NON-DESTURCTIVE TESTING : LPT & MPT

Presented By:

K Nagendran

JE(NQA), QAE(EFS) Chennai

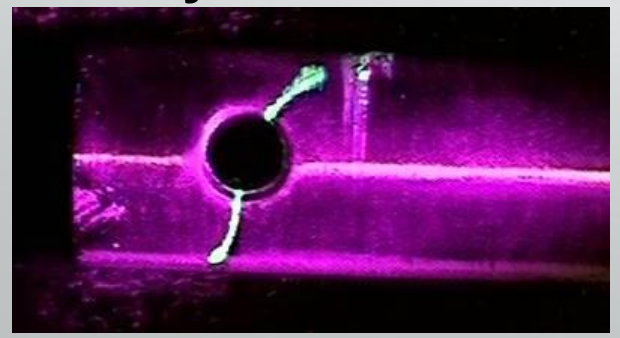
TYPES OF NDT

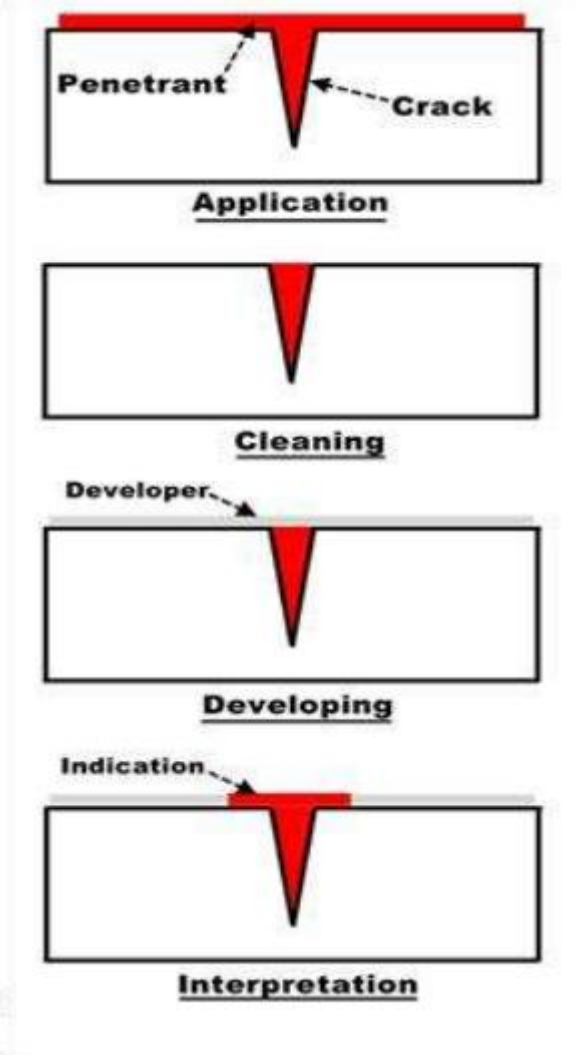
- **LIQUID PENETRATION TEST (LPT)**
- **MAGNETIC PARTICLE TESTING (MPT)**

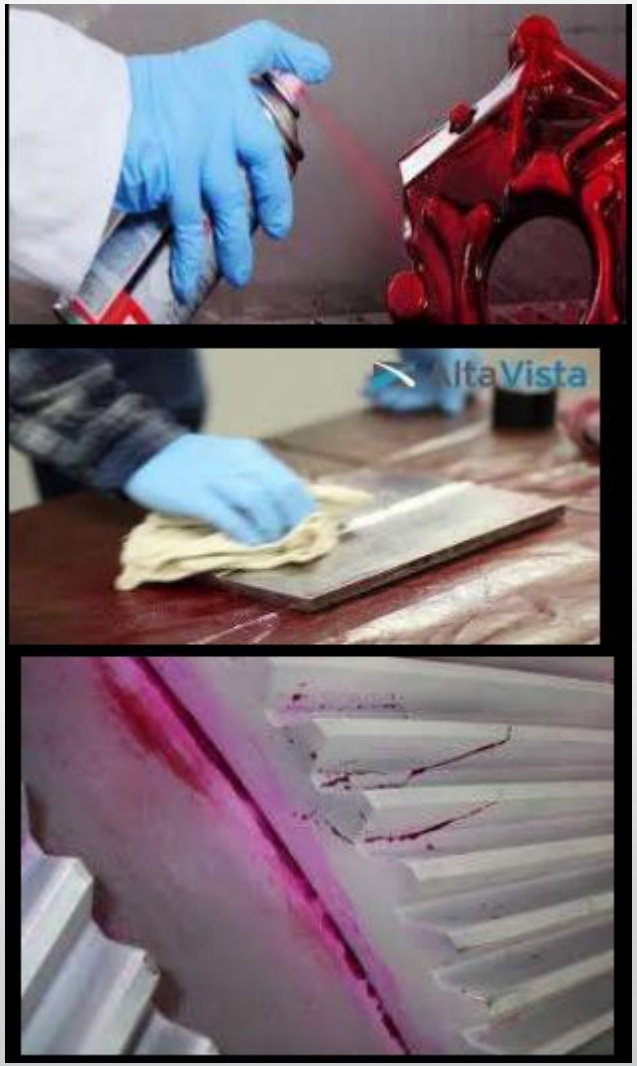
LIQUID PENTRANT TESTING

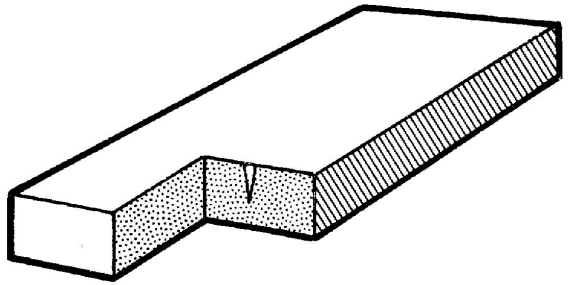
- Also called as, Dye Penetrant Inspection (DPI) and penetrant testing (PT)
- Used to detect surface defects in casting, forging, welding and possible fatigue failure areas. Can reveal cracks 2μm wide.
- Its popularity can be attributed to two main factors, which are its relative ease of use and its flexibility. LPI can be used to inspect almost any material provided that its surface is not extremely rough or porous.
- Standard: ASTM E165-80 Liquid Penetrant Inspection Method

- A liquid with high surface wetting characteristics is applied to the surface of the part and allowed time to seep into surface breaking defects.
- The excess liquid is removed from the surface of the part.
- A developer (powder) is applied to pull the trapped penetrant out the defect and spread it on the surface where it can be seen.
- Visual inspection is the final step in the process. The penetrant used is often loaded with a fluorescent dye and the inspection is done under UV light to increase test sensitivity.

