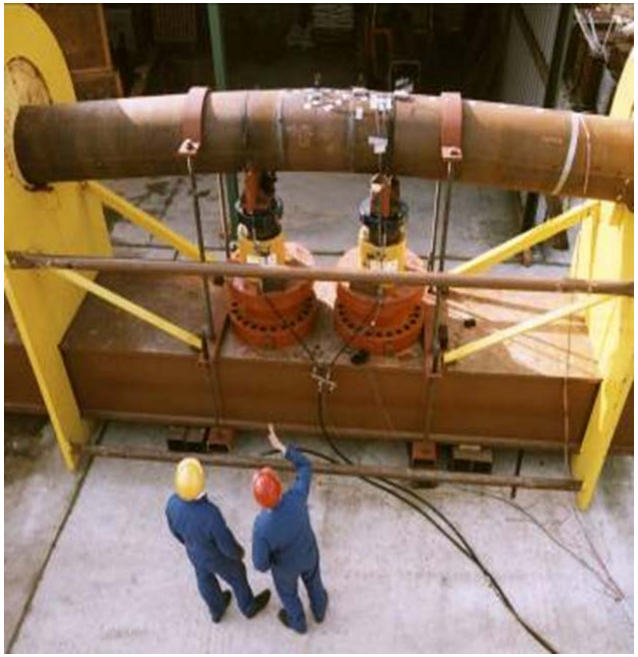
- More representative of the structure of interest
- Main example: fracture mechanics tests (K_{Ic}, CTOD, J-integral)
  - Can be used to relate materials properties to defect-tolerance

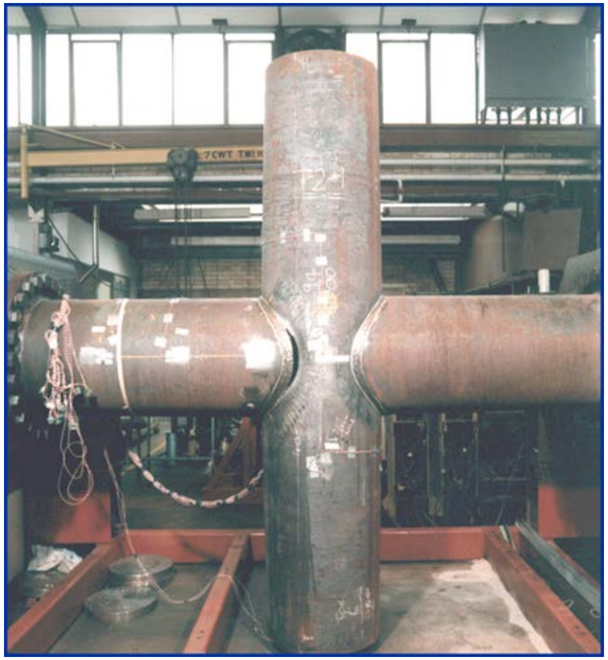




Why use large / full-scale tests?

- Replicate some aspect of the structure that is not easy to scale down, eg:
  - welding residual stress,
  - crack tip plasticity,
  - Weld misalignment,
  - Crack arrest





- Build confidence – a full-scale test is visually convincing, even exciting
- Validate predictions made from numerical analysis
- For a structure that is too complex to be tested/analysed using small-scale tests

Outline

- Distinction between small-, medium- and full-scale fracture tests
- Role of each in production, consultancy and research
- Examples of tests carried out in TWI's laboratories
- Current research themes in fracture technology

Pressure testing

- Up to 1000 bar pressure
- Apply external load and internal pressure together
- 700mm thick walls for blast containment

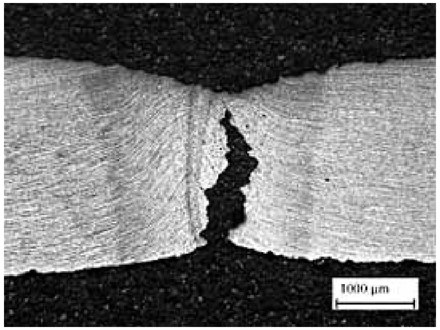
JIP recently completed; effects of biaxial loading on pipeline girth welds

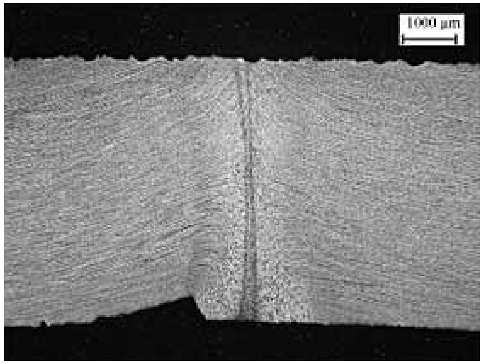
Uprating of an ERW pipeline

Combination of small- and large-scale testing plus ECA allowed operators to:

- increase working pressure
- Decrease minimum allowable temperature

in a 30-year-old pipeline

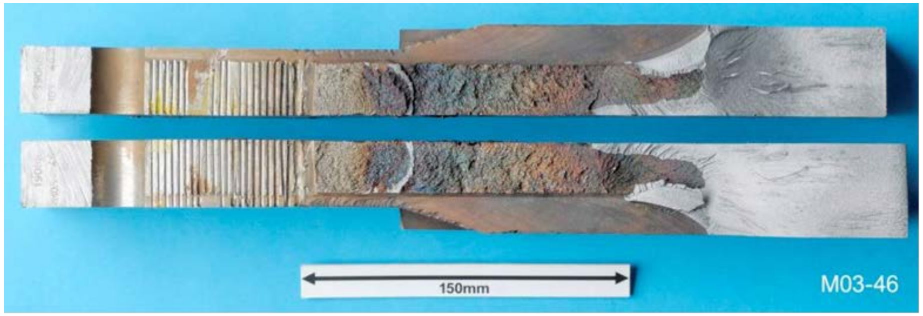


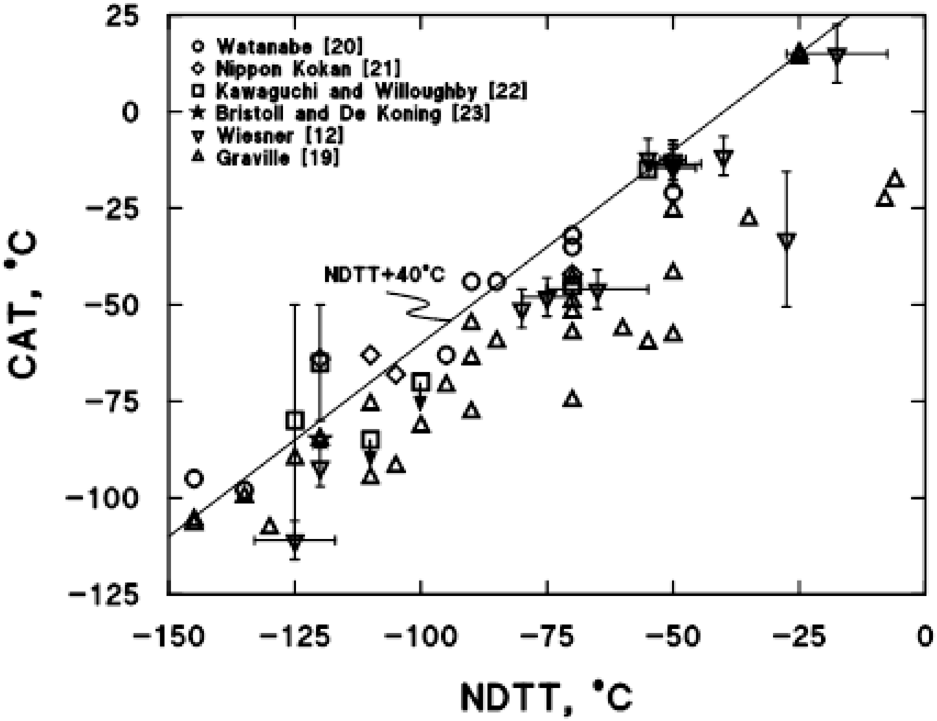


Crack arrest testing of ship steels

Can we use small-scale tests (Charpy/Pellini) to predict the results of this full-scale crack arrest test?

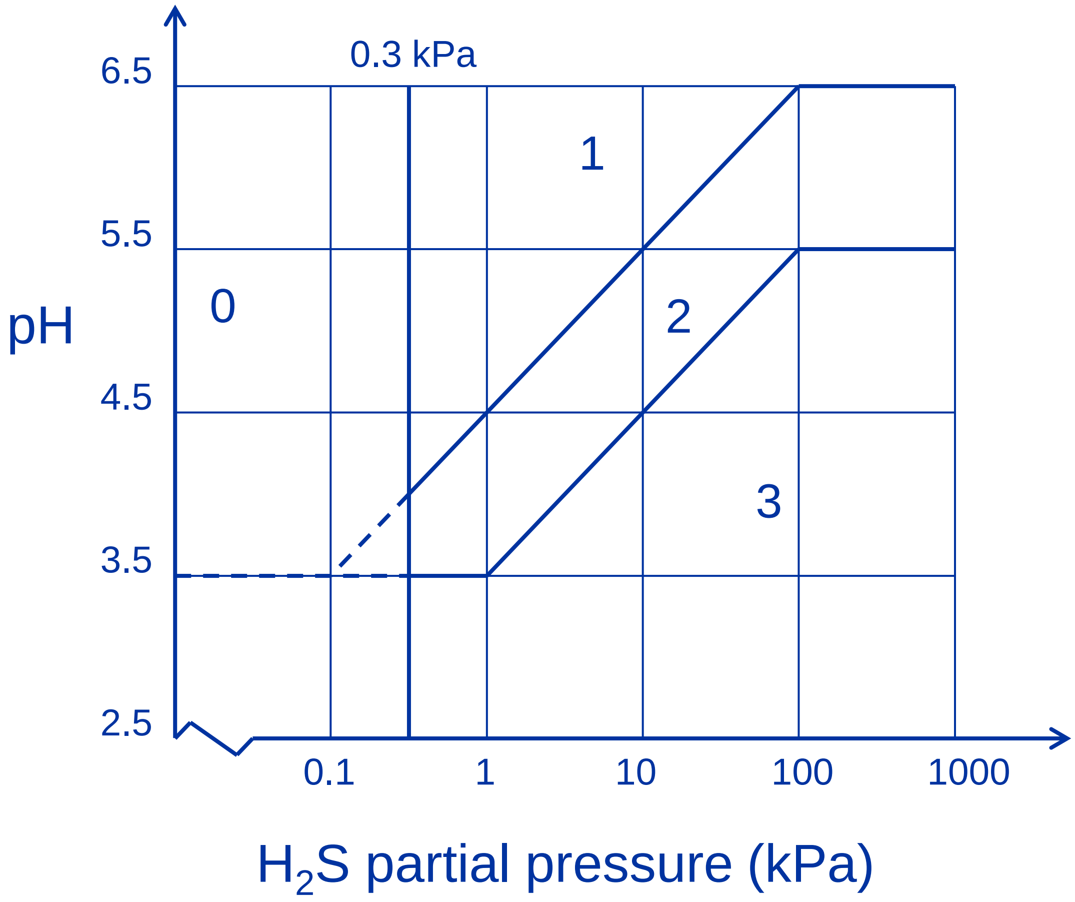
How well does even the full-scale test represent a large ship component?



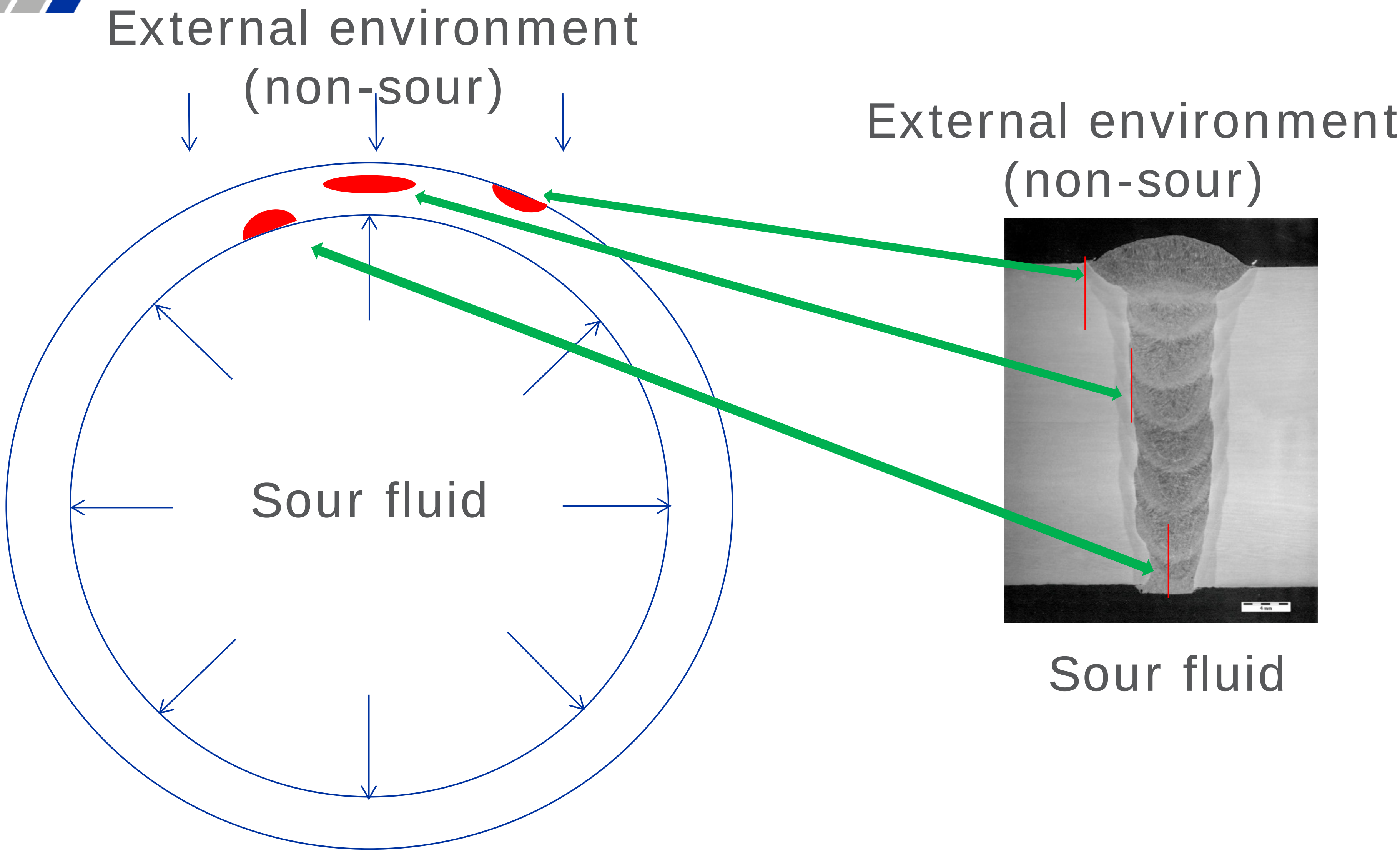


Sour testing of steels

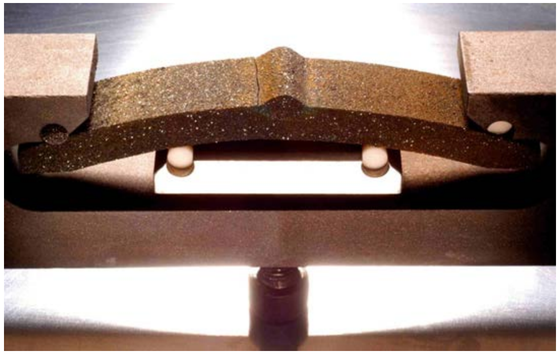
- ISO 15156 domain diagram
- Combines effects of H_2S partial pressure and pH
- 0 least severe; 3 most severe

