Michigan Bridge Conference

2016

Lansing, MI

COLLINS ENGINEERS INC.

# Practical NDT/PDT Methods for Bridge Inspection

Steve Miller, P.E.

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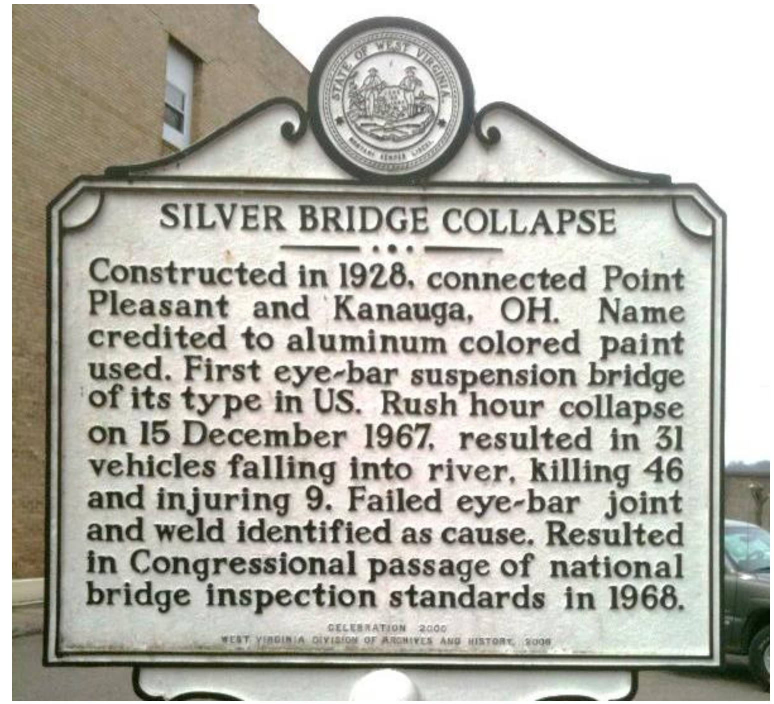
# Silver Bridge



# AGENDA

- 1.0 Visual (VT) Testing
- 2.0 Magnetic Particle (MT) Testing
- 3.0 Eddy Current (EC) Testing
- 4.0 Ultrasonic (UT) Testing

# FHWA Website for NDE


https://fhwaapps.fhwa.dot.gov/ndep/

***Navigating the NDE web manual***

- Find Technology tab identifies applicable NDE technologies when material, structure element, and target of investigation are known.
- Use NDE Technologies tab obtains information related to a specific NDE technology.
- Use the Glossary tab includes the definition of scientific terms relating to NDE of highway infrastructure
- Acronyms and Abbreviations tab covers common terms in NDE of highway infrastructure.


# 1.0) Visual testing methods

Visual inspection

Dye penetrant

# Visual Inspection

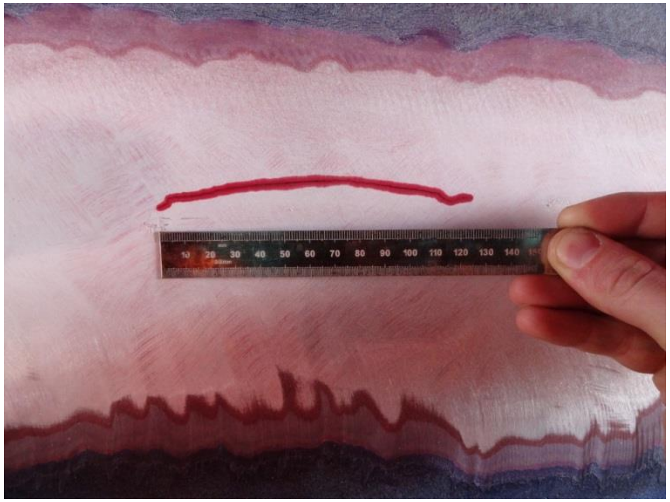
Visual acuity required


Visual inspection augmentation

- Magnifying devices
- Measuring devices (calipers, tape measures, etc.)
- Lighting
- Borescope
- Dye penetrant


# 1A) Dye Penetrant Testing


- Enhances flaw indications for visual detection
- Dye and developer produces high contrast
- Test surface must be smooth, clean and free of paint



# Dye Penetrant Procedure

- Remove paint and smooth to a surface free of paint and foreign material

Penetrant Application:

- Dwell time required for penetration ~ 5 mins


Excess penetrant removal:

Wipe with solvent, water or emulsifier

Developer Application:

- Extracts trapped penetrant


# 1B) Discuss advantages and limitations of dye penetrant

Dye penetrant advantages

Dye penetrant limitations

# Dye Penetrant Advantages

- Simple to use
- Less costly than other NDE methods
- Can be used on any non-porous material
- Portable and well-suited for field usage
- Sensitive to small defects

# Dye Penetrant Limitations

Surface discontinuities only

Surface must be clean and free of paint

Requires good visual acuity of inspector

Limited to moderate temperature range

Time consuming

# 2.0) Magnetic Particle Testing (MT)


## 2A) Define magnetic particle testing and the related attributes

# Magnetic Particle Testing

| Used on ferromagnetic materials to detect: | |
|---|---|
| | Surface discontinuities (gouges, cracks, holes) |
| | Near surface defects such as cracks, lack of fusion, voids, inclusions |
| | For subsurface flaws the effectiveness of MT decreases as the depth of flaw below the surface increases |

# Magnetic Particle Testing (con.)

Magnetic yoke is a hand-held device that induces a magnetic field between two poles

These systems use dry magnetic powders, wet powders, or aerosol cans

Common particle used to detect cracks is iron oxide, for both dry and wet systems

# Magnetic Particle Testing (con)

## Approach 1: Yokes

- Area to be tested is placed in magnetic field (EMF)
- EMF lines are uniform between if no discontinuities present

## Approach 2: Prods

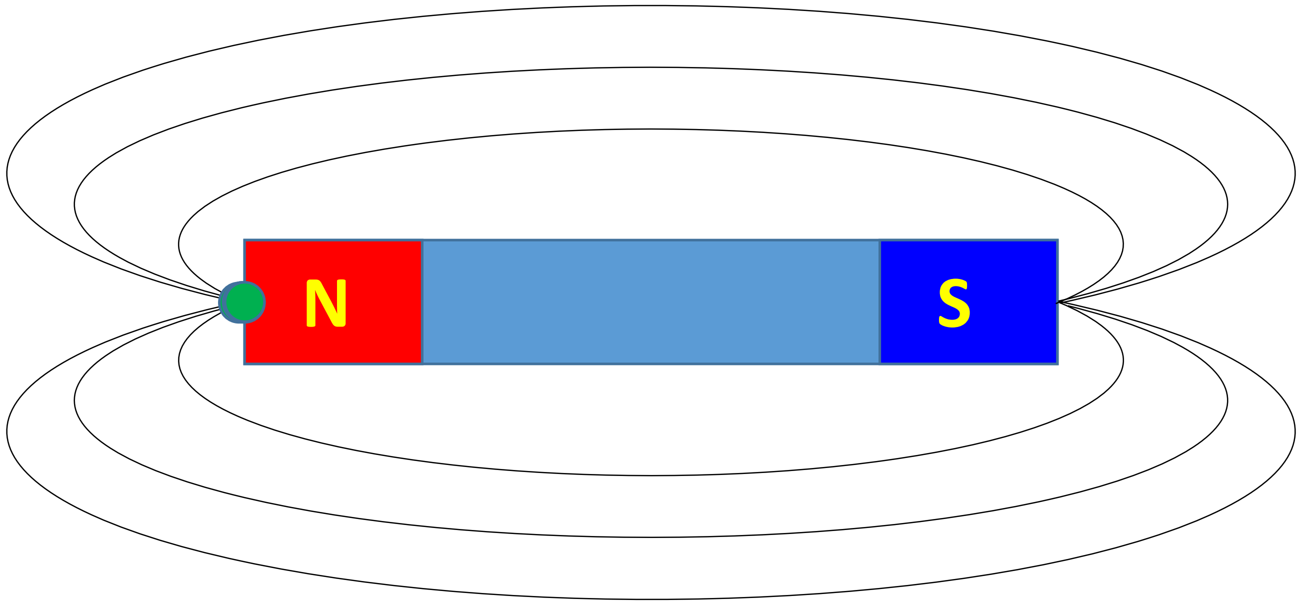
- Two current-carrying prods are placed on member
- Current flows between prods (running current magnetizes material)