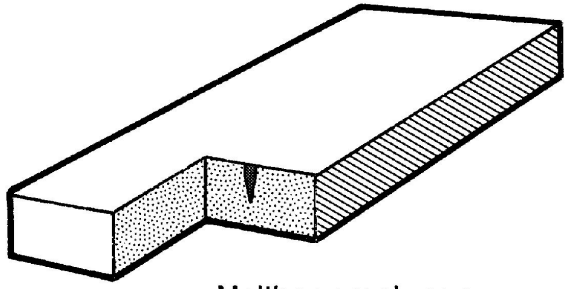



Penetrant
Crack
Application
Cleaning
Developer
Developing
Indication
Interpretation

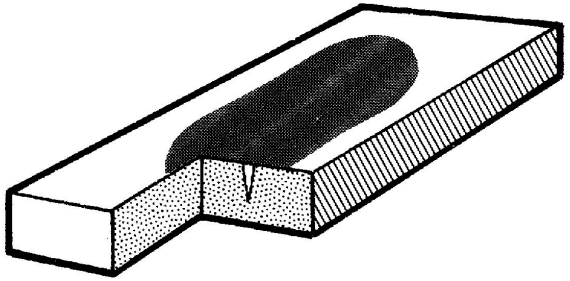

AltaVista



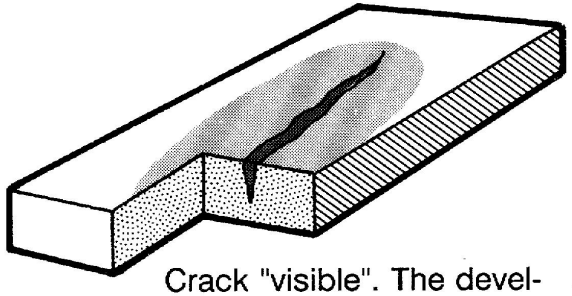
Crack not visible on surface



Neither crack nor penetrant is visible on the surface



Penetrant enters any cracks and porosities



Crack "visible". The developer has drawn the liquid out of the crack and formed a broad indication on top of the crack

The procedure used when performing an examination with a penetrant.

1. *Pre-clean, remove grease and dry the component.*
2. *Penetrant is applied to the component and acts for a brief period.*
3. *Excess penetrant is completely removed from the surface.*
4. *A developer is applied and dried off. Inspect for indication of defects.*

Penetrant testing materials

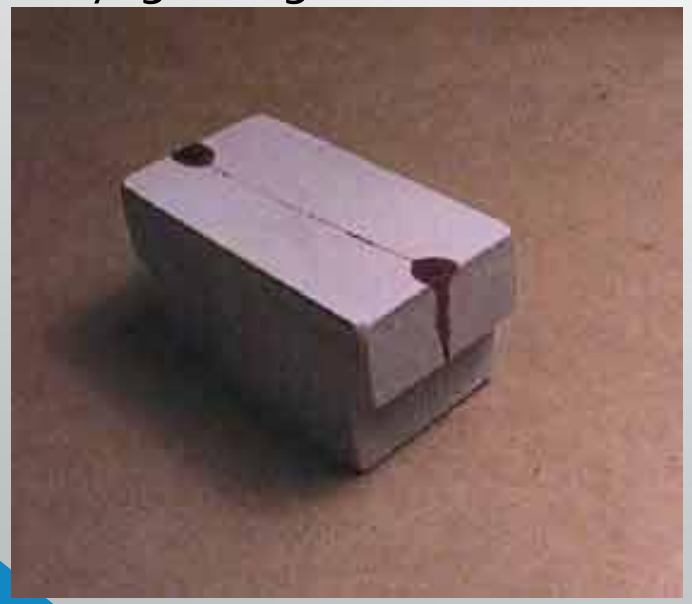
A penetrant must possess a number of important characteristics. A penetrant must

- spread easily over the surface of the material being inspected to provide complete and even coverage.
- be drawn into surface breaking defects by capillary action.
- remain in the defect but remove easily from the surface of the part.
- remain fluid so it can be drawn back to the surface of the part through the drying and developing steps.
- be highly visible or fluoresce brightly to produce easy to see indications.
- must not be harmful to the material being tested or the inspector.

Penetrant Types

Dye penetrants

- The liquids are coloured so that they provide good contrast against the developer
- Usually red liquid against white developer
- Observation performed in ordinary daylight or good indoor illumination



Fluorescent penetrants

- Liquid contain additives to give fluorescence under UV
- Object should be shielded from visible light during inspection
- Fluorescent indications are easy to see in the dark

Developer

- The role of the developer is to pull the trapped penetrant material out of defects and to spread the developer out on the surface of the part so it can be seen by an inspector.
- The fine developer particles both reflect and refract the incident ultraviolet light, allowing more of it to interact with the penetrant, causing more efficient fluorescence.
- Another function that some developers performs is to create a white background so there is a greater degree of contrast between the indication and the surrounding background.



Developer Types

- Dry powder developer –the least sensitive but inexpensive
- Water soluble – consist of a group of chemicals that are dissolved in water and form a developer layer when the water is evaporated away.
- Water suspendible – consist of insoluble developer particles suspended in water.
- Nonaqueous – suspend the developer in a volatile solvent and are typically applied with a spray gun.

Using dye and developer from different manufacturers should be avoided.

Advantages of LPT

- The method has high sensitive to small surface discontinuities.
- The method has few material limitations, i.e. metallic and nonmetallic, magnetic and nonmagnetic, and conductive and nonconductive materials may be inspected.
- Large areas and large volumes of parts/materials can be inspected rapidly and at low cost.
- Parts with complex geometric shapes are routinely inspected.
- Indications are produced directly on the surface of the part and constitute a visual representation of the flaw.
- Aerosol spray cans make penetrant materials very portable.
- Penetrant materials and associated equipment are relatively inexpensive.

Disadvantages of LPT

- Only surface breaking defects can be detected.
- Only materials with a relative nonporous surface can be inspected.
- Precleaning is critical as contaminants can mask defects.
- Metal smearing from machining, grinding, and grit or vapor blasting must be removed prior to LPI.
- The inspector must have direct access to the surface being inspected.
- Surface finish and roughness can affect inspection sensitivity.
- Multiple process operations must be performed and controlled.
- Post cleaning of acceptable parts or materials is required.
- Chemical handling and proper disposal is required.

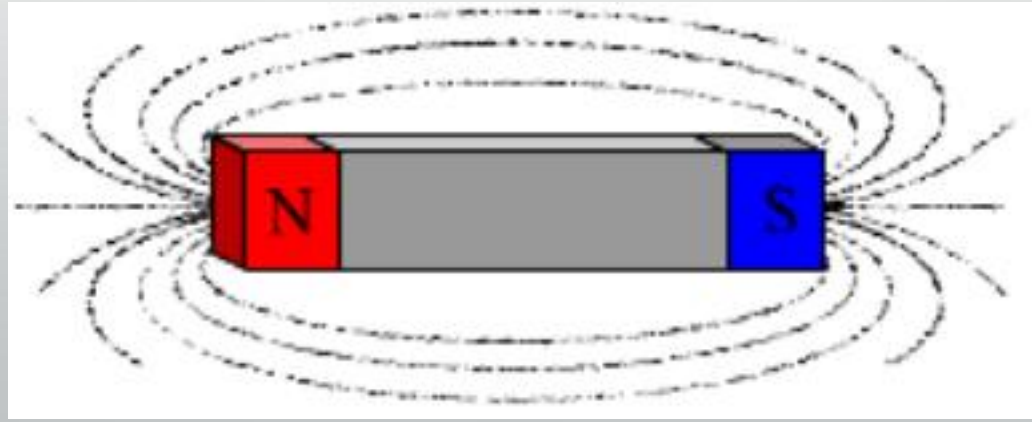
Magnetic Particle Inspection (MPI)

- MPI uses magnetic fields and small magnetic particles, such as iron filings to detect flaws in components.
- The only requirement from an inspectability standpoint is that the component being inspected must be made of a ferromagnetic material such as iron, nickel, cobalt, or some of their alloys
- The method is used to inspect a variety of product forms such as castings, forgings, and weldments.
- Underwater inspection is another area where magnetic particle inspection may be used to test such things as offshore structures and underwater pipelines.

