Rohini College of Engineering and Technology
(Autonomous)

DEPARTMENT OF MECHANICAL ENGINEERING

OML351
INTRODUCTION TO NON-DESTRUCTIVE TESTING

UNIT 2 LIQUID PENETRANT & MAGNETIC PARTICLE TESTING

Liquid Penetrant Testing: Principles, types and properties of liquid penetrants, developers, advantages and limitations of various methods, testing procedure, interpretation of results. Magnetic Particle Testing: Theory of magnetism, inspection materials magnetisation methods, interpretation and evaluation of test indications, principles and methods of demagnetization, residual magnetism.

LIQUID PENETRANT TESTING (LPT)

INTRODUCTION

- *Liquid penetrant method is an effective method of detecting surface discontinuities in metals and other non-porous material surfaces.*
- It detects flaws that are open to the surface e.g., cracks, seams, laps, lack of bond, porosity, cold shut etc.
- It can be effectively used for the inspection of
    1. ferrous metals,
    2. non-ferrous metals;
    3. non-porous, non-metallic materials such as ceramics, plastics and glass; and
    4. non-magnetic materials.
- *The principle of liquid penetrant test is that the liquid penetrant is drawn into surface flaws such as cracks porosities by capillary action. Then the developer material conjunction with visual inspection reveals the surface flaw.*
- This method is popularly used due to two main factor it's relative ease of use and its flexibility.

Characteristics detected (Applicability): Liquid penetrant testing is widely used:

1. To locate cracks, porosity and other defects that break the surface at a material and have enough volume to trap and hold the penetrant material.
2. To inspect large areas very efficiently and will work most non-porous materials.

PRINCIPLE OF LIQUID PENETRANT TESTING

Principle

- ✓ In this method, a penetrating liquid (known as penetrant) is applied over the cleaned surface of the test specimen by dipping, spraying, or brushing; and it is allowed to remain long enough to seep into surface openings through capillary action.
- ✓ Excess penetrant liquid is then wiped off and the surface is dried. The surface is then coated with a thin film of developer
- ✓ A developer is applied, to allow the penetrant to seep back to the surface (by action) and to spread to the edges of openings, this addition of developer magnifies the surface of the defects.
- ✓ The surface is then inspected for defects, either visually (in case of dye penetrants) or with fluorescent lighting After inspection, the developer and residual penetrant are removed by a second cleaning operation.
- ✓ Figure illustrates the principle of liquid penetrant testing.

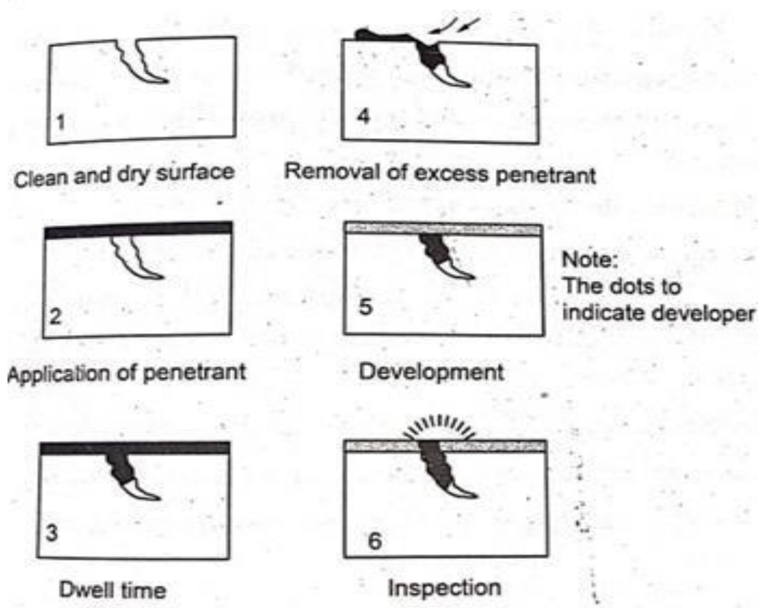

Figure *Mechanism of penetrant flaw detection*

Advantages of Liquid Penetrant Testing

Some of the advantages of liquid penetrant testing method are as follows:

i. Simple and easy to use.
ii. Inexpensive and versatile.
iii. Highly sensitive to fine, tight discontinuities
iv. Highly portable
v. Applicable to variety of materials.
vi. Applicable to complex shapes
vii. Large surface areas or large volumes of parts/materials can inspected quickly and at low cost.
viii. All surface discontinuities are detected in one operation regardless of orientation

Limitations of Liquid Penetrant Testing

Some of the limitations of liquid penetrant testing method are as follows:

1. It can only detect flaws that are open to the surface.
2. It cannot be used on porous and very rough surfaces.
3. Surface preparation before testing is critical as contaminants can mask defects. So test surface must be free of all dirt, oil, grease, paint, rust etc.
4. Deformed surfaces and surface coatings may prevent detection.
5. It is necessary to remove all penetrant materials after testing.
6. Chemical handling precautions are necessary (toxicity, fire, waste)
7. There is no easy method to produce permanent record.

LIQUID PENETRANT TEST PROCESS

(Test Procedure of Liquid Penetrant Testing) (Stages of Liquid Penetrant Process)

- The liquid penetrant test essentially involves the sequence of operation listed in the table below.

Step 1: Surface Preparation The surface of components to be inspected is prepared by cleaning, creating a clean dry surface
Step 2: Application of Penetrant Penetrant is applied by dipping, spraying or brushing on the prepared surface to be inspected
Step 3: Dwell Penetrant Time Sufficient period of time is allowed for the penetrant to enter any discontinuity open to that surface
Step 4: Removal of Excess Penetrant The excess penetrant is removed in such a manner that will ensure retention of penetrant inside of the discontinuity
Step 5: Application of Developer A developer agent is applied to draw the penetrant liquid from the discontinuities out to the surface and thereby give an enhanced indication of such discontinuities.
Step 6: Examination, Interpretation and Evaluation After the developing time, the discontinuities are visually examined, interpreted and evaluated under appropriate viewing conditions.
Step 7: Post-Process Cleaning Finally the surface of the component is cleaned and a corrosion penetrant is applied, if necessary.

