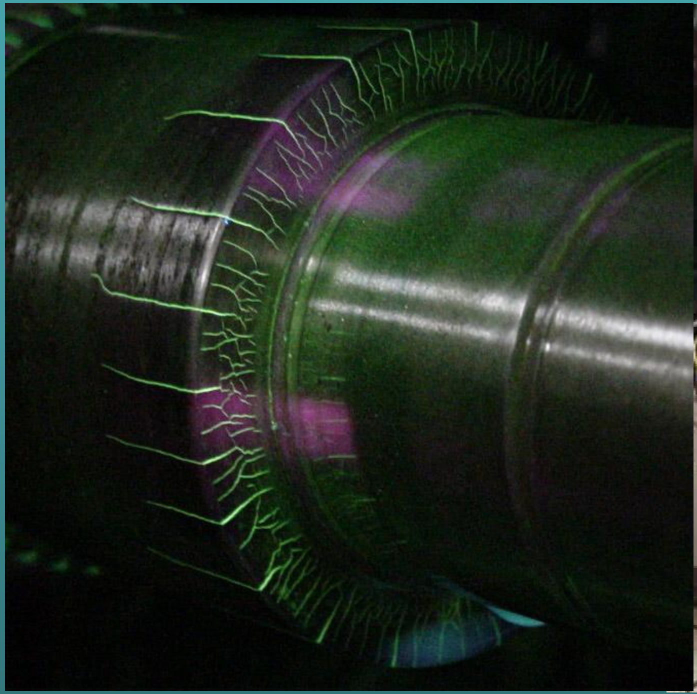
MAGNETIC PARTICLE TESTING



Introduction

- This module is intended to present information on the widely used method of magnetic particle inspection.
- Magnetic particle inspection can detect both production discontinuities (seams, laps, grinding cracks and quenching cracks) and in-service damage (fatigue and overload cracks).

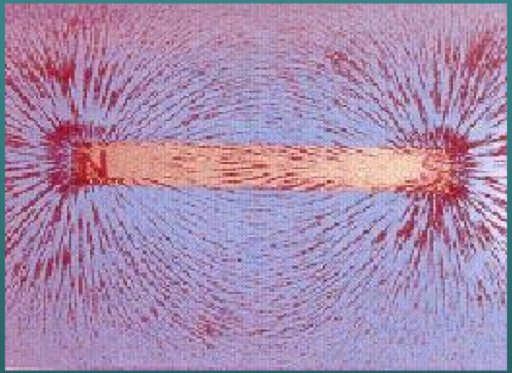
Outline

- Magnetism and Ferromagnetic Materials
- Introduction of Magnetic Particle Inspection
- Basic Procedure and Important Considerations
    1. Component pre-cleaning
    2. Introduction of magnetic field
    3. Application of magnetic media
    4. Interpretation of magnetic particle indications
- Examples of MPI Indications

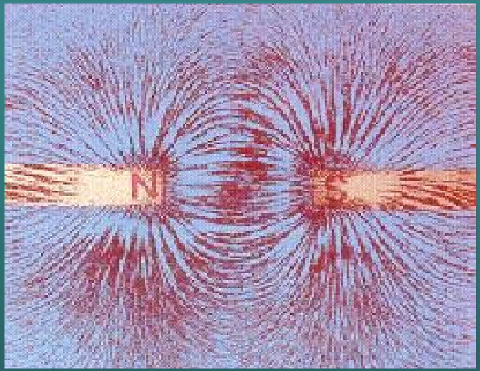
Introduction to Magnetism

Magnetism is the ability of matter to attract other matter to itself. Objects that possess the property of magnetism are said to be magnetic or magnetized and magnetic lines of force can be found in and around the objects. A magnetic pole is a point where the a magnetic line of force exits or enters a material.

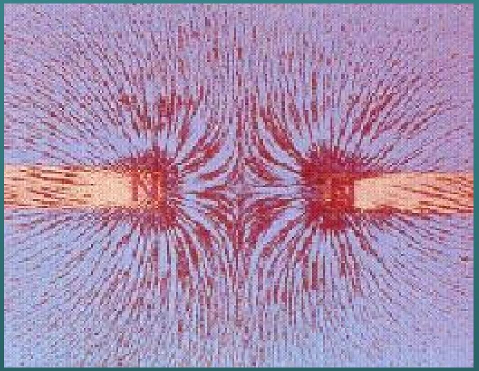
Magnetic field lines:
- Form complete loops.
- Do not cross.
- Follow the path of least resistance.
- All have the same strength.
- Have a direction such that they cause poles to attract or repel.



Magnetic lines of force around a bar magnet



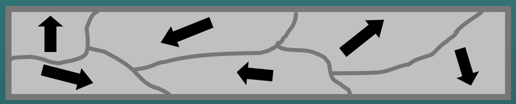
Opposite poles attracting

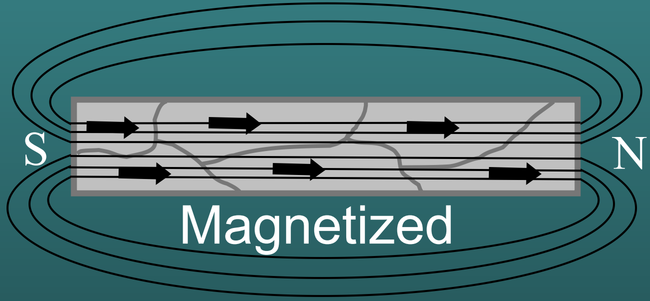


Similar poles repelling

Ferromagnetic Materials

- A material is considered ferromagnetic if it can be magnetized. Materials with a significant Iron, nickel or cobalt content are generally ferromagnetic.
- Ferromagnetic materials are made up of many regions in which the magnetic fields of atoms are aligned. These regions are call magnetic domains.
- Magnetic domains point randomly in demagnetized material, but can be aligned using electrical current or an external magnetic field to magnetize the material.