B) Explain basic theory of magnetic particle testing

# Magnetic Particle Testing Theory

At north pole, magnetic lines of force exit the magnet

At south pole, magnetic lines of force enter the magnet

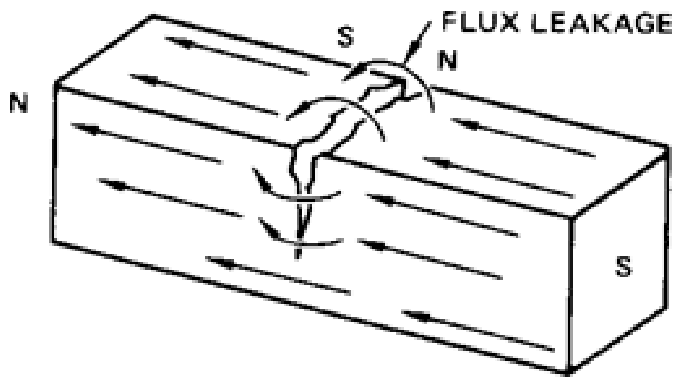


# Magnetic Particle Testing Theory (con.)

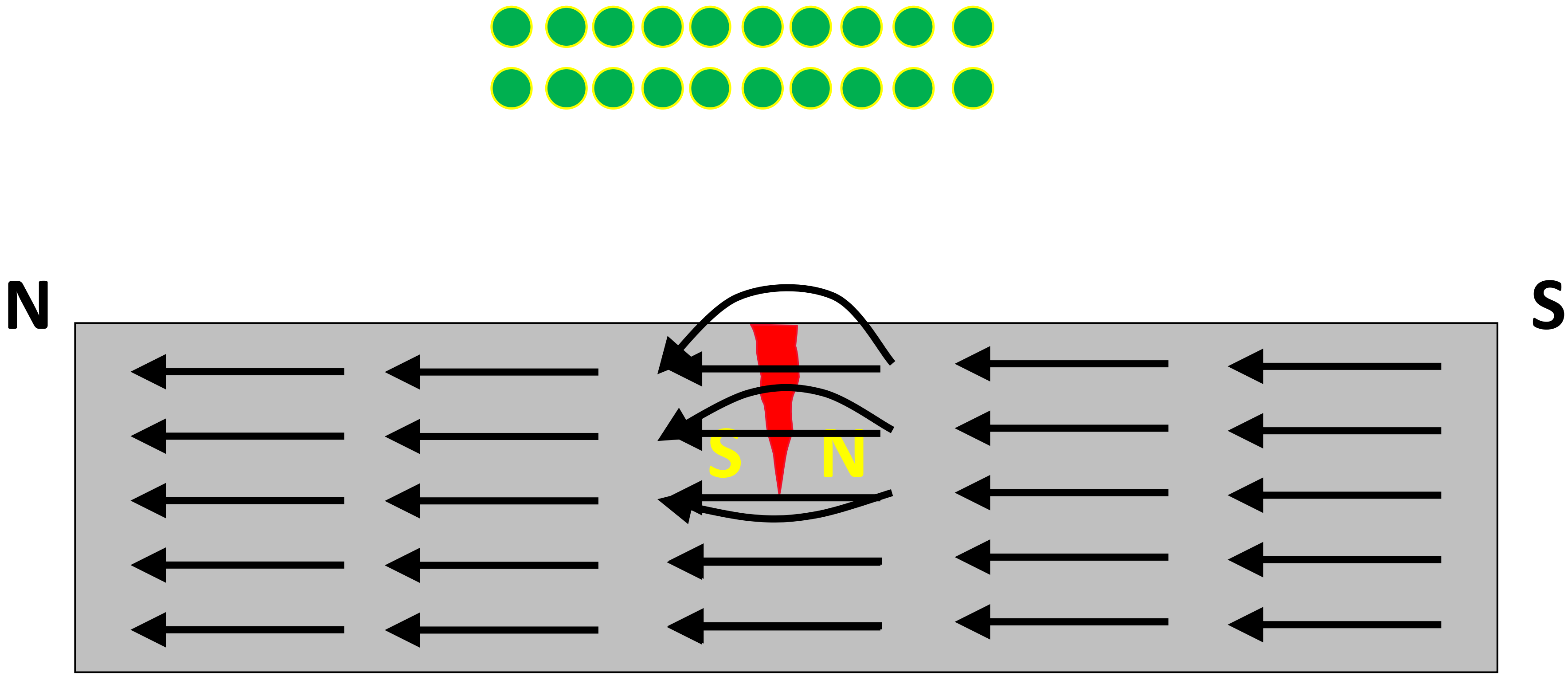
If a magnet is completely severed, two new magnets will result

If  a magnet is just cracked but not severed, north and south poles will form at each edge of the crack

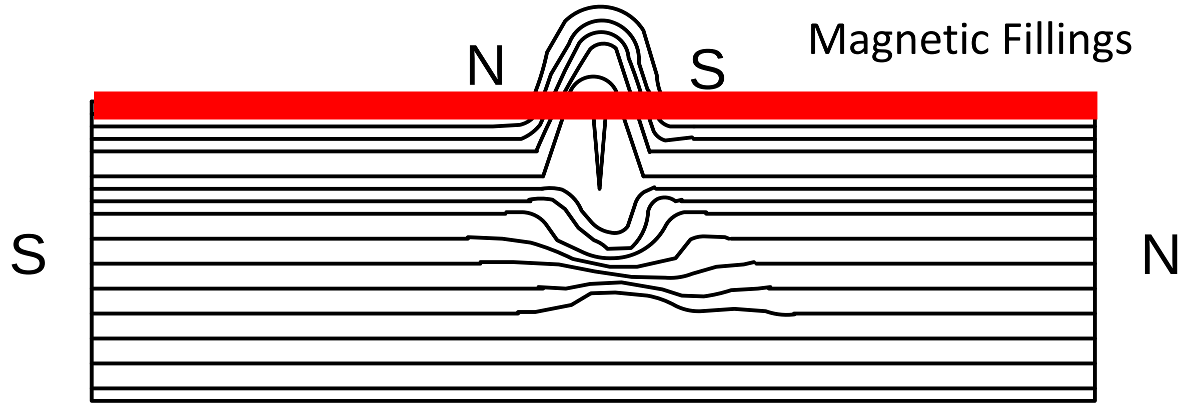
Iron particles cluster at the poles at the edges of the crack