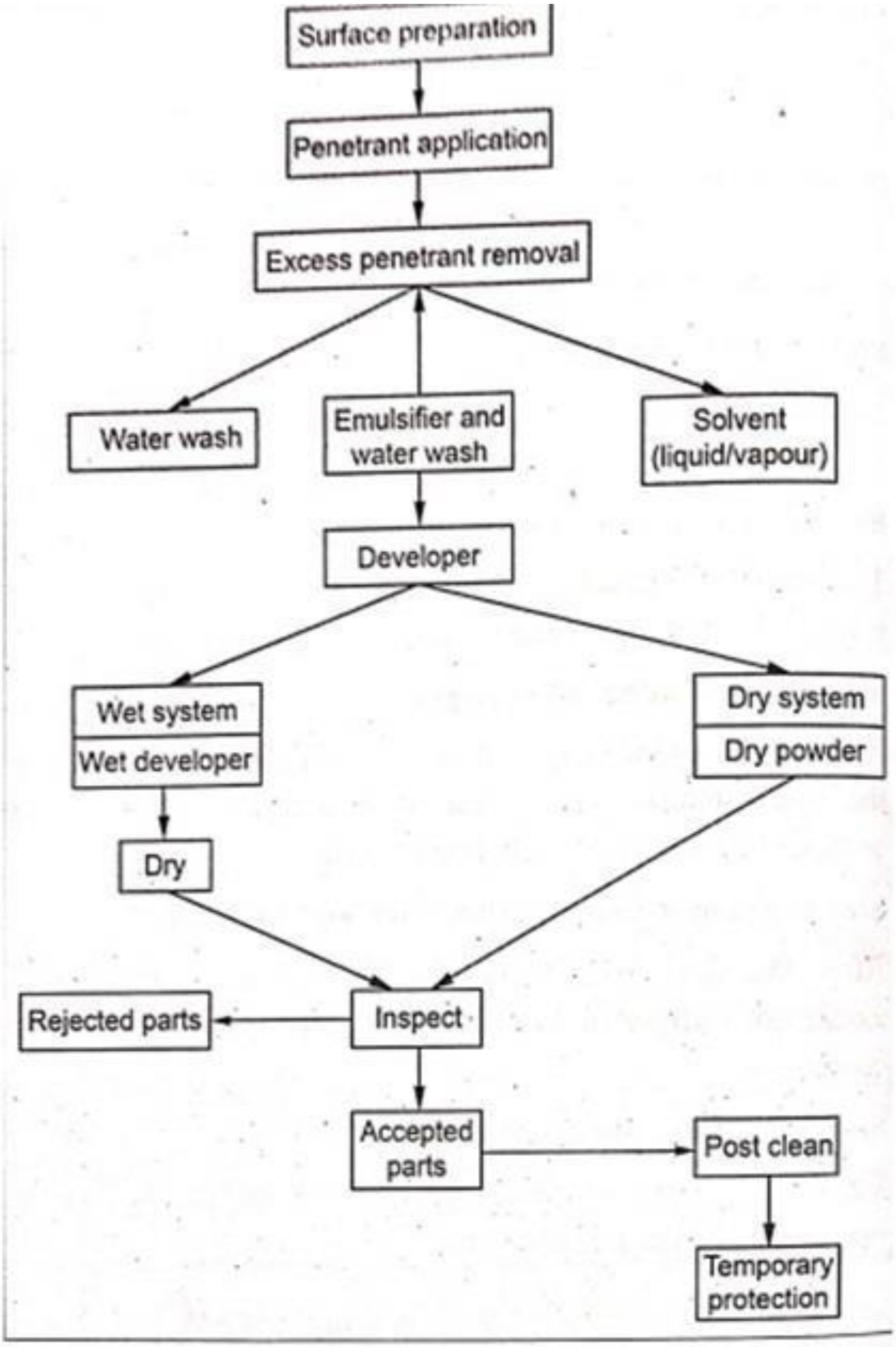

Figure . *Liquid penetrant process flow chart*

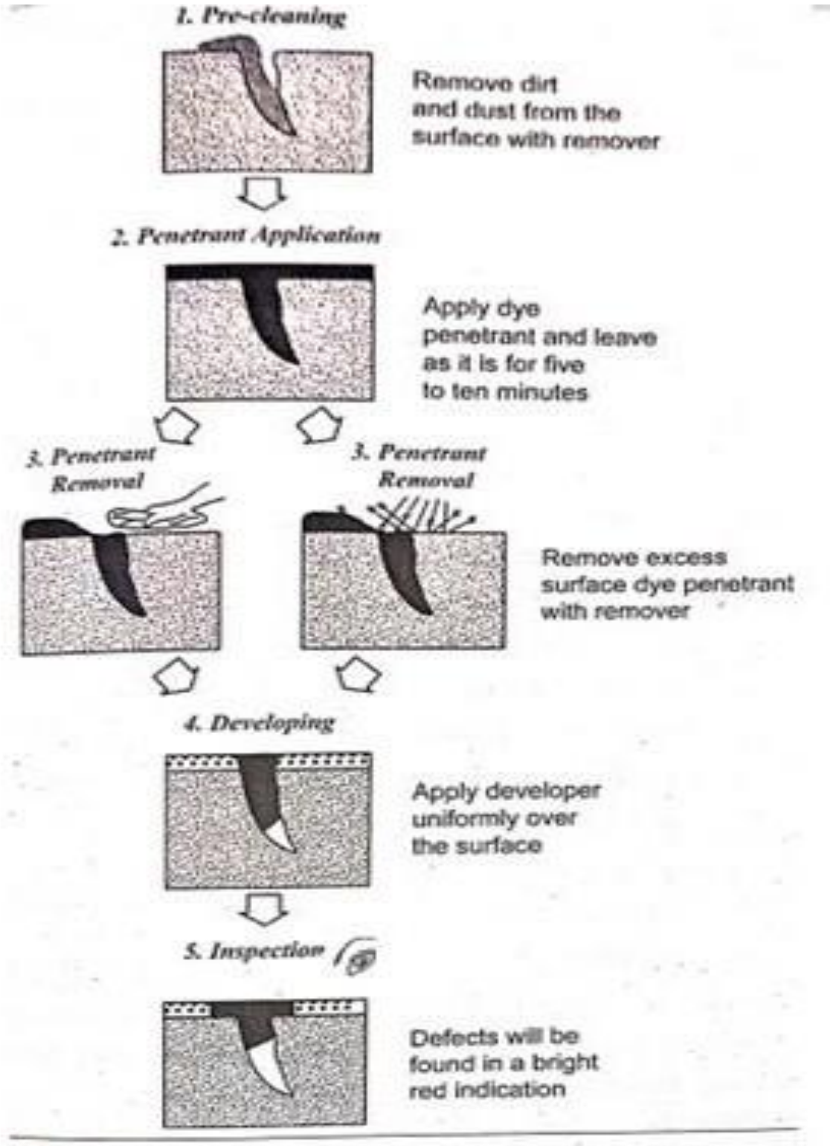

Figure *Different stages of liquid penetrant process*

Surface Preparation

- The test surface should be thoroughly cleaned and dried before the penetrant is applied
- The test surface should be free of contaminants such as rust, scale, welding flux, spatter, grease, paint, oily films, dirt, etc.
- The presence of contaminants on the test surface can result in the failure of penetrant:
    a) To wet the test surface,
    b) To enter into discontinuities, and
    c) To bleed out of discontinuities.
- Cleaning methods: Depending on the surface contamination, any one of the following cleaning methods can be used for surface preparation

1. Mechanical Cleaning Methods

Mechanical cleaning methods include:

a) Abrasive tumbling
b) Dry abrasive grit blasting
c) Wet abrasive grit blasting
d) Wire brushing grit blasting
e) High-pressure water and steam
f) Ultrasonic cleaning
g) Sand blasting

2. Chemical Cleaning Methods

Chemical Cleaning methods include

a) Alkaline cleaning
b) Acid cleaning
c) Molten salt bath cleaning
d) Pickling
e) Chemical etching

3. Solvent Cleaning Methods

Solved cleaning methods include

a) Vapour degreasing
b) Solvent wiping
c) Solvent spraying
d) Ultrasonic immersion using solvents

Table. Applications of various methods of pre-cleaning for liquid penetrant inspection