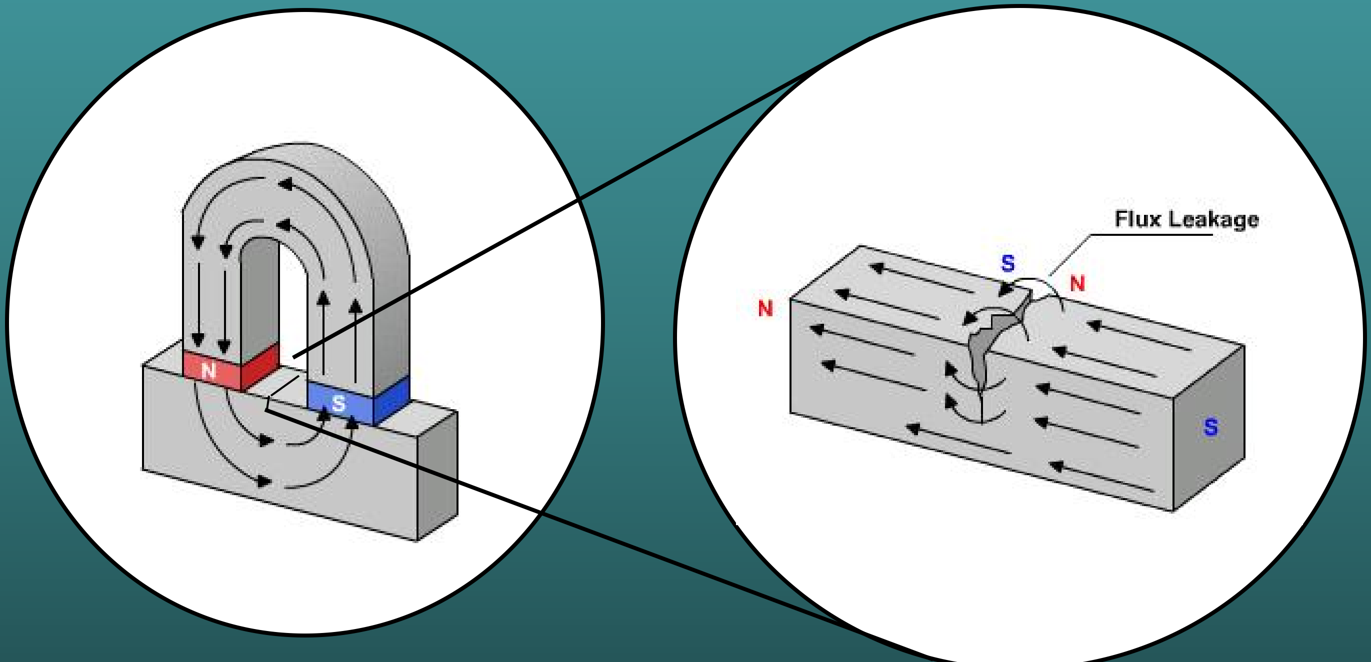

Demagnetized



Magnetized

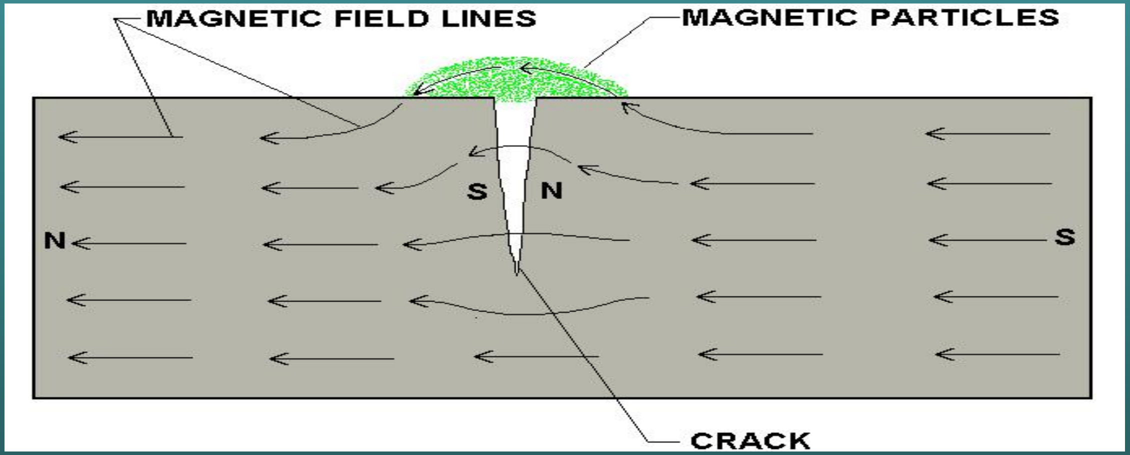
How Does Magnetic Particle Inspection Work?

A ferromagnetic test specimen is magnetized with a strong magnetic field created by a magnet or special equipment. If the specimen has a discontinuity, the discontinuity will interrupt the magnetic field flowing through the specimen and a leakage field will occur.



How Does Magnetic Particle Inspection Work? (Cont.)

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



Basic Procedure

Basic steps involved:

1. Component pre-cleaning
2. Introduction of magnetic field
3. Application of magnetic media
4. Interpretation of magnetic particle indications

Pre-cleaning

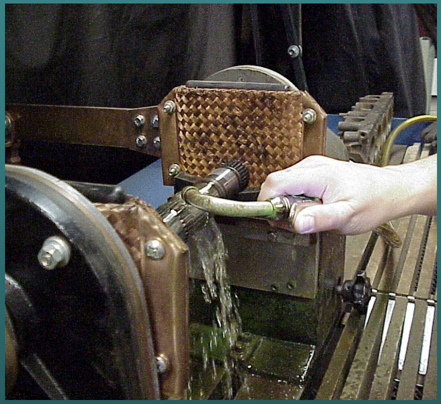
The part's surface should be clean and dry before inspection.

