6000. STEEL

- 6130 - Design Data, Principles and Tools
- 6140 - Codes and Standards
- 6200 - Material
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- 6330 - Frames and Assemblies
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6500. Construction Testing and Examination -
6510. Nondestructive Testing Methods

- Definition of NDT
- Methods of NDT
  - Visual
  - Liquid Penetrant
  - Magnetic
  - Ultrasonic
  - Eddy Current
  - X-ray
- Usage of NDT

Definition of NDT

The use of noninvasive techniques to determine the integrity of a material, component or structure or quantitatively measure some characteristic of an object.

i.e. Inspect or measure without doing harm.

What are Some Uses of NDE Methods?

- Flaw Detection and Evaluation
- Leak Detection
- Location Determination
- Dimensional Measurements
- Structure and Microstructure Characterization
- Estimation of Mechanical and Physical Properties
- Stress (Strain) and Dynamic Response Measurements
- Material Sorting and Chemical Composition Determination
When are NDE Methods Used?

There are NDE applications at almost any stage in the production or life cycle of a component

– To assist in product development
– To screen or sort incoming materials
– To monitor, improve or control manufacturing processes
– To verify proper processing such as heat treating
– To verify proper assembly
– To inspect for in-service damage

Nondestructive Testing

• Advantages
  – Can test in-service structures
  – Evaluate surface and internal conditions
  – Cost efficient

• Disadvantages
  – Reliability (measurements are made indirectly)
  – Qualitative
  – Requires a skilled professional for interpretation of results

Destructive Testing

• Advantages
  – Reliable (direct measurements)
  – Quantitative
  – Directly relates to material properties

• Disadvantages
  – Cannot test in-service structures
  – Requires a model
    • Costly & Time Consuming
  – Multiple tests are sometimes required

Methods of NDT

- Visua
- Tap Testing
- Microwave
- Magnetic Particle
- Acoustic Emission
- X-ray
- Acoustic Microscopy
- Magnetic Measurements
- Liquid Penetrant
- Replication
- Ultrasonic
- Laser Interferometry
- Eddy Current
- Flux Leakage
Six Most Common NDT Methods

- Visual
- Liquid Penetrant
- Magnetic
- Ultrasonic
- Eddy Current
- X-ray

Visual Inspection

Most basic and common inspection method.

Tools include fiberscopes, borescopes, magnifying glasses and mirrors.

Portable video inspection unit with zoom allows inspection of large tanks and vessels, railroad tank cars, sewer lines.

Robotic crawlers permit observation in hazardous or tight areas, such as air ducts, reactors, pipelines.

Liquid Penetrant Inspection

- A liquid with high surface wetting characteristics is applied to the surface of the part and allowed time to seep into surface breaking defects.
- The excess liquid is removed from the surface of the part.
- A developer (powder) is applied to pull the trapped penetrant out the defect and spread it on the surface where it can be seen.
- Visual inspection is the final step in the process. The penetrant used is often loaded with a fluorescent dye and the inspection is done under UV light to increase test sensitivity.

Process:

- Clean surface
- Apply liquid penetrant
- Remove excess penetrant
- Apply developer
- Inspect
- Post-cleaning
**Magnetic Particle Inspection**

The part is magnetized. Finely milled iron particles coated with a dye pigment are then applied to the specimen. These particles are attracted to magnetic flux leakage fields and will cluster to form an indication directly over the discontinuity. This indication can be visually detected under proper lighting conditions.

**Magnetic Particle Process:**
- Magnetize surface
  - Discontinuities create a magnetic flux
- Sprinkle magnetic particles
- Inspect

**Magnetic Particle Crack Indications**

**Radiography**

The radiation used in radiography testing is a higher energy (shorter wavelength) version of the electromagnetic waves that we see as visible light. The radiation can come from an X-ray generator or a radioactive source.
**Film Radiography**

The part is placed between the radiation source and a piece of film. The part will stop some of the radiation. Thicker and more dense area will stop more of the radiation.

The film darkness (density) will vary with the amount of radiation reaching the film through the test object.

- Lighter = less exposure
- Darker = more exposure

Top view of developed film

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**Radiographic Images**

- Ultrasonic
- Eddy Current Testing

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**Eddy Current Testing**

- Coil
- Coils' magnetic field
- Eddy current's magnetic field
- Conductive material
- Eddy currents
**Eddy Current Testing**

Eddy current testing is particularly well suited for detecting surface cracks but can also be used to make electrical conductivity and coating thickness measurements. Here a small surface probe is scanned over the part surface in an attempt to detect a crack.

**Ultrasonic Inspection (Pulse-Echo)**

High frequency sound waves are introduced into a material and they are reflected back from surfaces or flaws.

Reflected sound energy is displayed versus time, and inspector can visualize a cross section of the specimen showing the depth of features that reflect sound.

**Ultrasonic Imaging**

High resolution images can be produced by plotting signal strength or time-of-flight using a computer-controlled scanning system.

**Usage: Inspection of Raw Products**

- Forgings,
- Castings,
- Extrusions,
- etc.
Usage: Inspection Following Secondary Processing

- Machining
- Welding
- Grinding
- Heat treating
- Plating
- etc.

Usage: Inspection For In-Service Damage

- Cracking
- Corrosion
- Erosion/Wear
- Heat Damage
- etc.

Usage: Power Plant Inspection

Periodically, power plants are shutdown for inspection. Inspectors feed eddy current probes into heat exchanger tubes to check for corrosion damage.

Usage: Storage Tank Inspection

Robotic crawlers use ultrasound to inspect the walls of large above ground tanks for signs of thinning due to corrosion.

Cameras on long articulating arms are used to inspect underground storage tanks for damage.
Usage: Pressure Vessel Inspection

The failure of a pressure vessel can result in the rapid release of a large amount of energy. To protect against this dangerous event, the tanks are inspected using radiography and ultrasonic testing.