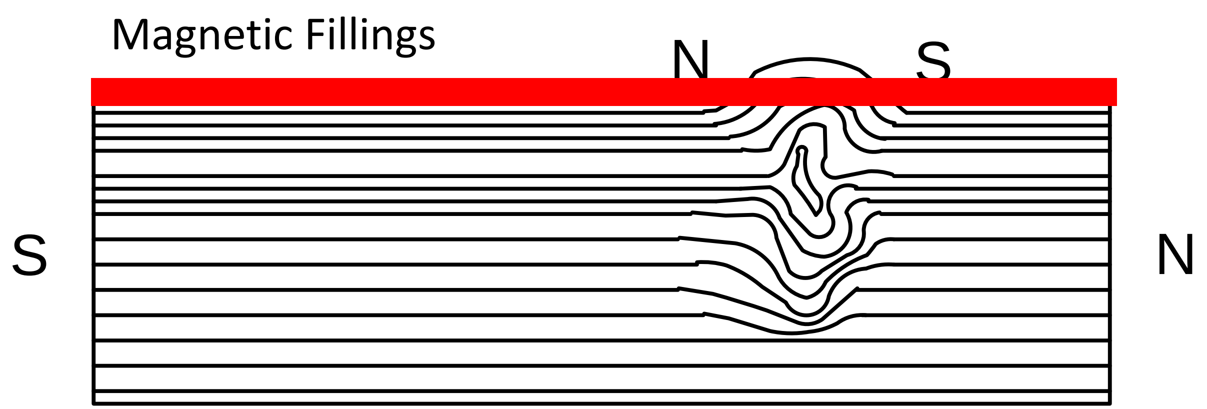
# Magnetic Flux Leakage



# Flux Lines with Surface Flaws




# Flux Lines with Interior Flaws



# C) List applications of magnetic particle testing

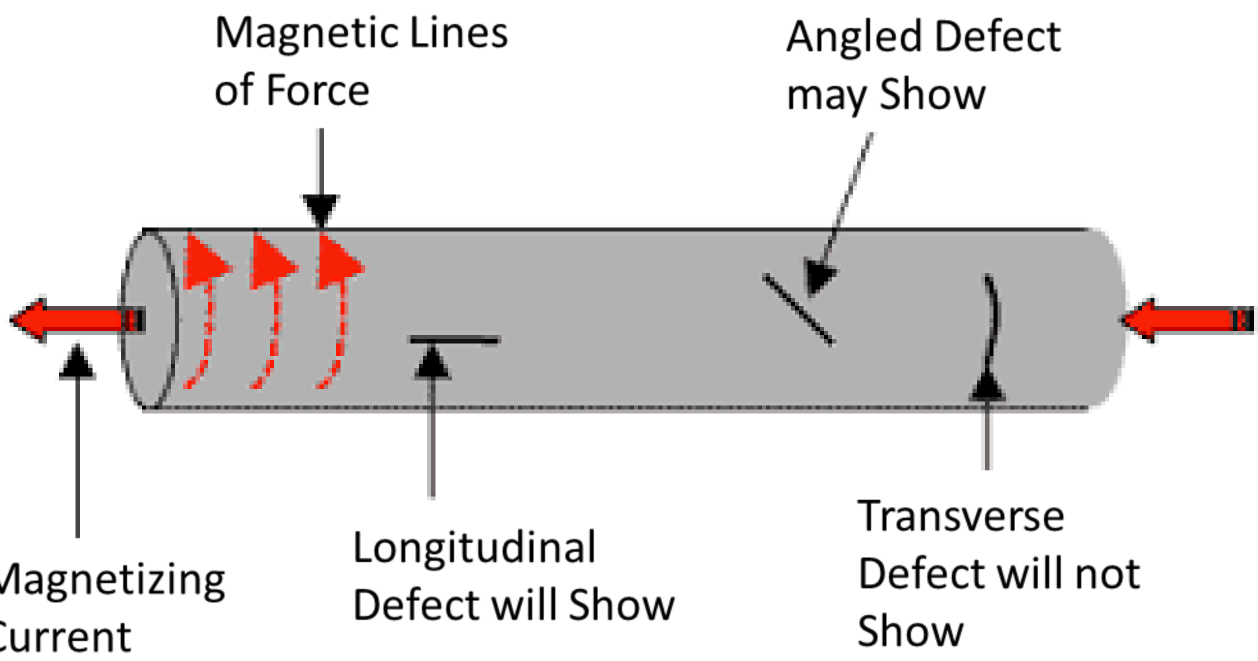
# MT Applications

Used to determine discontinuities on ferromagnetic surfaces

Weld or base metal defects including:

- Cracking
- Incomplete fusion
- Slag inclusions
- Undercuts

# Defect Detection



# Out of Plane Bending

# Attachment Plate End Weld Crack


## D) Discuss advantages and limitations of MT

MT advantages

MT limitations

# MT Advantages

Sensitive to small or shallow surface cracks

Ability to locate “near” surface discontinuities

Reasonably fast, inexpensive and portable

Can detect “filled” cracks

Not limited by size or shape of the piece being inspected

# MT Limitations

Works only on ferromagnetic material

Dependent on defect orientation

Weld geometry causes false indications

Detection of subsurface defects not reliable

Surface preparation required

# 3.0) Eddy Current (EC)


# 3A) Define eddy current testing and the related attributes

# Eddy Current (EC)

Method for detecting surface breaking or near surface flaws

Induces current within conductive specimen

Measures changes in current

# Testing Apparatus

**Typical Properties**

Weight: 2 - 4 lbs.

Power: Rechargeable, 6 - 8 hour life

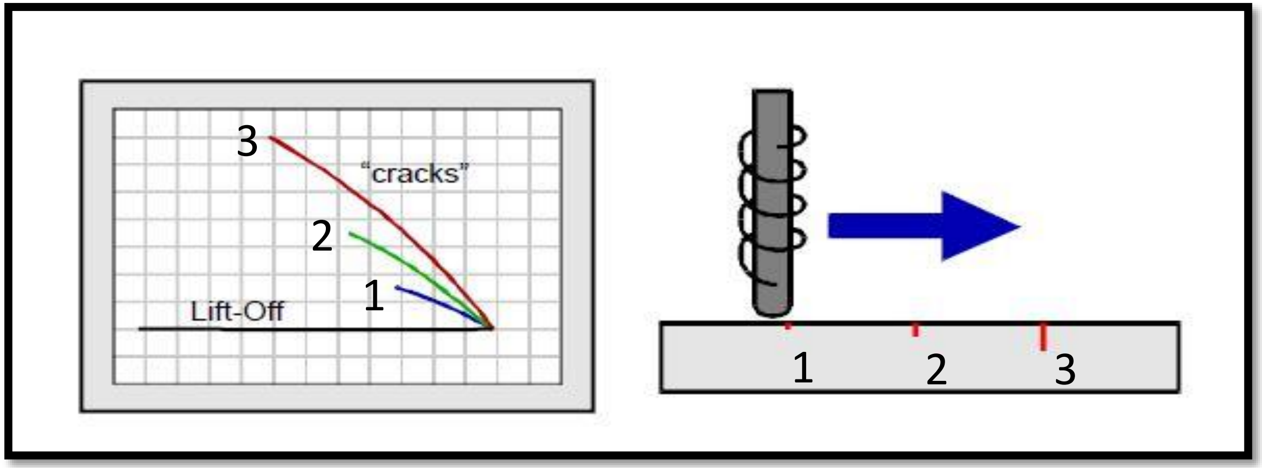
Flaw Resolution: 0.001 in.

Scan Rate: 4 – 6 in./sec.