Basic Principles

- In theory, magnetic particle inspection (MPI) is a relatively simple concept. It can be considered as a combination of two nondestructive testing methods: magnetic flux leakage testing and visual testing.

- Consider a bar magnet. It has a magnetic field in and around the magnet. Any place that a magnetic line of force exits or enters the magnet is called a pole. A pole where a magnetic line of force exits the magnet is called a north pole and a pole where a line of force enters the magnet is called a south pole.



Interaction of materials with an external magnetic field

- When a material is placed within a magnetic field, the magnetic forces of the material's electrons will be affected. This effect is known as *Faraday's Law of Magnetic Induction*.

- This reaction is dependent on a number of factors such as the atomic and molecular structure of the material, and the net magnetic field associated with the atoms.

- The magnetic moments associated with atoms have three origins. These are the electron orbital motion, the change in orbital motion caused by an external magnetic field, and the spin of the electrons.

Diamagnetic, Paramagnetic, and Ferromagnetic Materials

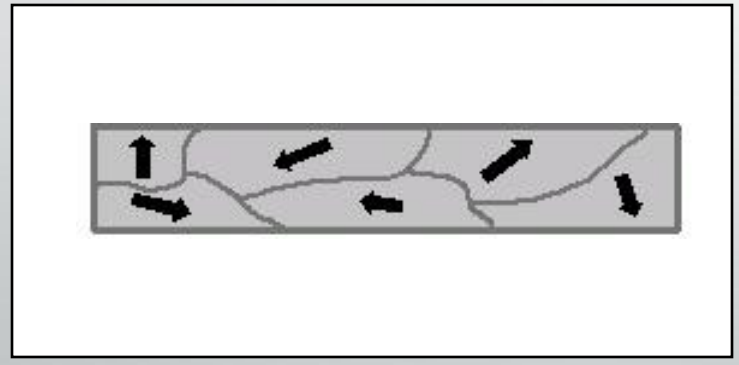
Diamagnetic metals: very weak and negative susceptibility to magnetic fields. Diamagnetic materials are slightly repelled by a magnetic field and the material does not retain the magnetic properties when the external field is removed.

Paramagnetic metals: small and positive susceptibility to magnetic fields. These materials are slightly attracted by a magnetic field and the material does not retain the magnetic properties when the external field is removed.

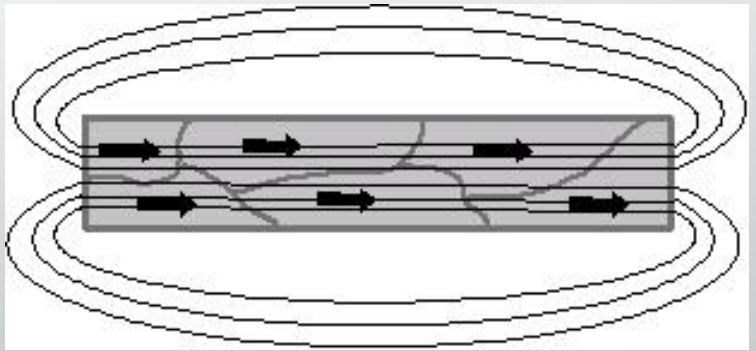
Ferromagnetic materials: large and positive susceptibility to an external magnetic field. They exhibit a strong attraction to magnetic fields and are able to retain their magnetic properties after the external field has been removed.

Ferromagnetic materials become magnetized when the magnetic domains within the material are aligned. This can be done by placing the material in a strong external magnetic field or by passes electrical current through the material.

Some or all of the domains can become aligned. The more domains that are aligned, the stronger the magnetic field in the material. When all of the domains are aligned, the material is said to be magnetically saturated. When a material is magnetically saturated, no additional amount of external magnetization force will cause an increase in its internal level of magnetization.