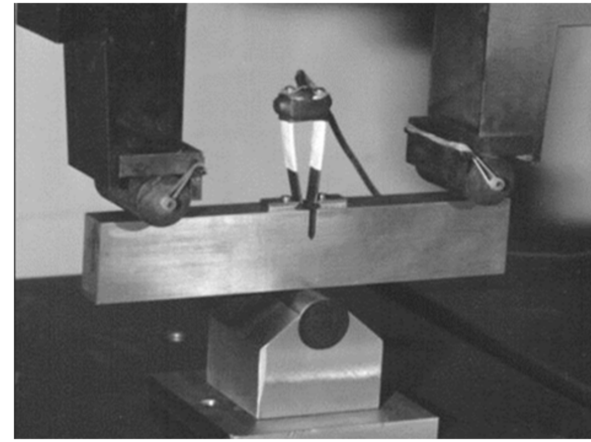


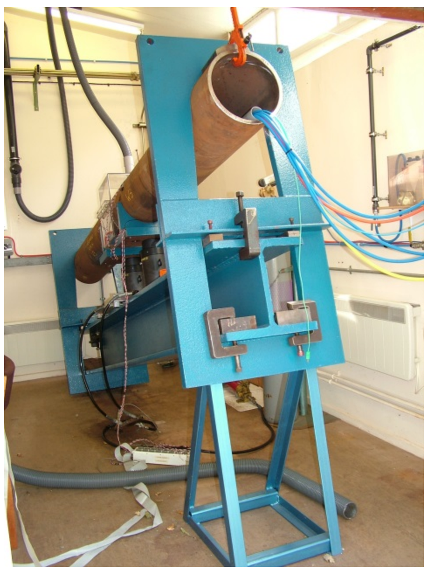
Effects of sour fluid on fracture



Possible sour test setups



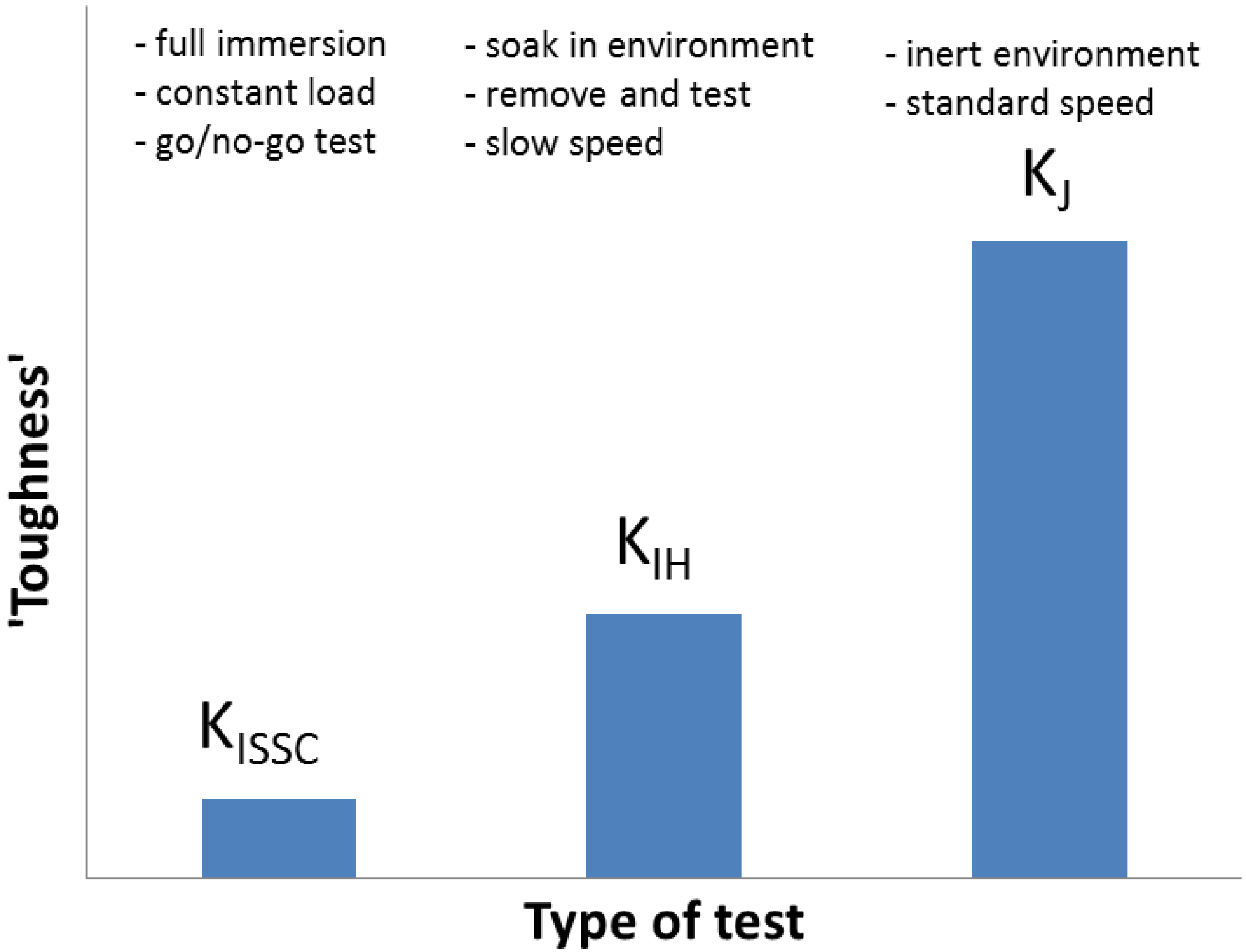




Small- medium- and large-scale tests all applicable

1000m^2 of laboratory space available at TWI for sour testing

Fracture mechanics testing for sour service



Outline

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Current TWI research themes

- Effects of sour service on fracture and fatigue
- Strain-based analysis and design
- Automated FEA of cracked bodies
- Characterisation, modelling and analysis of ‘blunt’ flaws
- Modelling and measurement of residual stress (RS), and interaction between RS and fracture

TWI project 23192 (1)

- Fabricate a pipeline girth weld under carefully-controlled laboratory conditions (eg monitor temperatures, using thermocouples embedded in the testpiece at various locations)
- Model the development of welding residual stresses using FEA and materials testing
- Determine welding residual stress distribution:
  - Non-destructive techniques
  - Destructive techniques

TWI project 23192 (2)

- Predict the behaviour of a girth weld containing a flaw, based on:
  - materials testing,
  - RS modelling,
  - RS measurement,
  - BS 7910 and similar
- Validate using large-scale destructive tests

- Work underway under TWI CRP

Further information

See our corporate website:
http://www.twi-global.com/

Video showing mechanical testing:
https://www.youtube.com/watch?v=0WMWUP5ZHSY&list=PL3f0O-D3NXi-jKdWH-m_rn_k5rhlg78F0&index=2

Overview of Non Destructive Testing at TWI

Fred Delany, TWI Seminars, Japan, November 2014

Materials Joining and Engineering Technologies

NDT Services

- Development of Innovative Inspection Solutions
- Statistics & Reliability
  - Determining and using detection and sizing data
- Validation and Qualification
  - Software Modelling and Application validation
  - Qualification to ENIQ or other
- Third Party Audits and Assessments
- Training, education and certification
- Standards development
- Site inspection services

NDT Services

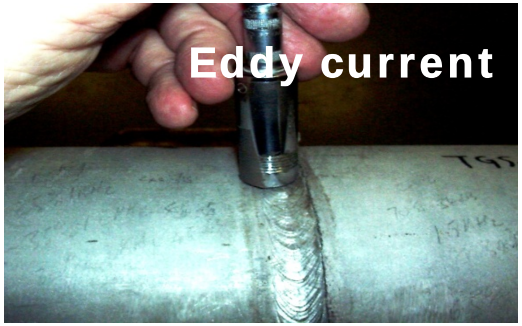
Site services

- UT on process plant, offshore platforms, bridges, buildings
- AUT/PAUT/Pipewizard of pipelines and pressure vessels
  - ASME V (Code case 2235) for pressure vessels and ASME B31 boiler tube inspection
- LRUT of risers, crossings, pipework
- ECT and ACFM of pipelines and risers
- Thermography inspection
- Radiography inspection
- AE – In collaboration with MTI, Ireland

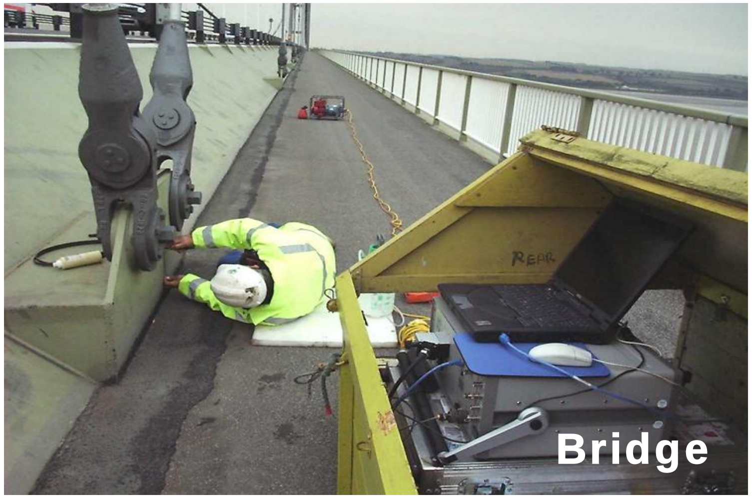
Training

- LRUT, AUT, DR,PAUT, e-learning (CSWIP Level I, II and III)
- Automated UT - pipelines, pressure vessels, tanks, etc
- General NDT - all methods (ET,RT,MT,PT, UT)

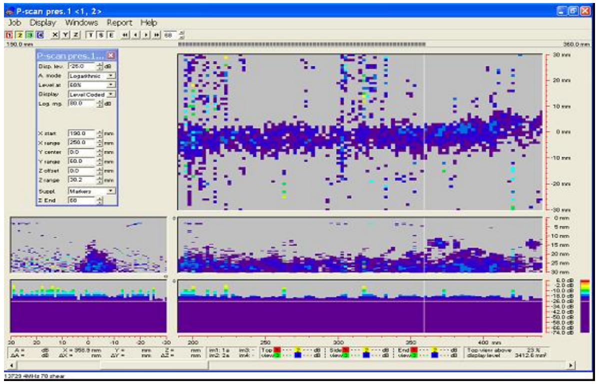
NDT Inspection Services

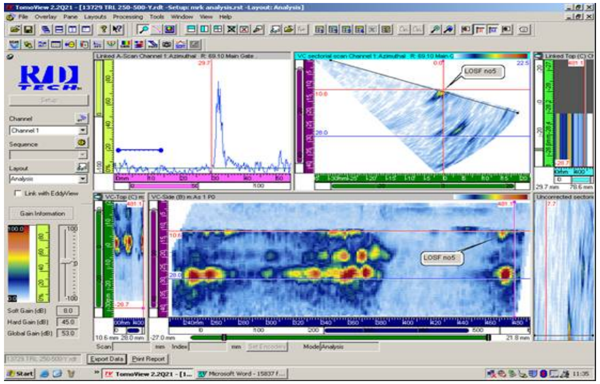


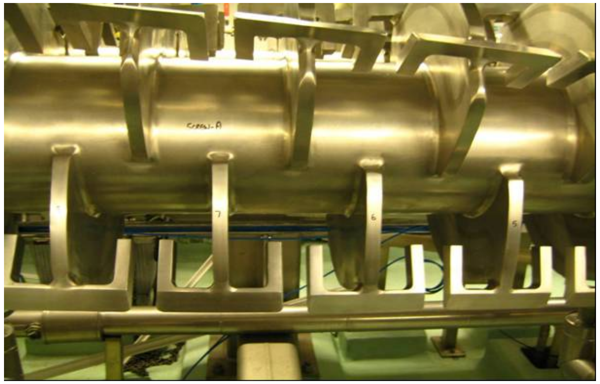
NDT Inspection Services

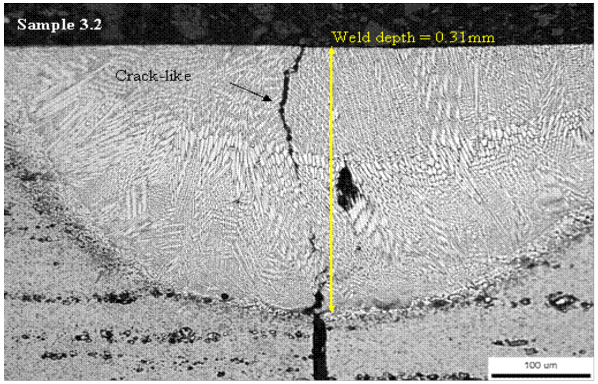


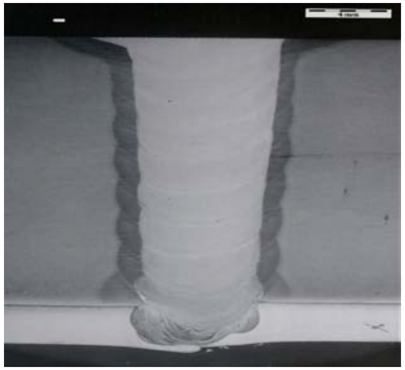
NDT Inspection Services



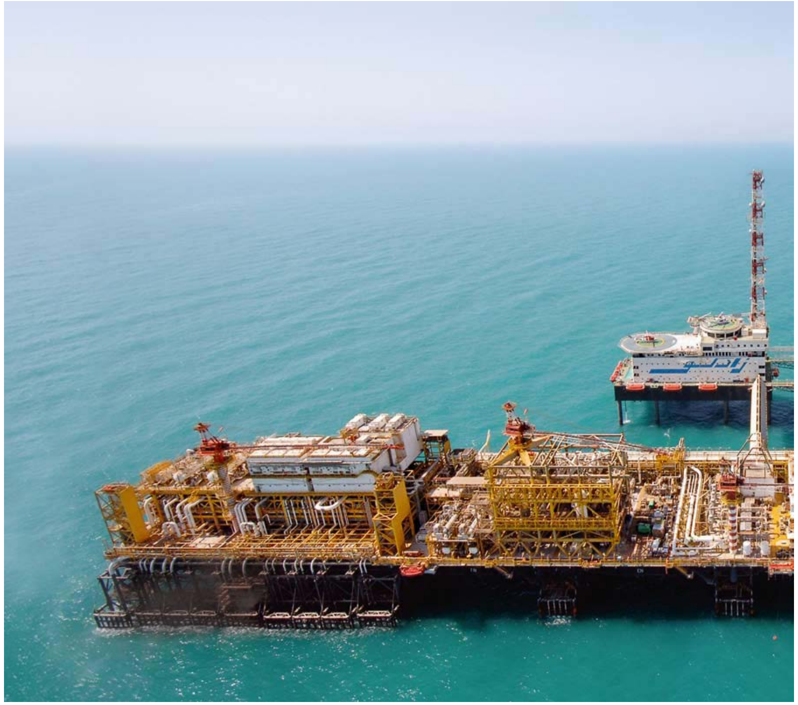








ACFM Inspection of Platform structure weld nodes



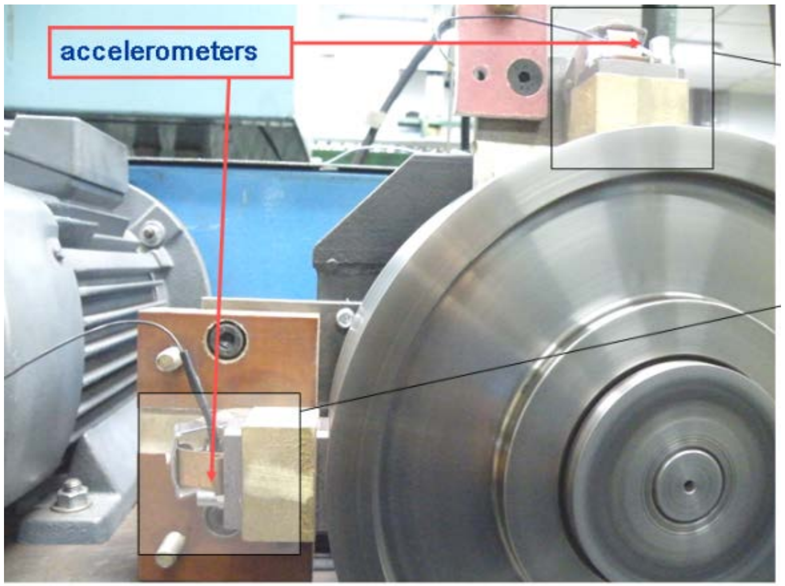
- Suspect overloading of an offshore oil production platform
- Inspection of structural tubular node weld joints surface breaking fatigue or stress cracking
- Joints were coated and many were at heights of up to 15m
- ACFM was selected to avoid the need to remove the surface coating and the probe could be operated at height by a rope access

ACFM inspection of FPSO deck plate reinforcement

- FPSO deck plate reinforcement attachment welds were exhibiting signs of cracking in the areas where support stools had been attached to the topside of the deck plate

- ACFM inspection was selected to inspect the welds for any production or stress related cracking without the need to remove the paint coating

Condition monitoring



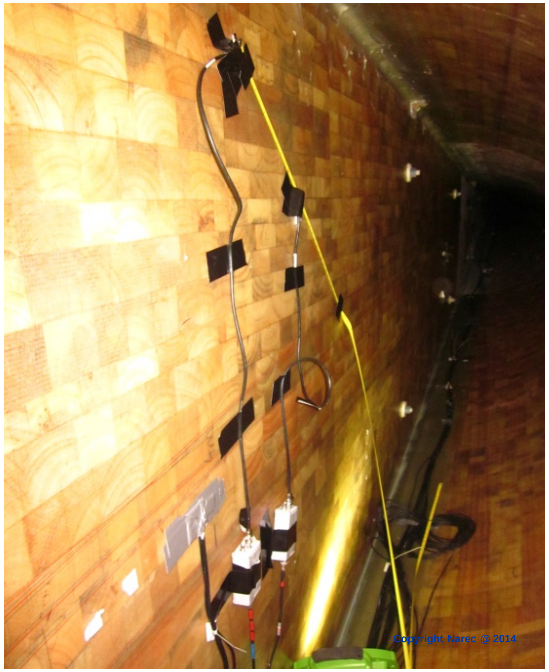
Real-time condition monitoring system for wind turbine rotating components