S.No	Method	Uses
1.Mechanical Methods		
a)	Abrasive tumbling	Removing light scale, burrs, welding flux, braze stop off, rust, casting mold, and core material; should not be used on soft metals such as aluminum, magnesium, or titanium.
b)	Dry abrasive grit blasting	Removing light or heavy scale, flux stop off, rust, casting mold and core material, sprayed coatings, carbon deposits-in general, any friable deposit; can be fixed or portable.
c)	Wet abrasive grit blasting	Same as dry except, where deposits are light, better surface and better control of dimensions are required.
d)	Wire brushing	Removing light deposits of scale, flux, and stop off.
e)	High-pressure water and steam	Ordinarily used with an alkaline cleaner of detergent; removing typical machine shop soils such as cutting oils, polishing compounds, grease, chips, and deposit from electrical discharge machining; us when surface finish must be maintained inexpensive
f)	Ultrasonic cleaning	Ordinarily used with detergent and water or with a solvent; removing adherent shop soil from large quantities of small parts.
2. Chemical Methods		
a)	Alkaline cleaning	Removing braze stop off, rust, scale, oils, greases, polishing material, and carbon deposits; ordinarily used on large articles where hand methods are too laborious; also used on aluminum for gross metal removal.
b)	Acid cleaning	Strong solutions for removing heavy scale: mild solutions for light scale; weak (etching) solutions for removing lightly smeared metal.
c)	Molten salt bath cleaning	Conditioning and removing heavy scale.
3. Solvent Methods		
a)	Vapor degreasing	Removing typical shop soil, oil, and grease: usually employs chlorinated solvents; not suitable for titanium.
b)	Solvent wiping	Same as for vapor degreasing except a hand operation; may employ non-chlorinated solvents; used for localized low-volume cleaning.

Application of Penetrants

- In the second stage, the liquid penetrant is applied by dipping. spraying, brushing or flowing on the cleaned test surface.
- Penetrant is a liquid capable of wetting the entire surface, and being drawn into fine openings.
- Methods of penetrant application: The four methods employed for penetrant application are as follows:

i.	**Dipping method:** In the dipping method, the test component is immersed/dipped into a task containing the penetrant liquid. It is then raised and allowed to drain.
ii.	**Spraying method:** In the spraying method, the conventional spray guns or pressurized spray cans are used to spray the penetrant on the test component.
iii.	**Brushing method:** In this method, the penetrant is brushed using brushes or swabs.
iv.	**Flowing method:** In this method, the penetrant is poured over the test component and allowed it to drain.

Dwell or Penetrant Time

- Dwell time, also known as penetration time, is the period of time from when the penetrant is applied to the surface until it is removed.
- This dwell period varies according to the type of penetrant used, material on which penetrant is applied, type of defect for which it is applied, etc.
- Usually a dwell time of 15 to 30 minutes is practiced for many applications.

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S.No	Material	Form	Type Of Defects	Minimum Penetration Time (Minutes)
1.	Aluminum And Magnesium Alloys	Castings, forgings. Welds, all forms	Porosity, cold shut, laps, fatigue cracks, porosity	15 30
2.	Stainless Steel	Castings, forgings. Welds, all forms	Porosity, cold shut, laps, fatigue cracks, porosity	30 60
3.	Brass And Bronze	Castings, forging. Brazed parts, all fonns	Porosity, cold shut, laps, fatigue cracks, porosity	10 15-30
4.	Plastics	All forms	Cracks	5-30
5.	Glass	All forms	Cracks	5-30
6.	Carbide Tipped Tools	Lack of bond, porosity, grinding crack		10

Removal of Excess Penetrant

- In this fourth stage, the excess surface penetrant is removed from the test component surface.
- The removal method is determined by the type of penetrant used.
- **Methods of removal:** Three methods/techniques used for excess surface penetrant removal are:
  - i. Water washing.
  - ii. Post-emulsifying, and
  - iii. Solvent removing.

(i) Water washing method

- This method is used when self-emulsifying penetrants are employed. Here the excess penetrant is removed by simply washing with water.
- When post-emulsible penetrant are employed, they are not directly water-washable. They require the use of an emulsifier (oil or water base).

(ii) Post-emulsification method

- This is post emulsifier process of excess penetrant removal is carried out in two steps
- First, the excess penetrant is treated with an emulsifier for stipulated period of time as recommended by the manufacturer.
- Then, the excess penetrant is removed by usual water washing.
- In this method, emulsifying time is a critical factor.

(iii) Solvent removal method

- In this method, the organic solvents are used for penetrant removal.
- Solvent removal is carried out in two steps:
- First, the excess penetrant is wiped from the test surface as much as possible with a clean, dry, lint-free cloth.
- Then a second cleaning is carried out with a clean, lint-free cloth moistened with a solvent cleaner.

Application of Developer

- *Developer is an absorbent material capable of drawing traces of penetrant from the discontinuities back into the surface.*
- The purpose of developer is to increase the brightness intensity of fluorescent indications and the visible contrast of visible-penetrant indications.

Types of developers: The four types of developers used in liquid penetrant testing are

i. Powder developers,
ii. Water solvable developers,
iii. Water-suspendable developers, and
iv. Non-aqueous wet developers

- Developing time: Developing time is the time it takes the application of the developer until the actual evaluation commences

Examination, Interpretation and Evaluation

- Upon completion of the development time, the indications from discontinuities that have formed on the test surface should be examined, interpreted and evaluated.
- The penetrant indications can be examined under natural daylight or with ultraviolet or laser incident light; and the defect recognition may be made with the human eye or with automated optical scanners.
- Visible penetrant indications can be inspected in either natural or artificial white light.
- In case of fluorescent penetrants, examination is carried out in a dark enclosure under black light (UV light) of minimum 70 LUX intensity.
- The identification and interpretation of indications requires high degree of skills and experience.

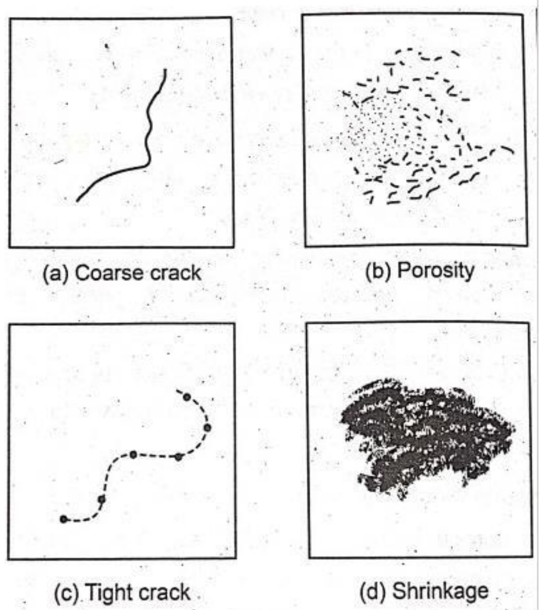

Figure. *Typical penetrant indications*

Table. Indications of some defects

S.No	Name of Defect	Visible Penetrant	Fluorescent Penetrant
1.	Cracks	Thin red lines-depth indicated by the degree of spread	Thin, greenish yellow lines
2.	Very tight crack	Series of very small red dots in continuous formation	Series of very small, greenish-yellow dots
3.	Porosity	Series of red spots spread over the surface	Series greenish yellow spots
4.	Shrinkage/ micro shrinkage	Pale red blotches	Pale greenish-yellow blotches