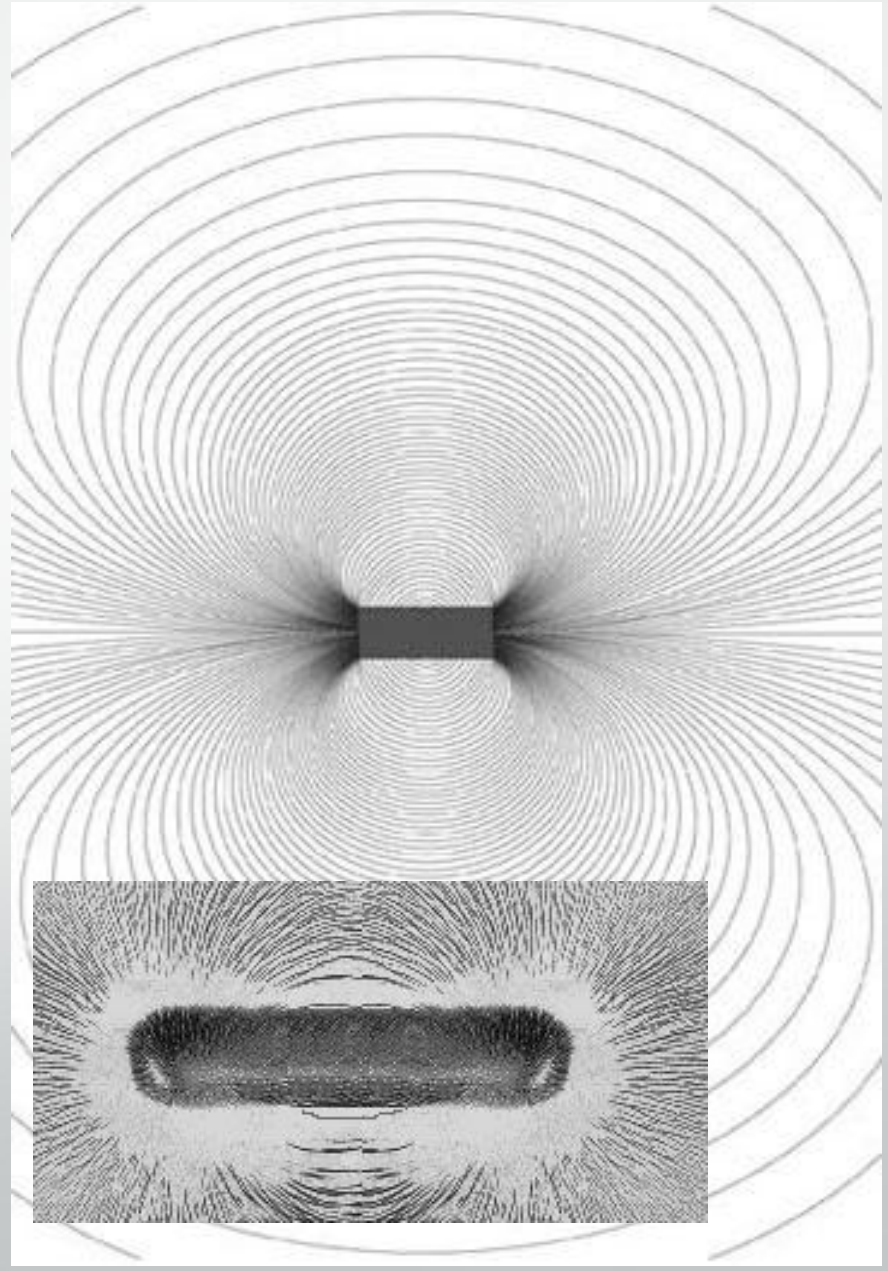
Unmagnetized material



Magnetized material

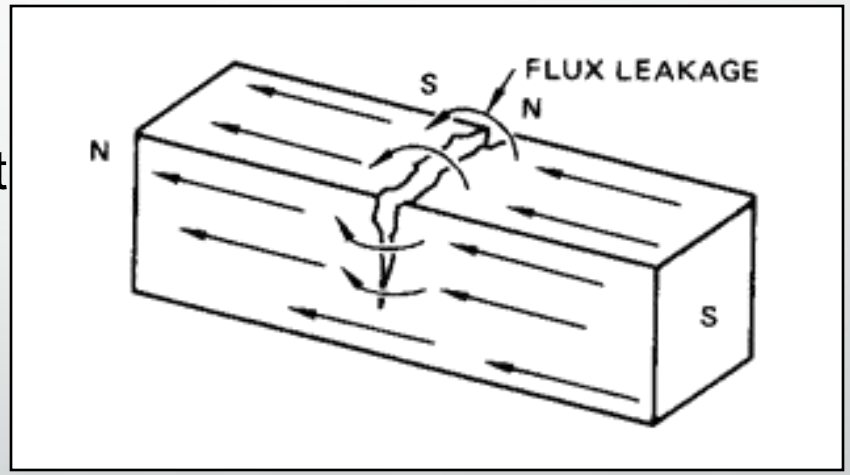
General Properties of Magnetic Lines of Force

- Follow the path of least resistance between opposite magnetic poles.
- Never cross one another.
- All have the same strength.
- Their density decreases (they spread out) when they move from an area of higher permeability to an area of lower permeability.
- Their density decreases with increasing distance from the poles.
- flow from the south pole to the north pole within the material and north pole to south pole in air.



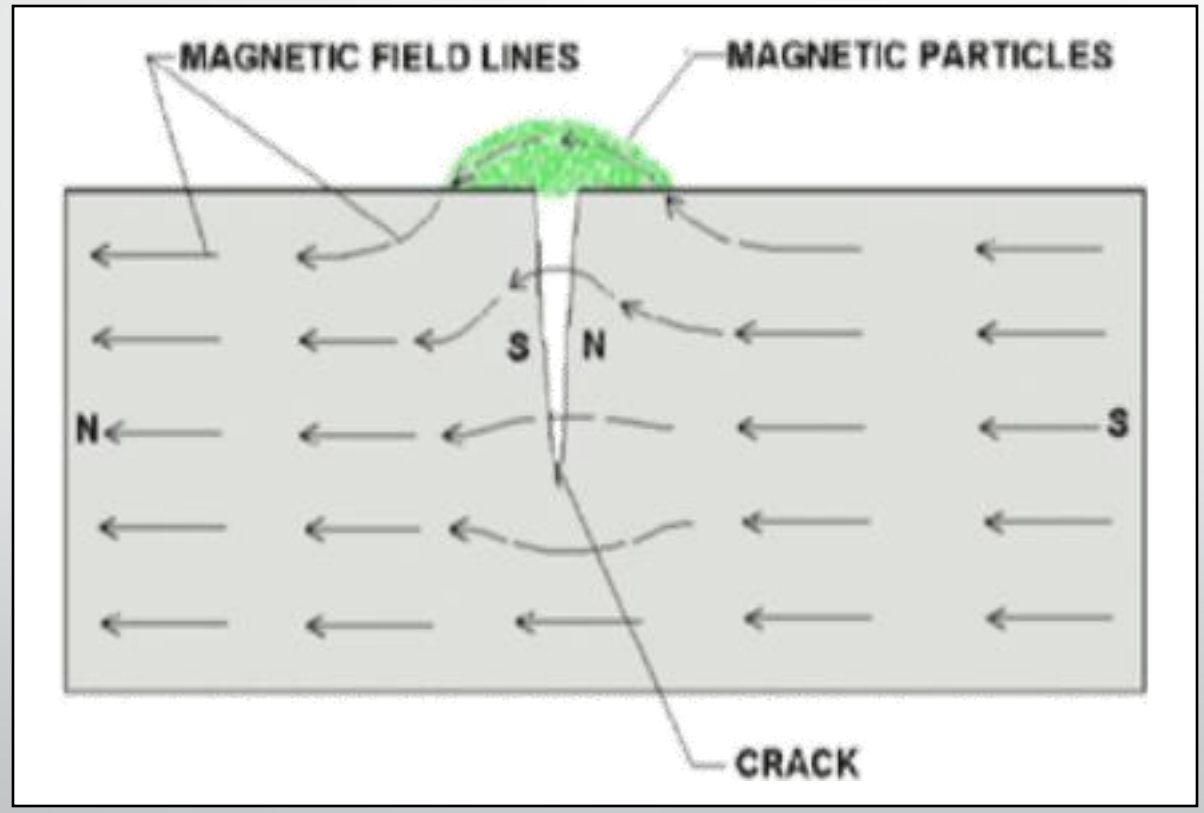
When a bar magnet is broken in the center of its length, two complete bar magnets with magnetic poles on each end of each piece will result. If the magnet is just cracked but not broken completely in two, a north and south pole will form at each edge of the crack.

The magnetic field exits the north pole and reenters the at the south pole. The magnetic field spreads out when it encounter the small air gap created by the crack because the air can not support as much magnetic field per unit volume as the magnet can.