Contaminants such as oil, grease, or scale may not only prevent particles from being attracted to leakage fields, they may also interfere with interpretation of indications.

Introduction of the Magnetic Field

The required magnetic field can be introduced into a component in a number of different ways.

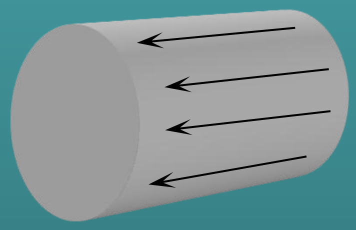
1. Using a permanent magnet or an electromagnet that contacts the test piece
2. Flowing an electrical current through the specimen
3. Flowing an electrical current through a coil of wire around the part or through a central conductor running near the part.

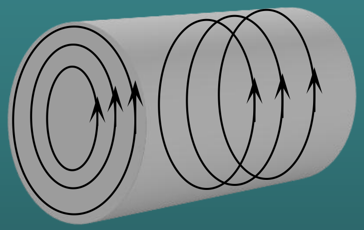

Direction of the Magnetic Field

Two general types of magnetic fields (longitudinal and circular) may be established within the specimen. The type of magnetic field established is determined by the method used to magnetize the specimen.

- A longitudinal magnetic field has magnetic lines of force that run parallel to the long axis of the part.

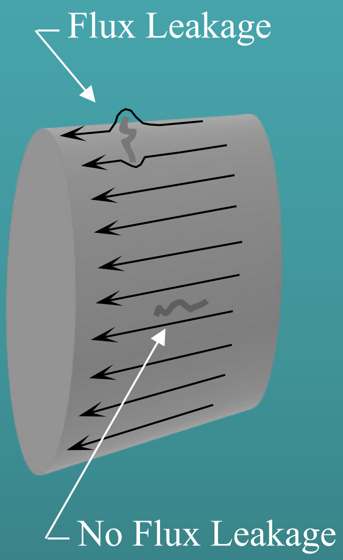


- A circular magnetic field has magnetic lines of force that run circumferentially around the perimeter of a part.

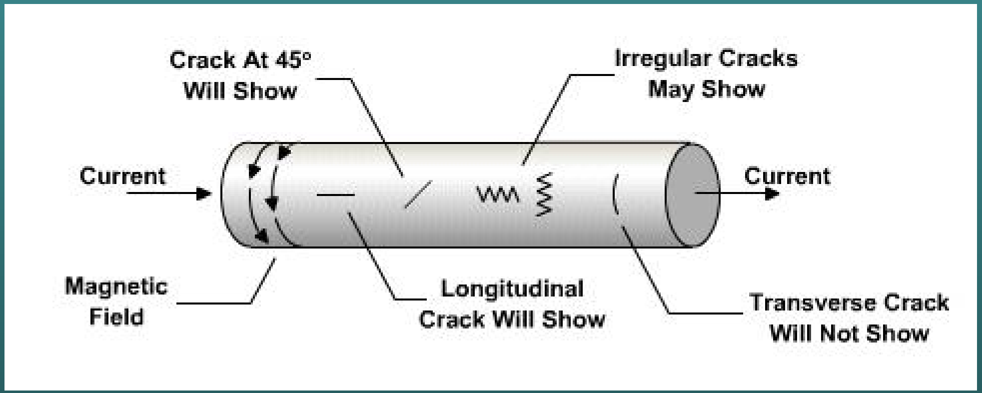


Importance of Magnetic Field Direction

Being able to magnetize the part in two directions is important because the best detection of defects occurs when the lines of magnetic force are established at right angles to the longest dimension of the defect. This orientation creates the largest disruption of the magnetic field within the part and the greatest flux leakage at the surface of the part. An orientation of 45 to 90 degrees between the magnetic field and the defect is necessary to form an indication.

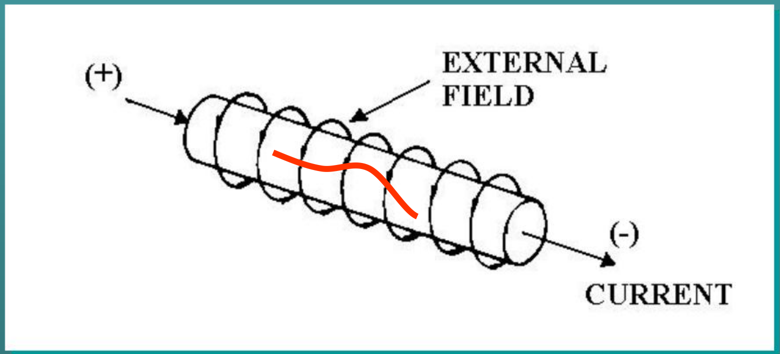


Since defects may occur in various and unknown directions, each part is normally magnetized in two directions at right angles to each other.

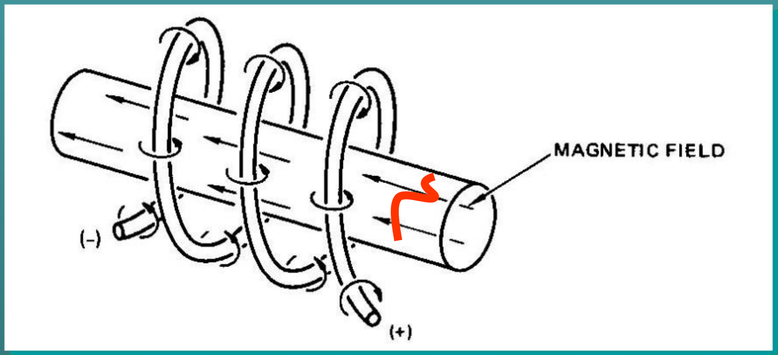


Question

? From the previous slide regarding the optimum test sensitivity, which kinds of defect are easily found in the images below?