Table. Detectable discontinuities and their indications

S.No	Types of Defect	Description
1.	Casting porosity	Spherical surface indications
2.	Porosity (glass)	Spherical surface indications
3.	Casting cold shut	Dotted or smooth continuous lines
4.	Cracks	Straight or jagged continuous surface lines
5.	Hot tears	Ragged line of variable width, numerous branches
6.	Sand casting shrinkage	Crack indications where part thickness changes

7.	Forging lap (AI)	Sharp crescent-shaped indications on aluminum
8.	Forging lap (partial)	An intermittent line indication
9.	Rolling lap	Continuous line on rolled bar stock
10.	Crater crack (Al)	Dish-shaped indication with spoke propagation
11.	Crater crack (deep)	Rounded indication
12.	Lamination (rolling)	Seams on rolled plate
13.	Inclusion (rolling)	Broad elongated indications in rolled plate
14.	Heat-treat cracks	Multiple irregular lines in fired ceramics
15.	Thermal cracks (glass)	Jagged interconnecting lines fired ceramics
16.	Lack of fusion (welds)	Broken line of varying width near centerline
17.	Fatigue cracks	Continuous line in parts that have been in service

Post-Process Cleaning

- The last step in the process is post-cleaning after the examination.
- After the examination, all traces of any remaining penetrant and developer must be thoroughly removed from the surface before it is being placed into service.
- Also post-cleaning is carried out to avoid corrosion and to facilitate further processing of the test component.
- In general, the cleaning methods employed in post-cleaning are the same as those applied for pre-cleaning

PENETRANT MATERIALS

What are Penetrant Materials?

- The various materials used in the penetrant process are known as penetrant materials
- The penetrant materials can be classified into four groups as
  1. Penetrant,
  2. Developers,
  3. Pre-cleaners, and
  4. Emulsifiers and solvent removers.

PENETRANTS

What are Penetrants?

- Penetrant is a liquid capable of wetting the entire surface, and being drawn into fine openings.
- The penetrant material consists of the indicating (tracer) dye and the carrier (vehicle) fluid.
- The indicating dye is used to provide a colour contrast with respect to the surroundings.

Types of Penetrant

The two basic types of penetrants are:

1. Fluorescent penetrants, and
2. Visible penetrants.

1. Fluorescent Penetrants

- *Fluorescent penetrants are usually green in colour and they contain a dye or several dyes that fluoresce' when exposed to ultraviolet radiation.*
- The sensitivity of a fluorescent penetrant depends on its ability to form indications that appear as small sources of light in a dark area.

2. Visible Penetrants

- *Visible penetrants contain a red dye that provides high contrast against the white developer background.*
- Visible penetrants do not require a darkened area and an ultraviolet light in order to make an inspection.

Fluorescent Penetrant Vs Visible Penetrants

Table. Fluorescent penetrants Vs Visible penetrants

S.No	Fluorescent Penetrants	Visible Penetrants
1.	They contain a dye or several dyes that fluoresce when exposed to ultraviolet radiation.	They contain a red dye that provides high contrast against the white developer background.
2.	They are more sensitive (because the eye is drawn to the glow of the fluorescent indication).	They are less sensitive.
3.	They require a darkened area and ultraviolet light for inspection.	They do not require any darkened area and ultraviolet light for inspection.
4.	They are more vulnerable to contamination.	They are less vulnerable to contamination.

Characteristics of Good Penetrants (Principal Requirements of Penetrants)

A good penetrant should possess the following important characteristics

1. It should have the ability to penetrate discontinuities quickly and completely.
2. It should be easily drawn into discontinuities by capillary action.
3. It should remain in the discontinuity, but it should be easier to remove from the surface at the component.
4. It should remain in fluid state, so that it can be drawn back to the surface of the component through drying and developing steps.
5. It should be highly visible or fluoresce brightly to produce easy to see indications.
6. It should not be harmful to the material being tested or to the inspector
7. It should not exhibit any chemical reaction with the test component.
8. It should not evaporate or dry rapidly.
9. It should be non-flammable, odourless and non-toxic
10. It should possess stability under conditions of storage
11. It should be cohesive, adhesive and relatively low in cost.

Properties of Penetrants

The various properties of penetrants that can affect the result at the penetrant testing include:

1. Wettability (ie, surface wetting capability),
(i) Contact angle, and
(ii) Surface tension
2. Capillarity,
3 Viscosity,
4. Specific gravity,
5. Flash point,
6. Volatility,
7. Penetrant colour and fluorescence, and
8. Removability

1. Surface Wetting Capability (Wettability)

- The most important property of a penetrant is its surface wetting capability.
- *Wettability, also known as surface wetting capability, is the ability of the penetrant to freely wet the surface of the object being inspected*.
- The wettability of the penetrant depends on the factors such as contact angle and surface tension.

(i) Contact Angle

- The contact angle is the angle formed by the solid-liquid interface and the liquid-vapour interface measured from the side of the liquid, as shown in Figure below

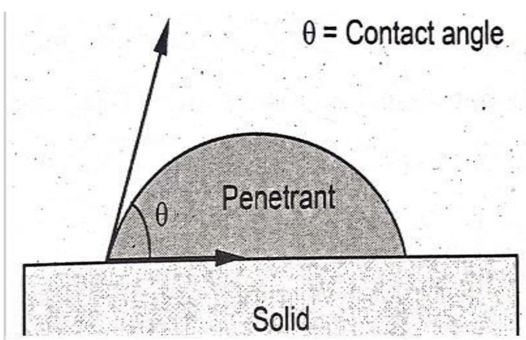

Figure. Measurement of contact angle

- Liquid wet surfaces when the angle is less than 90°
- For a penetrant material to be effective, the contact angle should be as small as possible.
- The contact angle for most liquid penetrant is very close to 0°.
- The wetting ability can be improved by adding a wetting agent which reduces the contact angle drastically.

(ii) Surface Energy (Surface Tension)

- The wetting ability of a liquid penetrant is s function of the surface tension for the surface energy) at the interface.
- *The surface tension or surface energy at the interface is a measure of the energy required to form a unit area of new surface at the interface*
- The intermolecular bonds or cohesive forces between the molecules of a liquid cause surface tension.

2. Capillarity

- Capillarity is the ability of the penetrant to fill a void.
- Penetrants are pulled into surface breaking defects by capillary action. The capaillary force driving the penetrant into the crack is a function of
    - the surface tension of the liquid-gas interface,
    - the contact angle, and
    - the size of the defect opening.

3. Viscosity

- Viscosity of a liquid is a measure of its internal resistance to flow
- The reciprocal of co-efficient of viscosity is called fluidity. Fluidity is a measure of the ease with which a liquid can flow.
- *Viscosity is an important factor in determining the speed with which a penetrant will enter the defect.*
- *In a nutshell, viscosity has little effect on the ability of a penetrant material to enter a defect, but it does have an effect on the speed at which the penetrant fills a defect.*

4. Specific Gravity

- Specific gravity is the ratio of the density of a substance to the density of distilled water at 4°C.
- Specific gravity has no direct effect on the performance of a penetrant.
- Most commercial penetrants have a specific gravity of less than one, primarily because they are made up of organic materials having low specific gravities.