Usage: Pipeline Inspection

NDT is used to inspect pipelines to prevent leaks that could damage the environment. Visual inspection, radiography and electromagnetic testing are some of the NDT methods used.

6500. Construction Testing and Examination -

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Objective and Scope Met

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- Destructive Test for Welds
- Nondestructive Test for Welds
  - Dye Penetrate Testing
  - Magnetic Particle Testing
  - Radiographic Testing of Groove Welds in Butt Joints
  - Ultrasonic Testing of Groove Welds
  - Acoustic & Pressure Testing

Weldability

- Capacity to be welded into a specific structure that has certain properties and characteristics and will satisfactorily meet service requirements
- Thorough knowledge of the phase diagram is essential
- Factors such as strength, toughness, ductility, notch sensitivity, elastic modulus, specific heat, melting point, thermal expansion, surface tension characteristics of the molten metal, corrosion resistance.

Testing Welded Joints

- Quality of the welding joint is established by welded joint
- Each technique has capabilities, limitations and sensitivity reliability and requirement for special equipment and operator skill.

Destructive Techniques

Tension Test:
- Longitudinal and transverse tension tests are performed
- Stress strain curves are obtained

Tension-Shear Test
- Specifically prepared to simulate actual welded joints and procedures.
- Specimen subjected to tension and shear strength of the weld metal

Bend test:
- Determines ductility and strength of welded joints.
- The welded specimen is bend around a fixture
- The specimens are tested in three-point transverse bending
- These tests help to determine the relative ductility and strength of the welded joints

Two types of specimens for tension-shear testing of welded joints.

(a) Wrap-around bend test method.
(b) Three-point bending of welded specimens.
Other destructive testing

- Fracture Toughness Test:
- Corrosion and creep tests
- Testing of spot welds
- Tension-Hear
- Cross-tension
- Twist
- Peel

Non-Destructive testing

- Often weld structures need to be tested Non-Destructively
- Non-Destructive testing are:
  - Visual
  - Radiographic
  - Magnetic-particle
  - Liquid-penetrant
  - Ultrasonic

Testing of Spot Welds

- (a) Tension-shear test for spot welds.
- (b) Cross-Tension test.
- (c) Twist test.
- (d) Peel test

TENSILE

Material is sectioned and edges rounded of to prevent cracking.

Punch marks are made to see elongation.

BEND TESTING

- Shows
- Physical condition of the weld

Determine welds efficiency

- Tensile strength
- Ductility
- Fusion and penetration
BEND TEST

- Bend through 180°
- the specimen should be a minimum of 30mm wide
- The fulcrums diameter is 3x thickness of the plate
- The bottom rollers have a distance of the diameter of the former + 2.2 times the thickness of the plate
- Upper and lower surfaces ground or filed flat and edges rounded off.
- the tests should be one against the root -another against the face ,and in some cases a side bend.

FACE BEND

D = 3T

D + 2.2T

IMPACT

- CHARPY AND IZOD
- Gives the toughness and shock loading of the material and weld at varying temperatures with a notch such as under cut
- The measurement is the energy required to to break a specimen with a given notch
- 2mm depth at a 45° bevel or a “U” notch.
HARDNESS TESTS.

- This gives the metals ability to show resistance to indentation which show its resistance to wear and abrasion.
- The tests are
  - Brinell
  - Rockwell
  - Vickers diamond pyramid
  - Scleroscope
DYE PENETRANTS

• These are an aid to visual inspection

• Will only find surface defects

• Use correct type

DYE PENETRANTS

• Types
  – Red
  – Flouresant

• CAUTION
  – Oil based
  – Water washable

Dye Penetrant Test

• Dye penetrant testing locates minute surface cracks and porosity

• Dye types that may be used include:
  • Color contrast dye - which shows up under ordinary light
  • Fluorescent dye – which shows up under black light
  • The dye is normally applied by spraying it directly on the weld

(AISC & NISD 2000)
MAGNETIC PARTICLE

- Mainly for surface defects
- Some sub surface defects can be found
- Only ferrous metal

Magnetic Particle Inspection

- Magnetic particle inspection uses powdered magnetic particles to indicate defects in magnetic materials
- A magnetic field is induced in the part
- The magnetic powder is attracted to and outlines cracks within the material

(AISC & NISD 2000)

RADIOGRAPHIC

X-RAY
GAMMA RAY
Electro magnetic radiation of short duration
Both of these methods are a danger to health

Radiographic Inspection

- Radiographic inspection, or X-ray, can also be used to detect flaws inside welds
- Invisible rays penetrate the metal and reveal flaws on an x-ray film or fluorescent screen (above)
- This is the most costly of the inspection methods

(AISC & NISD 2000)
Pictures taken are viewed as negatives. They will only give flat images not in three-dimensional space. The darkened area must be used for viewing.
ULTRASONIC TESTING

This uses high pitched sound
The sound will not pass through an air gap so bounces back and is picked up on a receiver
The reader is an oscilloscope

ULTRA SONIC Device

Ultrasonic Inspection

- Ultrasonic inspection can be used to detect flaws inside welds
- High frequency sound waves are directed into the metal with a probe held at a specific angle
- The flaws reflect some energy back to the probe
- Flaws show up as indications on a screen (above) and are subject to interpretation by an inspector

(AISC & NISD 2000)
ACOUSTICS

Striking with a rounded object

Ringing tone if no defect

Tone changes when object is cracked

APPLICATION OF A LOAD

- Used to test pressure vessels
- Pipe lines
- The item for testing is filled with water or oil it is then pressurised using a pump
- A safety valve is set 1.5 to 2 times below the working pressure.

PRESSURE TEST
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