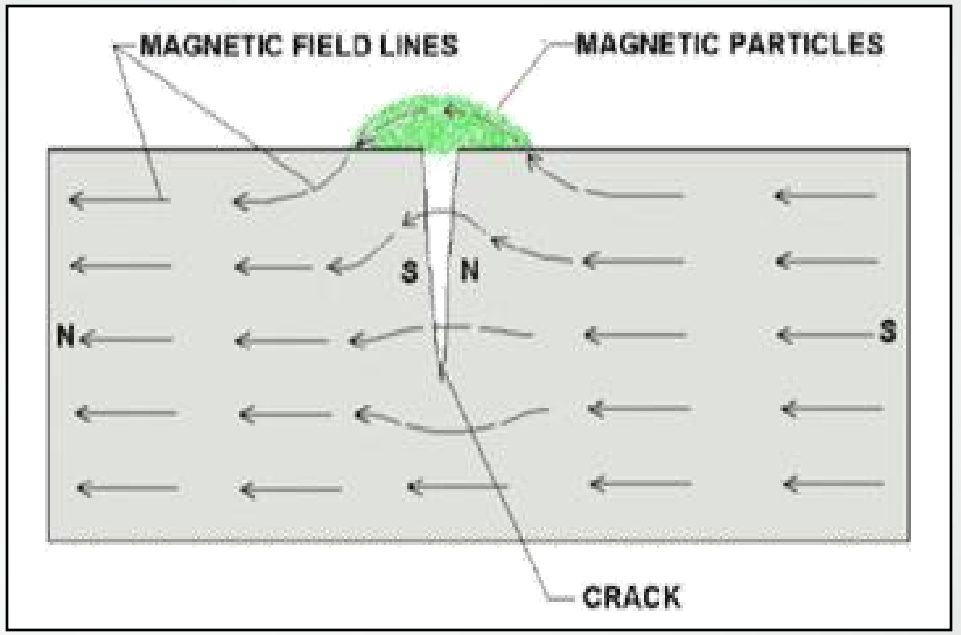


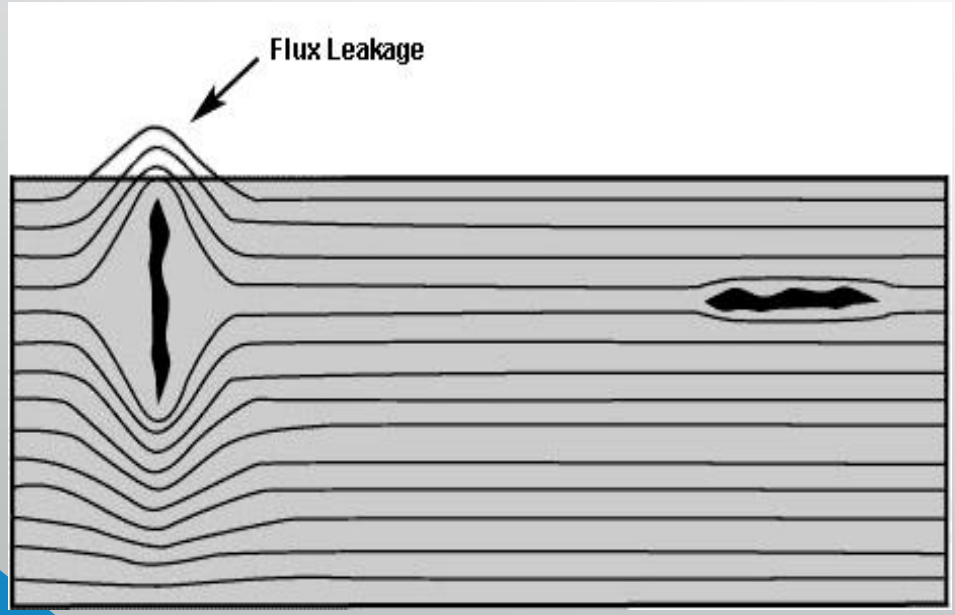
When the field spreads out, it appears to leak out of the material and, thus, it is called a *flux leakage field*.

If iron particles are sprinkled on a cracked magnet, the particles will be attracted to and cluster not only at the poles at the ends of the magnet but also at the poles at the edges of the crack. This cluster of particles is much easier to see than the actual crack and this is the basis for magnetic particle inspection.



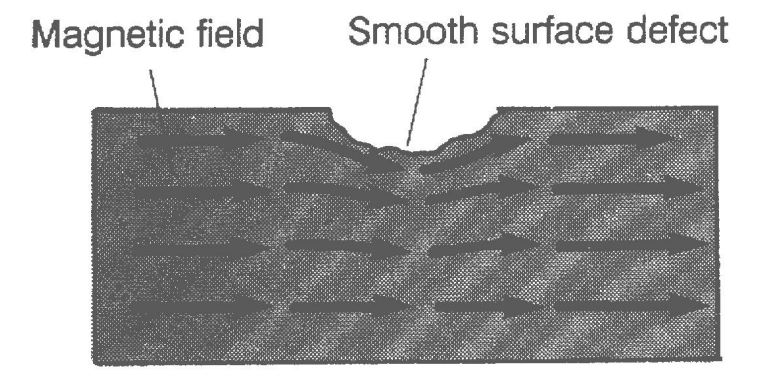
The magnetic particles form a ridge many times wider than the crack itself, thus making the otherwise invisible crack visible

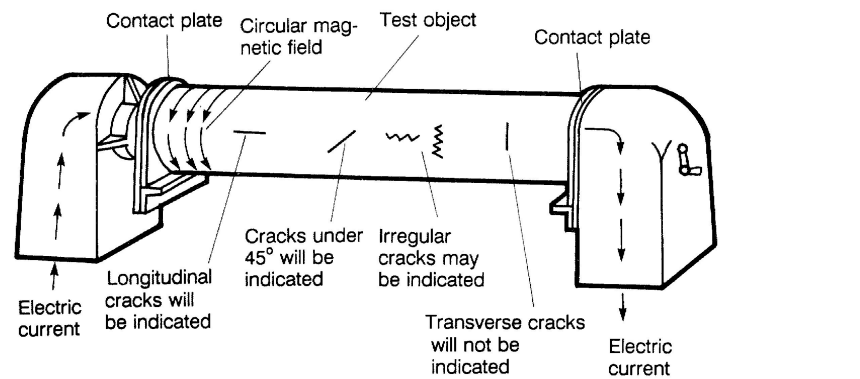




Cracks just below the surface can also be revealed

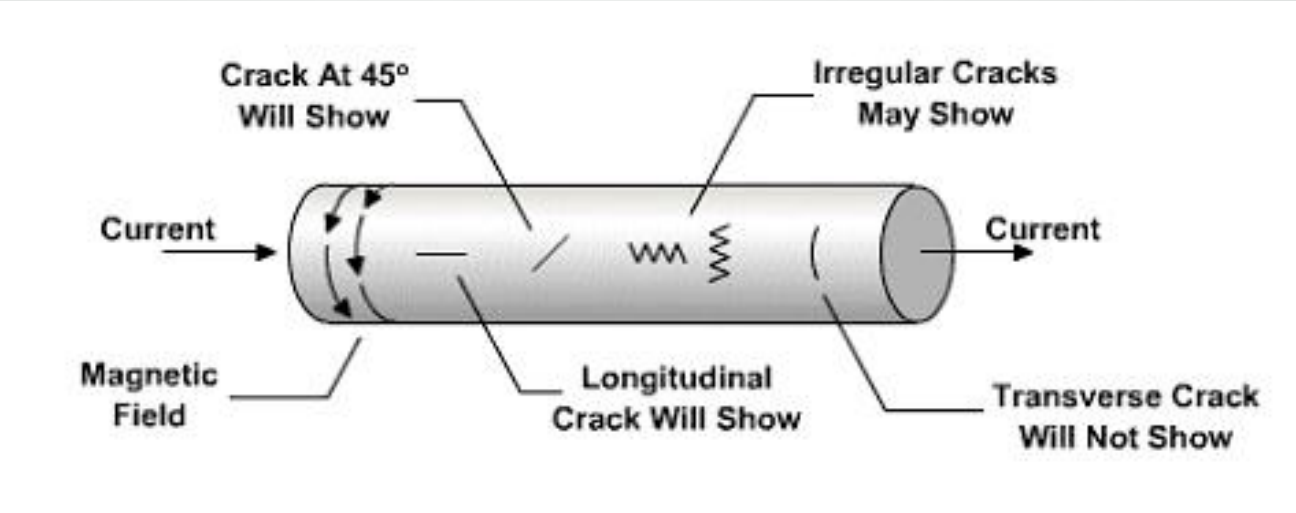
MPI is not sensitive to shallow and smooth surface defects





Stationary bench unit. The importance of the orientation of a defect in relation to the magnetic field lines is shown.