# Eddy Current Testing

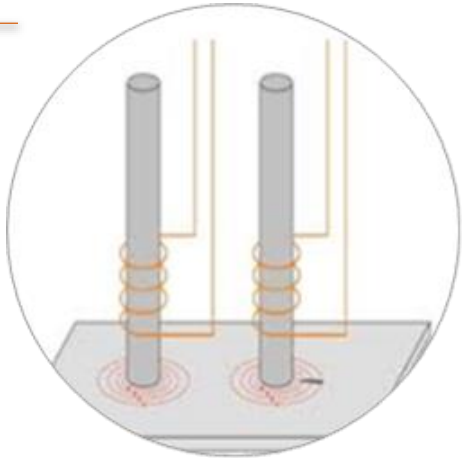
Surface probe scanned across the surface of the specimen

Probe moving over a series of simulated cracks of varying depths



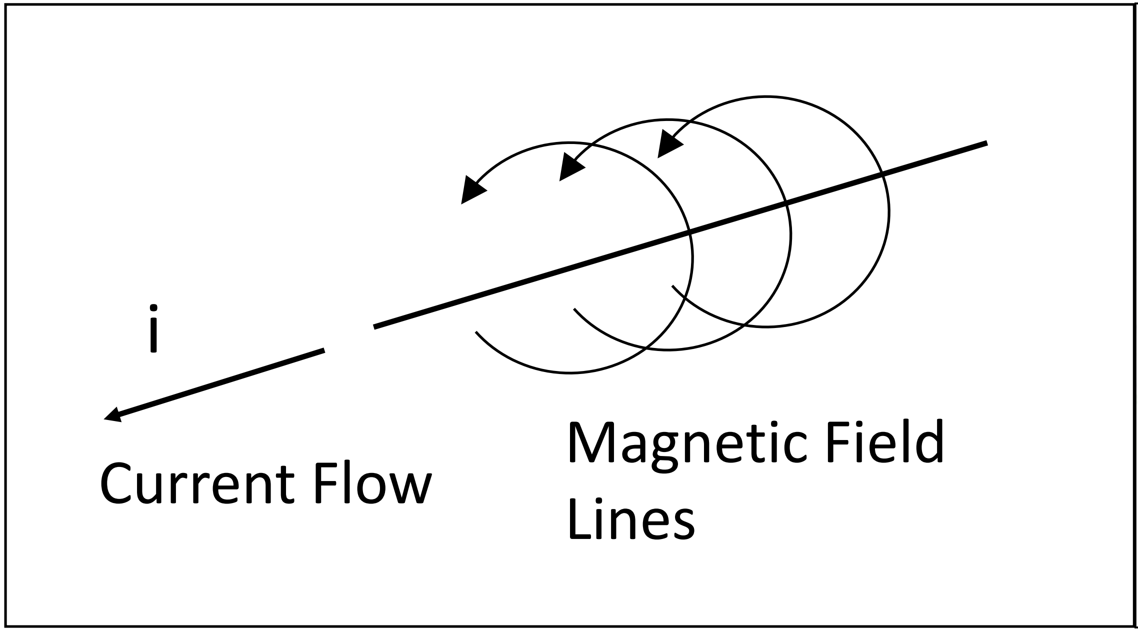

## 3B) Explain basic theory of eddy current testing

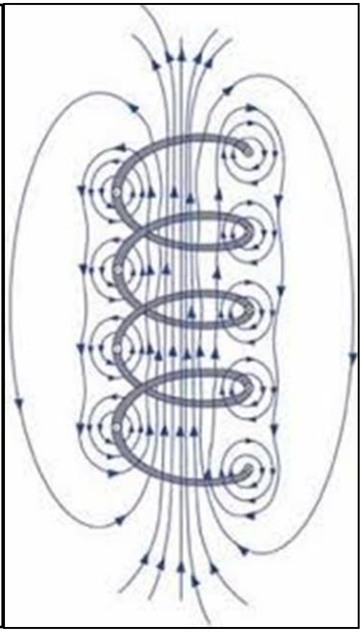
EC is based on the principle of induction



# Basic EC Theory

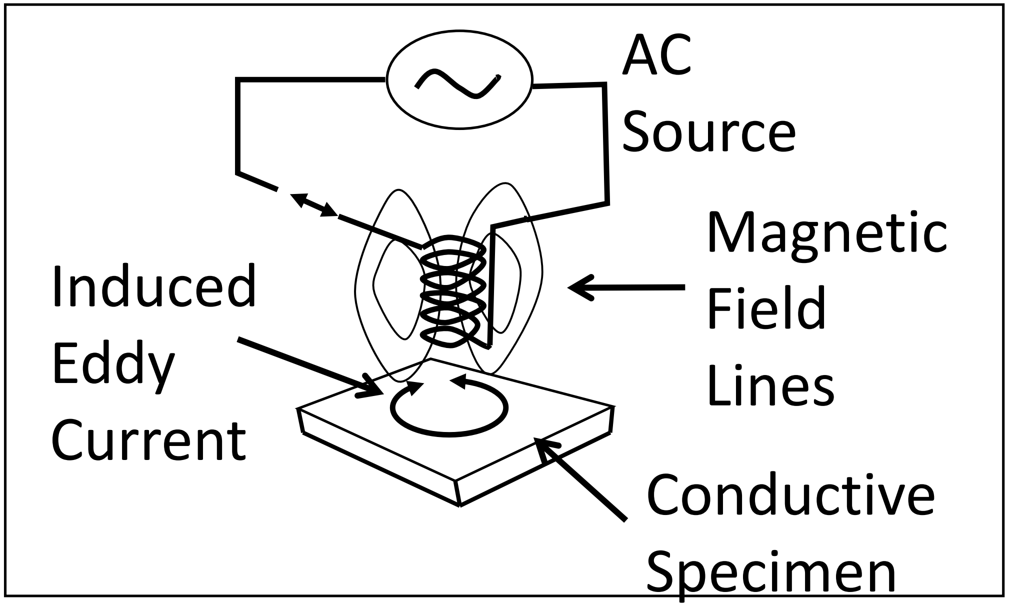
A current flowing through a wire produces a magnetic field about the wire



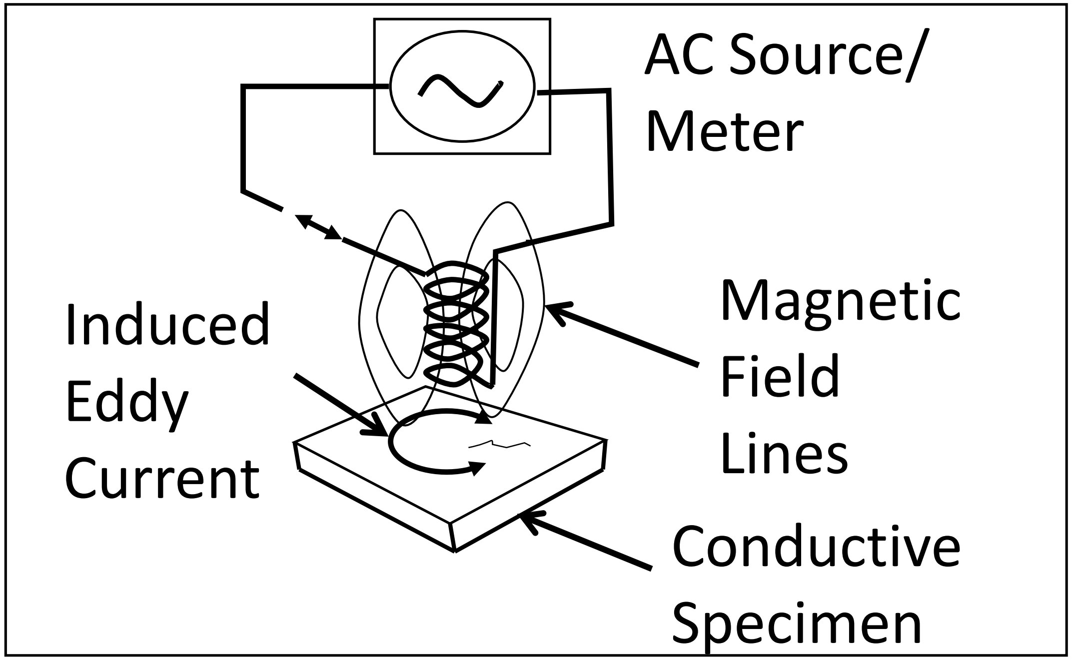
# Basic EC Theory (con.)

