Magnetic Particle Testing

Magnetic Particle Testing

Overview of Magnetic Particle Testing (MT)/Inspection:

- What is MT?
- Theory of Magnetism
- MT Materials/Equipment
- Certification Requirements

Magnetic Particle Testing

Definition: An NDT method for location of discontinuities in ferromagnetic materials through utilization of flux leakage that forms magnetic poles to attract finely divided magnetic particles.

- One of the oldest and most widely used NDT methods
- Its use is limited to ferromagnetic materials
  - Ferromagnetic materials are materials that can be magnetized to a level that will allow the inspection to be effective
  - Ex. Iron, nickel, cobalt, and their alloys
  - “Ferro” is Latin for iron

Magnetic Particle Testing

Uses in Industry

- Used for inspection of castings, forgings, and weldments on bridges, storage tanks, etc.
- Used by the structural steel, automotive, petrochemical, power generation, and aerospace industries
- Even used for underwater inspections

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Basic Steps in an MT Inspection

1) Magnetization of the article
2) Application of the particles (iron filings)
3) Interpretation of the patterns formed by the particles as they are attracted by magnetic leakage fields
4) Demagnetization of the article if required

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What is a Magnet?

- A magnet is a material that has its north and south poles aligned and will attract iron
- Magnetism may be naturally present in a material or the material may be artificially magnetized by various methods
- Magnets may be permanent or temporary

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Magnetic Poles

- A magnetic pole is any place where magnetic lines of force enter or exit a magnet
- A magnet has two opposite poles that are attracted by the Earth's magnetic poles
- If a magnet has poles it exhibits polarity
- Lines of force
  - Called magnetic flux
  - Exit the magnet at the north pole
  - Enter the magnet at the south pole
  - Never cross
  - Seek the path of least magnetic resistance

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More About Magnetic Poles

- Like poles repel (N and N, S and S)
- Opposite poles attract (N and S)
- Longitudinal magnetization occurs in bar magnets which have two poles
- No external poles exist in a circular magnetic field

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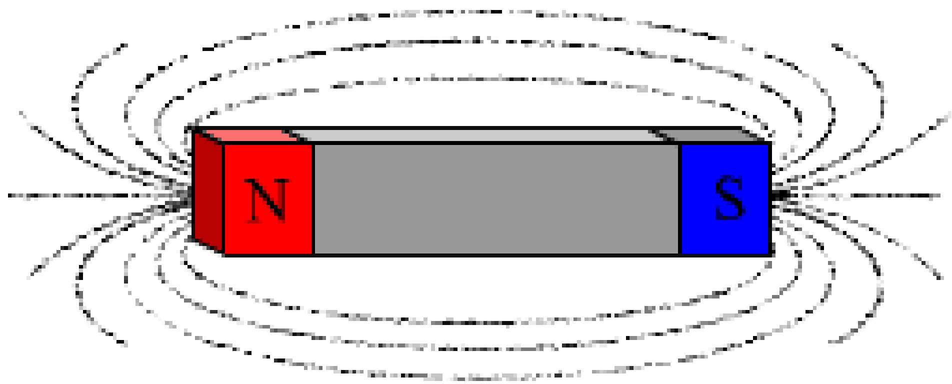
Magnetic Fields

- A magnetic field is the space within and surrounding a magnetized article, or a conductor carrying a current, in which a magnetic force is present
- A magnetic field surrounding a bar magnet is shown below