- Monitoring the condition of the drive train (gearbox, generator, main bearing) of the turbine through the application of on vibration and AE monitoring for rotating components

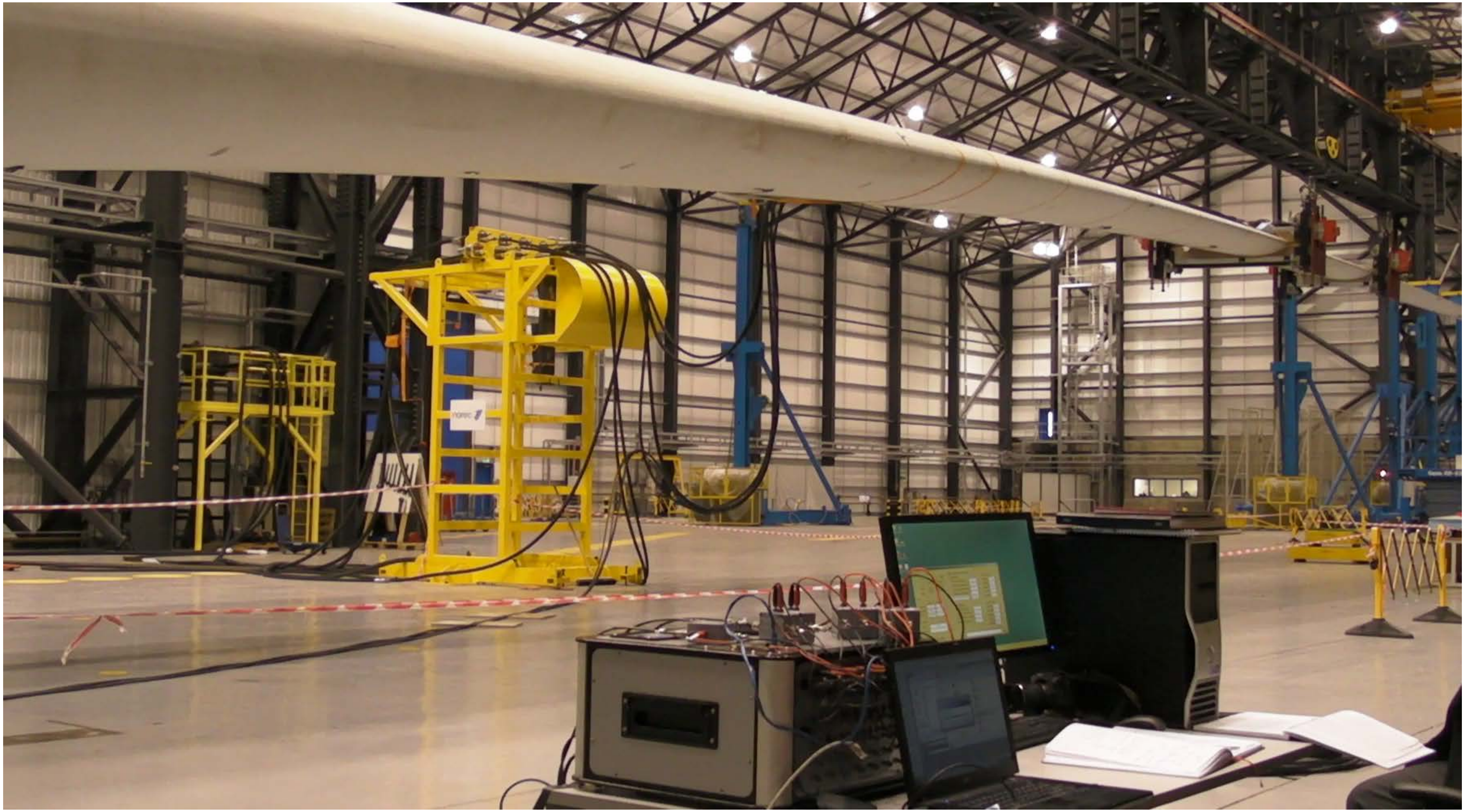
Wind SHM – Signature Identification

Trials performed on 45m blade

- Attenuation analysis
- Localisation
- Monitoring crack propagation under fatigue



Structural Health Monitoring Trials



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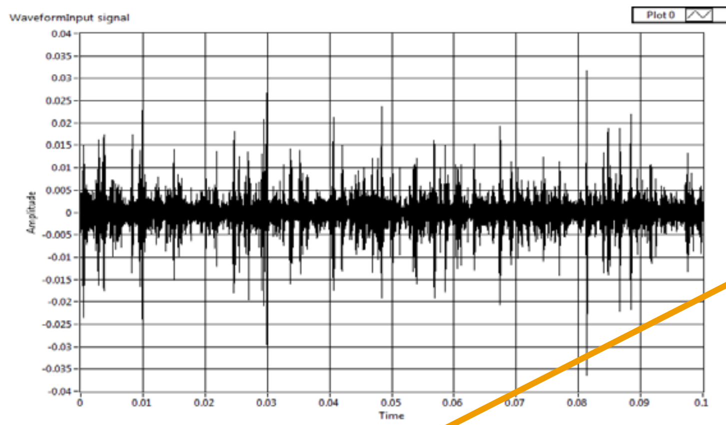
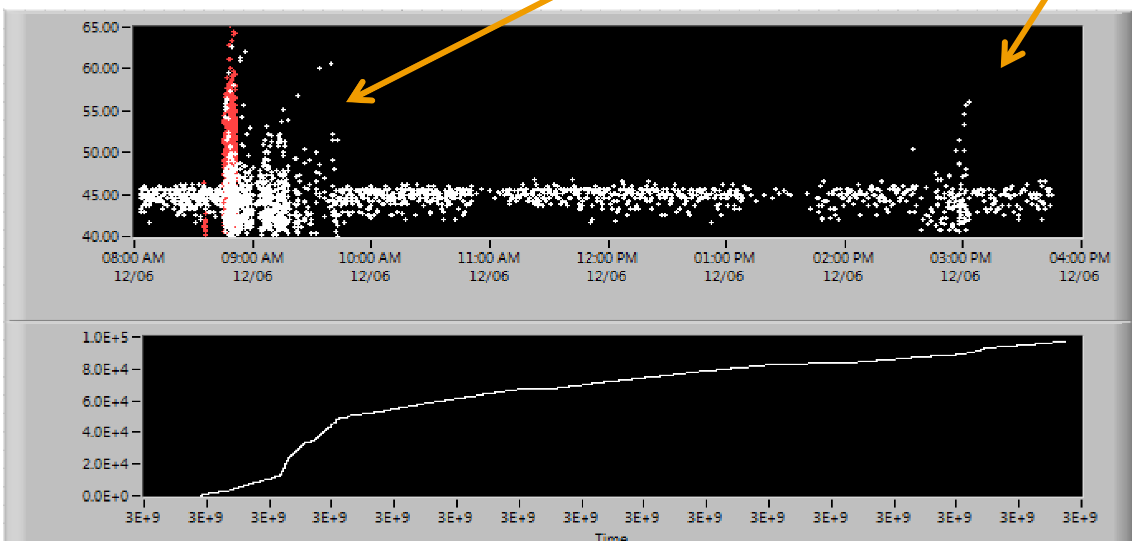
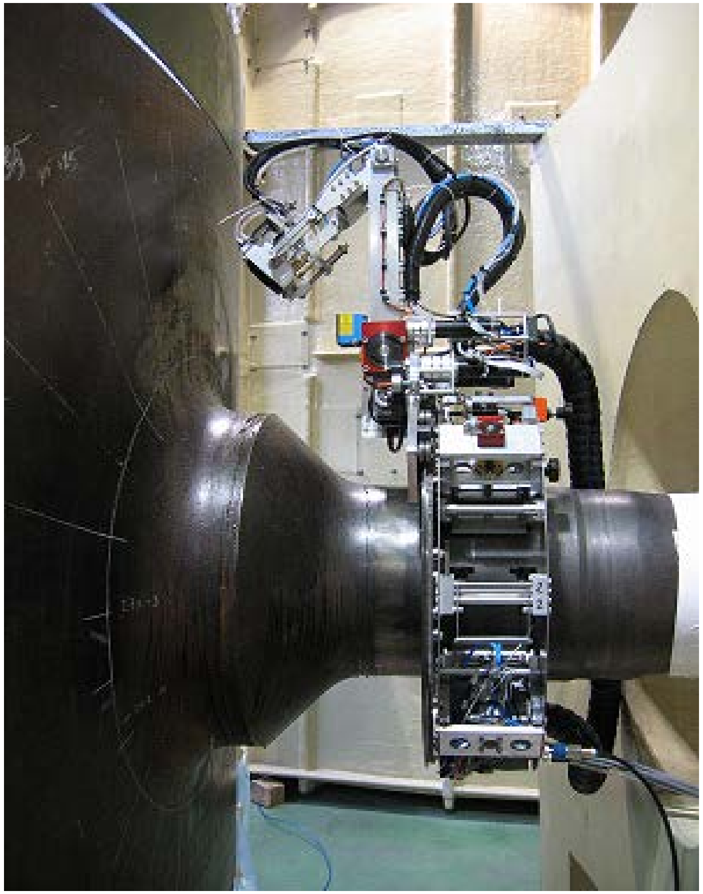
SHM Trials - Events



Symptoms of crack propagation



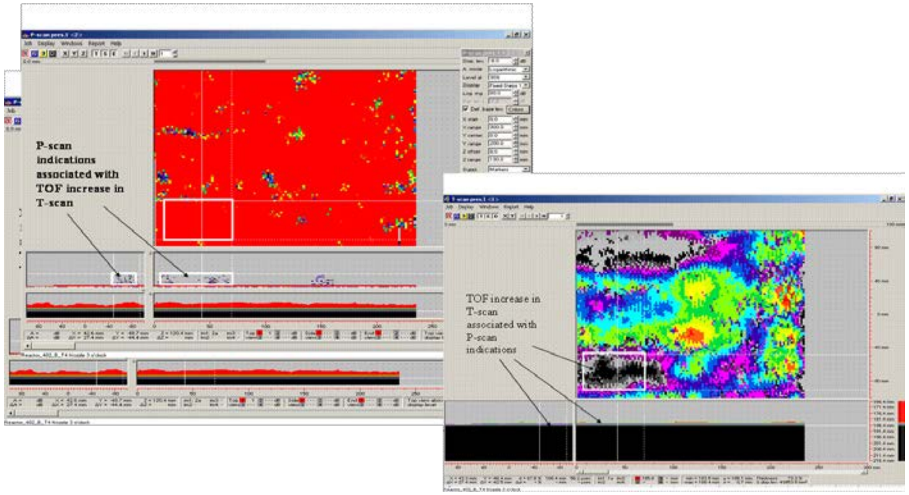
NDT Inspection Services



Autonomous robot for the automated inspection of nozzle welds in nuclear environments

- Automated manipulator system that can fit to different pipe sizes within ±30% of nominal OD
- Novel phased array matrix annular phased array probe that offers 3D beam steering capability
- Flexible membrane probe to conform to the curvature changes around the nozzle

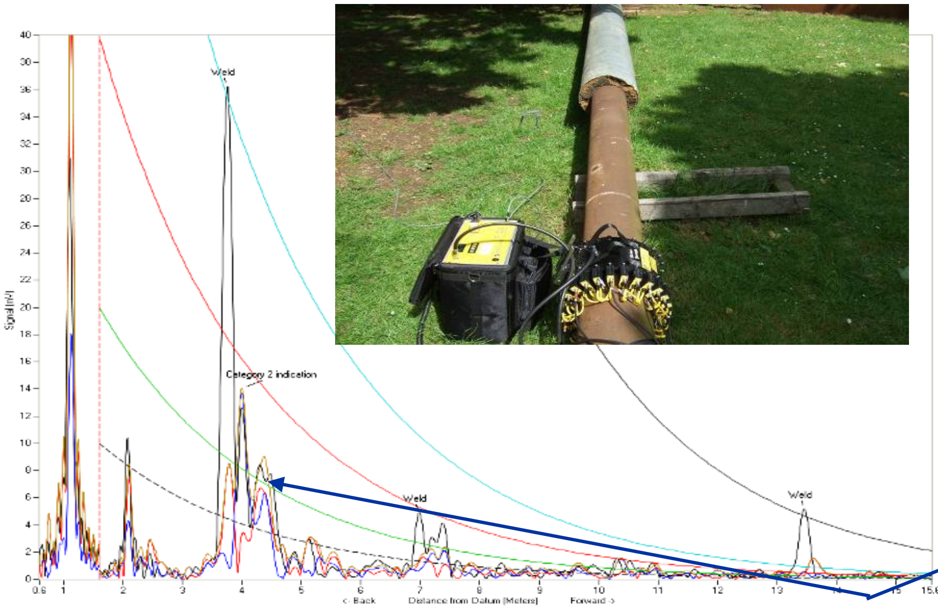
NDT Inspection Services



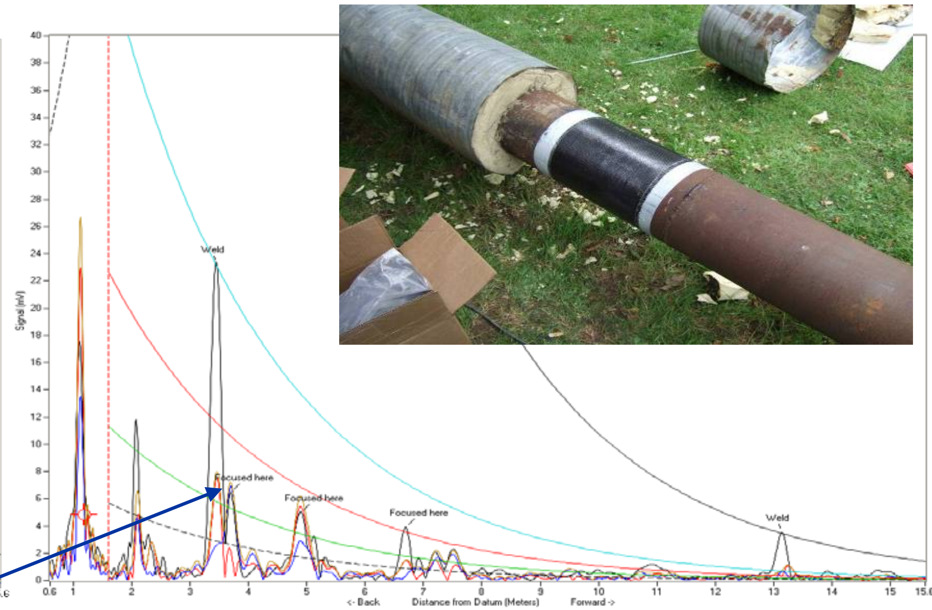
- Improvement over corrosion mapping by:
  - o Reducing costs by eliminating the invasive surface crack detection
  - o Adding value by providing much higher sensitivity to micro-cracks
- Human factors
  - o Proficiency in operating system software
- Equipment
  - o Reference samples containing damage for setting up equipment
- Information
  - o Producing meaningful P/T-scan images for the client

LRUT Teletest for pipe repair

- Before repair



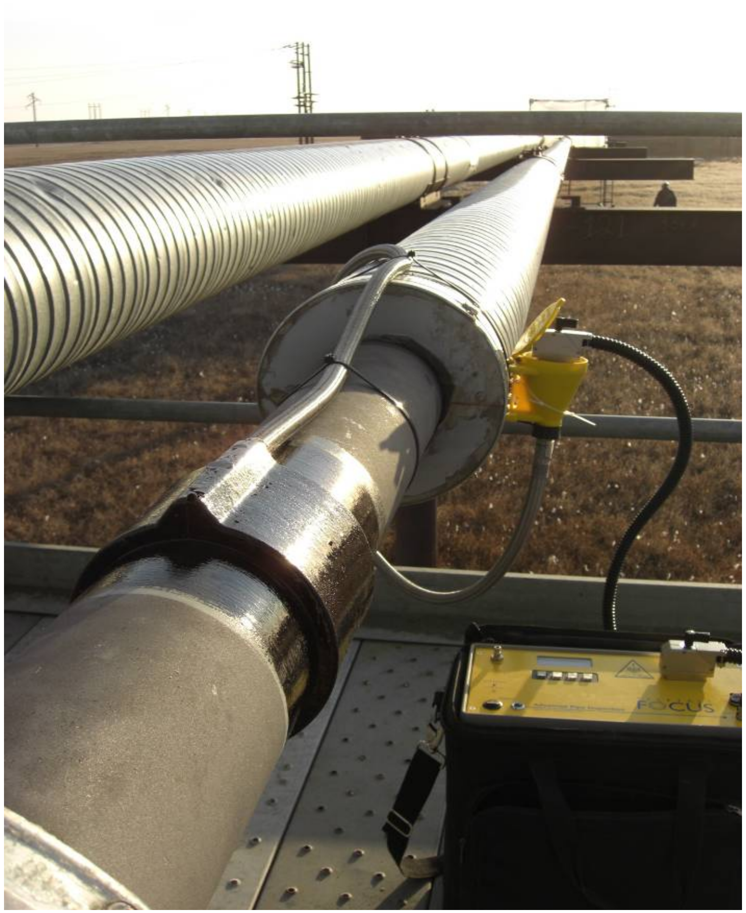
- After repair



Defect

- The defect is still visible under the wrapping
- Wrapping is nearly invisible to guided wave