Induces current (eddy current) into specimen which has corresponding magnetic field that works against coil's field (mutual inductance)



# Basic EC Theory (con.)

Interruptions (crack or discontinuity) to eddy currents create a measurable change in impedance



# Basic EC Theory (con.)

Works on conductive materials (including ferromagnetic)

Eddy current generation is influenced by:

- Material conductivity
- Magnetic permeability
- Excitation frequency
- Probe “lift-off” distance

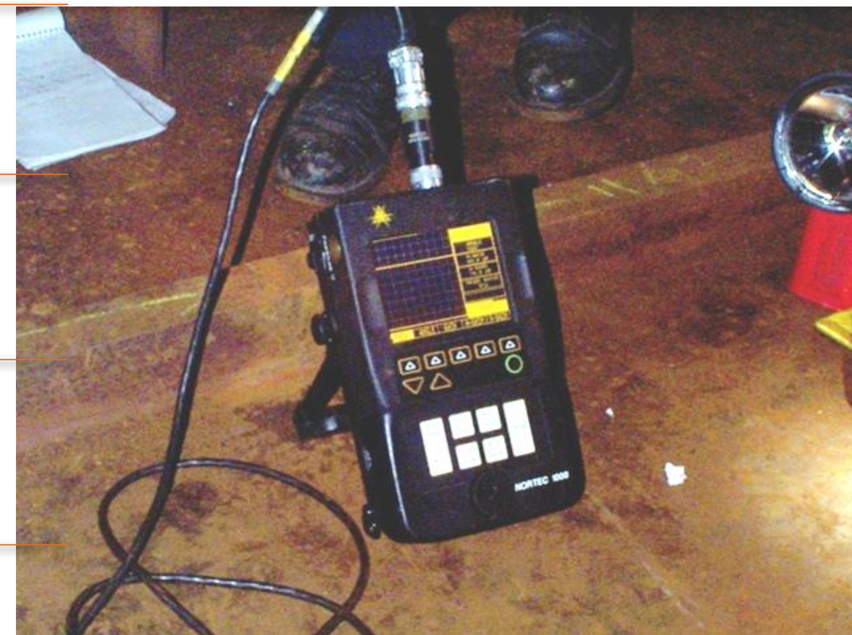
# 3C) List applications of eddy current testing

Crack detection

Thickness measurement of coatings

Thickness measurement of thin materials

Differentiation of metals




# 3D) Discuss advantages and limitations of eddy current testing

EC advantages

EC limitations

# EC Advantages

Fast

Detection of surface breaking and near surface defects

Not necessary for probe to contact specimen surface

Penetrate conductive and non-conductive paint coatings

# EC Limitations

Material property changes can affect results

Requires inspector interpretation of signals

Cannot determine the depth of a crack

More challenging to detect subsurface defects

# 4.0 Ultrasonic Testing (UT)


4A) Explain ultrasonic theory and testing methods for steel elements

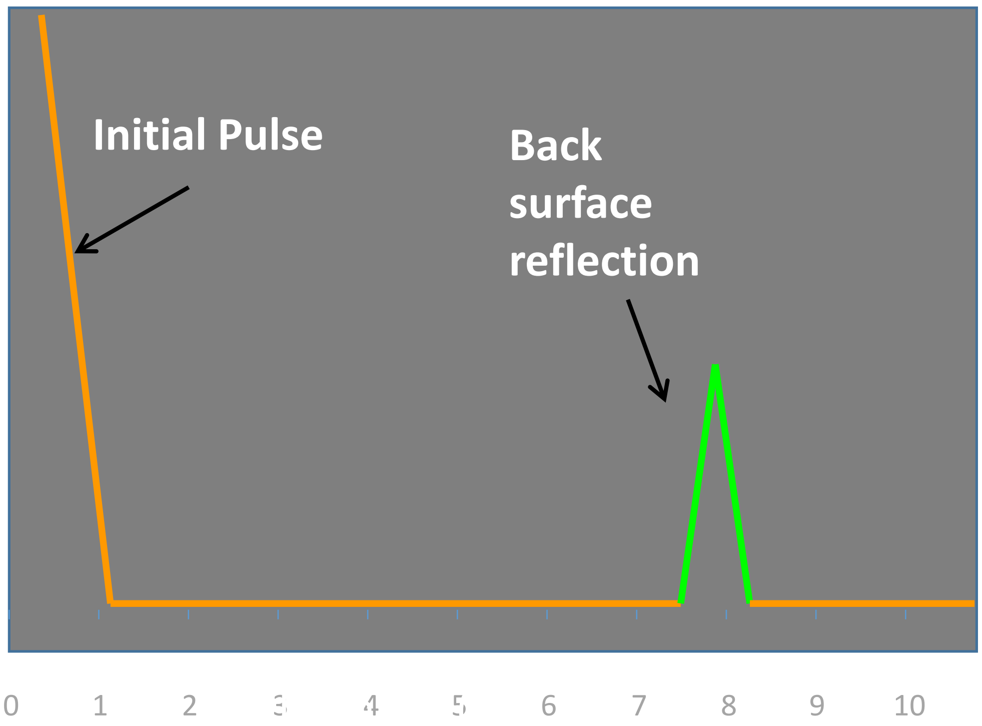
# Ultrasonic Testing

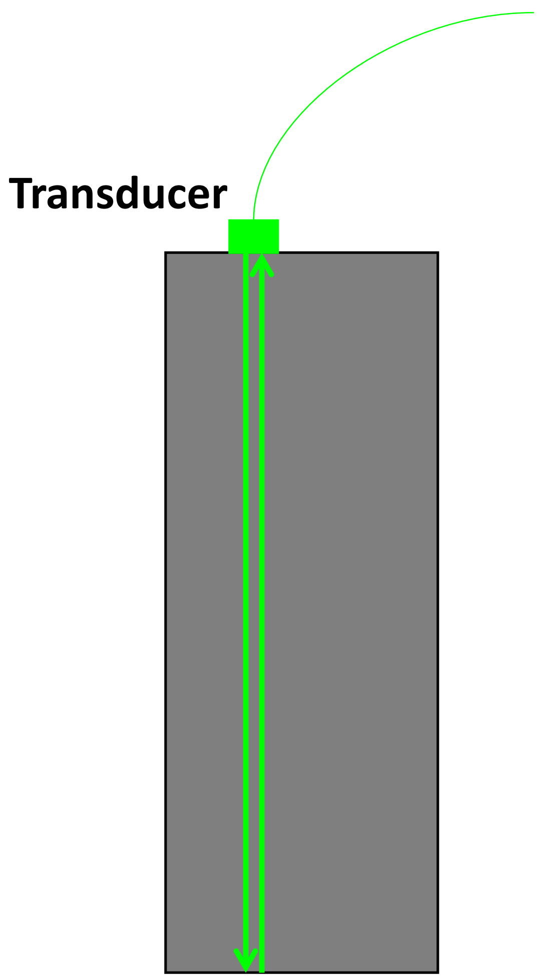
The utilization of high frequency acoustic waves emitted and received via a transducer

# Ultrasonic Testing

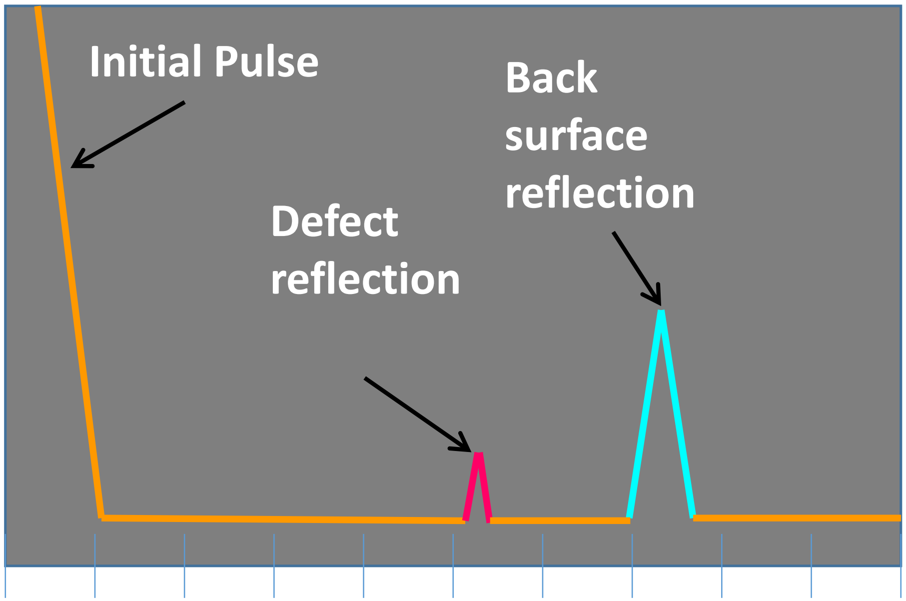
| | |
|---|---|
| Reflected waves are interpreted to determine: | Internal features, such as defects<br>Dimensions of the material |
| An internal defect will cause a reflection of the wave due to a change in impedance in the material. | $R = [(Z_2 - Z_1)/(Z_2 + Z_1]^2$<br>(R) is the Reflection<br>(Z) Is Acoustic Impedance |
| "Volumetric" method | Detect defects or damage hidden from view |