The effectiveness of MPI depends strongly on the orientation of the crack related to the flux lines



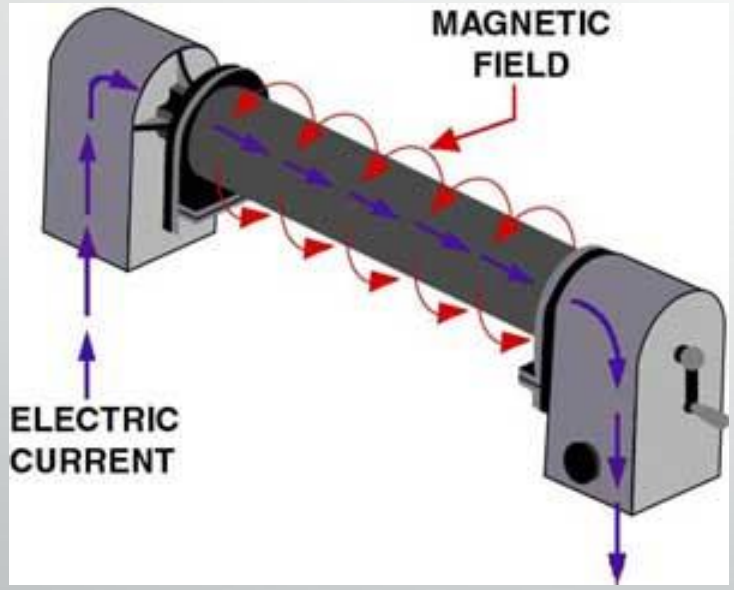
Testing Procedure of MPI

- Cleaning
- Demagnetization
- Contrast dyes (e.g. white paint for dark particles)
- Magnetizing the object
- Addition of magnetic particles
- Illumination during inspection (e.g. UV lamp)
- Interpretation
- Demagnetization - prevent accumulation of iron particles or influence to sensitive instruments

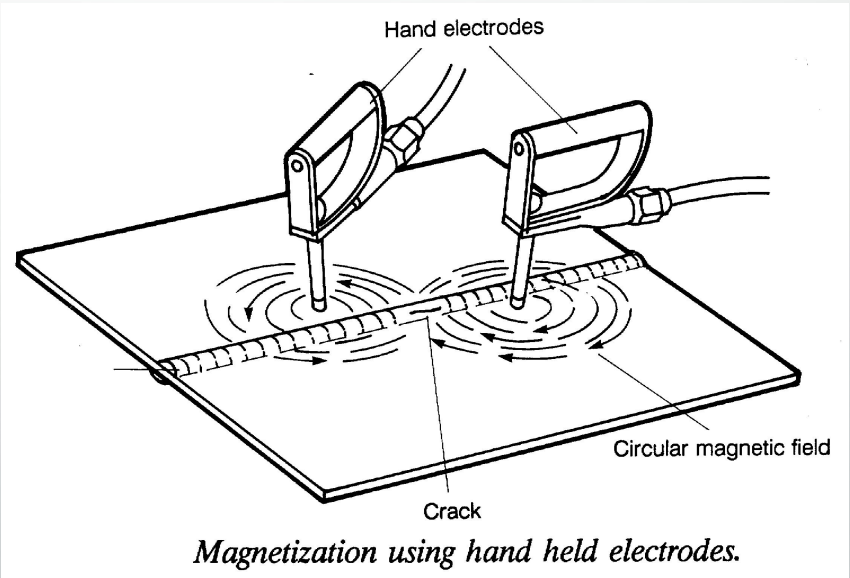
Magnetizing the object

There are a variety of methods that can be used to establish a magnetic field in a component for evaluation using magnetic particle inspection. It is common to classify the magnetizing methods as either ***direct*** or ***indirect***.

- Direct magnetization: current is passed directly through the component.



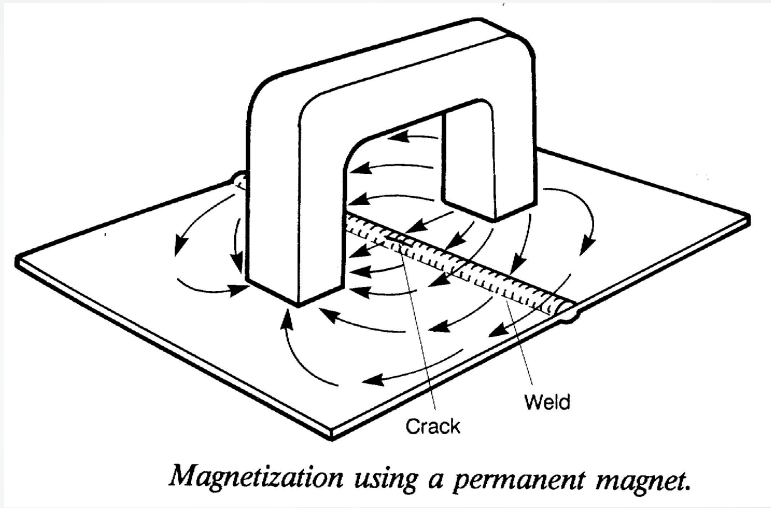
Clamping the component between two electrical contacts in a special piece of equipment



Magnetization using hand held electrodes.

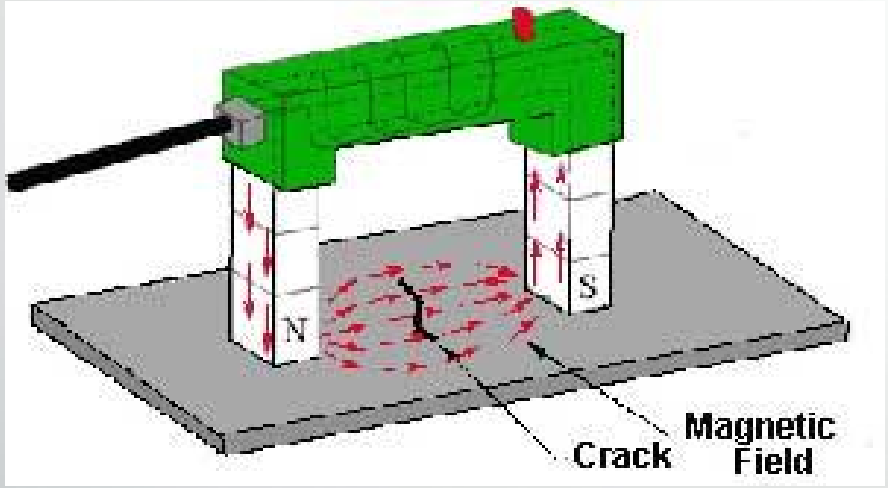
Using clams or prods, which are attached or placed in contact with the component