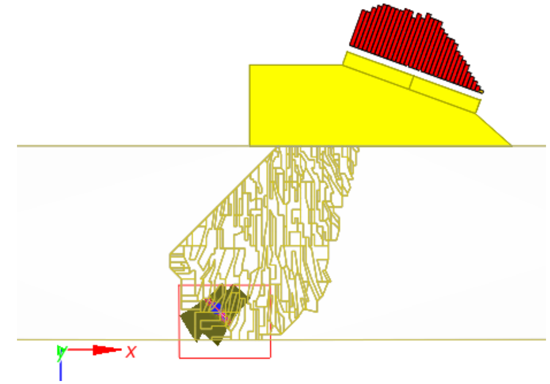
Teletest Focus+ Permamount

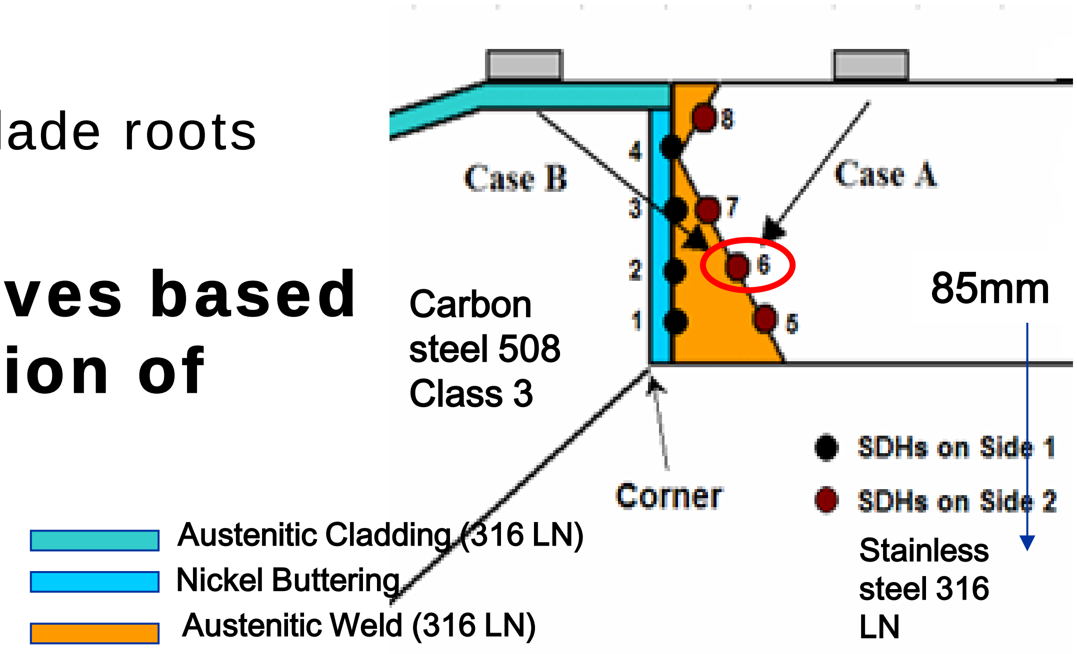


- All benefits of Teletest Focus
- Low profile
- Comparison of previous data
- Easy installation
- Remains stable over long times in harsh environments

Other NDT Inspection Services

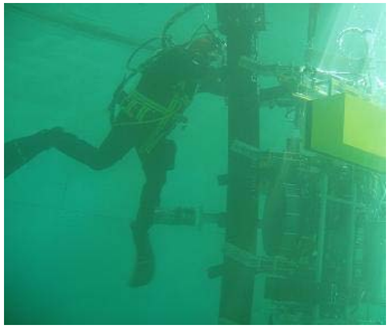
- **Phased array inspection**
  - Cladded pipe girth welds
  - Fillet weld of tank floors
  - Dissimilar/ austenitic welds
  - Plastic pipe
  - Mooring chain inspection
  - Wind turbine aluminium blade roots
  - Full Matrix Capture
- **Estimation of POD curves based on theoretical simulation of inspection process**

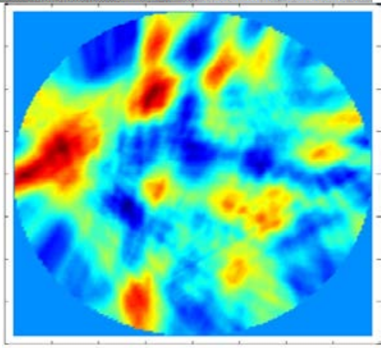




Other NDT Inspection Services

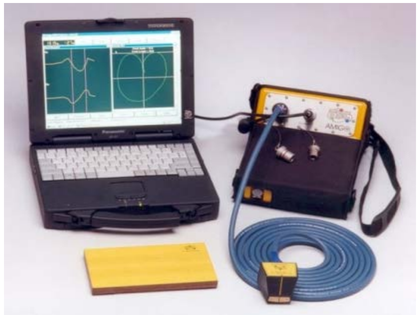
- **LRUT inspection of**
  - Storage tank floor using tomography approach
  - High temperature pipes
  - Ship hull structure
  - Mooring chain inspection
- **Digital Radiography**
  - Subsea pipelines and flexible risers
  - Online real-time inspection of electronic parts
- **3rd party validation of the use of AUT in lieu of RT for heavy wall high pressure pipe welds**





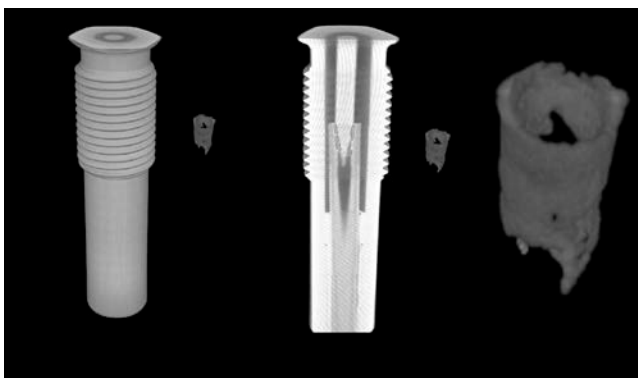
TWI's NDT Systems

- Computerised ultrasonic testing
- Ultrasonic Time Of Flight Diffraction (TOFD)
- Ultrasonic corrosion mapping
- Ultrasonic bond testing
- Ultrasonic flaw imaging
- Automated UT of pipeline girth welds (AUT)
- Long Range Ultrasonic Testing (LRUT)
- Acoustic emission
- Alternating Current Field Measurement (ACFM)



TWI's NDT Systems (2)

- Eddy current testing
- Optical imaging / image processing
- Laser shearography
- Thermography
- Digital radiography
- Computed radiographic tomography (CT)
- Micro-focus X-ray
- Modelling of ultrasound



Collaborative R&D Projects

TWI

AWARE

AWARE NDT Inspection of Inaccessible Electrical Wiring in Ageing Aircraft

Technology Strategy Board
Driving Innovation

NDT Inspection of Inaccessible Electrical Wiring in Ageing Aircraft

Project Budget: £1.3m
End Users: BA, Airbus, Marshall Aerospace

This project developed three novel NDT techniques and delivery systems designed to increase confidence in the integrity of the wiring in an aircraft by detecting flaws in the wiring or insulation:

1) Enhanced Time Domain Reflectometry (TDR)
2) Long Range Ultrasonics System
3) Infra-red Thermal Imaging System

PICASSO

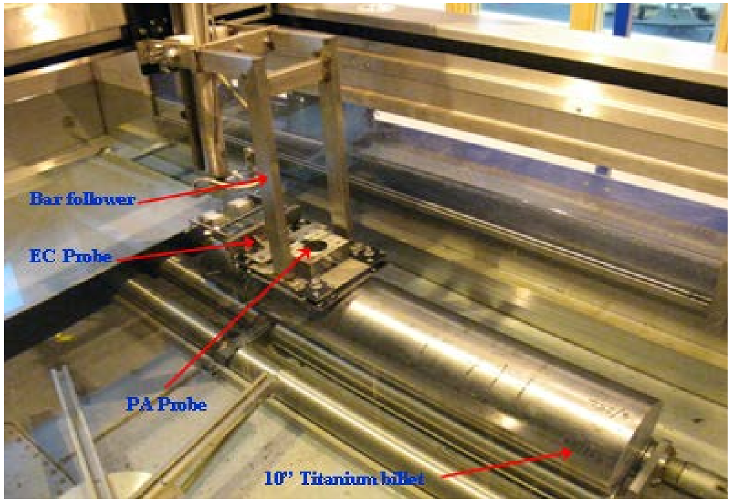
Improved Reliability of Inspection of Aeronautic Structure Through Simulation Supported POD

Project Budget: €4.8m
End Users: EADS,
MTU Aero Engines GmbH,
Rolls-Royce plc,
SNECMA, Turbomeca,
Volvo Aero Aktiebolag

To build a new and original concept of "simulation supported Probability of Detection (POD) curves based on Non Destructive Testing (NDT) simulation in addition to existing experimental database"

QUALITI Qualiti

Development of New and Novel Quality Control System for the Inspection of Titanium Components in Safety Critical Applications in the Aerospace Industry



Project Budget: €1.3m
End Users: TIMET

Developing inspection of titanium at the component manufacturing stage using an automated phased-array ultrasonic.

NDT system supported with eddy current technology, integrated with the manufacturing process.

TWI

SelfSCAN

Neural Net Based Defect Detection System using Long Range Ultrasonic Testing (LRUT) Technology for Aircraft Structure Health Monitoring

Project Budget: € 1.4m
End Users: NDT Expert

Developing new and novel structural monitoring techniques, which monitor all points in the complex airframe structure with a limited number of sensors.

SHeMS

Technology Strategy Board
Driving Innovation

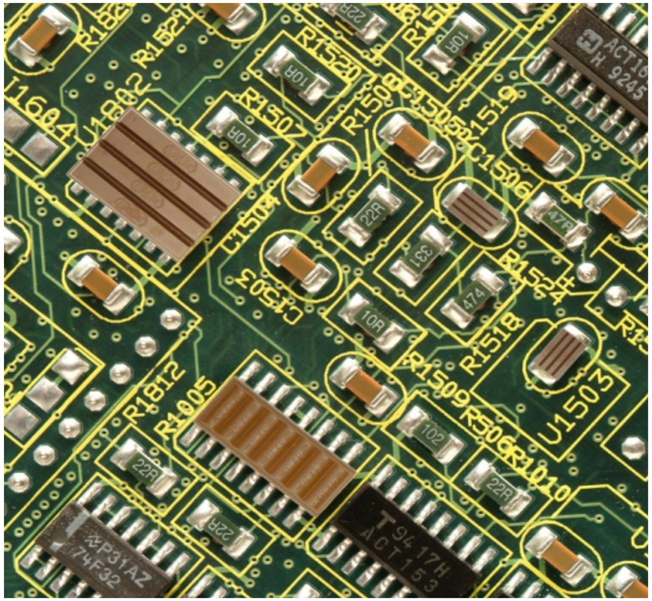
A Lightweight Structural Health Monitoring System

Project Budget: £1.4m
End Users: Airbus UK, Boeing, MoD, Marshall Aerospace

Through the development of energy harvesting, acoustic emission and acousto-ultrasonic techniques the project will deliver a lightweight structural health monitoring system that is suitable for deployment onto aircraft and capable of determining the structural integrity of critical components.

ChipCheck

Development of Novel X-ray Inspection System for Fast Automated Detection of Counterfeit PCB Components



Project Budget: €1.2m
End Users: SMART Group, Semicon

Developing a counterfeit electronic component detection system that will automatically inspect components in their original packaging.

LRUT Food

Technology Strategy Board
Driving Innovation

Advanced Long Range Ultrasonic Technology (LRUT) for Integrity Assessment

Project Budget: £1.3m
End Users: H J Heinz, Tetra Pak, Cadbury Schweppes

The project aimed to develop NDT methods of detecting chloride induced stress corrosion cracks as well as the build up of fouling deposits on the inside of process piping used in food production. Both aims were addressed using the same technology: Long Range Ultrasonic Testing (LRUT).

MICCS

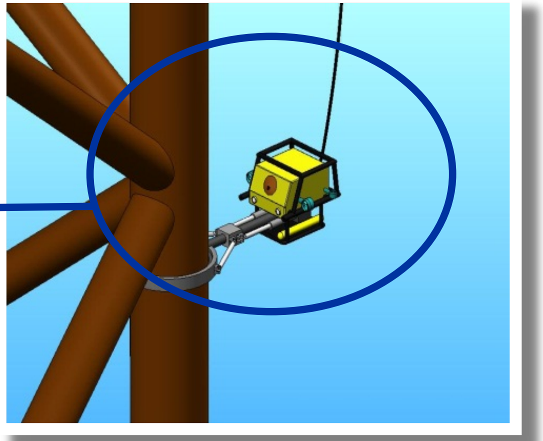
Methodology for fast and reliable investigation and characterisation of contaminated sites

Project budget: € 1.7m
End Users: BioREM,
Marijampole Municipality

This project will develop a more advanced in-situ investigation method for identifying and characterising pollution, achieved by integrating more sophisticated sensors (e.g. micro-chips, electrochemical sensors, spectrometry, and optical sensors) into a solid probe intended to drive down through the soil matrix to perform continuous or semi-continuous measurements.

Development of Novel Inspection NDT Techniques and Robots to be Deployed by ROVs for the Subsea Inspection of Offshore Structures

Project Budget: € 1.4m
End Users: HSE, PSA



Development of subsea NDT techniques suitable for deployment from small observation class remote operating vehicles (ROVs) for the examination of critical welds and lengths of subsea pipelines.

TestPEP

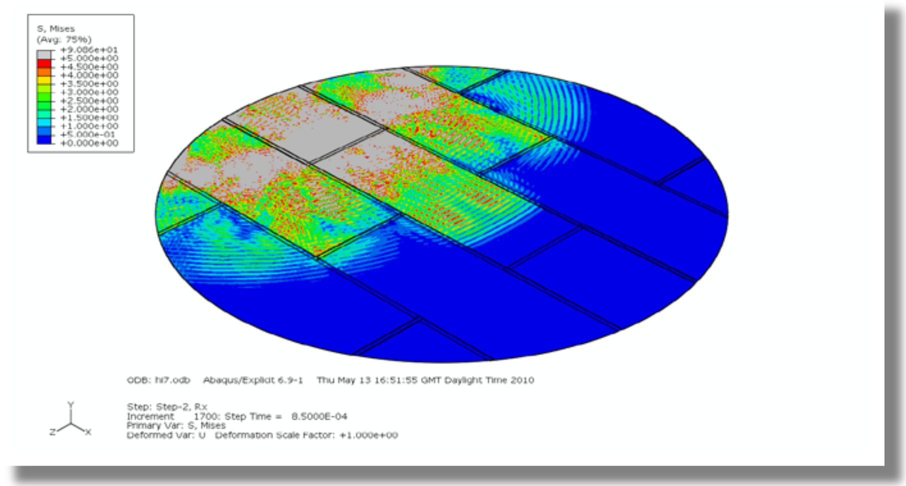
Development and Validation of an Automated NDE Approach for Testing Welded Joints in Plastics Pipes

Project Budget: € 3.2m
End Users: British Energy, E,ON Ruhrgas

Developing phased array ultrasonic NDE procedures, techniques and equipment for the volumetric examination of welded joints in plastics pipes of diameters up to 1m and an automated inspection system able to inspect pipe-to-pipe and pipe-to-fitting butt and socket joints.

Non-invasive monitoring of storage tanks

Project Budget: £800k
End Users: Vopak, Nu Star Terminals, Shell UK



The Tank Integrity Monitoring (TIM) project is working to develop a low frequency ultrasonic technique for the non-invasive condition monitoring of tank floors to detect corrosion or cracking degradation.

DISSIMILAR

Technology Strategy Board
Driving Innovation

Phased Array Ultrasonic Inspection of Dissimilar Metal Joints

Project Budget: £1.3m
End Users: British Energy, Shell, HSE

The project will deliver a revolutionary new technique for the inspection of dissimilar joints, two advanced phased array probes (TRL and annular) and a model based approach to compensating for metallurgical hurdles, which previously degrade inspection quality.

