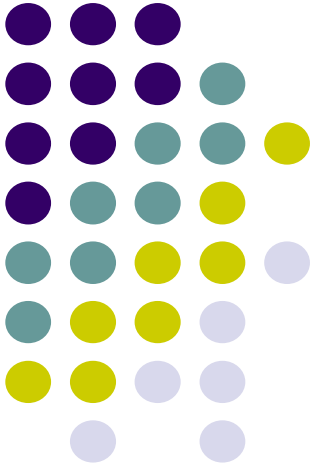
ME 216 – Engineering Materials II

Chapter 11

Failure and Testing



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Failure of Materials

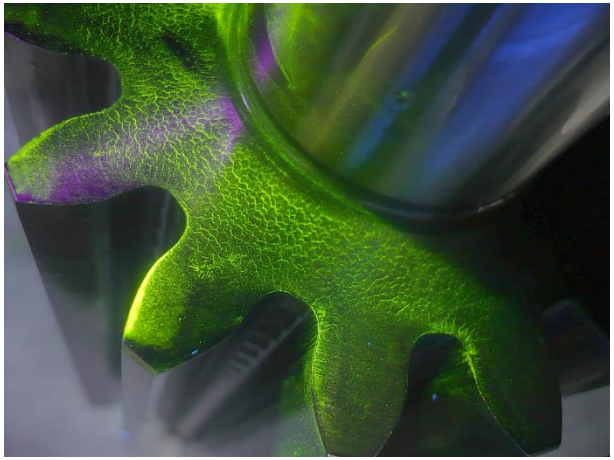
- Plastic deformation begins unexpectedly as result of slip or other deformation mechanisms.
- If continued, it leads to the formation of "emptyness" in materials (i.e. crack), which continues to grow as the material is stressed. At a critical load, the crack reaches its critical length, so the material cannot sustain the applied load any longer, and hence **the material fails**.
- Possible failure modes during service are as follows:
  - **Excessive deformation:** yielding, buckling, stress rupture (creep)
  - **Fracture:** sudden (brittle), progressive (fatigue), time dependent (creep)
  - **Inordinate wear:** abrasion
  - **Deterioration:** chemical (corrosion or oxidation), embrittlement (ductile to brittle transition), irradiation, natural (fungus, other growths)
- Various tests (**destructive** or **non-destructive**) are carried out to assess the susceptibility of materials to fail in any of the above mentioned modes.
- This chapter will focus on most commonly used **Non-Destructive Tests (NDT)**.

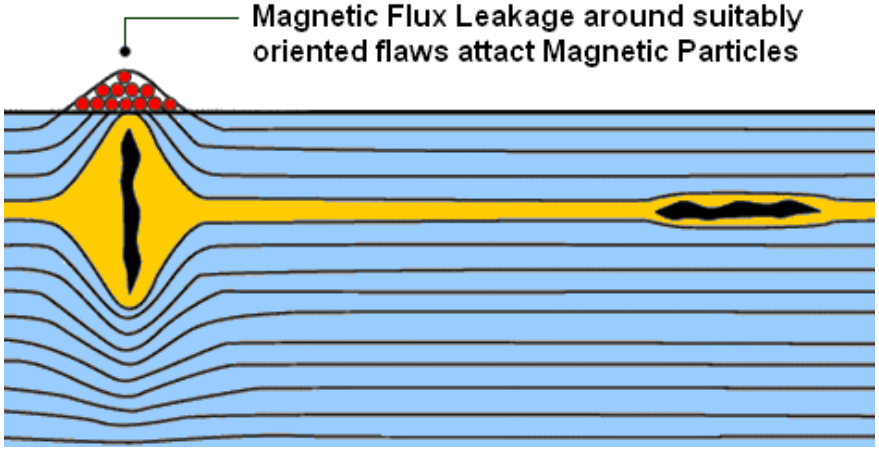
Non-Destructive Testing (NDT)