• Indirect magnetization: using a strong external magnetic field to establish a magnetic field within the component

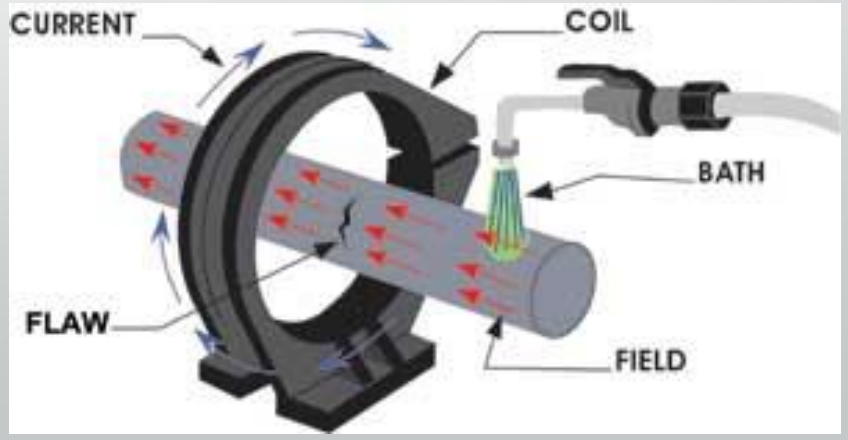


Magnetization using a permanent magnet.

(a) permanent magnets

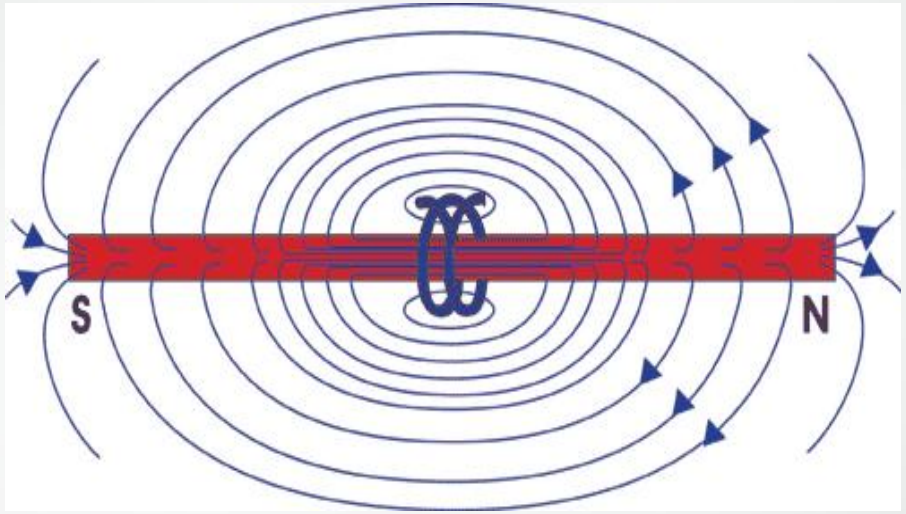


(b) **Electromagnets**

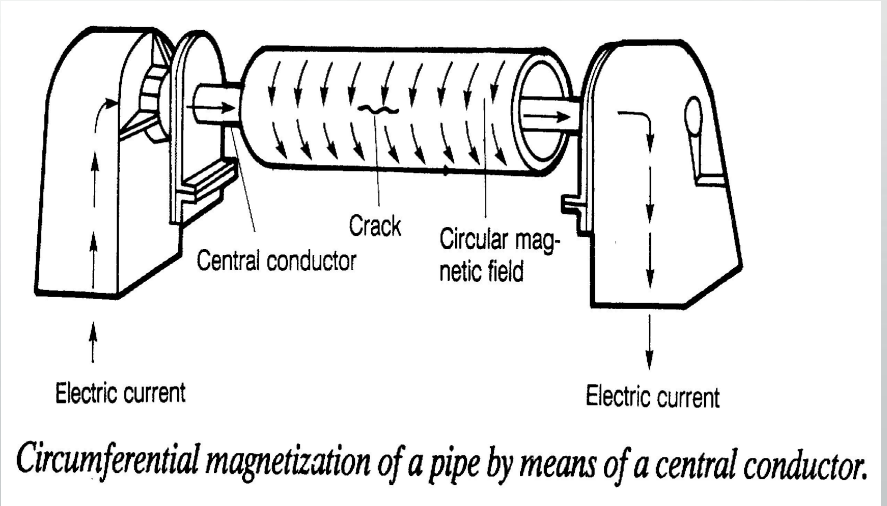


(c) coil shot

- Longitudinal magnetization: achieved by means of permanent magnet or electromagnet



- Circumferential magnetization: achieved by sending an electric current through the object



Circumferential magnetization of a pipe by means of a central conductor.

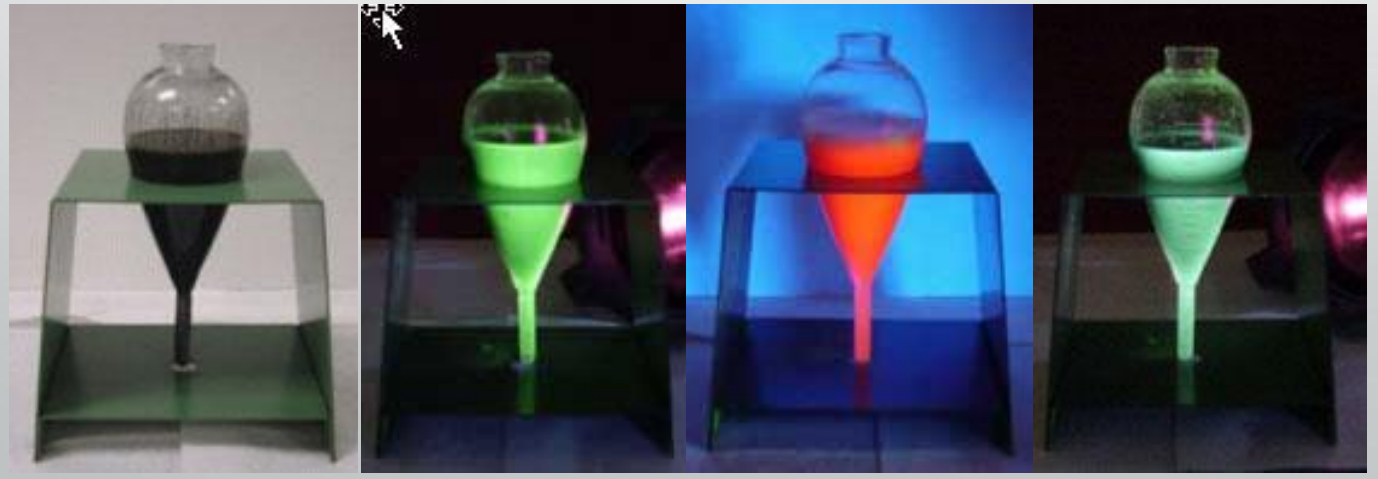
Demagnetization

After conducting a magnetic particle inspection, it is usually necessary to demagnetize the component. Remanent magnetic fields can:

- affect machining by causing cuttings to cling to a component.
- interfere with electronic equipment such as a compass.
- can create a condition known as "ark blow" in the welding process. Arc blow may causes the weld arc to wonder or filler metal to be repelled from the weld.
- cause abrasive particle to cling to bearing or faying surfaces and increase wear.