HEDRad

High Energy Digital Radiography

Project Budget: € 1.3m
End Users: E.ON
BIS Blohm & Voss

To develop digital computed radiography technology for the volumetric examination of large-scale safety critical pressure components for the detection of in-service defects, the presence of which could lead to catastrophic component failure.

INSIGHT

Technology Strategy Board
Driving Innovation

In-situ wireless monitoring of offshore wind towers and blades

Project Budget: £1.8m
End Users: RWE npower,
TUV NEL,
FUGRO

This project aims to develop a permanently mounted wireless monitoring system that will use a combination of LRUT and AE to continuously monitor the structural health of wind turbine towers.

Development and Demonstration of a Novel Integrated Condition Monitoring System for Wind Turbines

Project Budget: € 5.1m

End Users: TERNA,
ACCOINA ENERGIA,
Energias do Ocidente,
A. Silva Matos Energia

To develop and implement an integrated condition monitoring system for the continuous evaluation of the critical structural components, rotating parts and braking mechanisms of wind turbines.

TWI

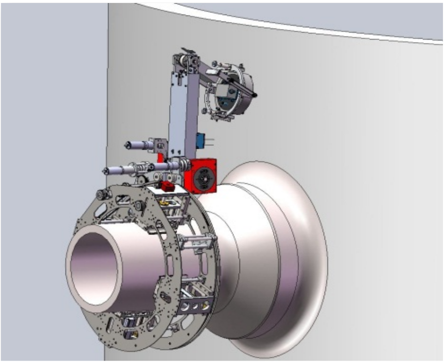
NozzleInspect

NOZZLE INSPECT
Automated Inspection of Nozzle Welds in Nuclear Environments

Autonomous Robot for the Automated Inspection of Nozzle Welds in Nuclear Environments

Project Budget: € 1.4m

End Users: Iberdrola Generation

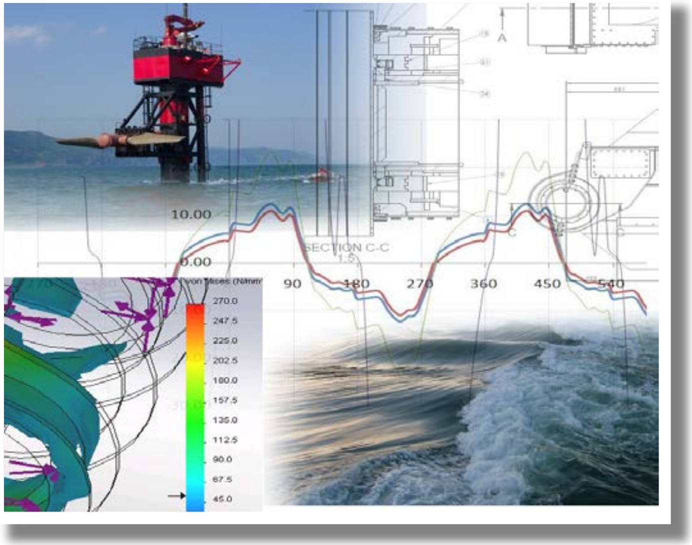


Developing a system that will use a scanner and manipulator robotic assembly for an automatic inspection of nozzle welds. The automatic robotic assembly will carry a novel matrix phased array probe which, combined with 3D beam steering capability, will enable a large area of the weld to be inspected in a single operation.

TidalSense

Development of Condition Monitoring System for Marine Current Turbine Structures

Project Budget: € 1.5m
End Users: Enerocean



The condition monitoring of marine turbine structures (blade and tower) will be developed by combining acoustic emission (AE) monitoring and long-range ultrasonic testing (LRUT).

WINTUR

In-situ wireless monitoring of on- and offshore wind towers and blades using energy harvesting technology

Project Budget: € 1.4m
End Users: Southern & Scottish Energy UK

The project will develop novel wireless and self-powered technology to monitor offshore wind tower structures and turbine blades continuously using combined passive (acoustic emission) and active (guided ultrasonic wave) methods.

INTERAIL

Development of a Novel Integrated Inspection System for the Accurate Evaluation of the Structural Integrity of Rail Tracks

Project Budget: € 4.3m
End Users: STIB, REFER

INTERAIL seeks to practically eliminate rail failures by developing and successfully implementing an integrated high-speed system for the fast and reliable inspection of rail tracks.

RAILECT

Development of an ultrasonic technique, sensors and systems for the volumetric examination of aluminothermic rail welds

Project Budget: € 1.5m
End Users: Network Rail

To develop, produce and demonstrate a novel prototype device that will ultrasonically carry out a volumetric examination of aluminothermic rail welds.

SafeRail

Development of Novel Inspection Systems for Railway Wheelsets

Project Budget: € 3.8m
End Users: SNCF, De Lijn, VTG, EMEF

Development of on-line equipment placed on tracks for monitoring of wheelsets of passing trains and the development of a combined ultrasonic-ACFM (Alternating Current Field Measurement) system for inspection of new and in-use wheelsets.

TWI

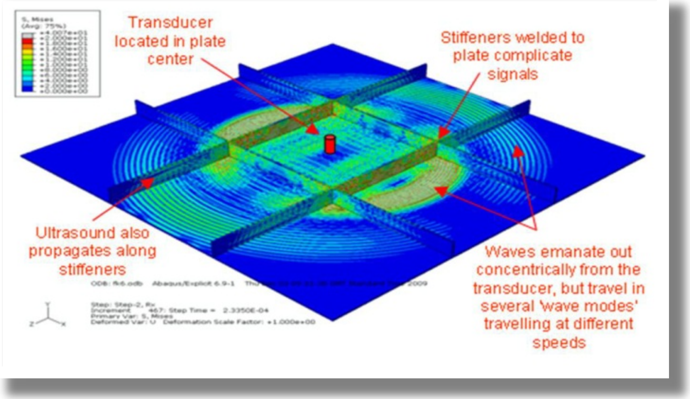
ShipInspector

SHIP INSPECTOR

Detection of Safety Critical Cracks and Corrosion in Ships using Novel Sensors and Systems based on Ultrasonic Linear Phased Array Technology

Project Budget: € 3.7m

End Users: Class NK,
HSE,
American Bureau of Shipping,
Lloyds Bureau of Shipping



Developing novel ultrasonic linear phased array techniques, sensors and systems for finding defects and corrosion in safety critical areas of ships and tankers without taking the vessel out of the water.

ComPair

Continuous Health Monitoring and Non-destructive Assessment of Composites and Composite Repairs on Surface Transport Applications

Project Budget: € 3.5m
End Users: ENEA,
Hexcel Composites

Development of advanced health monitoring of surface transport applications in real time, advanced and prompt non-invasive NDT inspection in manufacturing, assembly and maintenance of composites and composite repairs that find use in vehicles.

MonitoRail

Long Range Inspection and Condition Monitoring of Rails

Project Budget: € 1.5m
End Users: Network Rail

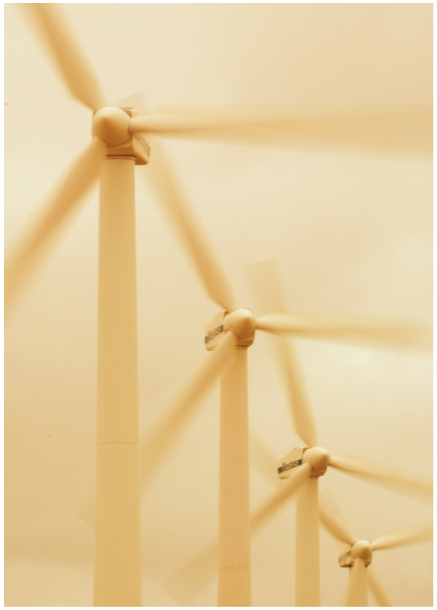
The objective of MonitoRail is to develop a cost-effective long-range ultrasonic inspection method as well as a wireless condition monitoring system in order to improve and maintain the European railway system for better efficiency and safety.

TWI

CMSWind

Advanced condition monitoring system for the assessment of wind turbines rotating parts

CMSWind will produce an advanced system for condition monitoring of wind turbine machinery components. Utilising three new and novel techniques; Motor Current Signature Analysis, Operational Modal Analysis and Acoustic Emission it will improve wind turbine machinery reliability by 50%. All systems will be tied together through SCADA to provide supervisory control, data logging & analysis.



Enhancing the Competitiveness of European Powder Metallurgy SMEs by an Improved Quality Assurance Tool based on Latest Digital Radiographic Achievements

The DIRA-GREEN project will aim at increasing the competitive advantage of the European Powder Metallurgy (P/M) sector by developing a highly effective non-destructive system to inspect 'green parts' resulting in a higher-level quality assurance of P/M components and savings in material, time as well as energy.

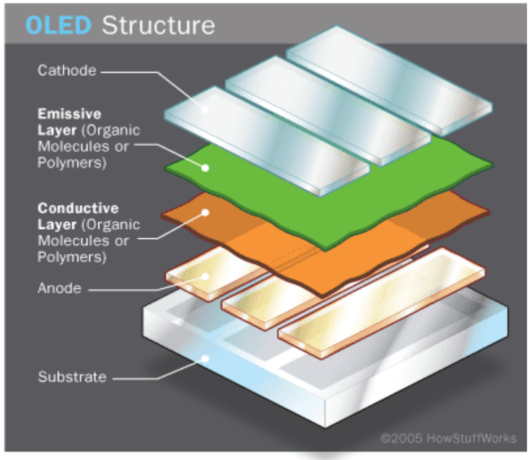
Innovative Inspection Techniques for Laser Powder Deposition Quality Control

The INTRAPID project aims to develop three non-destructive testing (NDT) techniques (laser ultrasonics, eddy currents and laser thermography) for inspection of parts and components manufactured by Additive Manufacturing Processes, in particular Laser Metal Deposition (LMD), to a stage where prototype systems have been integrated into a production process.

Development of an automated digital radiography system for the inspection of plastic electronics

This project will aim to develop a real time digital X-ray radiography system, integrated into a roll to roll type production line for plastic electronics panels, which will:

1) detect all significant defects in the plastic electronic panels
2) automatically issue a warning of the detection of a significant defect at the point of detection
3) inspect 100% of the product volume whilst keeping pace with the line, and
4) be usable on the line at any desired stage.



CRANEInspect

Continuous Reliable Advanced Novel Efficient Structural Health Monitoring System for Crane Inspection Applications

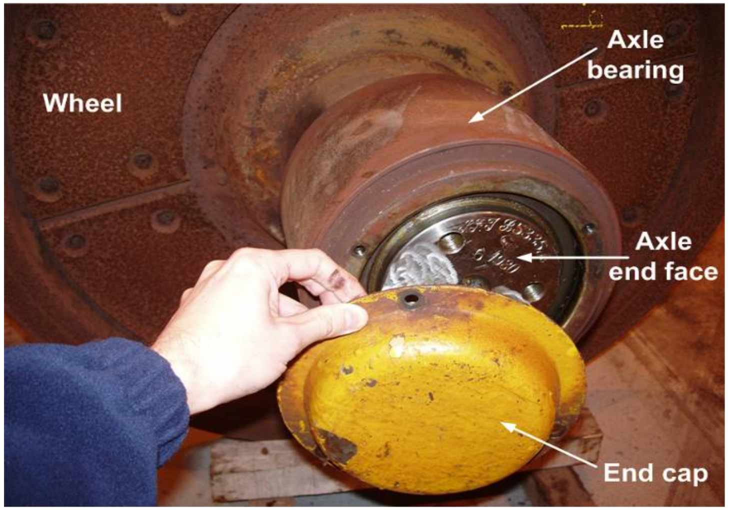
This project will address the challenge of implementing an automated, continuous health monitoring inspection system for large cranes (tower, gantry, etc), able to identify structural integrity faults before they lead to crane failure. Advanced NDT techniques such as AE and LRU will be used to constantly monitor the structural health of cranes and automatically detect and report any imminent failures.

A Wireless Network with Autonomously Powered and Active Long Range Acoustic Nodes for Total Structural Health Monitoring of Bridges

The project WI-HEALTH aims to develop an autonomous, wireless and self powered sensor network that will provide long term and continuous structural health monitoring (SHM) of bridges with total area coverage using a minimal number of network nodes and sensors.

Development of Novel Inspection Techniques for Train Axles

The AxleInspect project aims to develop new inspection technology based on Phased Array Ultrasonic Techniques (PAUT) and ElectroMagnetic (EM) techniques suitable for the inspection of both solid and hollow axles. These techniques will allow inspection to be conducted in-situ without any wheelset disassembly required other than the removal of the axle end caps.

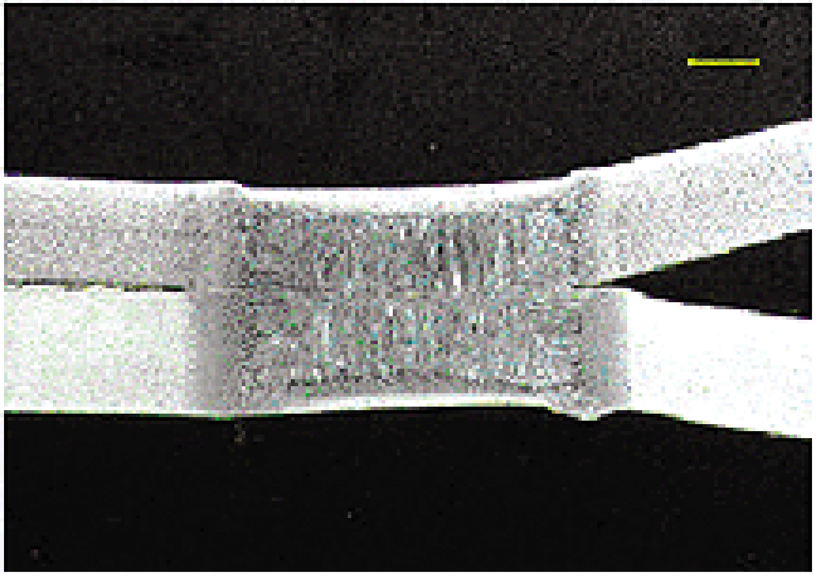


Laser Guided Inspection Robot for the Non Destructive Testing of Thin Steel Gauge Welds In The Shipping Industry

The X-Scan project will develop novel automated NDT techniques (ultrasonic and electromagnetic) for ship inspections that are more reliable, faster, cost effective and safer than the currently applied radiographic inspection techniques.

Development of an automated spot weld inspection device for safe vehicle repair

The project will develop novel modelling and signal processing techniques and use those techniques to develop novel routines and inspection procedures that enable a reliable pass or fail indication to be given in an easy to use robust device applicable to current and new materials.



MoorInpsect

Development of an Advanced Medium Range Ultrasonic Technique for Mooring Chains Inspection in Water

The aim of MoorInspect is to use an in-water novel electromagnetic acoustic transducer (EMAT) methodology to increase the Probability of early detection of defects, e.g. cracks and fatigues, in under surface of chain links for offshore and deepwater floating structures, to provide a reliable in-water testing alternative to costly in-air testing.

CROSS-IT

Smart Condition Monitoring and Prompt NDT Assessment of Large Concrete Bridge Structures

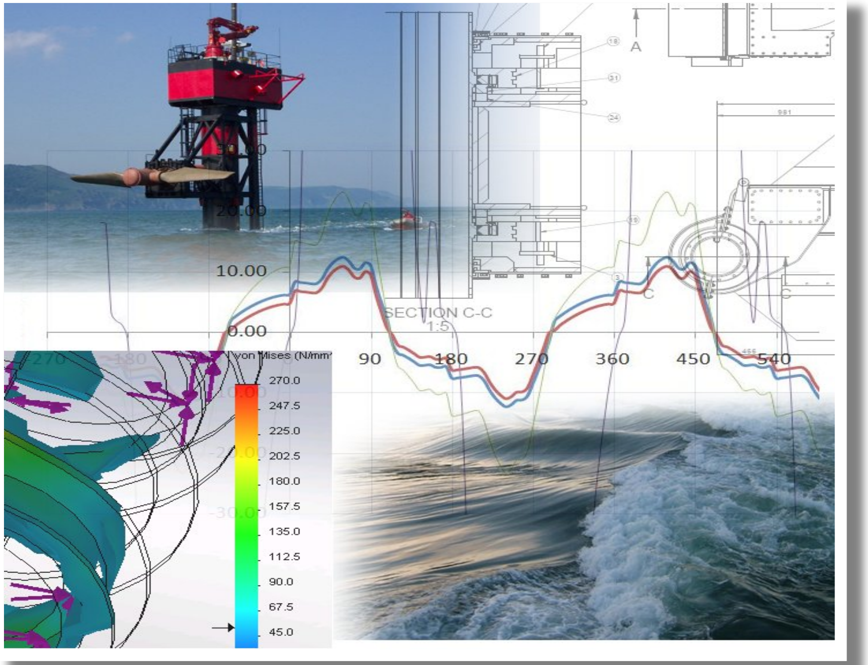
The project aim is to develop a rapid, economical, safe and reliable non-destructive inspection method using GPR (Ground Penetrating Radar) and UGW (Ultrasonic Guided Waves). These two processes will be used with new inspection procedures to locate and transmit the ultrasonic wave and software for image reconstruction. The new system will enable the volumetric examination of reinforced and pre-stressed large concrete structures typically used in bridges and buildings.

