

Nondestructive evaluation (NDE)

Topic 7

Reading assignment

- Notes on Nondestructive Evaluation in the course website.
- Sec. 8.2, 8.3 and 8.4, William Callister, Materials Science and Engineering, 6th Ed.

Nondestructive testing (NDT)

Conventional NDE methods

- Liquid penetrant inspection
- Ultrasonic inspection
- Acoustic emission
- Magnetic particle inspection
- Eddy current testing
- X-radiography

Liquid penetrant inspection

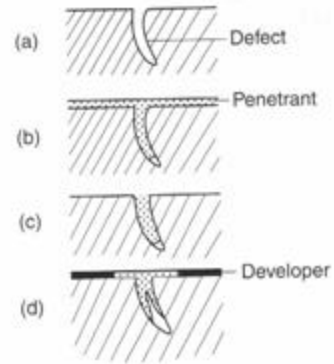
- For detection of surface defects
- Inexpensive and convenient
- Largely used on nonmagnetic materials for which magnetic particle inspection is not possible.
- Unable to inspect subsurface flaws.
- Loss of resolution on porous materials.

Penetrant

High-visibility liquid

Liquid penetrant inspection method

1. Apply a penetrant to the surface.
2. Pull penetrant to the surface crack by capillary action.
3. Remove excessive penetrant.
4. Extract some penetrant to the surface.



Ultrasonic inspection

Audible frequency range

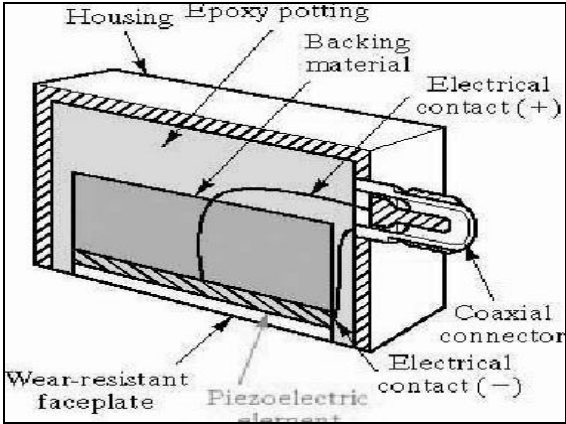
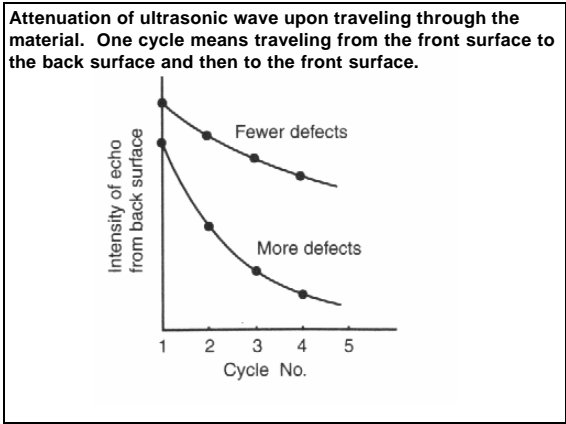
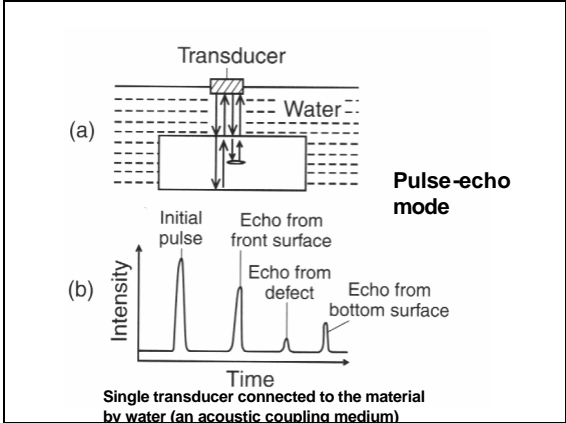
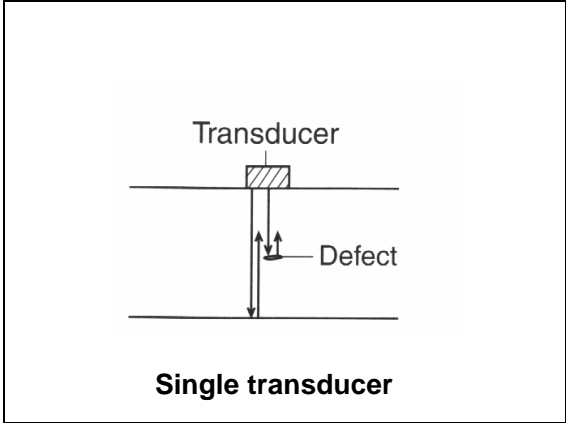
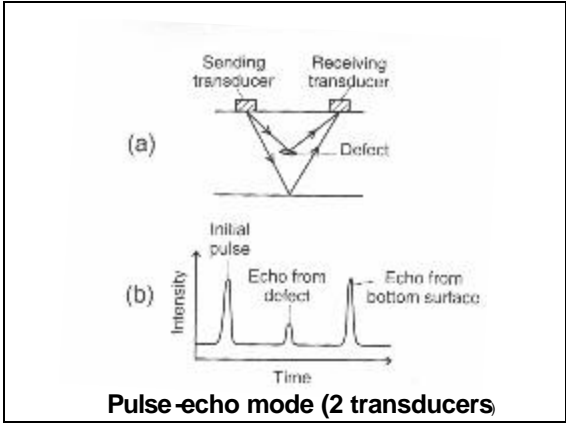
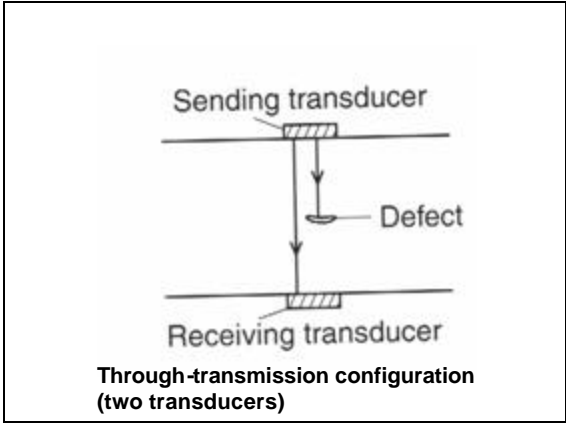
20 – 20,000 Hz