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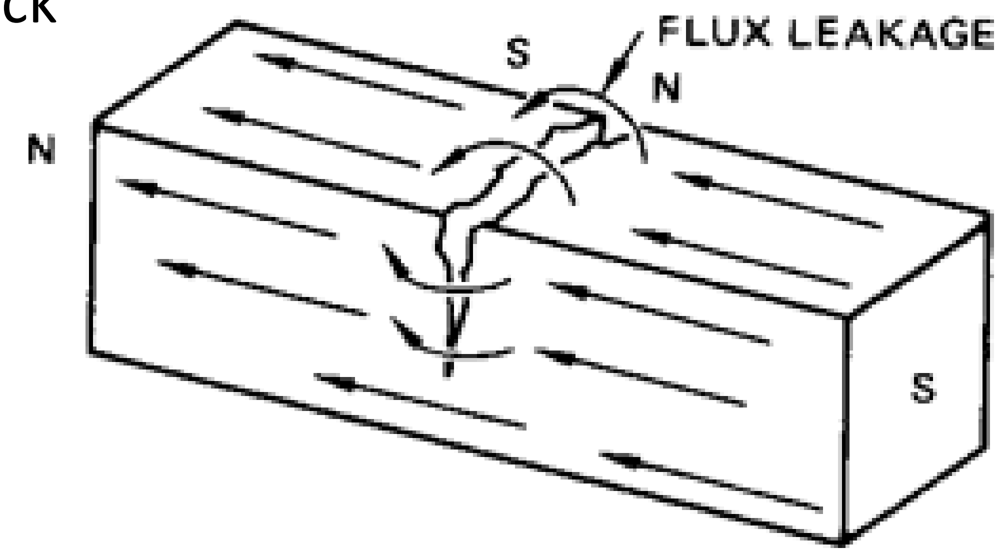
Flux Leakage

- If a bar magnet is broken in two, two complete bar magnets with magnetic poles on the ends of each piece will result
- However, if a magnet is just cracked but not broken completely in two, a north and south pole will form at each edge of the crack



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Flux Leakage (Continued)

- A magnetic field exists at the crack – it exits at the north pole, re-enters at the south pole
- It spreads out when it encounters the small air gap created by the crack because the air cannot support as much magnetic field per unit volume as the magnet can
- When the field spreads out, it appears to leak out of the material and, thus is called a flux leakage field.

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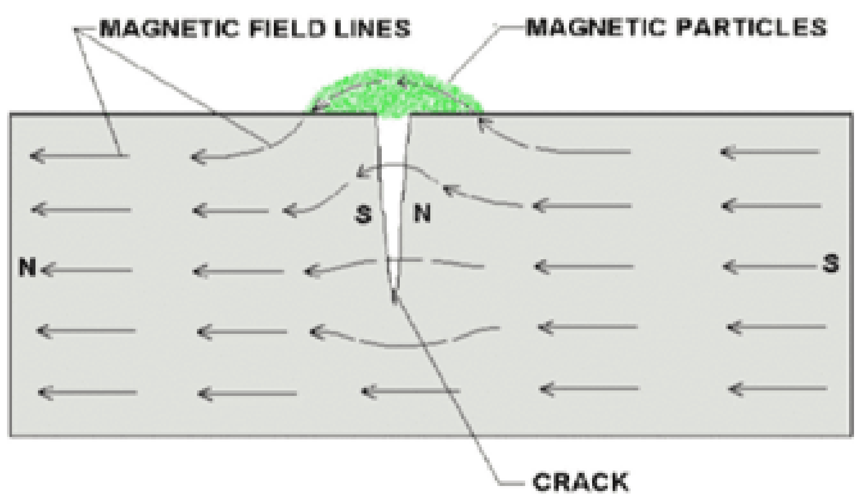
Flux Leakage (Continued)

- Magnetic particle testing uses the presence of leakage fields to detect the presence of discontinuities
- Iron filings are drawn to the leakage fields



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Brief History of MT

- 1868 – earliest known use of magnetism to inspect an object
  - Use of compasses to check for defects along a cannon barrel that had been magnetized
- 1920s – William Hoke noticed that metallic grindings from hard steel parts (held by a magnetic chuck while being ground) formed patterns on the face of the parts which corresponded to the cracks in the surface
- 1930s – MT replaced the “oil-and-whiting” method in the railroad industry

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Material Definitions

Diamagnetic materials (have paired electrons)