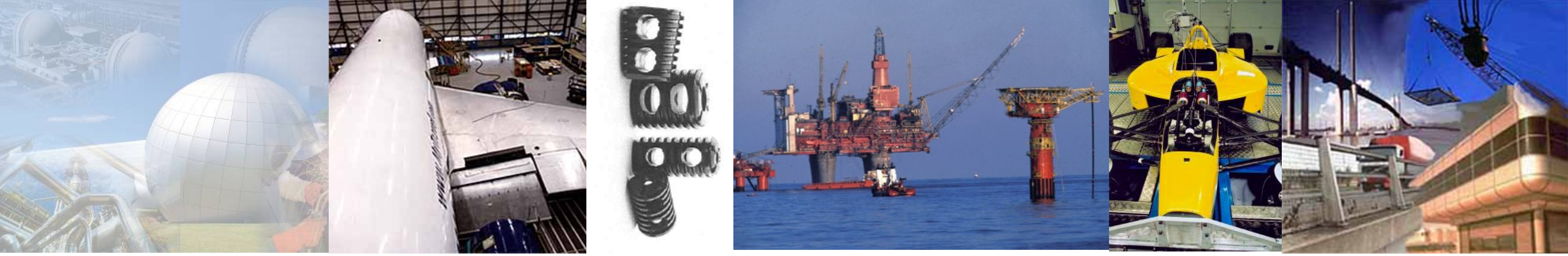
Automated Inspection for Sintered Parts by Non-destructive Techniques for Improved Quality in Production

The objective of the AUTOINSPECT project is to develop a new real time digital radiography inspection system for the detection of defects in sintered PM components. A prototype will be developed that will take the PM manufacturing sector into a new era where 100% inspection conducted at high throughput is the norm.

Demonstration of a Condition Monitoring System for Tidal Stream Generators

This demonstration project will comprise the industrialisation of the developed sensors in the TidalSense project for monitoring elements manufactured using modern composite materials, the study of their feasibility as condition monitoring equipment in several tidal energy converters (TEC) and the sea trials of the system.





Fatigue Testing at TWI

Yan-Hui Zhang, TWI Seminar, Japan, November 2014

Materials Joining and Engineering Technologies

Outline of presentation

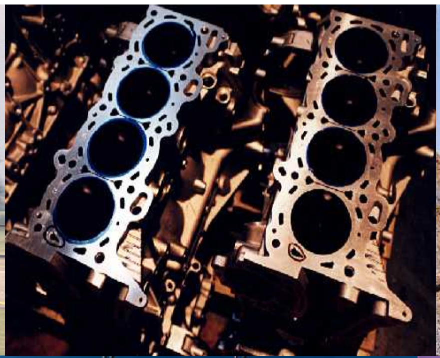
- Introduction
- Fatigue testing at TWI
  - Conventional fatigue tests
  - Resonance fatigue test machines
  - Full-scale fatigue testing of mooring chain
  - Fatigue endurance tests in corrosive environments (H_2S, CO_2, seawater, H_2, etc)
  - Fatigue crack growth tests in corrosive environments
- Summary

Fatigue is a key issue in all industry sectors

- 80-90% mechanical failures are caused by fatigue

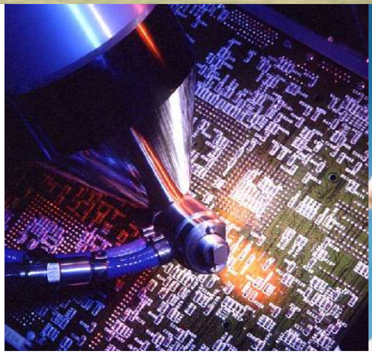
Aerospace

Automotive



Construction

Equipment, Consumables & Materials



Electronics

Medical

Oil, Gas & Chemicals

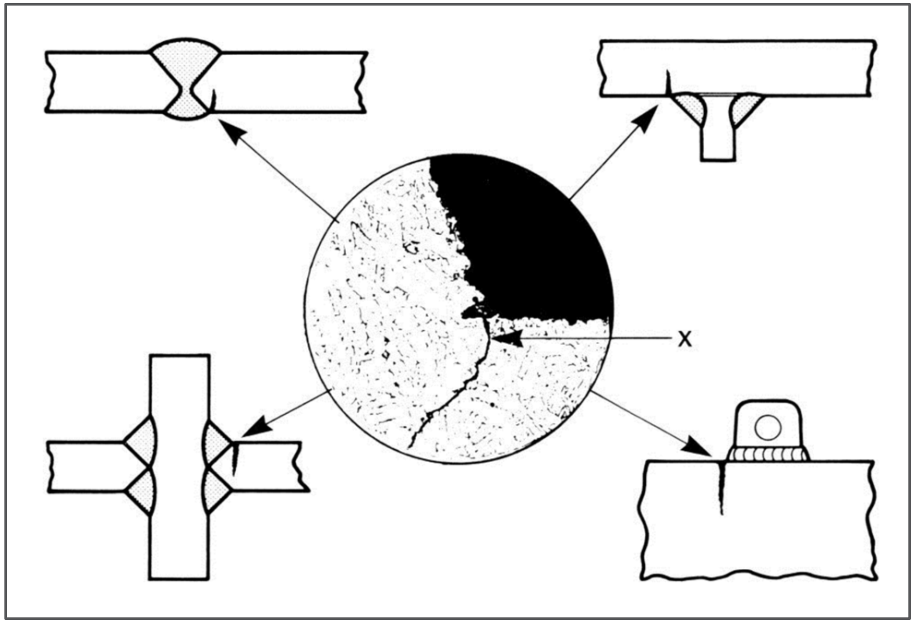
Power

Fatigue integrity management Section in TWI

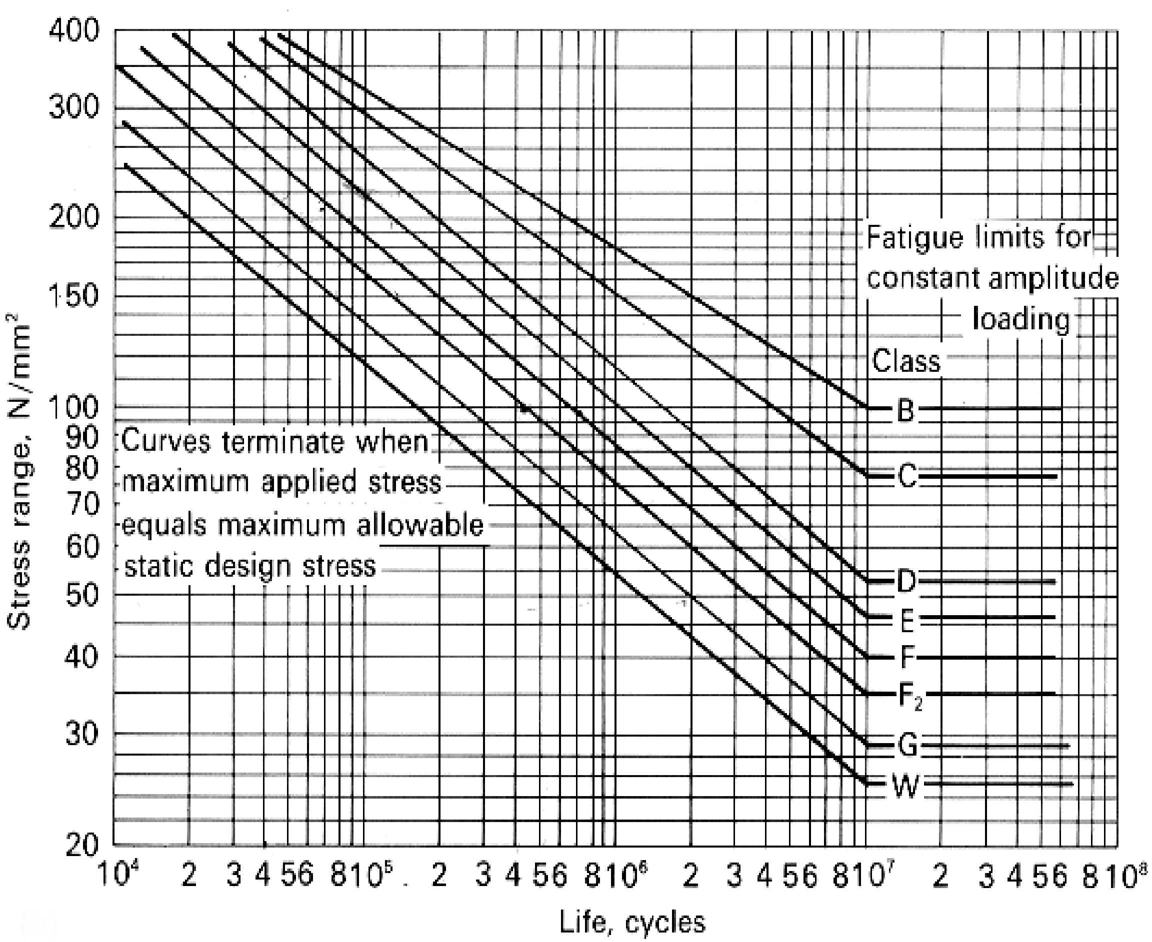
- We are part of Integrity Management Group (IMG)
- What we are doing in TWI:
  - Fatigue design and consultancy services
  - Fatigue testing: endurance & crack growth rate tests, in air and corrosive environments
  - Engineering critical assessment (based on BS 7910)
  - Failure investigation
  - R and D

Characteristics of fatigue in welds

- Stress concentration at weld toe – poor fatigue strength
- Small defects often present at weld toe: typically 0.1- 0.4mm deep
- Life dominated by crack growth
- High tensile residual stress - compressive stress cycles damaging

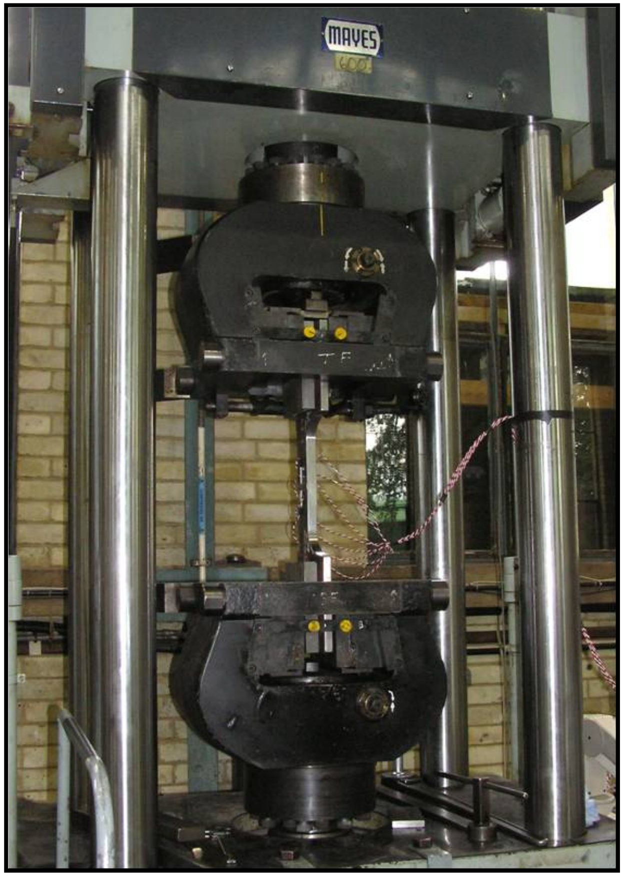


Fatigue design for welded joints

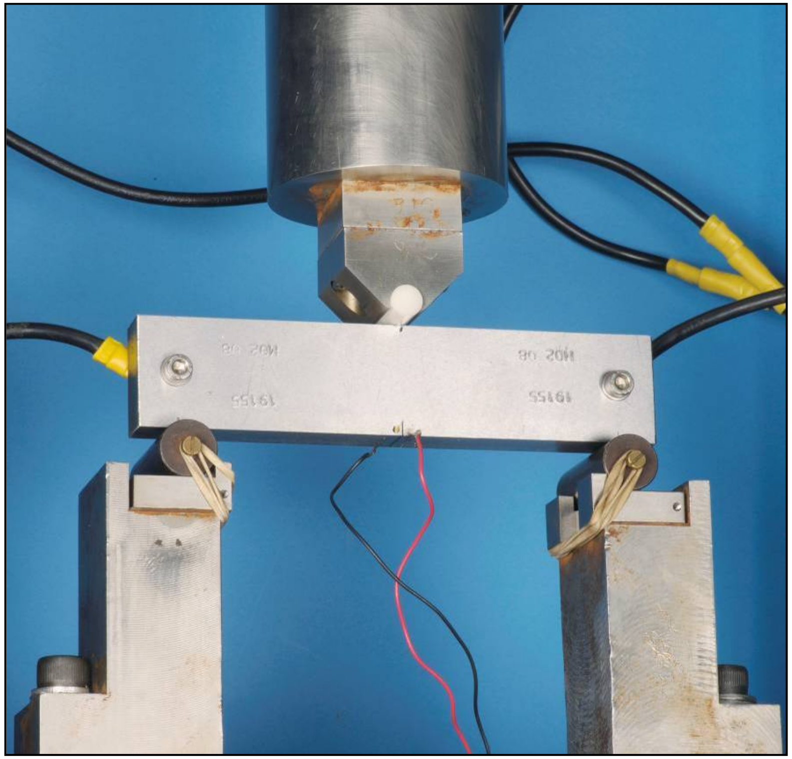


- S-N curves in standards: BS 7608
- Only suitable for simple weld geometries and in air and seawater
- For some applications, fatigue testing to generate particular fatigue data is required

Conventional fatigue testing



Fatigue endurance



Fatigue crack growth

Full-scale fatigue endurance tests

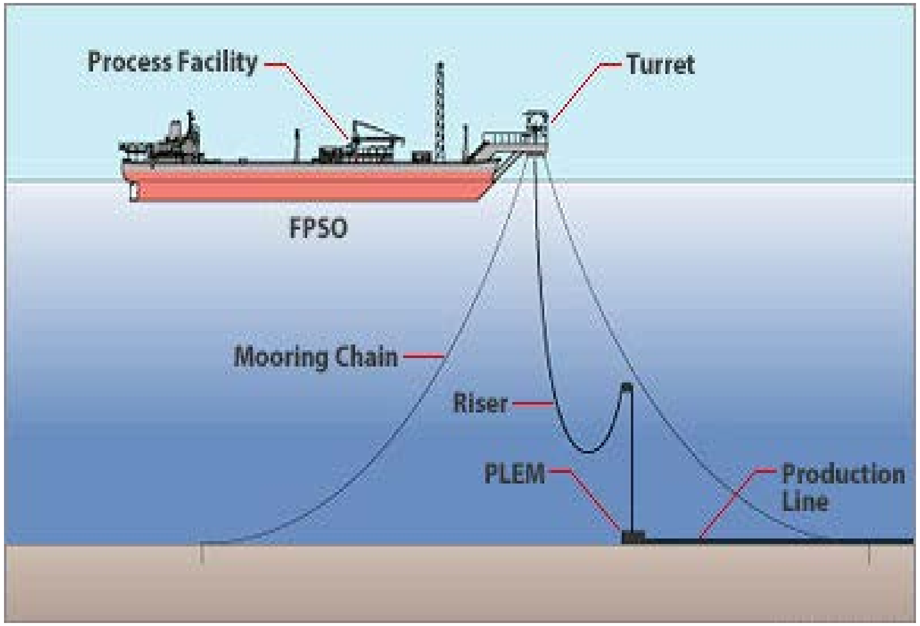
Steel catenary risers and flowlines

- Steel pipes are girth welded or connected by mechanical connectors
- They are fatigue-critical
- Full-scale fatigue qualification tests required for new welding procedure

Mooring chain

- Failure by fatigue often reported
- Design curves based on data from chain with relatively small diameter and low steel grades
- Fatigue data on high steel grade and large diameter required