5. Flash Point

- Flash point is the temperature at which sufficient flammable vapor is given off a liquid to form an explosive mixture in air over the liquid.
- *The flash point does not affect the performance of penetrant.*
- *High flash points are desirable to reduce the hazard of fire.*

6. Volatility

- Volatility is characterized by the vapour pressure or point of a liquid boiling
- *It is desirable for penetrants to have a low volatility Lea high boiling point But the viscosity of the penetrant increases as the boiling point increases*

7. Fluorescent Dye Thermal Stability

- The dyes used in fluorescent-dye penetrants lose the brightness or colour when subjected to elevated temperature This less is also known as heat fade"
- This thermal stability is an important consideration during her air drying before and after developer application.

8. Penetrant Colour and Fluorescence

- The colour of the penetrant is an important factor in a visible dye penetrant inspection.
- The dye used in the dye penetrant test should give good colour contrast against the developer or the surface to be inspected.

9. Removability

- A penetrant needs the following two conflicting requirements
    - the ability to be removed from a surface leaving little or no residual background, and
    - resistance to being removed from discontinuities.
- For better removability, the adhesive forces of the penetrant must be stronger than the cohesive forces.

DEVELOPERS

What are Developers?

- *Developer is an absorbant material capable of drawing traces of penetrants from the discontinuities back into the surface.*
- *The developer works to increase the thickness of the penetrant bleed-out to a level that exceeds the threshold of visibility*

Characteristics of Good Developers (Requirements of Developers)

A good developer should possess the following characteristics or properties:

1. The developer should have good absorption characteristics to maximize blotting of the penetrant.
2. It should be able to uniformly cover the surface with the thin, smooth coating.
3. It should provide a good contrast background for indications when colour-contrast penetrants are used.
4. It should be easily applied to the test specimen.
5. It should be easily wetted by the penetrant at the flaw.
6. It should be inert with respect to the test materials.
7. It should be non-toxic and compatible with the penetrant materials.

Types of Developers

There are four standard types forms of developers used (bused on the method that the developer is applied). They are:

1. Dry powder developers,
2. Water soluable developers,
3. Water suspendable developers, and
4. Nonaqueous developers

1. Dry Powder Developers

- *Dry powder developers are white fluffy powders that can be applied to a thoroughly dry surface in a number of ways*
- The developers can be applied to a test specimen
  (a) by dipping parts in a container of developer,
  (b) by using a puffer to dust parts with the developer, or (c) by placing parts in a dust cabinet where the developer is blown around

Advantages:

i. Inexpensive to use.
ii. Easy to apply
iii. Indications tend to remain brighter and more distinct over time.
iv. Can be easily cleaned from the surface after inspection.

Limitations:

i. Least sensitive to indications.
ii. It does not form contrast background, so it cannot be used with visible systems.
iii. It is difficult to assure entire part surface has been coated.

2. Water Soluable Developers

- *As the name implies, water salvable developers consist of a group of chemicals that are dissolved in water and form a developer layer when the water is evaporated away.*

Advantages:

i. Ease of coating the entire part.
ii. It can be easily cleaned from the surface after inspection.
iii. Fast and effective method of application
iv. It can be easily and completely removed after inspection by simple water rinsing.

Limitations:

i. Coating is translucent and provides poor contrast, which is not recommended for visual systems.
ii. Indications for water-washable systems are dim and blurred.

3. Water Suspendable Developers

- *Water suspendable developers consist of insolvable particles suspended in water.*
- Water suspendable developers require frequent stirring or agitation to keep the particles from setting out of suspension.
- Water suspendable developers are applied to test specimen in the same manner as water solvable developers. Then the test specimens are dried using warm air.

Advantages:

(i) Ease of coating the entire part.
(ii) Indications are bright and sharp.
(iii) White coating for good contrast can be produced which Works well for both visible and fluorescent systems.

Limitations:

(i) It requires frequent stirring or agitation.
(ii) Indications weaken and become diffused after time.

4. Nonaqueous Developers

- Nonaqueous developers suspend the developer in a volatile Solvent.
- Nonaqueous developers are typically applied by a spray gun on aerosol can.

Advantages:

i. It is the most sensitive form of developer.
ii. Easy to apply and ready to access surface.
iii. Very portable .Indications show up rapidly and are well defined.
iv. It does not require forced drying.

Limitations:

i. It is difficult to apply evenly to all surfaces.
ii. It is more difficult to clean test specimen after inspection.

EQUIPMENT FOR LIQUID PENETRANT TESTING

(Test Stations Used In Penetrant Testing)

The various stations/subunits used in a typical penetrant line Arrangement are:

(i) Draw and/or dwell stations
(ii) Penetrant and emulsifier stations,
(iii) Pre- and post-wash stations,
(iv) Drying stations,
(v) Developer stations,
(vi) Inspection stations, and
(vii) Cleaning stations.

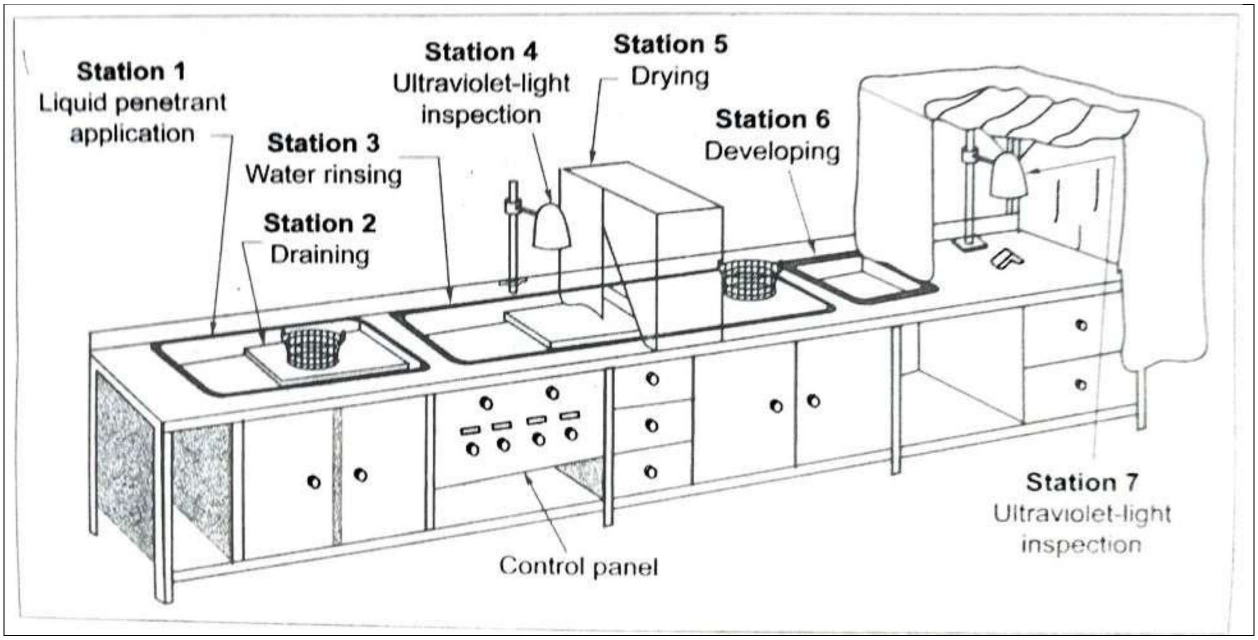

Figure. Equipment for Liquid Penetrant Testing

PENETRANT TESTING METHODS

(PENETRANT TECHNIQUES)

The methods/techniques of penetrant testing commonly used Are:

1. Water-washable penetrant technique,
2. Post-emulsifiable, penetrant technique, and
   (a) Post-emulsifiable, lipophilic, and
   (b) Post-emulsifiable, hydrophilic.
3. Solvent-removable penetrant techniques.