- Cannot be magnetized and are repelled by magnetism
- Include most elements (copper, gold, and silver)

Paramagnetic materials

- Have a weak magnetic field and do not retain magnetic properties once external field removed
- Ex. Magnesium, molybdenum, lithium, and tantalum

Ferromagnetic materials

- Can be strongly magnetized and retain magnetic properties once external field removed
- Can be tested by MT

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Electromagnetic Fields

When an electric current is passed through a conductor a magnetic field is formed

- Field is strongest at surface of the conductor
- Field strength decreases with distance from conductor

Direction of magnetic field (lines of force) perpendicular to current

- If current travels in a straight line, the lines of force will be circular
- If current travels in a loop (a coil), the lines of force will be in a straight line
  - *Field strength proportional to number of coil loops and amount of current*

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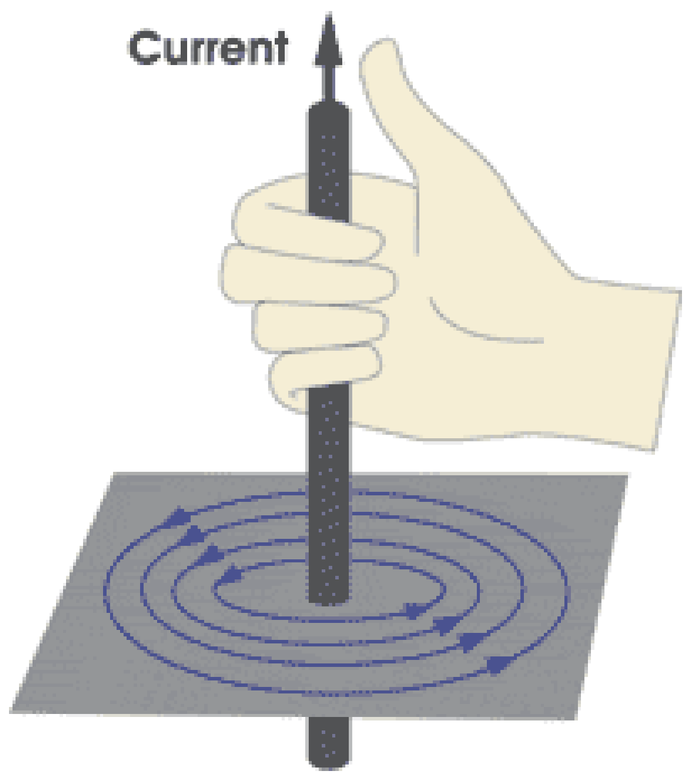
Example of the Right-Hand Rule



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Units

- Magnetizing force - the total electrical force required to set up a flux in a magnetic circuit
  - H (ampere/meter)
- Magnetic flux - the total number of lines of magnetic force in a material
  - Φ (weber = tesla/square meter in SI; maxwell in CGS)
- Flux density – flux per unit area through an element
  - B (tesla in SI units; gauss in CGS)

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Other Definitions

- **Permeability** – the ease with which a material can be magnetized
  - Can be calculated by B/H (ratio of flux density to magnetizing force)
- **Reluctance** - the opposition of a magnetic material to the establishment of a magnetic field
  - High permeability means low reluctance (and vice versa)
  - Analogous to resistance in an electrical circuit

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Other Definitions Continued

- **Residual magnetism** – the amount of magnetism that remains in a material after removal of the magnetizing force (also called its retentivity)
  - High residual magnetism calls for demagnetization
- **Coercive force** – the reverse magnetizing force necessary to remove the residual magnetism so as to demagnetize an article