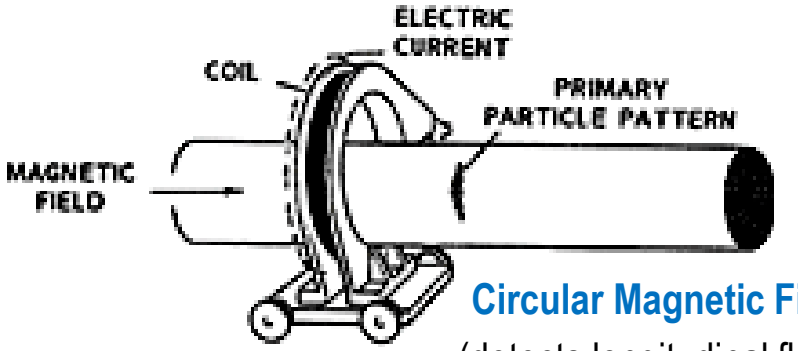
- Used to **examine surface/sub-surface defects** without changing the geometry of a part.
- Very useful for detecting cracks and flaws in **weldments**, **pipes**, **castings**, and so on.
- Most commonly used methods are:
  - **Magnetic Particle Inspection** (surface/sub-surface defects)
  - **Liquid Penetrant Inspection** (surface defects)
  - **Electromagnetic Testing** (surface/sub-surface defects)
  - **Ultrasonic Testing** (internal defects)
  - **Radiography** (internal defects)

Magnetic Particle Inspection (Magnaflux Examination)

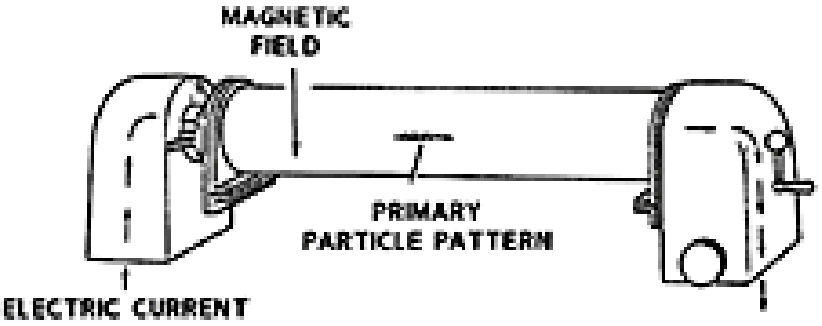
- Can be performed on ferromagnetic materials.
- **Dry method:** part is magnetised, and colored magnetic powder is sprayed on the part surface. Cracks (having higher magnetic intensity) attract magnetic powder, and making them detectable.
- **Wet method:** a flourescent magnetic powder in low-viscosity oil is employed so that cracks are observed under ultraviolet light.







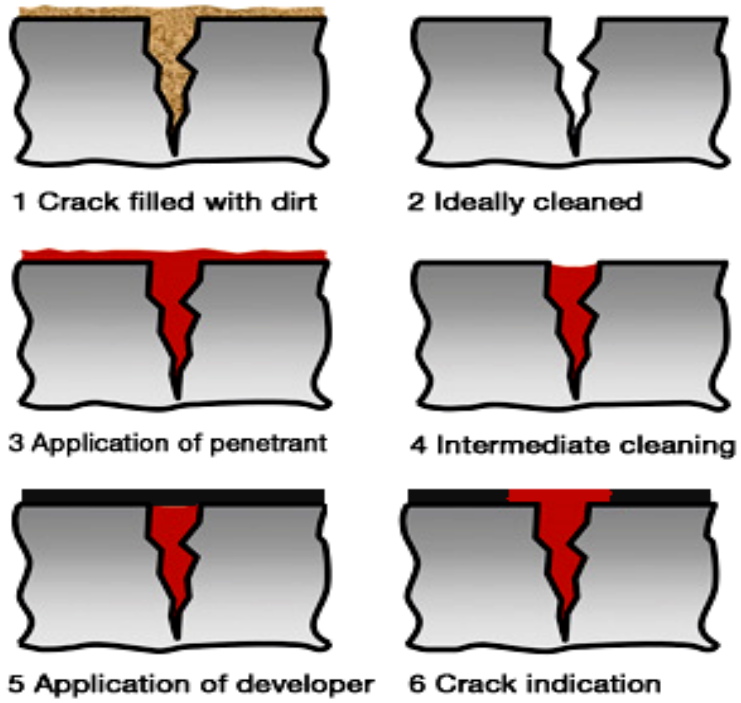
Circular Magnetic Field
(detects longitudinal flaws)