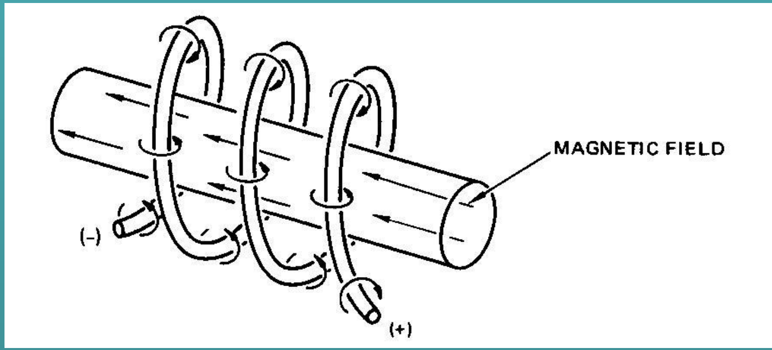


Longitudinal (along the axis)



Transverse (perpendicular the axis)

Producing a Longitudinal Magnetic Field Using a Coil



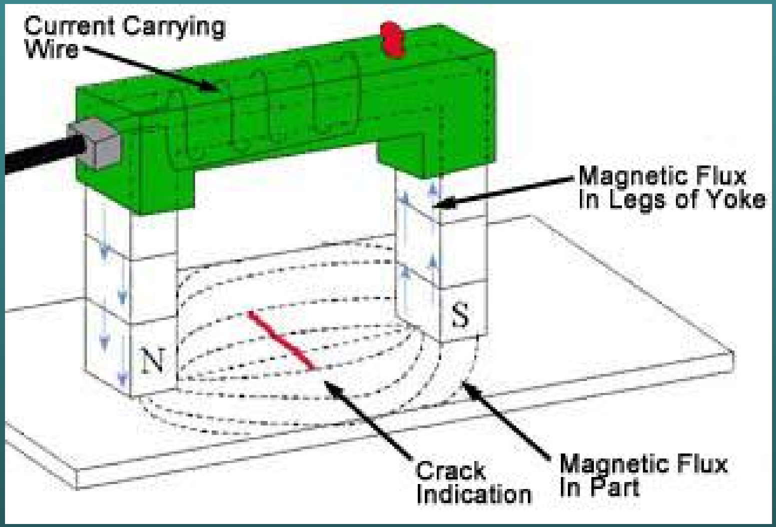

Coil on Wet Horizontal Inspection Unit


Portable Coil

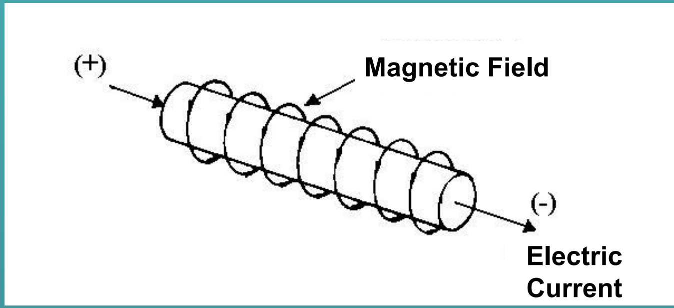
A longitudinal magnetic field is usually established by placing the part near the inside or a coil's annulus. This produces magnetic lines of force that are parallel to the long axis of the test part.

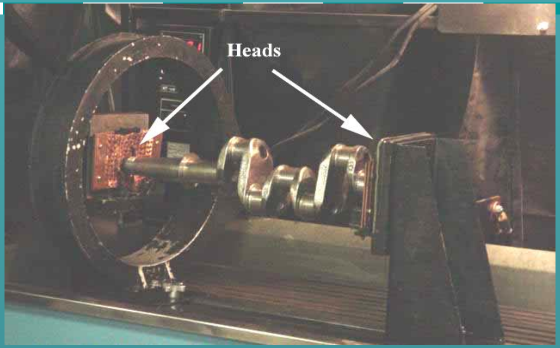
Producing a Longitudinal Field Using Permanent or Electromagnetic Magnets

Permanent magnets and electromagnetic yokes are also often used to produce a longitudinal magnetic field. The magnetic lines of force run from one pole to the other, and the poles are positioned such that any flaws present run normal to these lines of force.

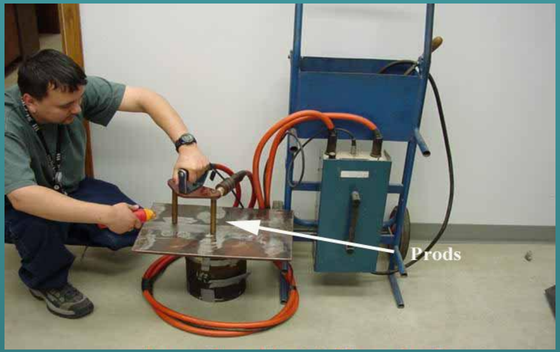


Circular Magnetic Fields

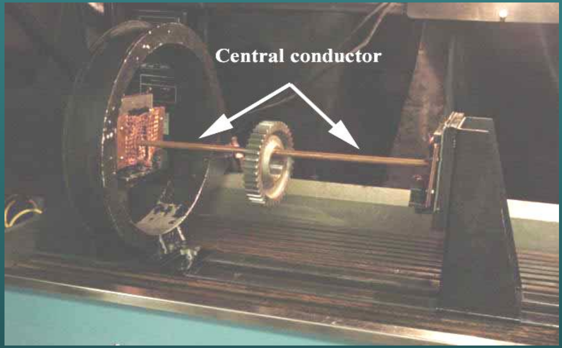




Circular magnetic fields are produced by passing current through the part or by placing the part in a strong circular magnet field.



