NDE Engineering- Materials Durability
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• Background
  – Faculty Grant- Sustainable System Design
  – Other Needs identified

• Overview of Materials Durability for NDE Engineering
  – Mechanical
  – Thermal
  – Chemical
Background

• ASNT Faculty Grant
  • Teaching Module Developed
  • Sustainable System Design
• Other needs were identified

Developed by Virginia Tech Professor John C. Duke, Jr. with support of a Faculty Grant of the American Society for Nondestructive Testing, Inc.
Traditional Scheme w/Life Extension

Requirements
- capabilities
- service life

Planning & Design

Quality Assurance NDI

Commissioning

NDI to support minor maintenance

Fabrication

Operation/Service

Constraints
- cost
- environment

Region not well defined so it was avoided with the original design

Note- The “Condition” plot is hypothetical since typically the condition is not being monitored.
Elements to support sustainable design education

- Material Science
  - Properties
  - Modes of degradation
- Manufacturing Processes and defects
- Mechanical Behavior
  - Fatigue
  - Fracture
  - Creep
- NDE capabilities
  - Method capabilities
  - Reliability (POD, POI, POF)
  - Interaction of probing energy with material degradation
Stuff degrades

June 7, 2010 One Dead after gas pipeline explosion, Texas.

September 10, 2010 San Bruno gas line explosion kills four

February 10, 2011 Allentown, PA neighborhood rocked by gas line explosion

January 24 Massive Water main break closes I-495 MD/DC Bridges

Power plants

Planes
Critical Systems Beyond Their Service Life
Materials begin to deteriorate as soon as they are placed in service.

- When does a reliably detectable flaw appear?
  - Uniaxial tension
  - Cyclic loading
  - Sustained loading

- The NDE Engineer needs to know what form the deterioration will take, where it will occur and when!
Materials Scientist use methods to understand deterioration that do not work for NDT!

Life: 1.1 million cycles

(N=0 → → → failure)
Service Induced Deterioration

• The NDE Engineer must understand how materials degrade, the type of damage modes this degradation causes how the synergistic effects of the environment?
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Modes of Service Induced Degradation

- Mechanical
- Chemical
- Thermal and radiation
- Combinations
- References are limited
  - “Materials Degradation and Its Control by Surface Engineering,” by Batchelor et. al. Imperial College Press
  - NASA NESC Academy- Materials Durability- Understanding Damage Modes, Piascik et al. NASA
Materials degradation - mechanical

• Mechanical causes
  – Wear
    • Abrasion
    • Erosion
  – Mechanical loading (quasi-static monotonic)
  – Creep (sustained)
  – Fatigue (cyclic)
  – Fracture (when macroscopic cracks are present)
Materials degradation - chemical

- Corrosion of metals
- Oxidation reactions with oxygen, sulphur and halogens
- Softening/embrittlement of wood and polymers
- Corrosion of concrete and ceramics
- Dissolution of metals and ceramics in liquid metals and inorganic salts and alkalis
- Biochemical and biological modes
Materials degradation – Thermal and Radiation

- Thermal degradation
  - Elevated
  - Cryogenic temperatures
- Photochemical
- High energy radiation
Materials degradation – synergistic effects

• Wear in a chemically active environment
  – Corrosive-abrasive
  – Corrosive effects on fretting
  – Abrasive wear in liquid metals

• Corrosion fatigue and fracture

• Corrosive embrittlement
Course or Database??

- Some have suggested that information of this sort should be placed in a database for engineers to access.
Course or Database??

• Often the data needed to make these decisions has not been collected.

• NDE Engineer often needs to do R&D not just selection.
Materials Durability affects NDT method selection

• For many NDI applications existing specifications determine what NDT method should be used to detect flaws of concern.

• WHEN NO SPECIFICATION EXISTS-
  – NDE Engineers must
    • Identify what to measure
    • Identify types of data required to assess the affects of the deterioration
    • Identify or overcome limitations imposed by constraints
The NDE Engineer must understand not only how NDT methods detect typical flaws, but also other forms of deterioration–

**NDT methods using mechanical energy**

- Ultrasound
- Acoustic Emission
- Acousto-ultrasound
- Dial gage
- Liquid Penetrant
- Impact echo
- Impulse response
- Resonance
Modes of detecting degradation-electromagnetic NDT

- Magnetic particles
- Magnetic flux leakage
- Electrical resistance
- Eddy current
- Infrared thermography
- Microwave/radar
- Radiography X&N
- Optical Fiber gages
- Resistance Strain gage
- LVDT
- Visual
Modes of detecting degradation-practical issues

Selection of appropriate nondestructive methods depends on:

• The nature of the degradation
• The process for analyzing the characterization data collected
• Constraints associated with the specific application
  – Access
  – Environment
  – Critical imperfection size
  – Etc.
Discipline Experts to support Sustainable design

Planning and design teams typically consult discipline experts for in depth input regarding aspects of the design. Examples of discipline experts:

- Structural analysis
- Loads associated with operation
- Materials

Since it is unrealistic to expect all design engineers to have strong background knowledge of materials degradation and the associated methods for detecting and tracking it a new discipline expert is needed - The NDE Engineer.