Ultrasonic inspection

- Ultrasonic wave has higher frequency than audible sound.
- Typical frequency from 25 to 100,000 MHz.
- Method: Send an ultrasonic wave (from a piezoelectric transducer) through the material (via a transmitting medium) and measure the intensity of the reflected or transmitted wave, and the time it takes for the wave to be detected.

Ultrasonic inspection

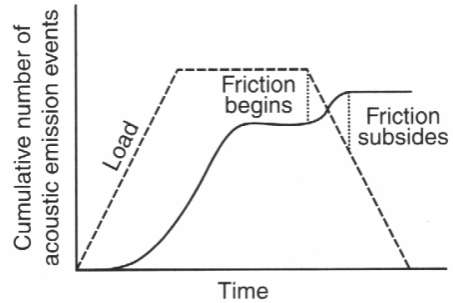
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Acoustic emission (AE) testing

- Process of developing defects such as cracks causes the emission of ultrasonic waves.
- AE measures the ultrasonic waves produced by defects in a material in response to an applied stress.
- Transducer serves as receiver, not ultrasonic emitter.

A fiber composite experiencing delamination during loading and friction between delaminated surfaces during unloading.



AE applications

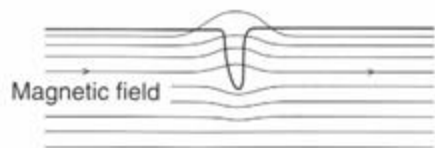
- Failure prevention (warning of impending failure; rate of AE events rising sharply just prior to failure)
- Locating defects

Magnetic particle inspection

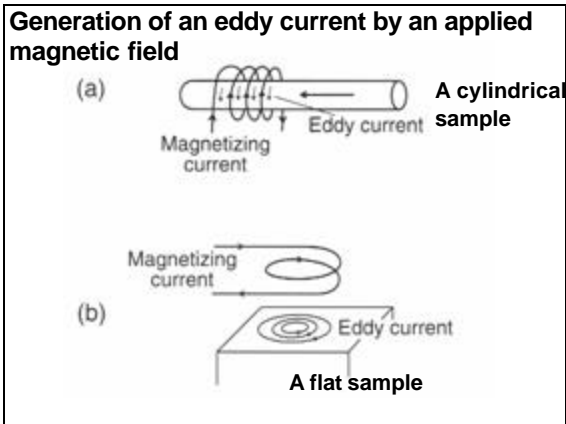
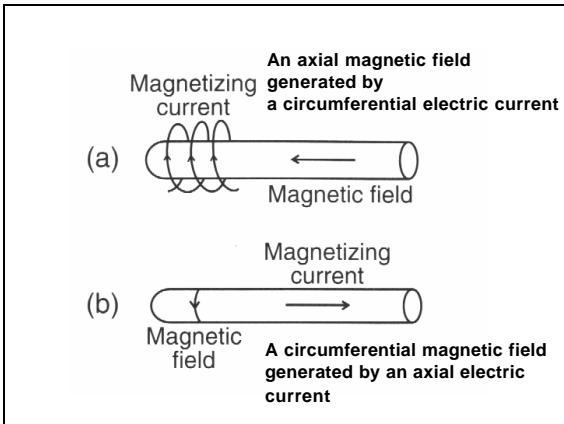
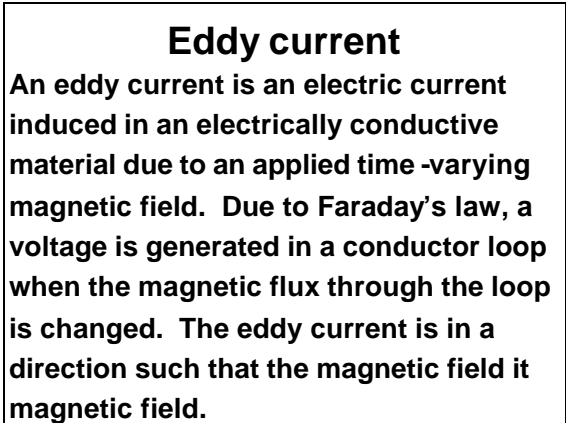
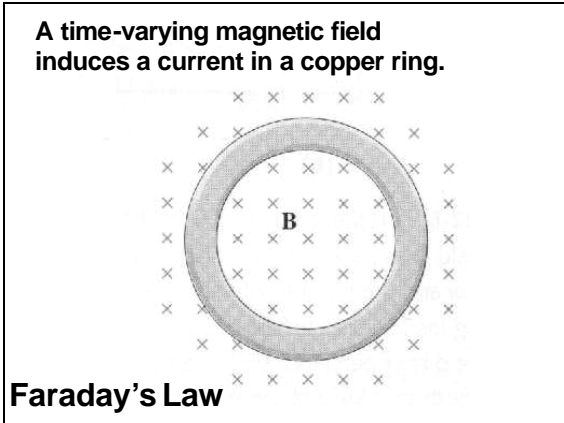
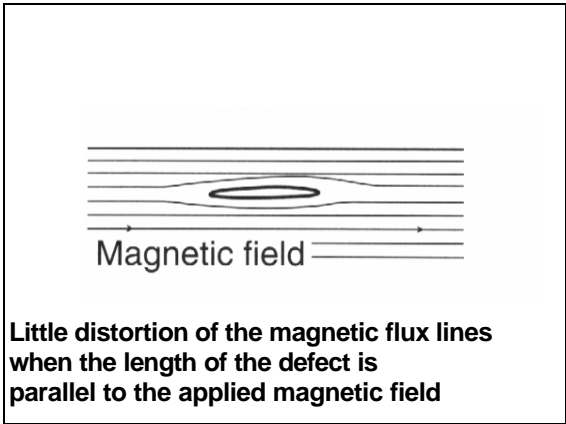
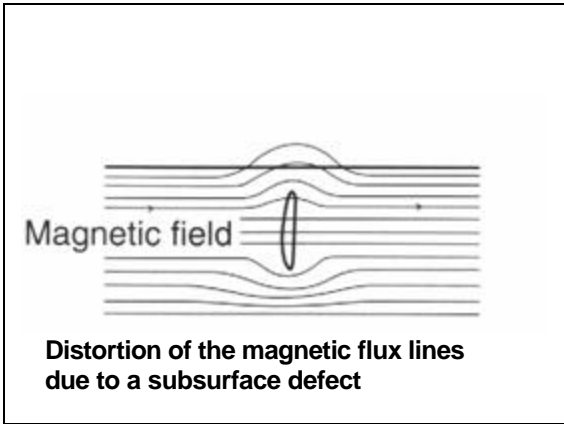
- Limited to magnetic materials.
- Inexpensive and convenient.