# Basic principles

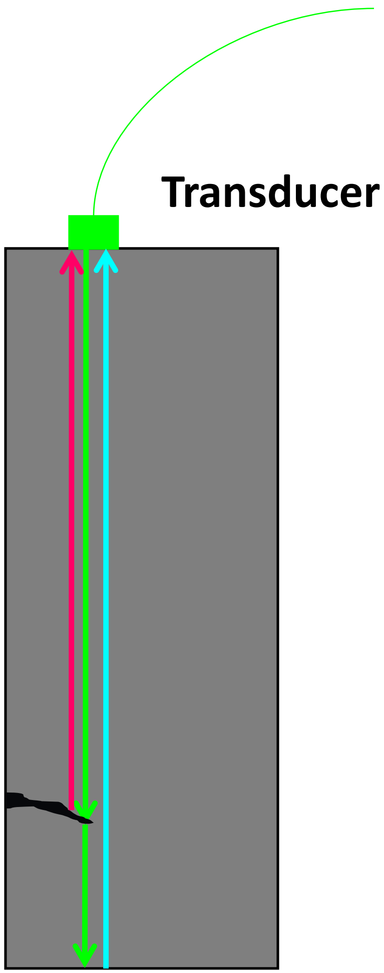


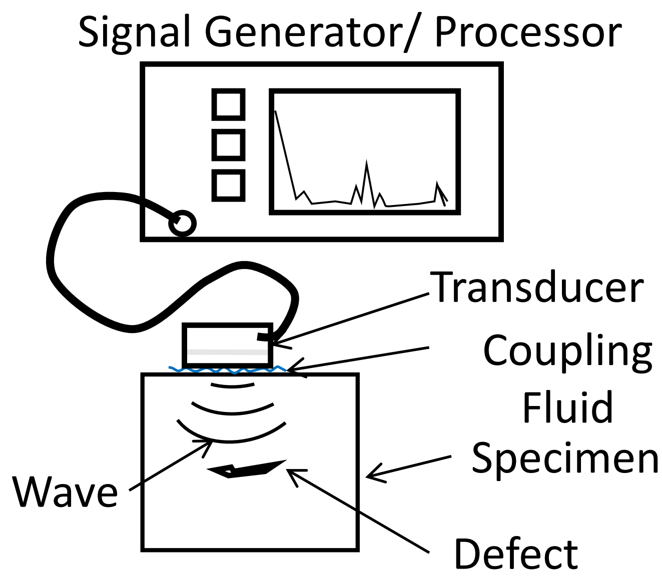
# Basic principles




Note: A crack normal to the beam path reflects more energy than a crack that is skewed



# Testing Apparatus




| | | |
|---|---|---|
| Surface tested must be smooth and clean | | |
| Couplant needed between surface and transducer | | |
| Typical properties | Weight: 1 - 9 lbs | |
| | Power: Rechargeable, 4 - 6 hour life | |
| | Freq. Range: 0.2 – 10 MHz | |

# 4B. List ultrasonic testing applications for steel

## Applications for common UT methods

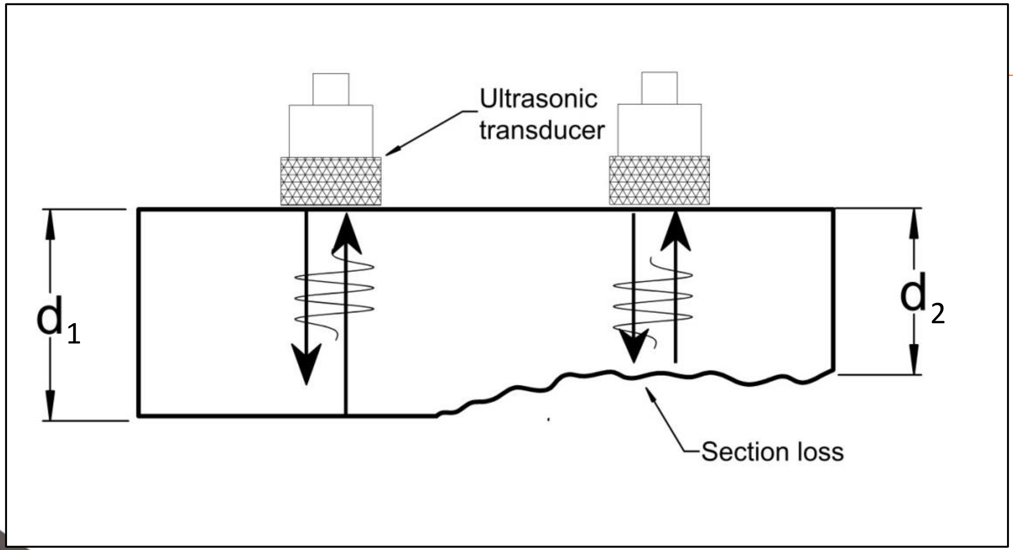
- Straight beam UT
- Angled beam UT
- Phased array UT