Floating production storage and offloading (FPSO) vessel

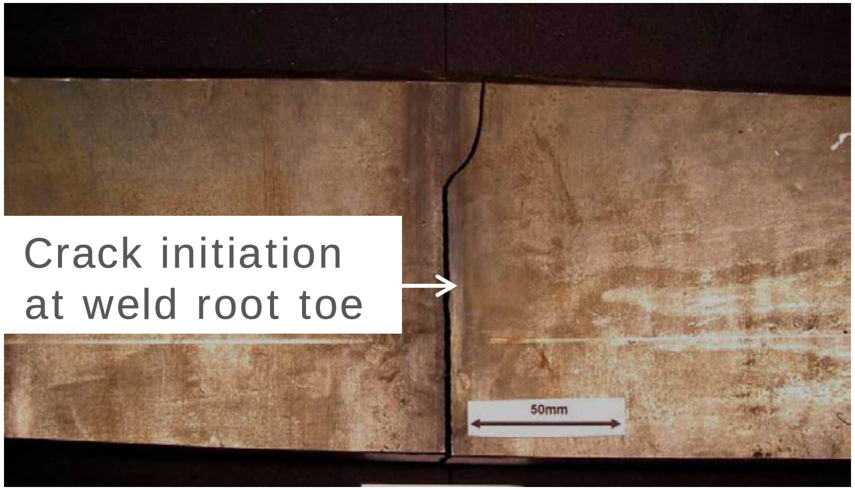


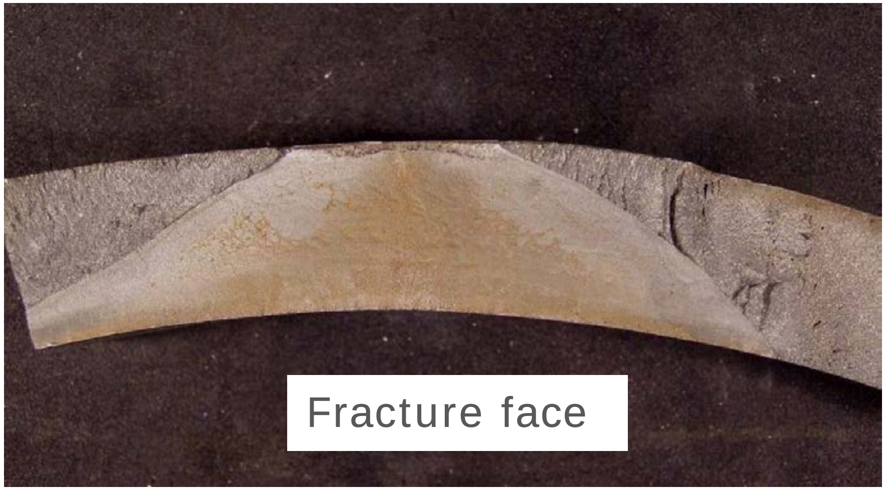
Fatigue testing of girth welded pipes

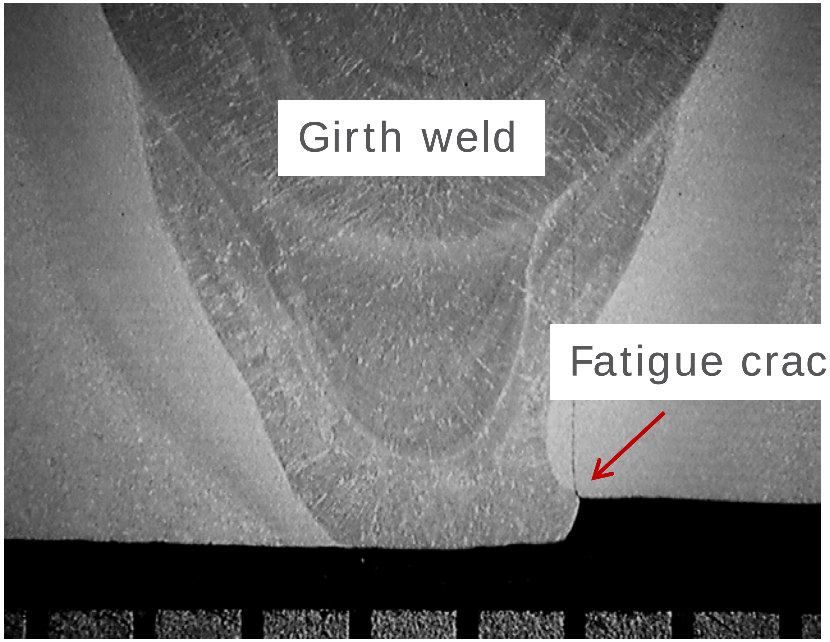
(video)

- Resonance test machines, producing rotating bending moment, at ~30Hz
- Fatigue lives up to 2x108 cycles achieved
- 4 to 36 inch outside diameter
- Tensile mean stress via internal water pressure or direct axial force

Post-test examination







Full-scale fatigue testing of mooring chain

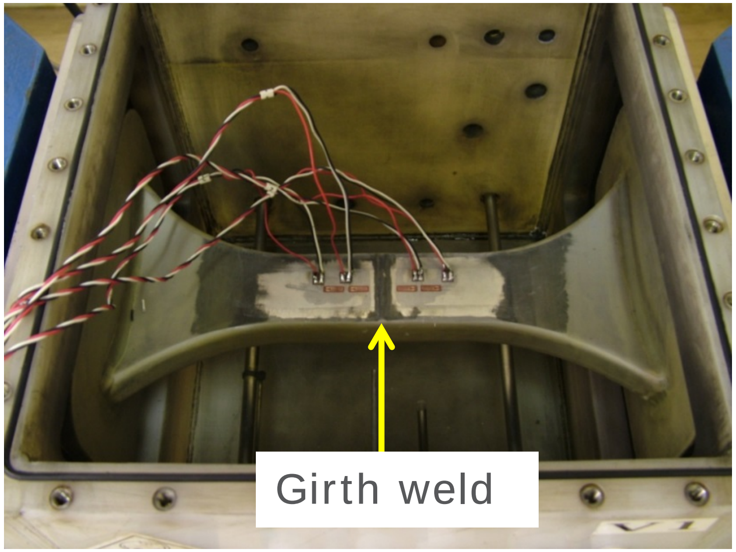
(video)

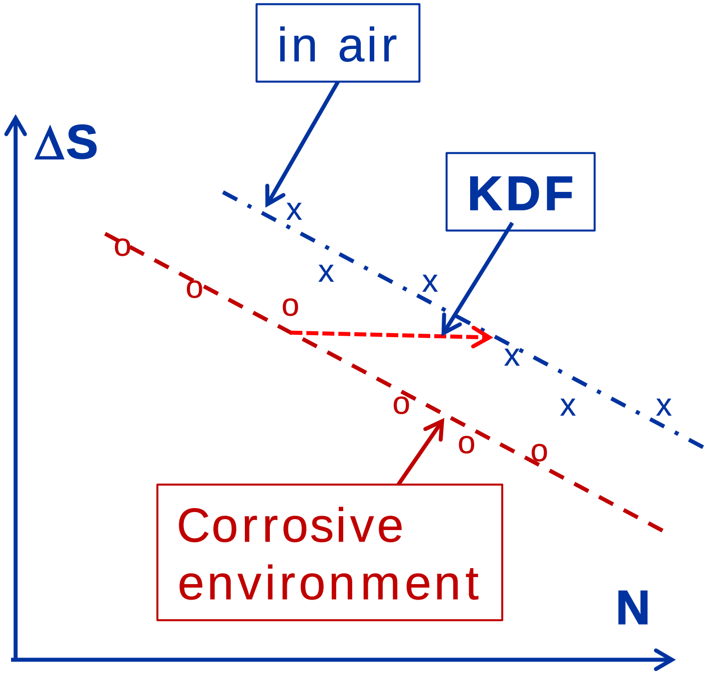
- 7 links for 127mm diameter chain, 11 links for 76mm chain
- Most tests in seawater
- Loading frequency:0.5Hz
- Inspection during testing

Fatigue endurance testing in corrosive environments

- Sea water with or without cathodic protection
- Simulated oil and gas environments, including H2S and CO2 conditions and HPHT
- High pressure hydrogen

Determination of environmental knock-down factor (KDF)

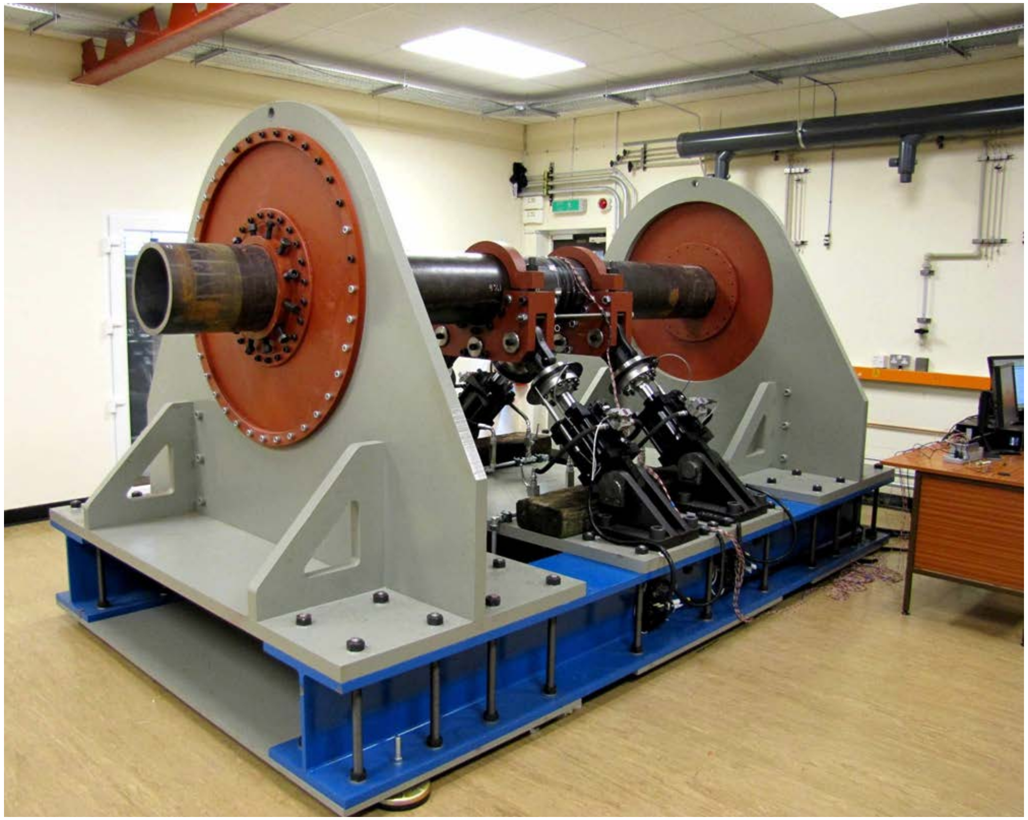




Full scale testing of girth-welded pipes in sour environment

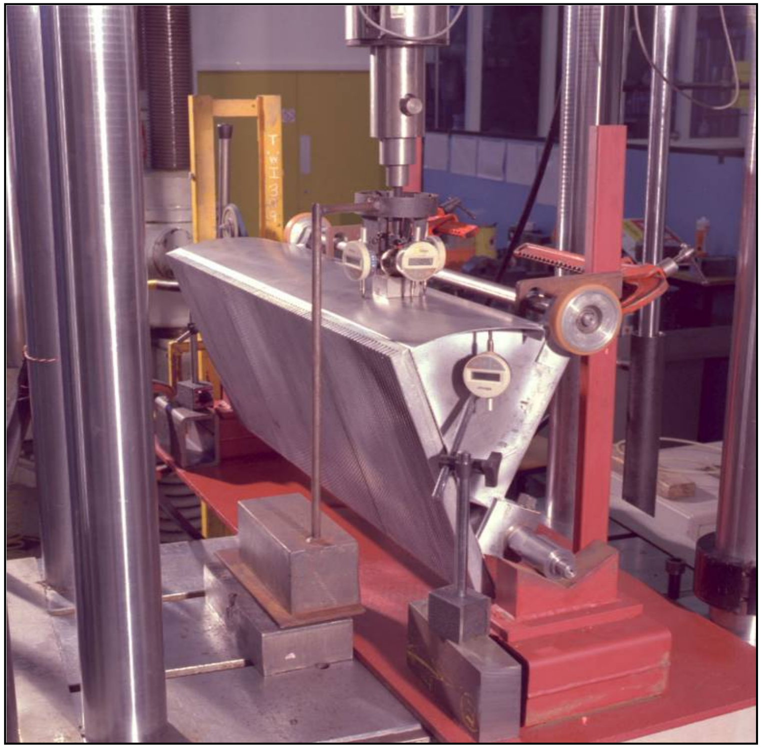
- TWI Joint-Industrial Project
- Loading at 0.2Hz
- Sour environment inside pipe
- Objective:

To examine the validity of the current two-stage design process



Other bespoke fatigue tests

Bending for tubular joints

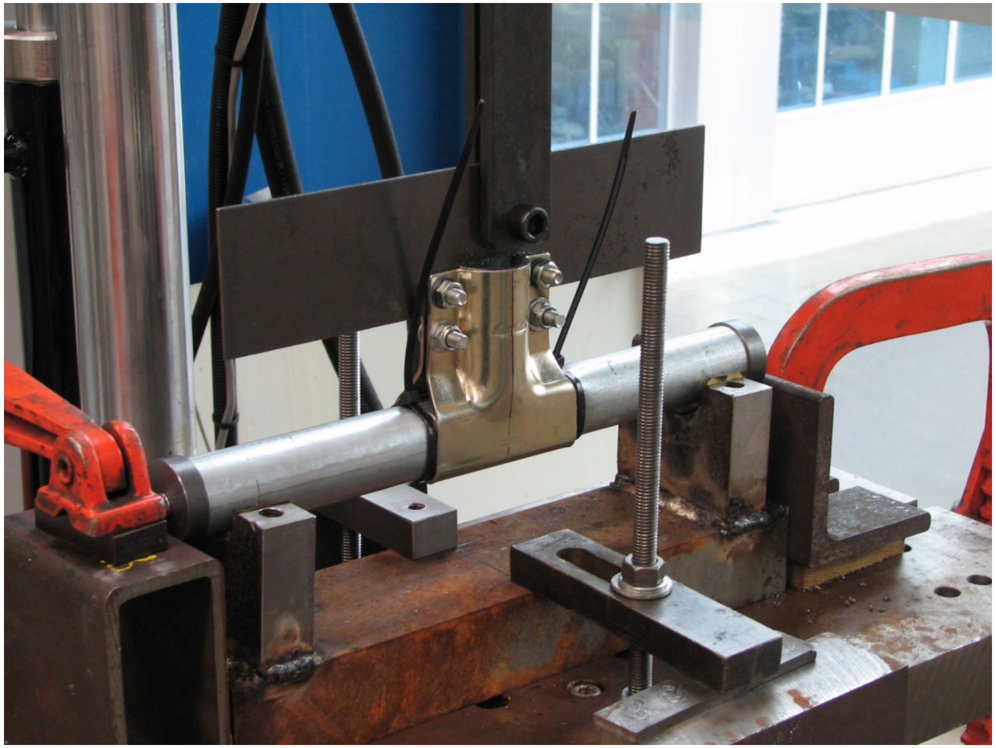


Escalator steps

Fatigue testing of trampoline

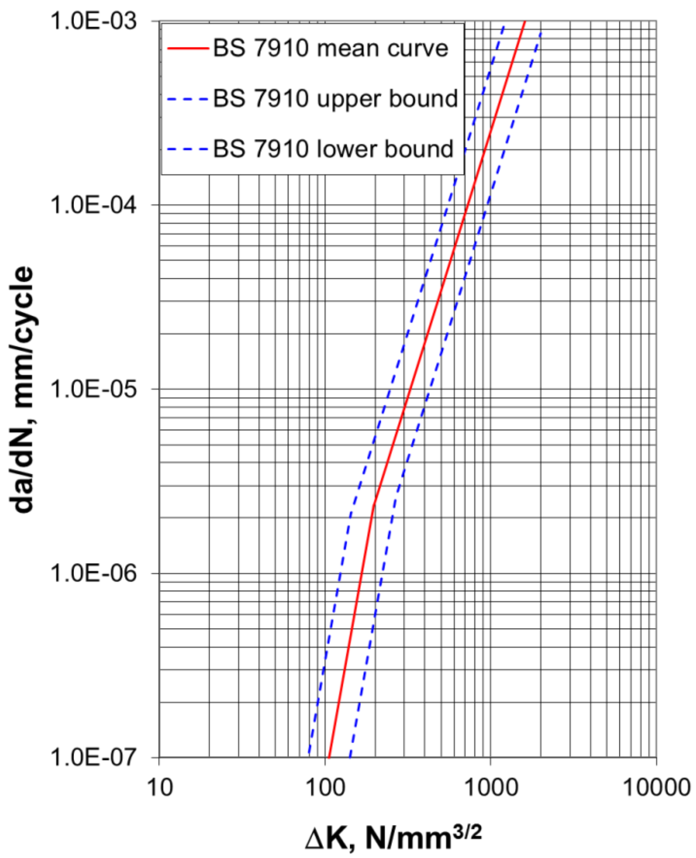
Determine the stress levels at the joints (strain gauged)