Magnetic particles

- Pulverized iron oxide (Fe_3O_4) or carbonyl iron powder can be used
- Coloured or even fluorescent magnetic powder can be used to increase visibility
- Powder can either be used dry or suspended in liquid



Some Standards for MPI Procedure

- British Standards
  - BS 4397: Methods for magnetic particle testing of welds
- ASTM Standards
  - ASTM E 709-80: Standard Practice for Magnetic Particle Examination
  - ASTM E 125-63: Standard reference photographs for magnetic particle indications on ferrous castings

Advantages of MPI

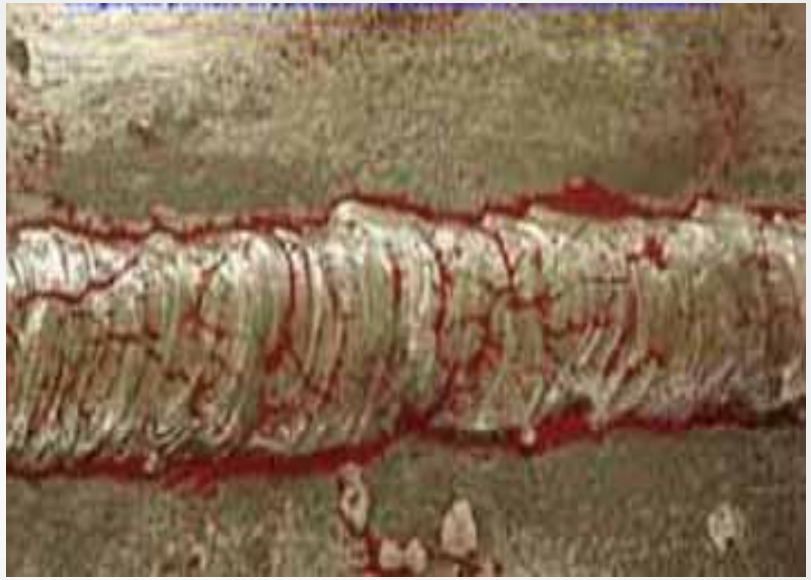
- One of the most dependable and sensitive methods for surface defects
- fast, simple and inexpensive
- direct, visible indication on surface
- unaffected by possible deposits, e.g. oil, grease or other metals chips, in the cracks
- can be used on painted objects
- surface preparation not required
- results readily documented with photo or tape impression

Limitations of MPI

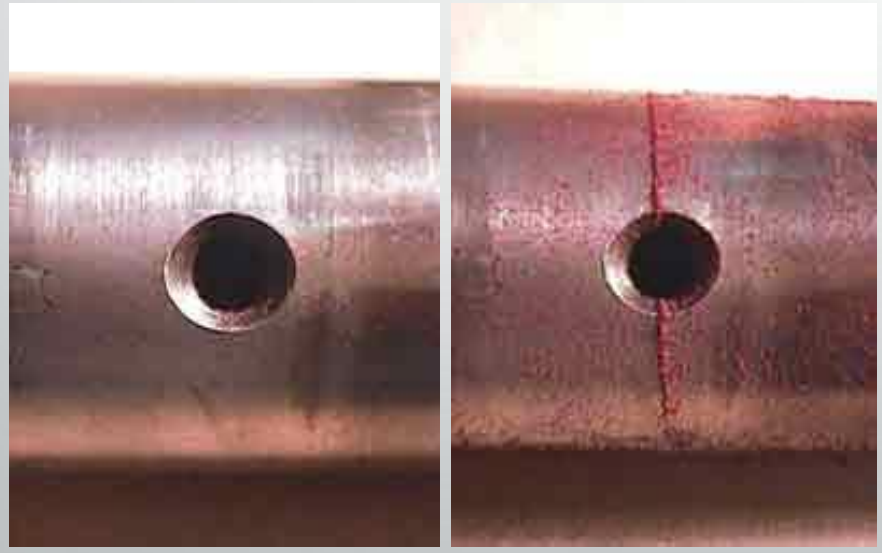
- Only good for ferromagnetic materials
- sub-surface defects will not always be indicated
- relative direction between the magnetic field and the defect line is important
- objects must be demagnetized before and after the examination
- the current magnetization may cause burn scars on the item examined

Examples of visible dry magnetic particle indications

Indication of a crack in a saw blade



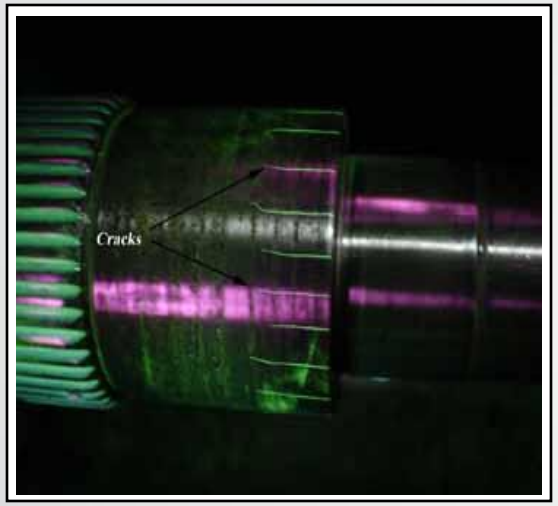
Indication of cracks in a weldment



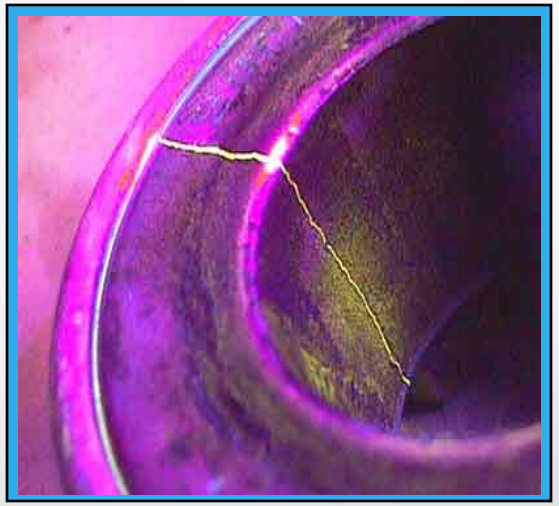
Before and after inspection pictures of cracks emanating from a hole

Indication of cracks running between attachment holes in a hinge

Examples of Fluorescent Wet Magnetic Particle Indications



Magnetic particle wet fluorescent indication of a cracks in a drive shaft



Magnetic particle wet fluorescent indication of a crack in a bearing

Magnetic particle wet fluorescent indication of a cracks at a fastener hole

THANK YOU