Water-Washable Penetrant Technique

What is it?

- *This technique uses a water-washable penetrant that can be used with either dry, aqueous, or non-aqueous developers.*
- Water-washable penetrant, also known as self-emulsifying penetrants, can be removed from the test specimen by rinsing with water alone.
- These water-washable contain an emulsifying agent (detergent) that makes it possible to wash the penetrant from the test surface with water alone

Process Flow Chart

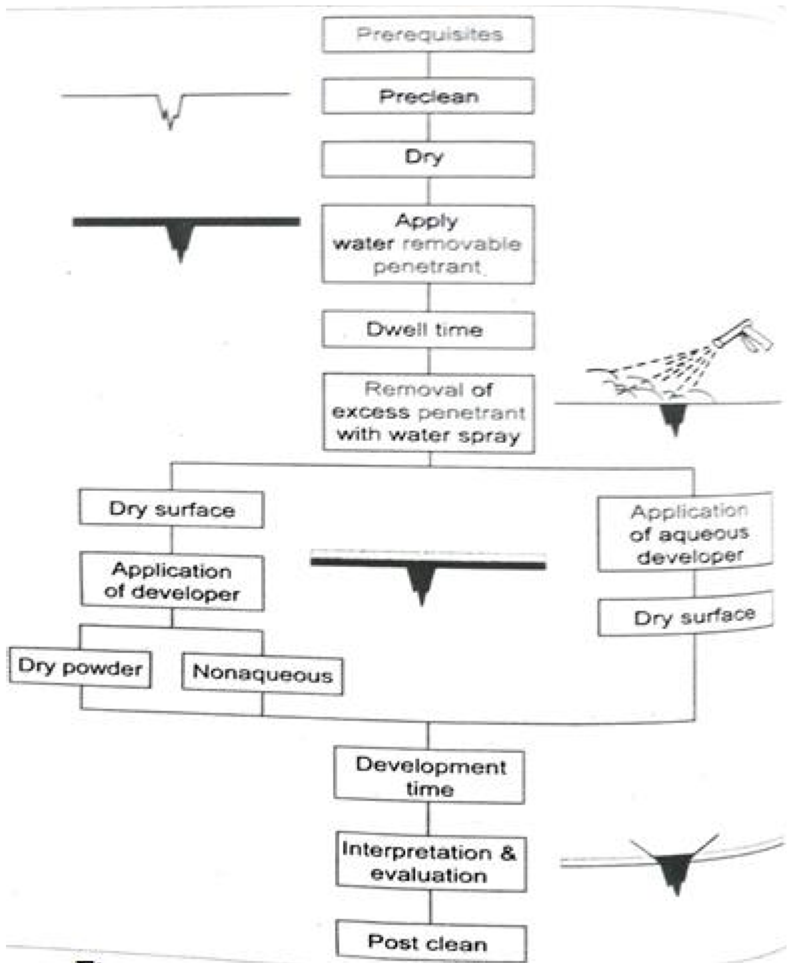

Figure *Process flow chart of water-removable technique*

Applicability

The water-washable penetrant technique is generally used in the following situations:

(i) When large surface areas or a large number of test parts are to be inspected;
(ii) When test parts to be examined have intricate and complex Configurations; and
(iii) When discontinuities that are not broad or shallow are anticipated.

Advantages

(i) Higher sensitivity.
(ii) Less costly.
(iii) Easy removal of excess penetrant.
(iv) Adjustable for inspection of large surfaces and large quantity of small parts.

Limitations

(i) Insensitive to shallow discontinuities.
(ii) Requires a darkened area for evaluation.
(iii) This technique is not portable.
(iv) Water contamination can degrade the quality of penetrants.
(v) Under- or over-removal of penetrant material is possible.

Post-Emulsifiable Penetrant Technique

What is it?

- *This technique was a post-emulsifiable penetrator, or lipophilic or hydrophilic emulsifier, and dry, aqueous or non-aqueous developers.*

- The post-emulsifiable penetrants are not directly water washable and they require the use of an emulsifier (oil or water base).
- Based On The type of emulsifier employed, the Post-emulsifiable method can be classified into two types:
  (a) Post-emulsifiable lipophilic method, and
  (b) Post-emulsifiable hydrophilic method.
- *In post-emulsifiable lipophilic method, the oil-based emulsifier is used to remove the excess penetrant from the test surface.*
- *In post-emulsifiable hydrophilic method, the water-soluable detergent based emulsifier is used to remove the excess penetrant from the test surface with a water wash.*

Process Flow Chart

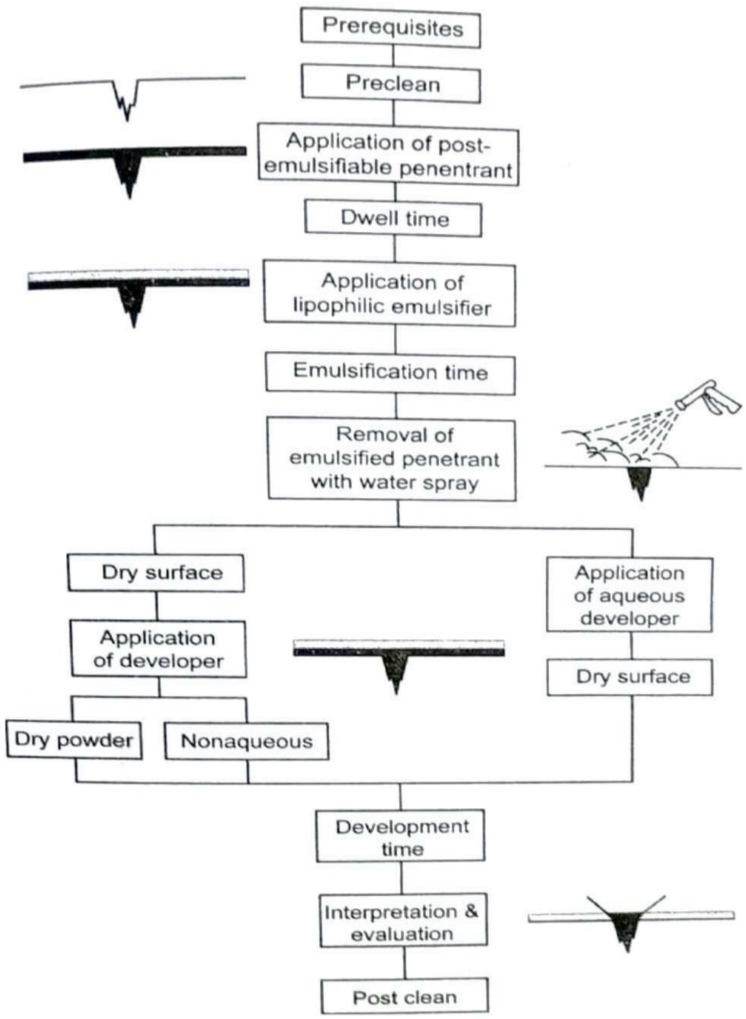

Figure *Process flow chart of post-emulsifiable lipophilic technique*

Applicability

The post-emulsifiable technique is generally used in the following situations:

(i) when a large quantity of test parts are to be inspected;

(ii) when discontinuities that are broad or shallow are Anticipated; and the detection of small discontinuities and stress cracks.