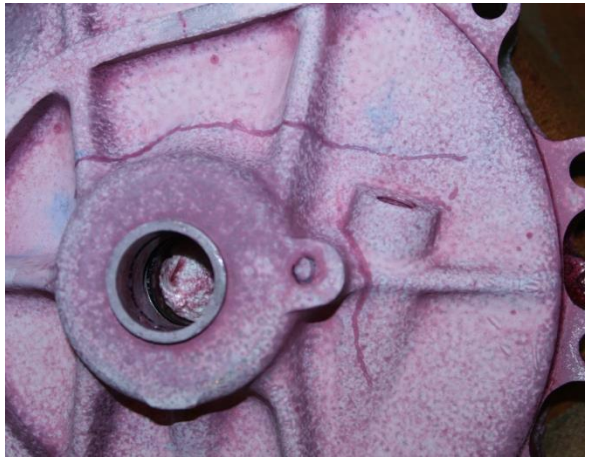


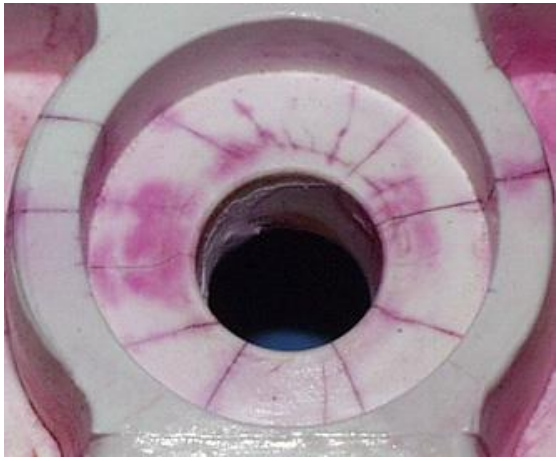
Longitudinal Magnetic Field (detects circular flaws)

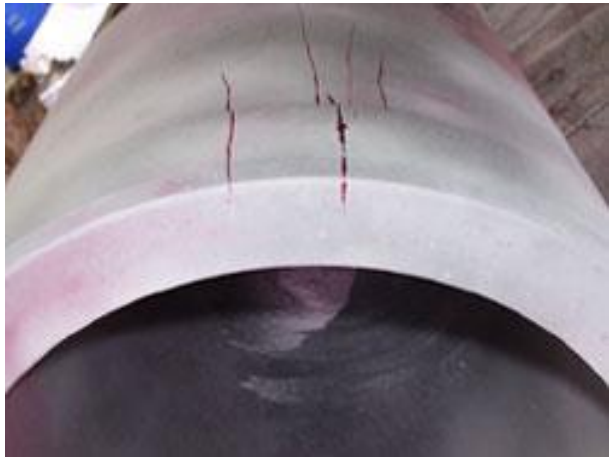
Liquid Penetrant Inspection (Dye Penetration)

- Used for nonmagnetic materials.
- Firstly, surface of the part to be inspected is cleaned.
- Then, the surface is sprayed with red-colored dye (oil), penetrating into defects.
- After that, dye is washed away from the surface leaving the residue in defects.
- Finally, white-coating (developer) is sprayed on surface so that dye in the defects gradually oozes out.