A headshot on a wet horizontal test unit and the use of prods are several common methods of injecting current in a part to produce a circular magnetic field. Placing parts on a central conductors carrying high current is another way to produce the field.



Application of Magnetic Media (Wet Versus Dry)

MPI can be performed using either dry particles, or particles suspended in a liquid. With the dry method, the particles are lightly dusted on to the surface. With the wet method, the part is flooded with a solution carrying the particles.

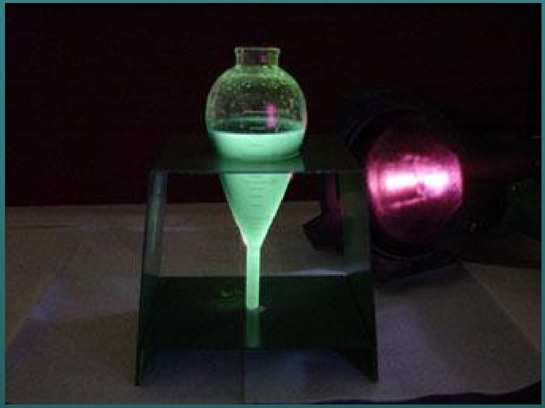
The dry method is more portable. The wet method is generally more sensitive since the liquid carrier gives the magnetic particles additional mobility.

Dry Magnetic Particles

Magnetic particles come in a variety of colors. A color that produces a high level of contrast against the background should be used.

Wet Magnetic Particles

Wet particles are typically supplied as visible or fluorescent. Visible particles are viewed under normal white light and fluorescent particles are viewed under black light.

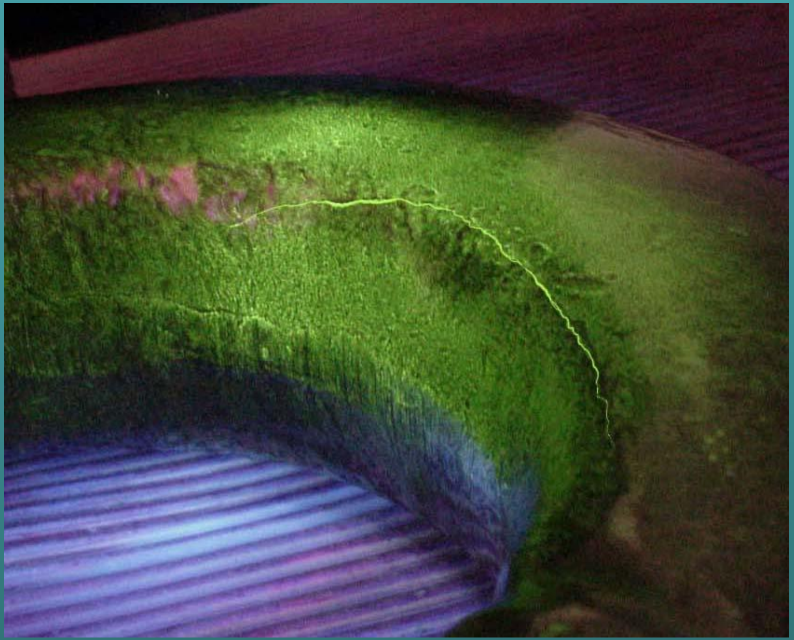


Interpretation of Indications

After applying the magnetic field, indications that form must interpreted. This process requires that the inspector distinguish between relevant and non-relevant indications.

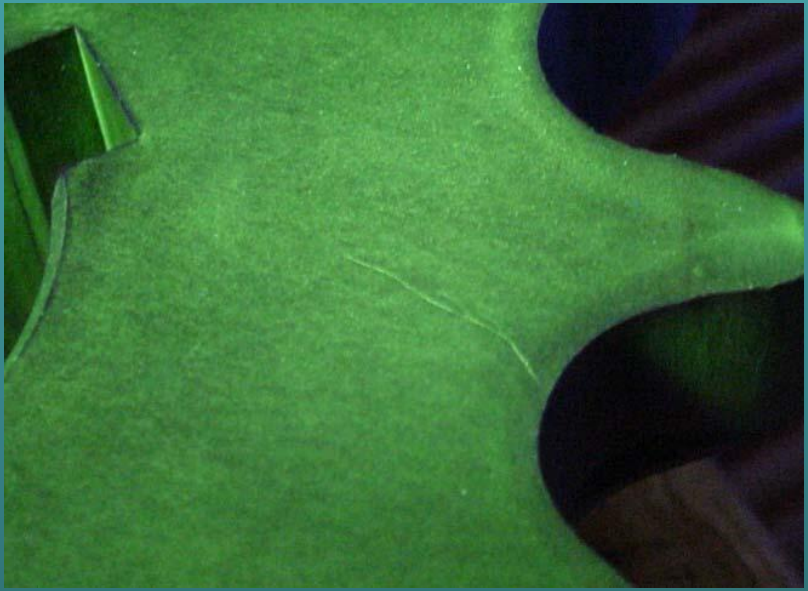
The following series of images depict relevant indications produced from a variety of components inspected with the magnetic particle method.