Magnetic particle inspection method

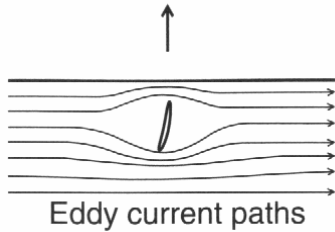
- Magnetic flux lines in a ferromagnetic or ferrimagnetic material (resulting from the application of a magnetic field) are distorted around a defect.
- Distortion causes magnetic flux lines to protrude from the surface at the location of the surface crack. This is known as "field leakage".
- Field leakage attracts magnetic particles (Fe or Fe_3O_4) that are applied to the surface.
- Subsurface cracks near the surface can also be detected.
- Applied magnetic field is preferably perpendicular to the length of the defect.



Distortion of the magnetic flux lines due to a surface crack in a magnetic material



Magnetic field induced
by eddy current



Distortion of eddy current paths around a defect

Eddy current testing method

The impedance of an inspection coil is affected by the presence of an adjacent, electrically conductive test piece, in which eddy current has been induced by the coil.

By varying the frequency, the method can be used for both surface and subsurface flaws.

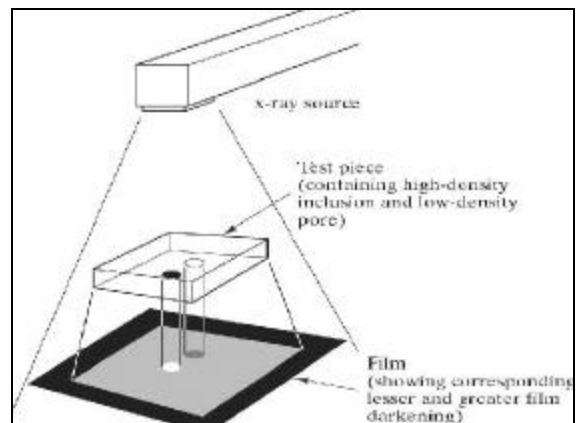
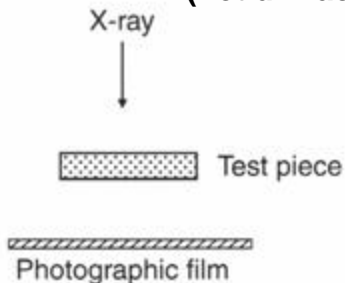
Eddy current testing limitations

- Limited to electrically conductive materials.
- Qualitative

X-radiography

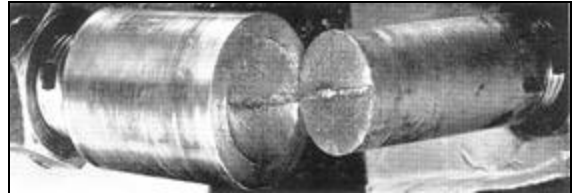
- Good for detecting internal defects.
- Method: Send x-rays through the material and detect the transmitted x-ray image using a photographic film.