Advantages

(i) High sensitivity for the detection of smaller discontinuities
(ii) Sensitive to broad and shallow discontinuities.
(iii) Adaptable for inspector of large quantity of small parts.
(iv) Unaffected by acids easily.

Limitations

(i) This technique requires an emulsifier
(ii) Requires more time, due to the emulsifiable time.

(iii) Ineffective for complex and rough surfaces.
(iv) It is not portable.

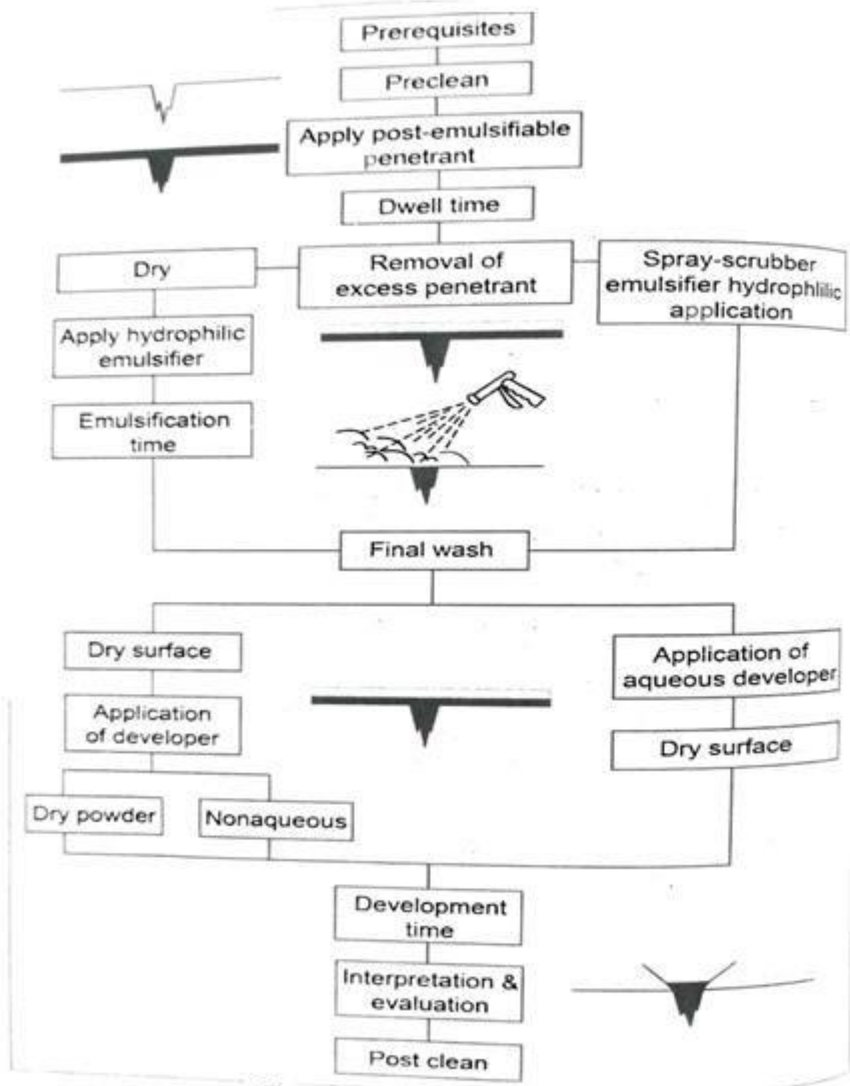

Figure *Process flow chart of post-emulsifiable hydrophilic technique*

Solvent Removable Penetrant Technique

- This technique uses a solvent-removable penetrant, a solvent cleaner/remover, and a non-aqueous developer.
- In the solvent-removable method, the excess penetrant is removed by wiping with clean, lint-free material moistened with a solvent remover.

Applicability

This solvent-removable technique is generally used in the following situations:

(i) When removal with water is not desirable due to part size, weight, surface condition, and water availability; or
(ii) When a heat source is not readily available for drying.

Advantages

(i) Can be used for spot examination or large parts.
(ii) This method is effective when water removal fails.

Limitations

(i) Limited to smaller surface areas.
(ii) Black light and dark environment are required.
(iii) Sensitivity reduces if excessive remover is applied.
(iv) Background indications may be generated

Process Flow chart

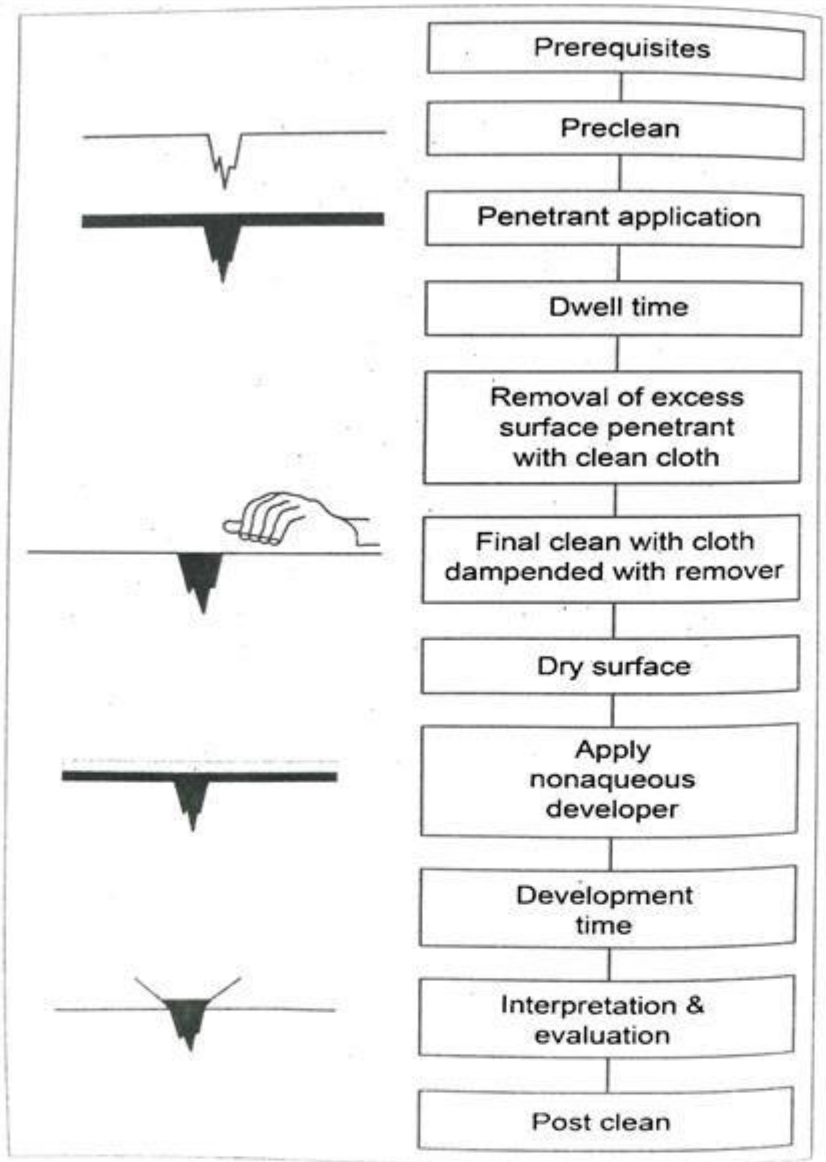

Figure ***Process flow chart of the solvent-removable penetrant technique***

APPLICATIONS OF LIQUID PENETRANT TESTING

Typical applications of liquid penetrant testing include:

(i) Inspection of tools and dies.