Crane Hook with Service Induced Crack



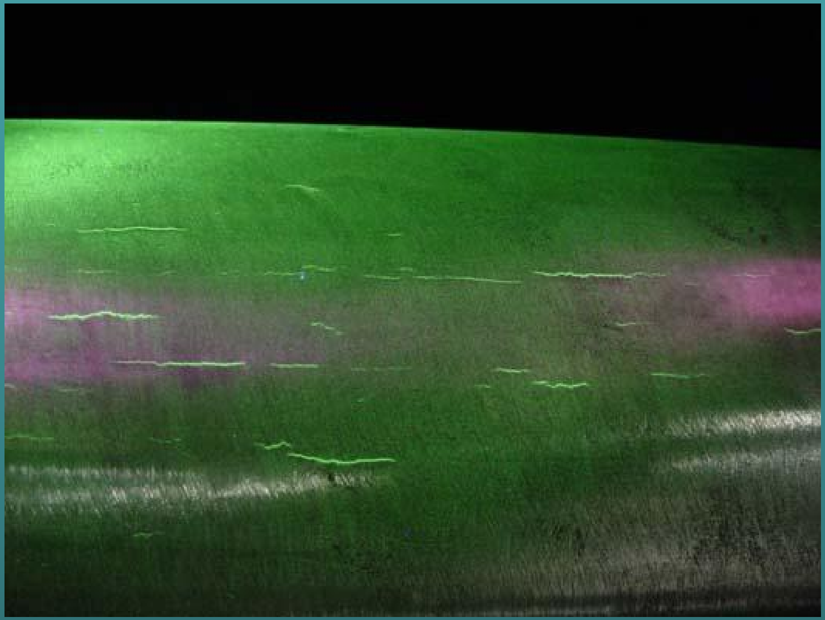
Fluorescent, Wet Particle Method

Gear with
Service Induced Crack



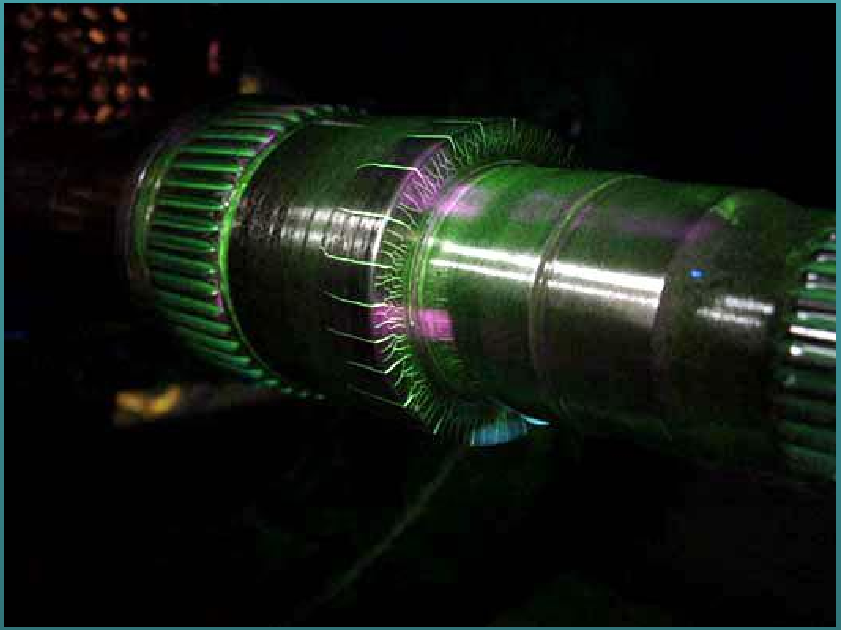
Fluorescent, Wet Particle Method

Drive Shaft with Heat Treatment Induced Cracks



Fluorescent, Wet Particle Method

Splined Shaft with Service Induced Cracks



Fluorescent, Wet Particle Method

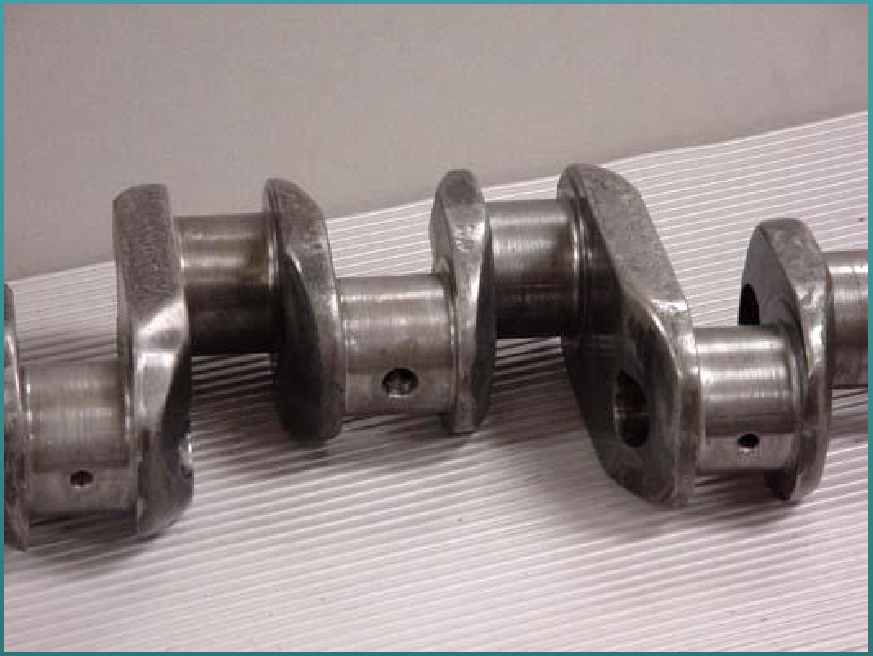
Threaded Shaft with Service Induced Crack