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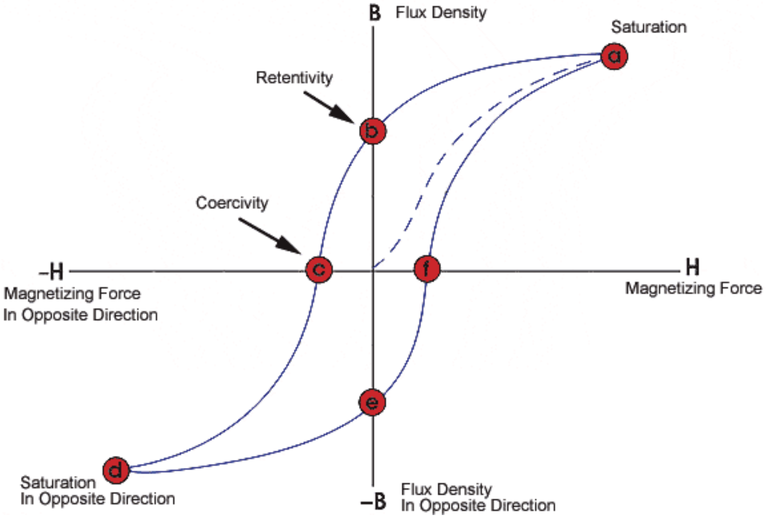
Hysteresis Loop

A great deal of information can be learned about the magnetic properties of a material by studying its hysteresis loop. A hysteresis loop shows the relationship between the induced magnetic flux density (**b)** and the magnetizing force **(h).** It is often referred to as the b-h loop. An example hysteresis loop is shown below and on the next slide.



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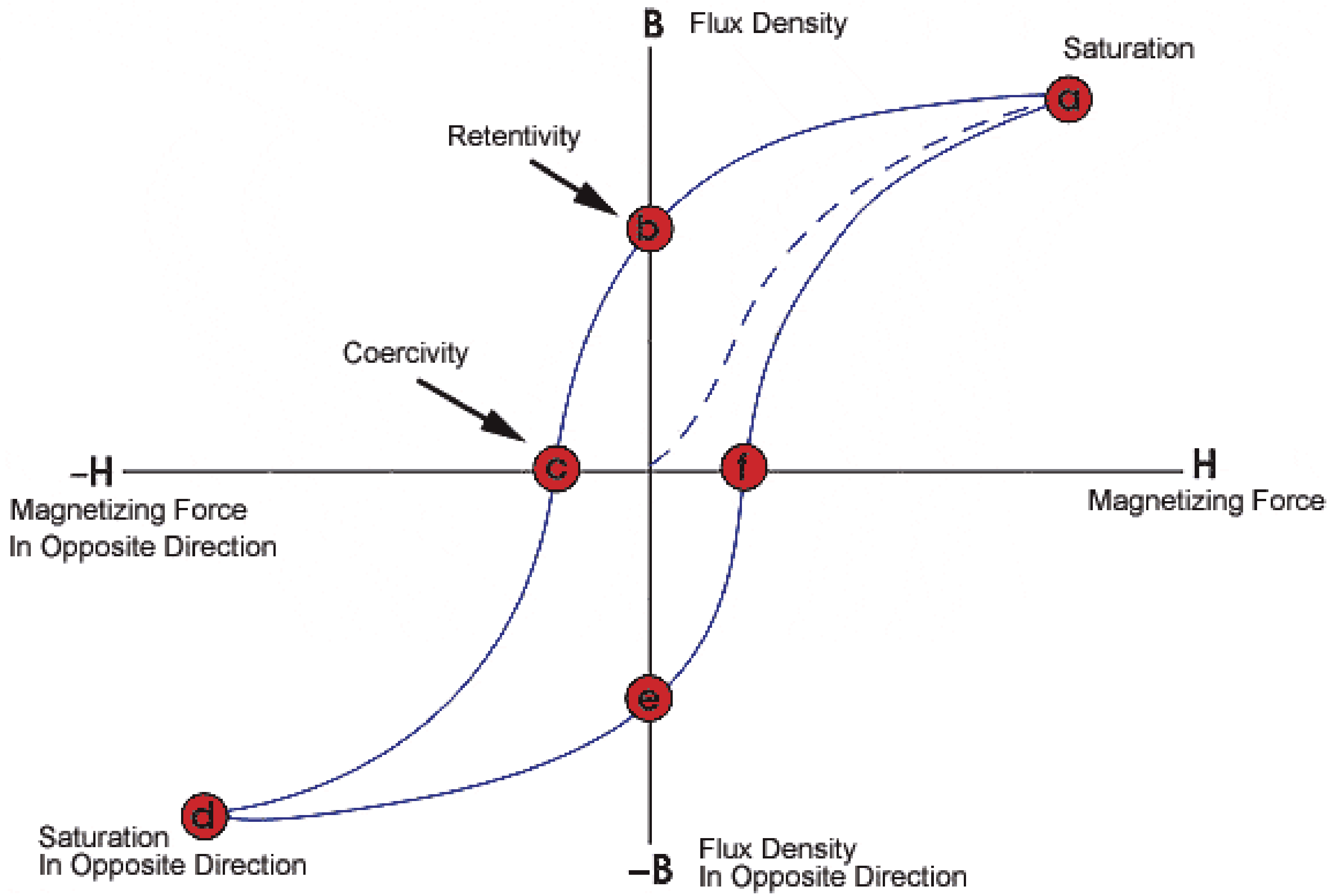