X-ray absorption (not diffraction)

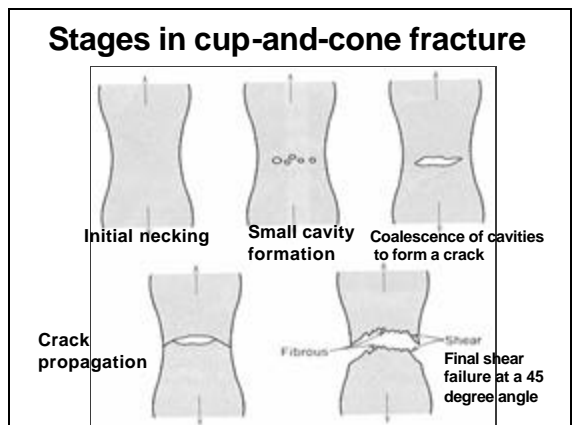
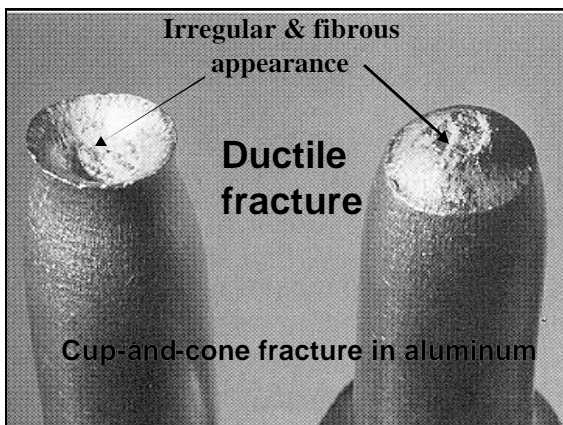
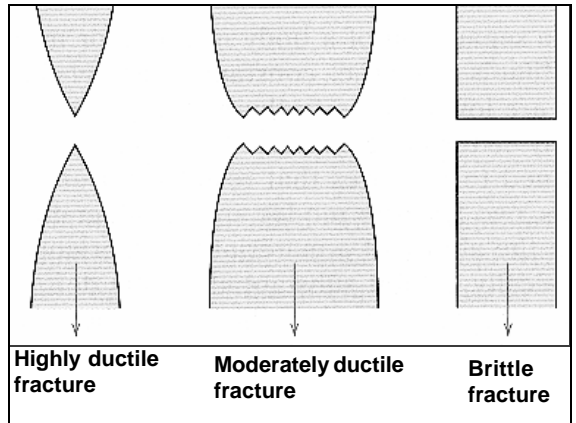