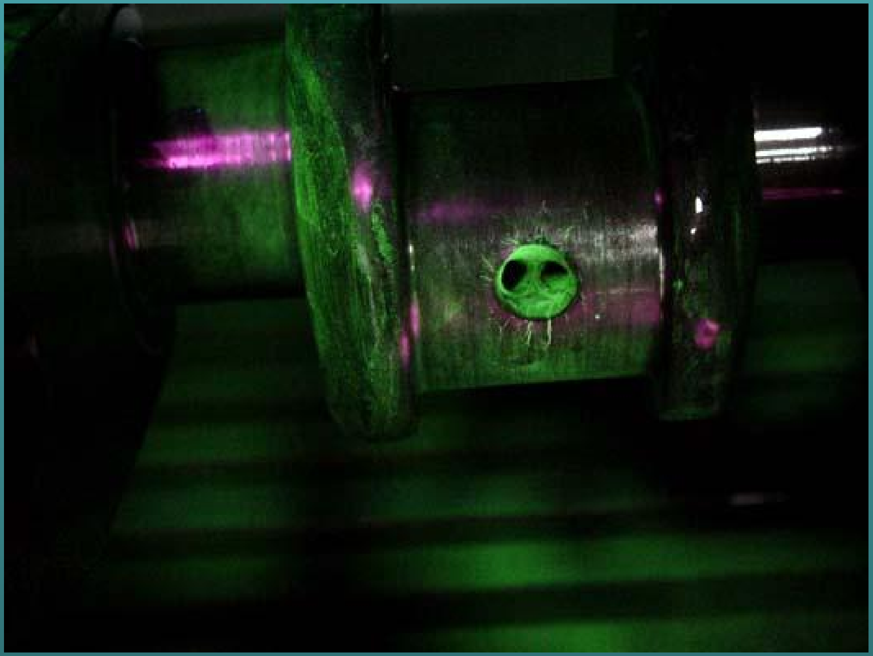
Fluorescent, Wet Particle Method

Large Bolt with Service Induced Crack

Fluorescent, Wet Particle Method

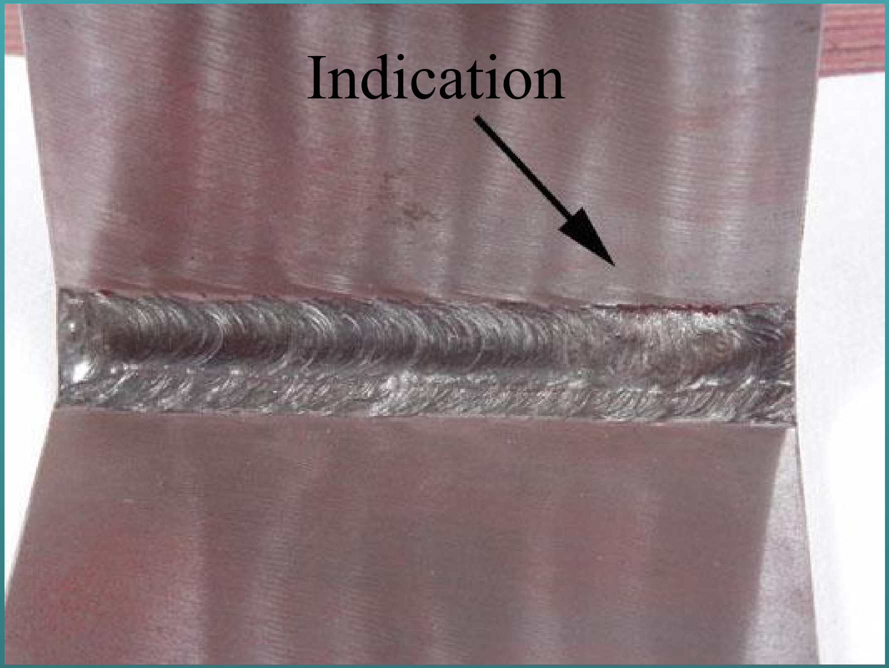
Crank Shaft with Service Induced Crack Near Lube Hole