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Hysteresis Loop

- Wide hysteresis loop
  - Low permeability therefore high reluctance (difficult to magnetize)
  - High retentivity and residual magnetism – once the part is magnetized it keeps its magnetism
  - Will make a good permanent magnet
- Slender hysteresis loop
  - High permeability therefore low reluctance (easy to magnetize)
  - Low reluctance and residual magnetism

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Direct Vs. Indirect Magnetization

There are two methods for inducing a magnetic field into a part:

- Direct Magnetization
  - Electric current is passed directly through the part
    - "head shot"
    - prods
- Indirect Magnetization
  - Electric current does *not* pass through the part
    - coil
    - central conductor
    - yoke

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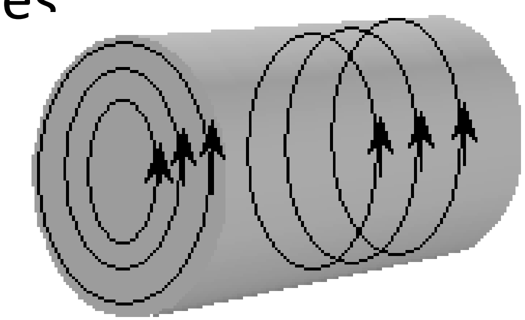
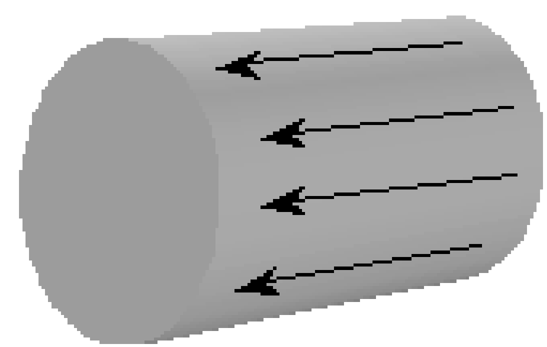
Circular vs. Longitudinal Magnetization

- Recall that MT detects discontinuities perpendicular to the magnetic lines of force
- Typically apply magnetic fields in two directions to improve opportunity for detecting all discontinuities
- Circular Magnetic Field
  - head shot
  - Central conductor
  - prods
- Induction of a longitudinal magnetic field
  - coil
  - yoke





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Certification Requirements

- Per ASNT Recommended Practice No. SNT-TC-1A, 2011 edition:

Certification Level	High School Graduate or Equivalent (hrs)	Two Years of Engineering or Technical School (hrs)	OJT (hours)
I	12	8	70
II	8	4	210
Totals:	20	12	280