Conduct fatigue testing with the appropriate loading mode and stress amplitude



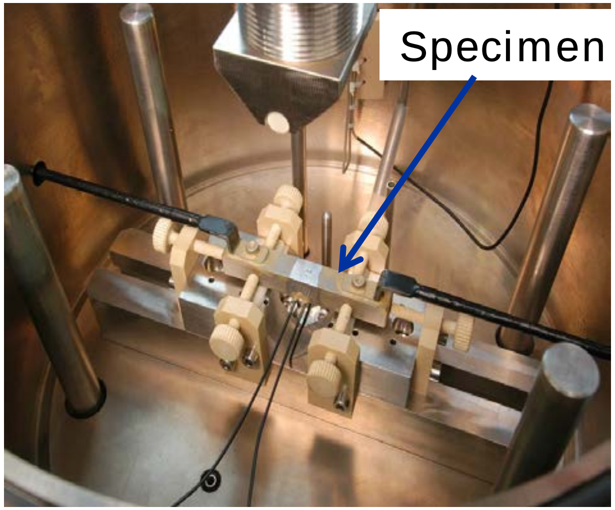
Fatigue crack growth rate

BS 7910 for steels in air



- FCGR curves in standards, eg BS 7910
- Only for steels in air / seawater environments
- May be too conservative for certain materials and in certain applications

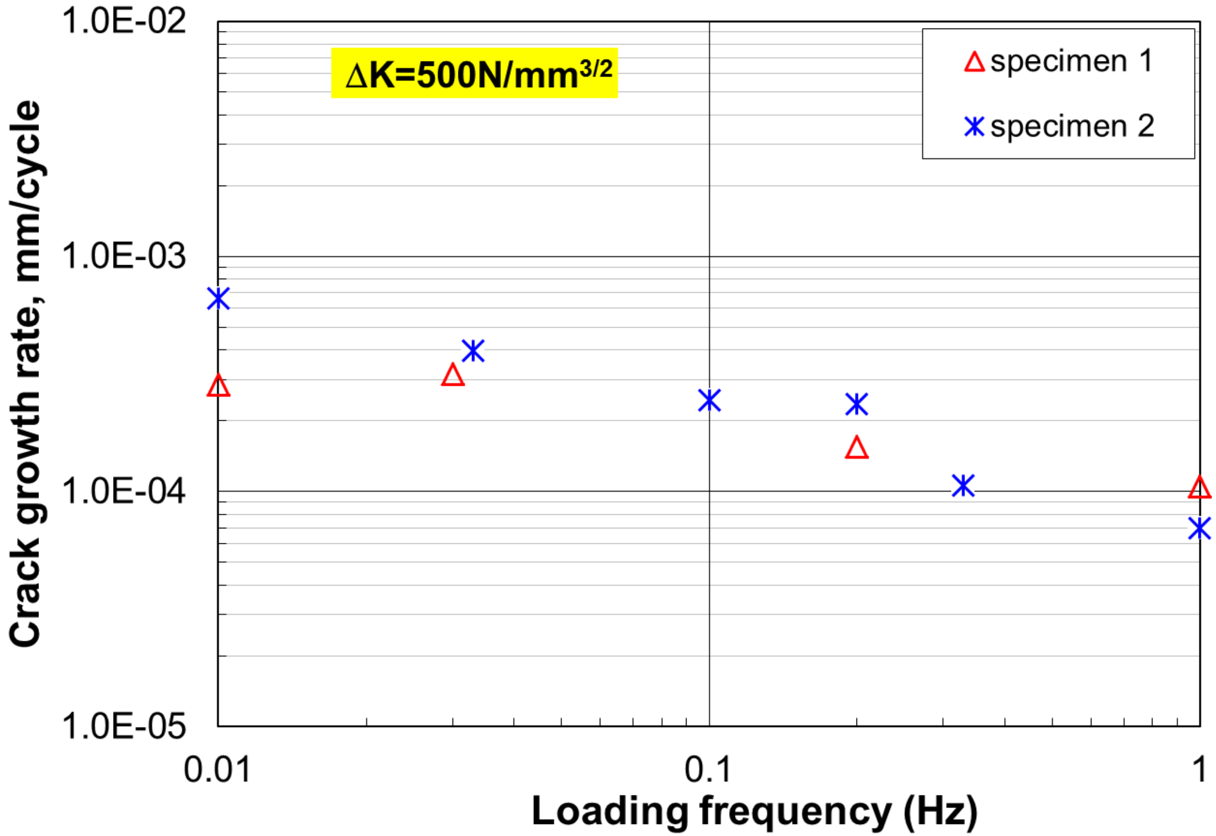
Fatigue crack growth rate testing



- Tests to BS or ASTM standards
- Parent material, weld or HAZ
- Air / corrosive environments
- Data analysis to obtain the upper-bound Paris law constants (mean+2SD)

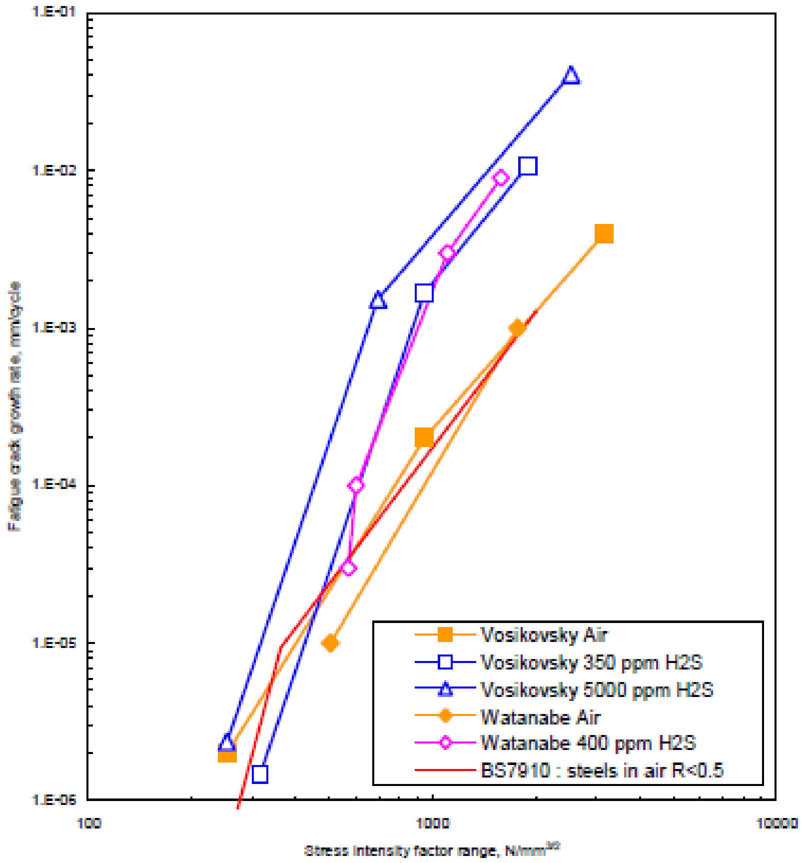
Frequency scanning test

Keep ΔK constant, increasing or decreasing loading frequency in steps after a certain crack extension (eg, 1mm)



FCGR in corrosive environment

Comparison of FCGR in air and sour environment



Corrosive environments (eg, CO_2 or H_2S) can significantly increase FCGR in intermediate and high ΔK regimes, up to 10 times in CO_2 and 35 times in H_2S

Summary

- It is often required to conduct fatigue tests to produce fatigue data specific for a project for fatigue design.
- Full-scale verification tests can provide further confidence
- S-N curves or FCGR curves in many corrosive environments are not available in standards. Fatigue testing in the relevant environment and appropriate testing conditions is necessary
- Fatigue testing of actual components can avoid many assumptions and uncertainties (eg, stress ratio, size effect)

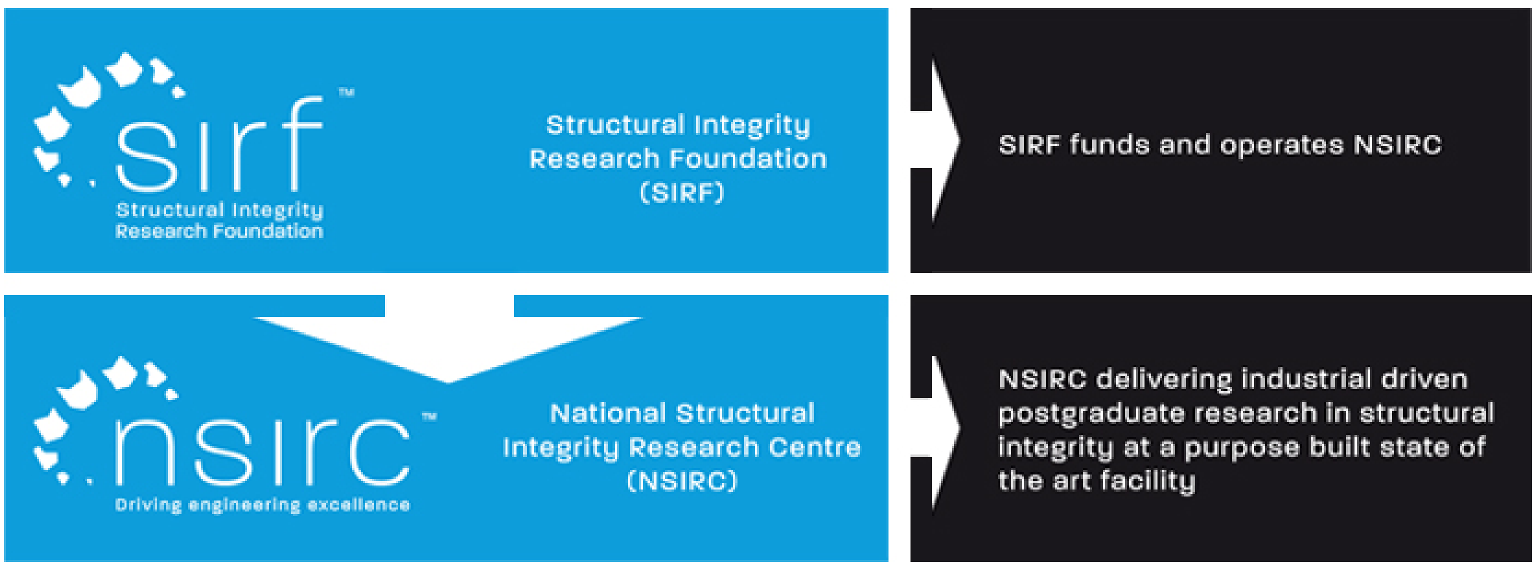
The Structural Integrity Research Foundation

Fred Delany, TWI Seminars, Japan, November 2014

Materials Joining and Engineering Technologies

Background

- SIRF is a unique collaboration between TWI / Universities / Industry
- Partly supported by the UK Government
- Established to bridge the divide that can exist between industry needs and engineering academic research



How did it all start?

- **When:** January 2012: Speech by David Willetts said that Government was looking for “a new type of industry-led post-graduate university”.
- **What:** Market failure in structural integrity in the UK
  - Need to support traditional and advanced manufacturing industries, new national infrastructure projects, and an ageing national asset base
  - More demanding, more arduous and more hazardous operating environments
- **How:** To develop a new & unique industry-driven research foundation (SIRF) for postgraduate engineering education which is a unique collaboration between TWI / Universities / Industry

What is this Initiative?

- To develop a new & unique industry-driven research foundation for postgraduate engineering education
- To create and manage the National Structural Integrity Research Centre (NSIRC) to:
  - Develop novel postgraduate programmes to train the next generation of researchers and engineers to support industry in the area of structural integrity
  - Develop a critical mass of research driven by the needs of industry, across the field of structural integrity
  - Deliver focussed fundamental research (low Technology Readiness Level (TRL)) directly linked to industrial (high TRL) development and deployment

Scale of the SIRF

- Overall budget: £185m over 10 years
- £16m for new equipment
- £18m for new building
- £600k for MSc students
- New, purpose built facility designed and equipped for structural integrity research March 2015
- 530 post graduate students over 10 years
- 60 staff spanning industrial and academic disciplines

Industrial approval: Update on the status of the SIRF Founder Sponsors

- **TWI:** The first sponsor fully committed (£15m) for the next 10 years
- **BP:** The contract has been signed and completed in April 2014. BP's Facilities Technology Flagships (FTF) require activities to be carried out by TWI experts and leveraged by SIRF through specialised equipment specified by BP and PhD students to carry out underpinning research in order to support the FTF
- **Lloyd's Register Foundation:** Proposal approved by the LRF Board. Heads of Terms agreement signed. The contract is in the process of being signed
- **Network Rail:** Advanced discussions

The Elements of Structural Integrity

SIRF Technology Areas

- Materials Properties
  - Defect initiation, formation & growth
  - Modelling & simulation
  - Environmental effects
- Structural Analysis
  - Prediction, calculation and modelling
  - Large scale testing
  - Influence of fabrication & repair
- Damage Assessment
  - NDT
  - Condition monitoring
  - Remote & intelligent sensors

Mission and Objectives of SIRF

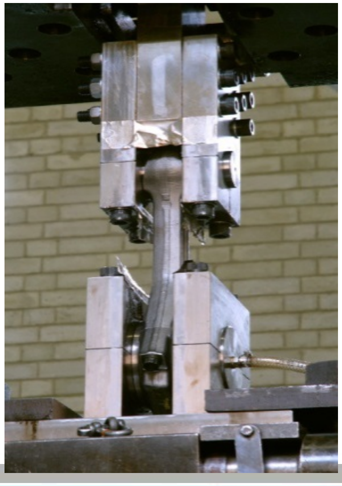
- SIRF will provide:
  - Research aligned with the Sponsor's Technical Strategy
  - A seamless transition between low and higher TRL activity, thus accelerating innovation
  - A flexible mechanism for translating fundamental research into industrially usable form
  - A forum for exchange of advanced research
- SIRF will promote the inflow of new ideas from other sectors

The Lloyds' Register Foundation Model: PhD Students' intake

Student Years	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Intake 1	10									
Intake 2		10								
Intake 3			10							
Intake 4				10						
Intake 5					10					
Intake 6						10				
Intake 7							10			
Intake 8								10		

The benefits of a strategic relationship with TWI

- Largest one-stop shop concept in structural integrity research and testing facility
- Access to wide range of services:
  - Academic research
  - Standard testing
  - Specialised testing (e.g. harsh environment testing and large scale testing)
  - Technique validation
  - Standards and guidance



Process from SIRF sponsor's vision to operational reality

Step 1 — **SIRF**
SIRF sponsors to identify the needs and list the technical priorities

Step 2 — **TWI**
TWI to Identify, what is required to deliver the technical challenges
(e.g., equipment, building, cost estimate, facility, resources)

Step 3 — **TWI**
Identification of the leverage funding source e.g.
(ERDF,RGF, HEFCE, LEP etc.)

Step 4 — **TWI**
TWI to write the proposal and submit the application

Step 5 — **TWI**
To build the required facility
(Building, Equipment, etc.)

Step 6 — **TWI**
Manage the operations of the new facility and deliver to the sponsors' technical requirements

SIRF SPONSORS → **TWI & SIRF; Lobbying the Government** → **TWI Operations Management**

Leveraged delivery of work managed by TWI; No cost for buildings, equipment, maintenance, etc. Expertise knowledge and service provided by TWI. TWI satisfies the government requirements such as creation of job, studentship, delivery of the project..

World class purpose built research facility

Site Development – 27 October 2014

New Entrance

The Street (Artist's Impression)

Street (facing East)

Restaurant & Conference Facilities

Library

Office Area

Boardroom

Engineering Hall

TWI's previous experience in development research centres

TWI North

- Operational since 1985
- Located in Middlesbrough
- Function:
  - Training (including underwater)
  - R&D for renewable energy fabrication
- Staff number: 33
- Turnover: £2.7m (2012)
- Funding:
  - Originally industrial + European and Regional public funding
  - Now industrial + bid for collaborative projects from UK and European programmes
  - Now in final stages of negotiation of additional funding for new R&D building with European and Local public funding
- Outputs: >1,000 direct jobs created or safe-guarded in local SMEs.

TWI Yorkshire

- Operational since 2002
- Located in Sheffield
- Function:
  - R&D
  - Friction stir welding
  - Additive manufacture
  - Surfacing by cold spray
  - Training
- Staff number: 24
- Turnover: £2m (2012)
- Funding:
  - Originally industrial + European and Regional public funding
  - Now industrial + bid for collaborative projects from UK and European programmes
- Outputs: >1,200 direct jobs created or safeguarded in local industry

TWI Wales

- Operational since 2003
- Located in Port Talbot
- Function:
  - R&D and validation of non-destructive inspection techniques
  - Training
- Staff number: 25
- Turnover: £2.6m (2012)
- Funding:
  - Originally industrial + Welsh Government
  - Now industrial, Welsh Government, and bid for collaborative programmes from UK and European programmes
  - Further expansion under discussion with Welsh government, working with leading Welsh universities.
- Outputs: >1,200 direct jobs created or safeguarded in Welsh industry

TWI's £300m, 10 Year Structural Integrity Programme 2012-2022

2015

Building representation - Middlesbrough

2016

Building representation - Alconbury

2012

Port Talbot

2014

The National Structural Integrity Research Centre - Cambridge