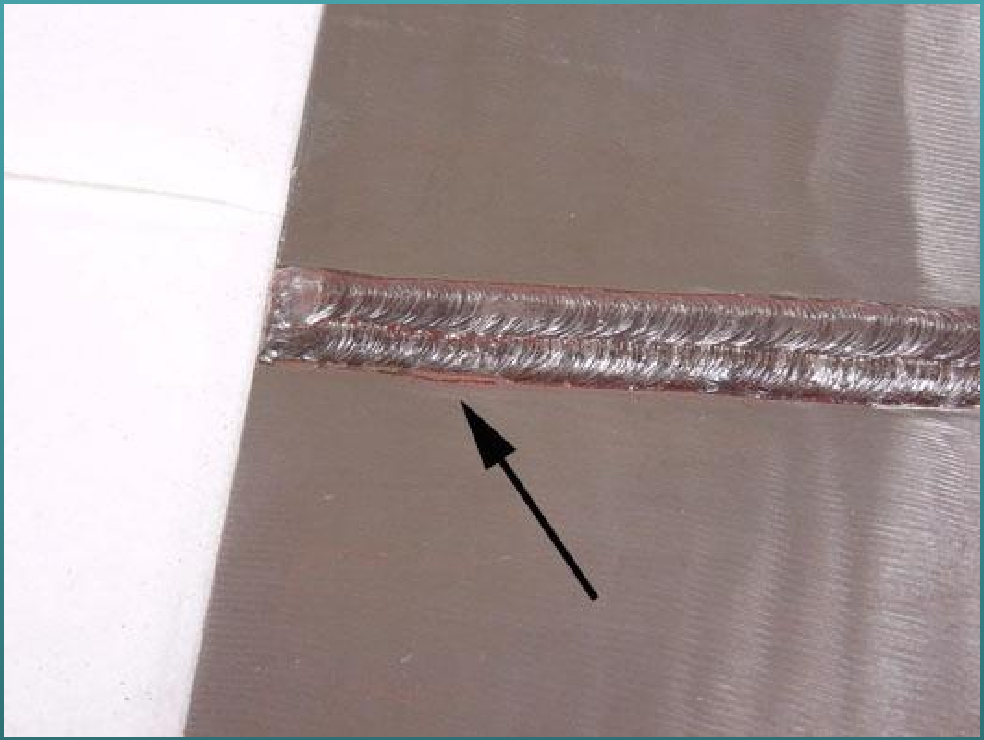
Fluorescent, Wet Particle Method

Lack of Fusion in SMAW Weld



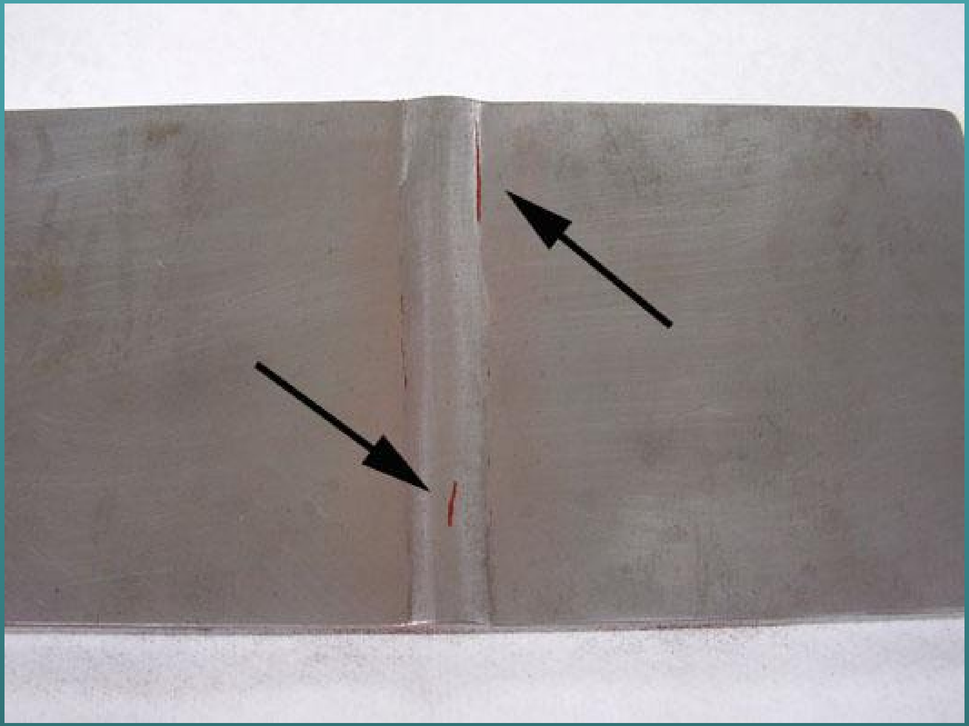
Visible, Dry Powder Method

Toe Crack in SMAW Weld



Visible, Dry Powder Method

Throat and Toe Cracks in Partially Ground Weld



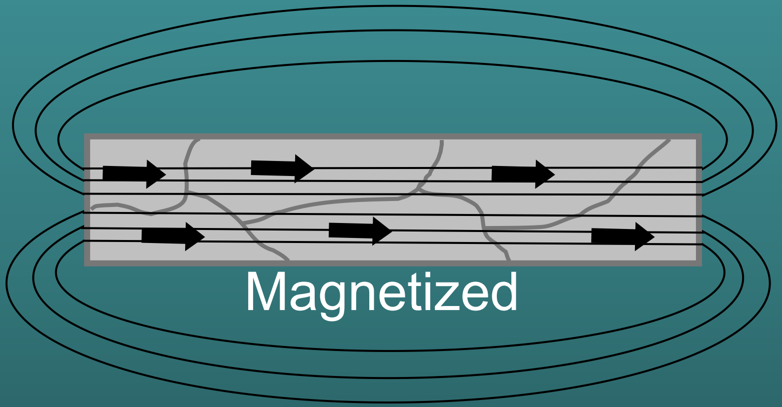
Visible, Dry Powder Method

Demagnetization

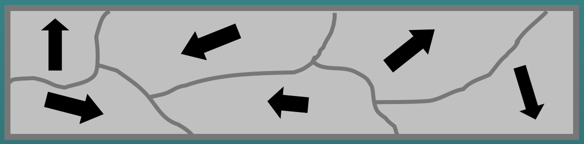
- Parts inspected by the magnetic particle method may sometimes have an objectionable residual magnetic field that may interfere with subsequent manufacturing operations or service of the component.
- Possible reasons for demagnetization include:
  - May interfere with welding and/or machining operations
  - Can effect gauges that are sensitive to magnetic fields if placed in close proximity.
  - Abrasive particles may adhere to components surface and cause and increase in wear to engines components, gears, bearings etc.

Demagnetization (Cont.)

- Demagnetization requires that the residual magnetic field is reversed and reduced by the inspector.
- This process will scramble the magnetic domains and reduce the strength of the residual field to an acceptable level.



Magnetized



Demagnetized

Advantages of Magnetic Particle Inspection

- Can detect both surface and near sub-surface defects.
- Can inspect parts with irregular shapes easily.
- Precleaning of components is not as critical as it is for some other inspection methods. Most contaminants within a flaw will not hinder flaw detectability.
- Fast method of inspection and indications are visible directly on the specimen surface.
- Considered low cost compared to many other NDT methods.
- Is a very portable inspection method especially when used with battery powered equipment.

Limitations of Magnetic Particle Inspection

- Cannot inspect non-ferrous materials such as aluminum, magnesium or most stainless steels.
- Inspection of large parts may require use of equipment with special power requirements.
- Some parts may require removal of coating or plating to achieve desired inspection sensitivity.
- Limited subsurface discontinuity detection capabilities. Maximum depth sensitivity is approximately 0.6” (under ideal conditions).
- Post cleaning, and post demagnetization is often necessary.
- Alignment between magnetic flux and defect is important

Thanks