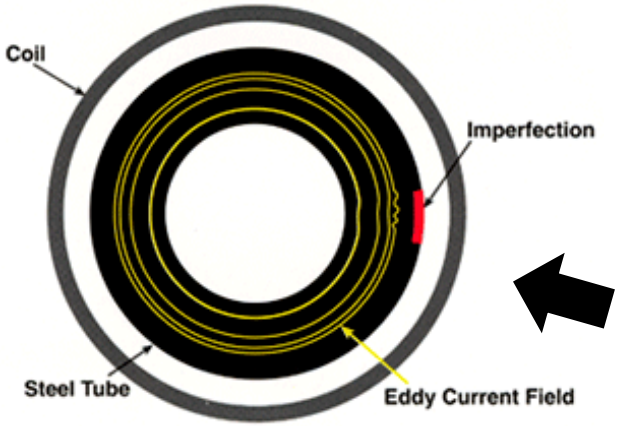




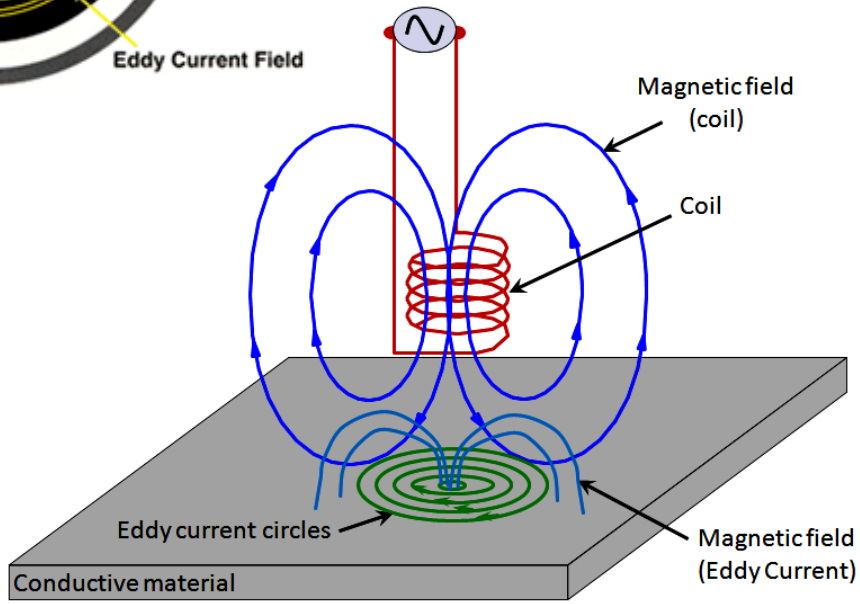


Electromagnetic (Eddy Current) Testing

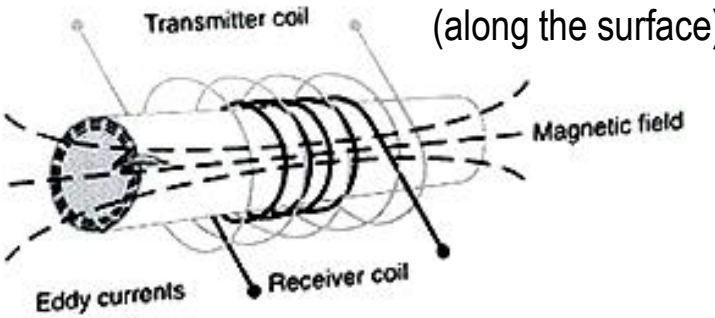
- Electric currents are induced on surface, generating magnetic fields circulating around them.
- Electromagnetic response of fields to defect is observed, and its location/size is detected.
- Two types of testing equipment are available: **probe-type coil** & **through-type coil**

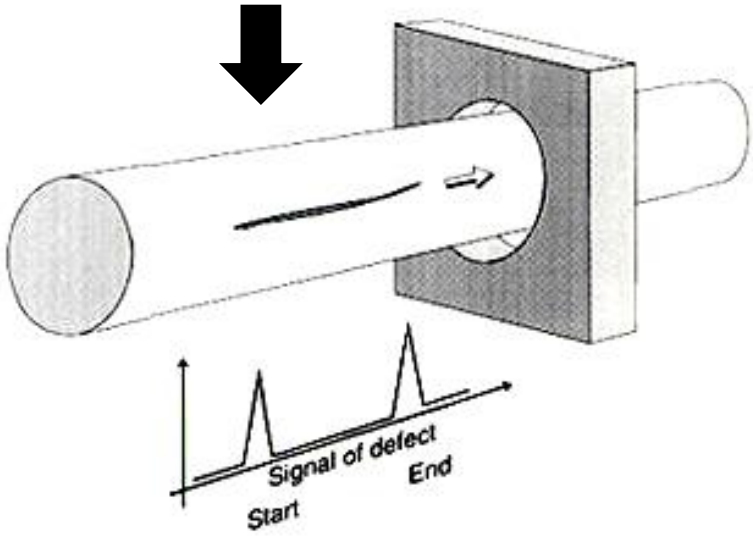


Probe-Type
(perpendicular to surface)