# Straight Beam UT Applications

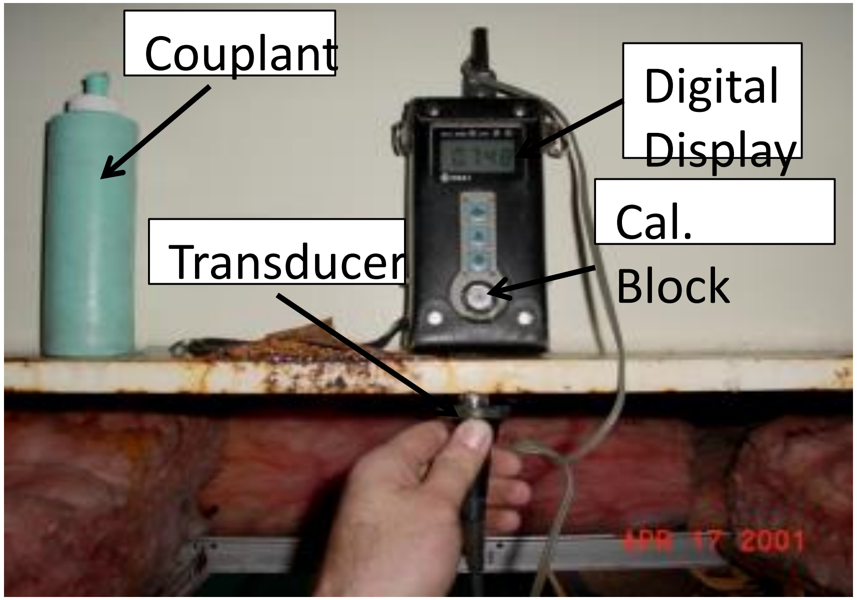
## Thickness measurement

Measure remaining thickness to determine section loss

Based on the time of flight of an ultrasonic wave



# Straight Beam UT Applications (con.)

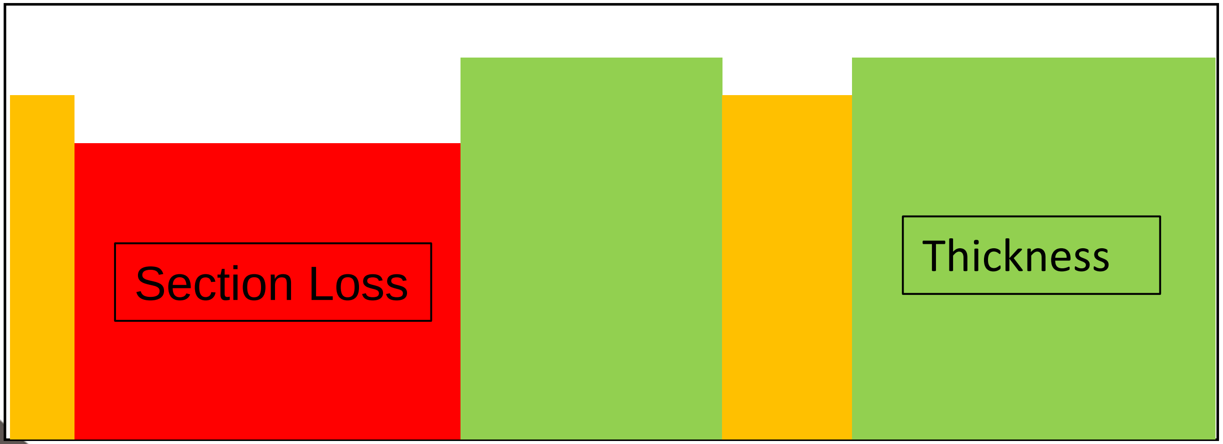



Typical technology uses a single transducer and a digital display showing thickness measurement

# Straight Beam Applications (con.)

**B-scan data collection**

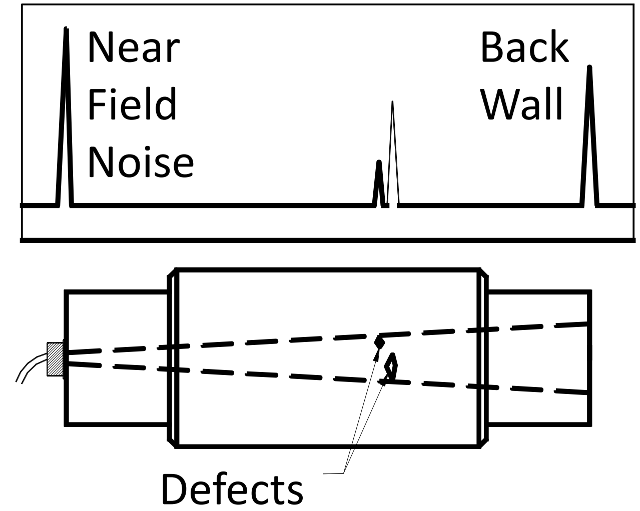
- "Scanning" thickness measurement
  - Measure thickness along a scanned line
- Graphical display of section loss along the line of the scan




# Straight Beam Applications (con.)

Longitudinal waves used:

| | |
|---|---|
| To detect subsurface defects (i.e., cracks, inclusions, etc.) | |
| Assess inaccessible areas for defects | |




Straight Beam UT

# Straight Beam Applications (con.)

Pin Inspection

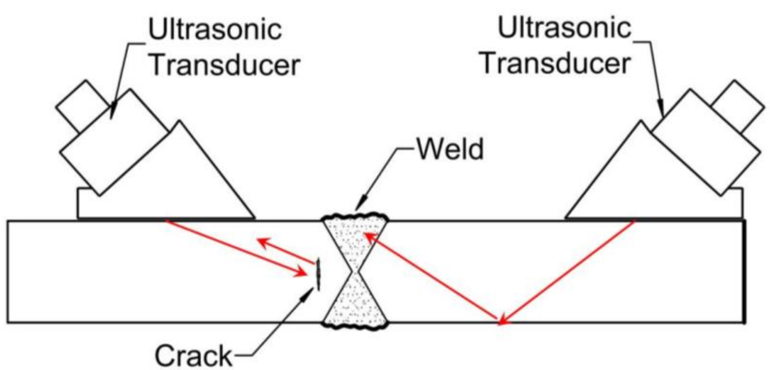
Testing is done from the exposed surface to find defects in the inaccessible area