Fractography

- Fracture surface examination
- Different from metallography



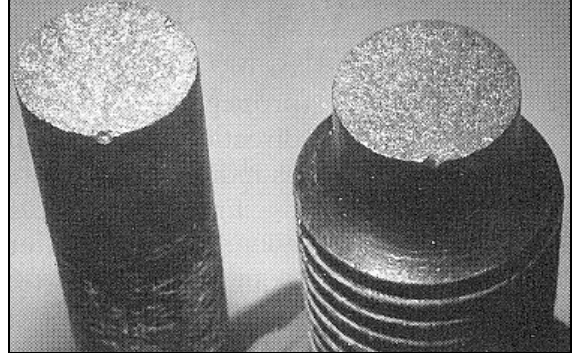
Broken cabin bolt from an elevator



Ductile Fracture

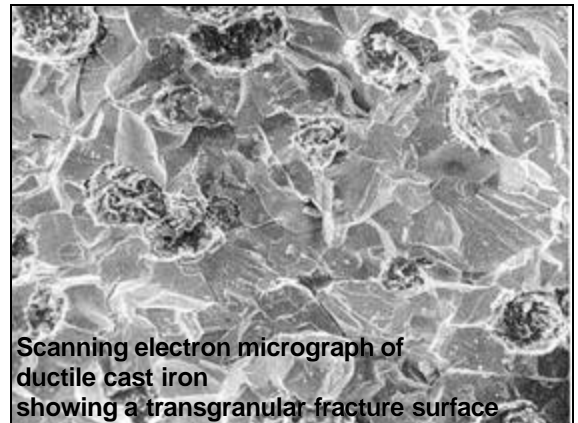
- moderately ductile: most common, moderate necking before fracture.
- Stages: i) microvoid formation, ii) microvoid coalescence leading to “microcrack” formation normal to the applied stress, iii) rapid crack propagation at about 45° to tensile axis (t_{max}).
- cup and cone fracture.

Brittle fracture in mild steel

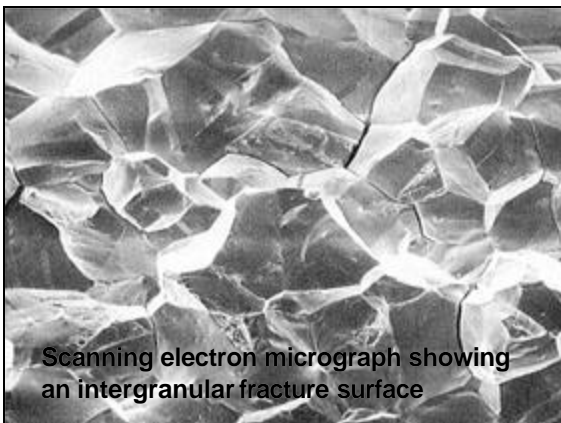


Brittle fracture

- In hard & fine-grained metals, there will be no discernible pattern.
- In amorphous materials, the fracture surface is relatively shiny & smooth.
- In most brittle crystalline materials crack propagates along specific crystallographic planes → cleavage.



Scanning electron micrograph of ductile cast iron showing a transgranular fracture surface



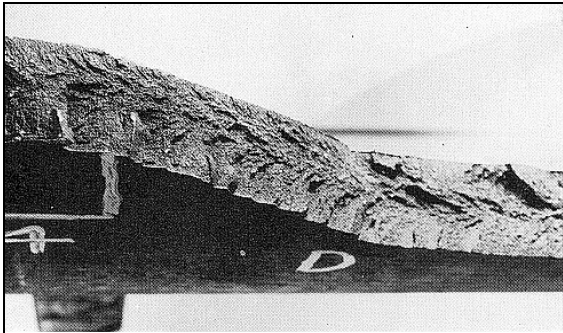
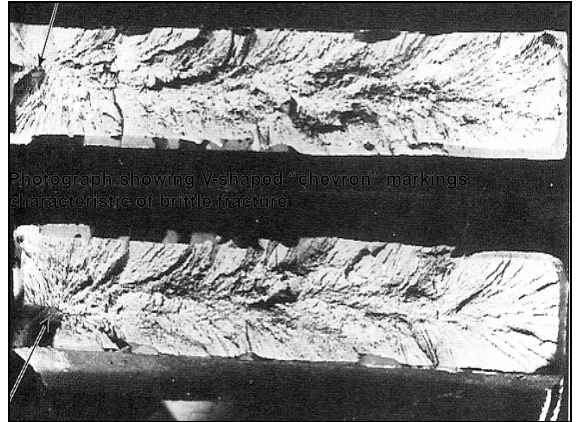
Scanning electron micrograph showing an intergranular fracture surface

Brittle fracture

- The cleavage fracture is transgranular (transcrystalline)
- Macroscopically the fracture surface has a grainy or faceted texture due to changes in orientation of cleavage plains from grain to grain.
- Intergranular fracture crack propagates along grain boundaries. This shows evidence of a weaker material, → embrittlement.

Brittle fracture

- ❑ Fracture with no obvious deformation, fast crack growth normal to the applied s .
- ❑ Relative flat fracture surface.
- ❑ Some steels may show V-shaped “chevron” markings that point back to crack initiation.



Fractured pressure vessel shell showing “chevron marks”. Note that marks point to the right.