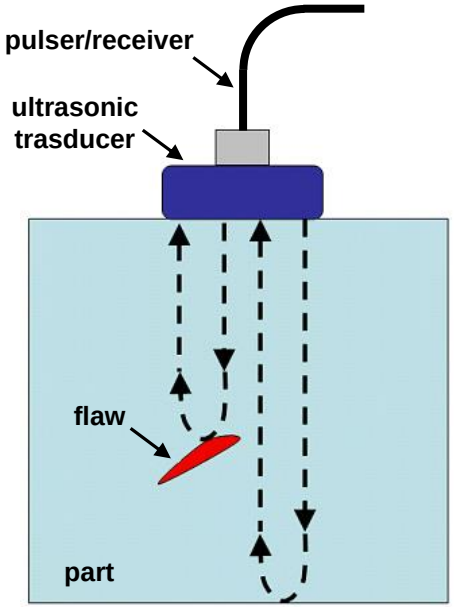


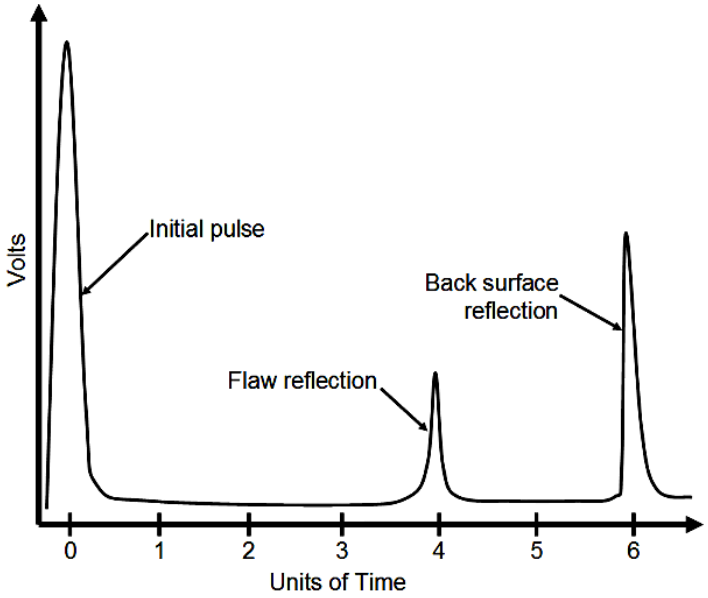
Through-Type
(along the surface)

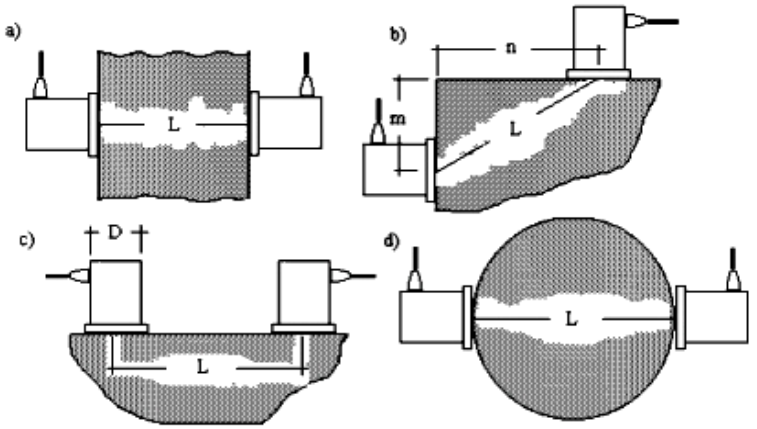




- Uses high-frequency sound energy to conduct flaw detection, dimensional inspection, material characterization, and more.
- Typical UT system consists of a pulser/receiver, a transducer, and a display software/device. Pulser/receiver produces high voltage electrical pulses. Driven by the pulser, the transducer generates high frequency ultrasonic energy, which propagates through the part in form of waves. When there is discontinuity (such as crack/flaw) in the wave path, some part of energy is reflected back from the flaw surface. Based on voltage signals of reflecting energy, location and size of flaws are displayed.







Typical schemes of UT

a) one axis through testing **b)** angle testing

c) one surface testing **d)** curve surface testing

Radiographic Inspection

- Uses a high-energy source (X-rays & gamma rays) to produce radiation penetrating into part.
- Radiation is received on a photographic plate, showing defects (in a similar manner of X-ray radiographs used for medical purposes).