# Angled Beam Applications

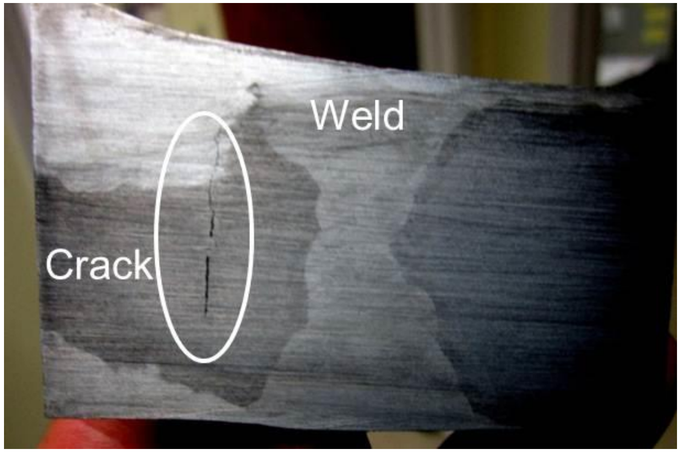
Typically used for weld inspections

Detect subsurface defects such as cracks

"Skip" shear wave inaccessible areas



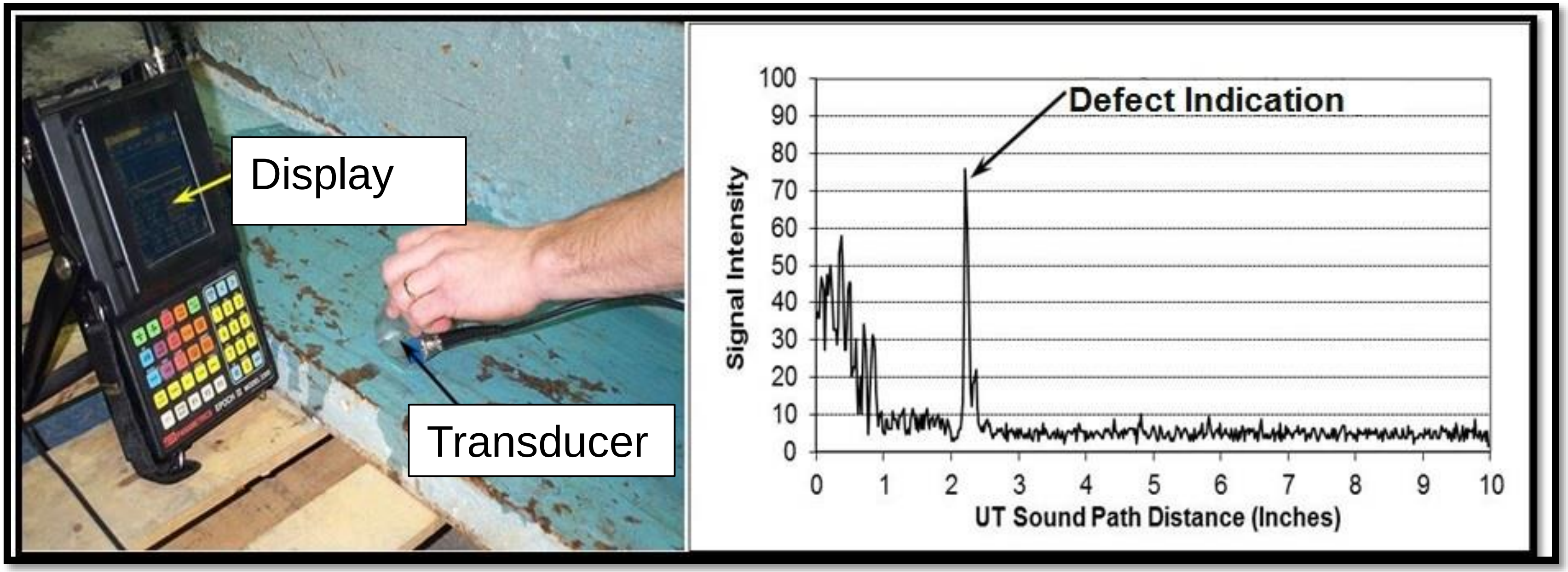

Example: Under weld reinforcement



# Angled Beam Applications (con.)

Detects cracks and weld flaws

Example: Butt welds in flange

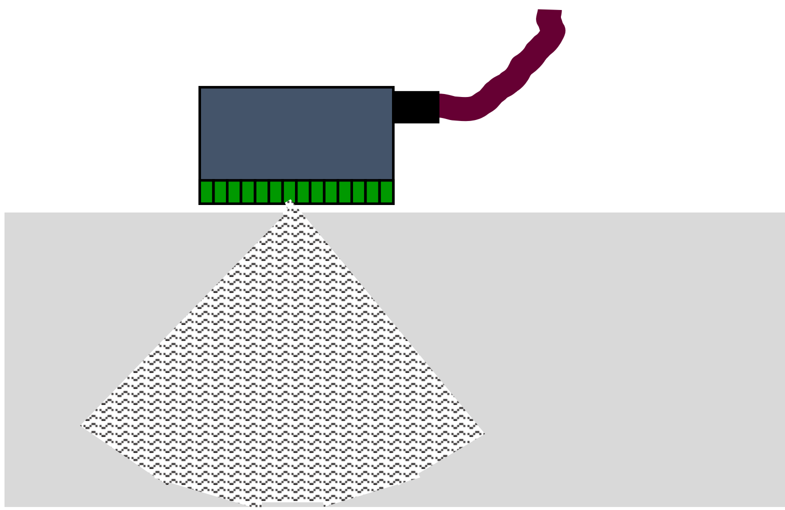


# Phased Array Applications

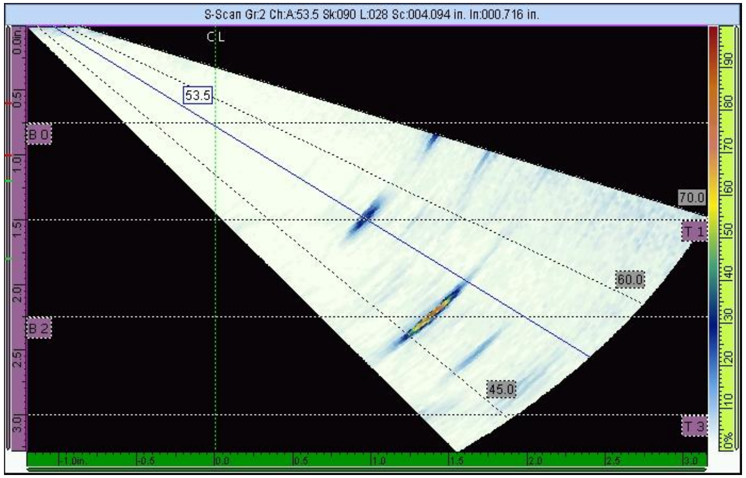
Multiple sensor elements in transducer

Pulsed in sequence to "steer" beam

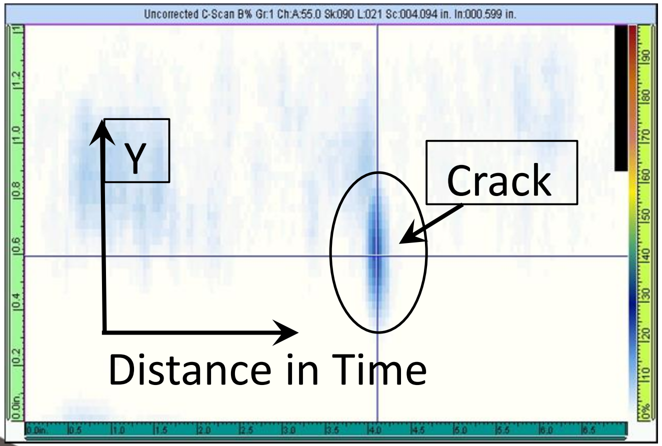
Straight beam, angled beam, combination



# Phased Array Applications: Crack Detection and Evaluation

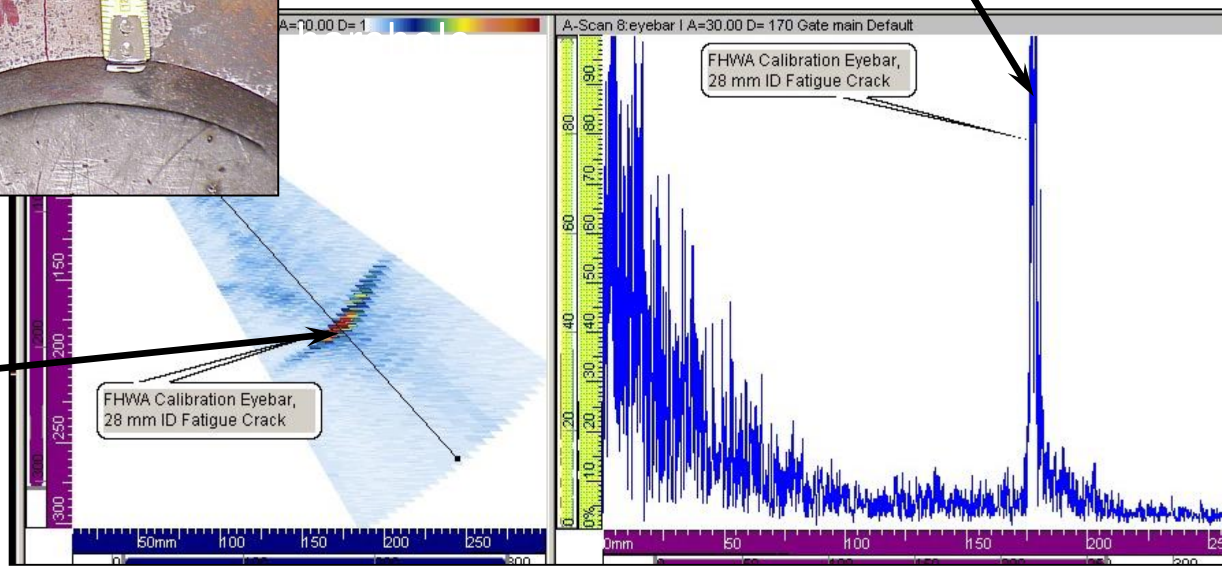


S-scan image of crack signals




C-scan image of crack signals

# Phased Array Applications (con.)


Sectorial Scan

A-Scan

3.1-61


# 4C) Discuss ultrasonic testing advantages and limitations for steel

| | |
|---|---|
| **Advantages** | Straight beam |
| | Angled beam |
| | Phased array |
| **Limitations** | Straight beam |
| | Angled beam |
| | Phased array |

# UT Advantages

| | | | |
|---|---|---|---|
| **Straight Beam** | Detects subsurface defects | **Angled Beam** | Same |
| | Portable | | Same |
| | Inexpensive | | Same |
| | Accurate measurement of remaining section | | Sensitive to cracking |

# UT Advantages (con.)

| | |
|---|---|
| **Phased Array** | Better volumetric coverage |
| | Challenging and unusual geometries |
| | Produce images of ultrasonic responses from defects and damage |

# UT Limitations

| | | | |
|---|---|---|---|
| **Straight Beam** | Surface preparation required | **Angled Beam** | Same |
| | Time consuming | | Same |
| | Interpretation can be complex | | Same |

# UT Limitations (con.)

**Phased Array**

- Requires specialized training beyond traditional certification or training practices
- Interpretation can be difficult
- Lack of standardization for bridges
- Expensive ($$$)

Questions?

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