Stress Corrosion Cracking Test Pieces for Inspection Qualification and NDT Development

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BINDT & ICORR Symposium on Inspection and Monitoring Techniques to Manage the Corrosion of Valuable Assets

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Overview

- What do we do
- Stress corrosion cracking (SCC)
- Inspection
- NDT test pieces
- MISTIQ SCC test pieces
- NDT developments
- Case study
- Future developments
- Conclusions
AMEC NDT Inspection Capability

Monitoring & Inspection Design

Concept Development
- Problem Understanding
- Research
- Inspection Specification

Design
- Inspection Techniques
- Modelling and Simulation
- Reliability Testing
- Technical Justifications
- Technology Transfer
- Rigs and Test Pieces
- Deployment
- Human Factors

Plant Implementation
- Procedure Development
- Training
- Human Factors
- Data Analysis
- Site Support

Inspection Validation Centre

- Qualification Strategy
- Independent Qualification Body
- Qualification Consultancy
- Inspection Audit
- Training Audit
Why Inspect?

Plant Failures:
- Flixborough explosion – SCC of chemical reactor, UK 1974
- Bhopal accident, India 1984
- Swiss swimming pool collapse caused by SCC, 1985
- Carlsbad pipeline explosion, New Mexico, 2000
- El Al Boeing 747 crash caused by SCC, Amsterdam 1992

SCC is major degradation mechanism & difficult to detect
Stress Corrosion Cracking

MECHANICAL LOADING:
- OPERATIONAL TENSILE STRESSES
- RESIDUAL TENSILE STRESSES
- TRANSIENTS
- DYNAMIC STRAINING

SUSCEPTIBLE MATERIAL CONDITION:
- CHEMICAL COMPOSITION
- MICROSTRUCTURE
- COLD WORK
- IRRADIATION DAMAGE

ENVIRONMENT:
- FLOW CONDITIONS
- CORROSION POTENTIAL
- TEMPERATURE
- pH-VALUE
- IMPURITIES
- CREVICE EFFECTS
- RADIOLYSIS

SCC
SCC Initiation & Growth

Schematic diagram showing SCC initiation and growth

(Ref. R. Staehle, “Predicting the SCC of Reactor Components from First Principles”, EUROCORR, 2009, Nice, France, Acropolis Palais de Congress, 6-10 September, 2009)
SCC 2-D Morphology

TGSCC
Chloride SCC in 304L ASS
Ref. Colorado Metallurgical Services

IGSCC
Left Ref. NACE (Inconel heat exchanger)
Right Ref. Okamura, Japan NPP
SKI Report 2006:24 Crack Characterisation for In-service Inspection Planning
Nearly 100 SCC defects characterised from plant, 77% IGSCC
SCC 3-D Morphology
Inspection

Holy Grail

- Universal Technique
- No Operational Interference
- Early Warning

Now?

Targeted Online Monitoring

Future

Structural Health Monitoring
NDT Techniques

SCC Surface
- Visual
- Liquid dye penetrant (LPI)
- Magnetic particle (MPI)
- Eddy current (ECT)
- Electro-magnetic

Volumetric
- Ultrasonics
- Radiography
- Acoustic emission
NDT Test Piece Development

- **Representative test pieces**
  - Material, geometry, defects

- **Crack defects**
  - EDM notches, fatigue cracks (smooth defects)

E.g. UT response weaker for SCC compared to fatigue cracks leading to SCC defects being missed / unreported during plant inspections

Requirement for realistic SCC defects (rough defects)
AMEC MISTIQ SCC Process

- Need for IGSCC in Inconel alloys
- Control over crack length & depth
- Accelerated process
- Stainless steels & DM welds
- Standard plate specimens
- Bespoke specimens
- Dedicated rigs
- FE analysis support
SCC Images

Plant SCC

AMEC MISTIQ SCC
- Online data collection
- Gates & alarms
- Signal processing
- Enhanced visual display
- Data analysis
- Phased array
  - Total focusing method (TFM)
  - Full matrix capture (FMC)
**UT Online Monitoring**

- **Pulse echo**
  - SCC initiation
  - First stages of growth

- **Time of flight diffraction (TOFD)**
  - SCC crack depth
Online Data Collection

Pre SCC TOFD A-scan

B-scan showing SCC initiation & growth

SCC TOFD A-scan
Online Data Analysis: Gates & Alarms

Automated Recognition

- Signal Change Alarms
- Data Removed
- Gate Alarm - Decreasing Signal Dropping Below Threshold
- Gate Alarm - Increasing Signal Growing Above Threshold
Enhanced Visual Display

Prototype UT software with enhanced visualisation
Phased array TFM image superimposed on MISTIQ SCC (grade 304 plate)

FMC is data collection for every transmit-receive combination.
Case Study

Objective

- To deliver large DM weld SCC specimen to Japan for round robin trials

Challenges

- Largest SCC bespoke specimen
- DM weld composition
- Rig design & loading conditions
- NDT
- Delivery schedule
- SCC target: 20mm wide & 20mm deep
Case Study

- Weld metal trials
- Loading conditions: FE analysis
- NDT
  - UT specialised probes
  - DPI
- Destructive Examination

Ref. E. Journal of Advanced Manufacturing, Vol.3 No.3 NT40 & Vol.2 No.2 NT24

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Future Developments

- SCC in ferritic steels & Al alloys
- TGSCC NDT specimens
- Complicated geometries e.g. full pipe sections
- Degradation mechanisms – pitting, general corrosion
- Thermal fatigue & H cracking specimens
Conclusions

- There is a real need for realistic SCC specimens to improve inspection systems for SCC detection & sizing

- AMEC MISTIQ SCC test pieces offer a step improvement over conventional test pieces for SCC inspections
  - Widely used in qualified inspections for NPP

- Targeted NDT techniques can be adapted for online condition monitoring
Questions?

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