(ii) Inspection of tanks, vessels, reactors, piping, dryers, and pumps in the chemical, petrochemical, food, paper, and processing industries.

(iii) Inspection of diesel locomotive, truck, and bus parts (such as axles, wheels, gears, crankshafts, cylinder blocks, Connecting rods, cylinders, transmissions and frames).

(iv) Inspection of field drilling rays, drill pipe, castings, and drilling equipments.

(v) Inspection of aircraft engine parts, propellers, wing fittings, Castings and so on.

Illustration of Some Applications of Liquid Penetrant Testing

Leakage Testing using Liquid Penetrant

The liquid penetrant method is used not only for the detection of surface discontinuities but also to find leaks in a component or product.

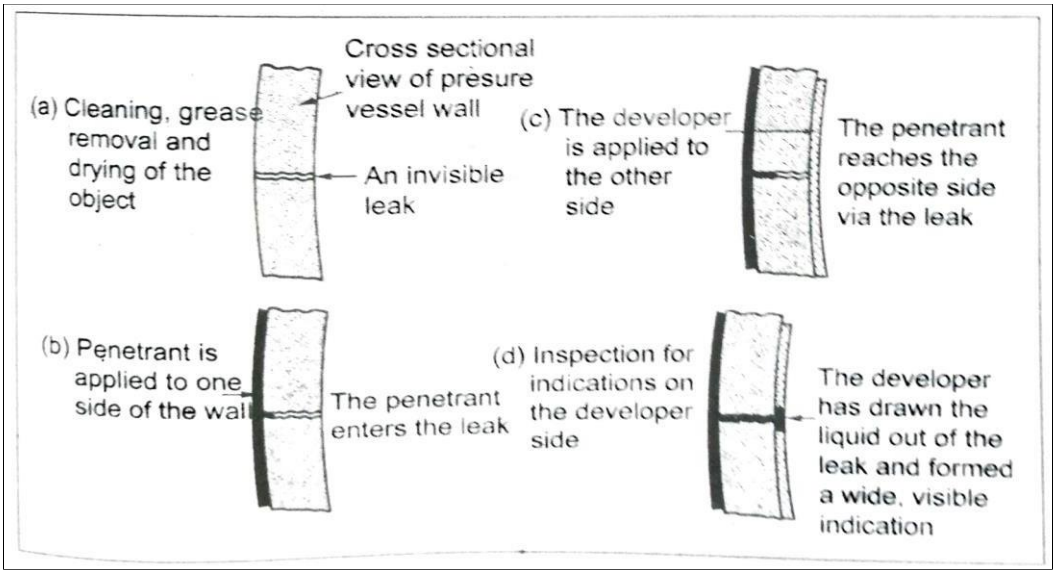

Figure. Leakage testing using dye penetrant

The above figure illustrates the leakage testing of an open tank, which is self-explanatory. It involves

(a) Cleaning, grease removal and drying of the component
(b) Penetrant is applied to one side of the component
(c) The developer is applied to the other side
(d) Inspection for indications on the developer side

Weld Inspection using Liquid Penetrant Testing

- The liquid penetrant testing method is widely used to detect the presence of surface flaws in a work piece, for example in the weld inspection applications.
- The weld inspection using liquid penetrants is carried out in rail tankers which carry chemicals, pressured gases, and toxic or corrosive liquids.
- The figure illustrates a typical sequence of operations for liquid penetrant inspection to detect the presence of surface flaw in a weld workpiece.

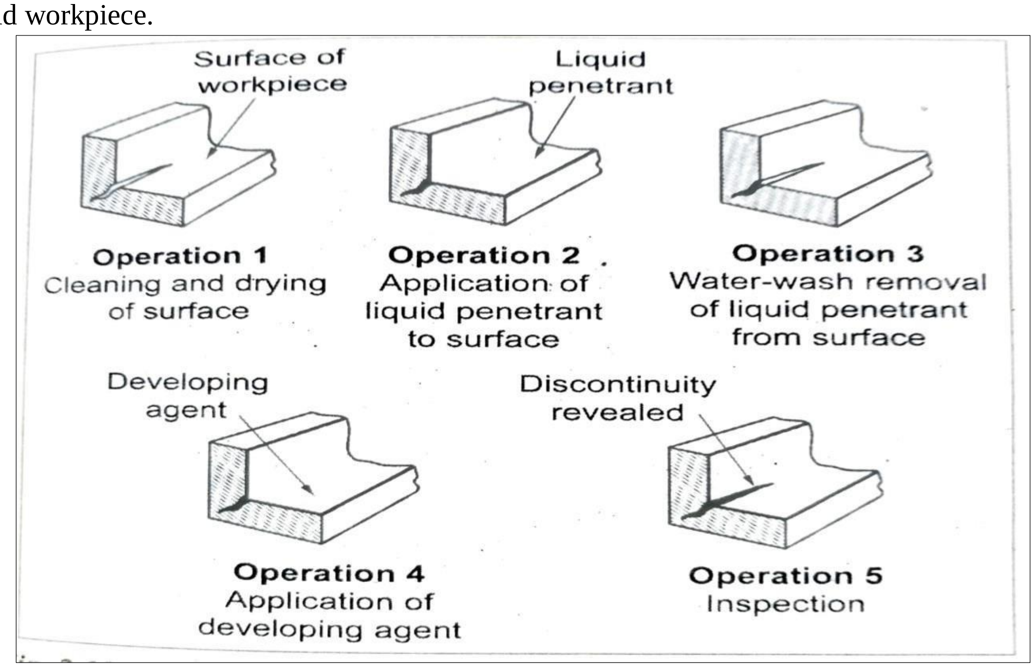

Figure. Weld Inspection using Liquid Penetrant Testing

MAGNETIC PARTICLE TESTING (MT)

INTRODUCTION

- *Magnetic particle testing (MT) is a non-destructive testing to locate surface and subsurface discontinuities in parts made by ferromagnetic materials.*
- Magnetic particle testing is governed by the laws of magnetism and is therefore restricted to the inspection of materials that can support magnetic flux lines.
- Non-magnetizing materials like austenitic stainless steel (paramagnetic) and gold, antimony, bismuth (diamagnetic) are difficult to identify defects by this method. Only those metals Classified as ferromagnetic (e.g., iron, nickel, cobalt) can effectively inspected by magnetic particle testing.

PRINCIPLE OF MAGNETIC PARTICLE TESTING

- In a Magnetized material, Surface and subsurface Discontinuities like cracks and seams, cause a break in the Magnetic uniformity or sudden change in the permeability These breaks in magnetic uniformity set up a minute magnetic Poles and leakage flux paths attract fine magnetic powder Particles to the discontinuity forming a reliable visual Indication of the discontinuity.

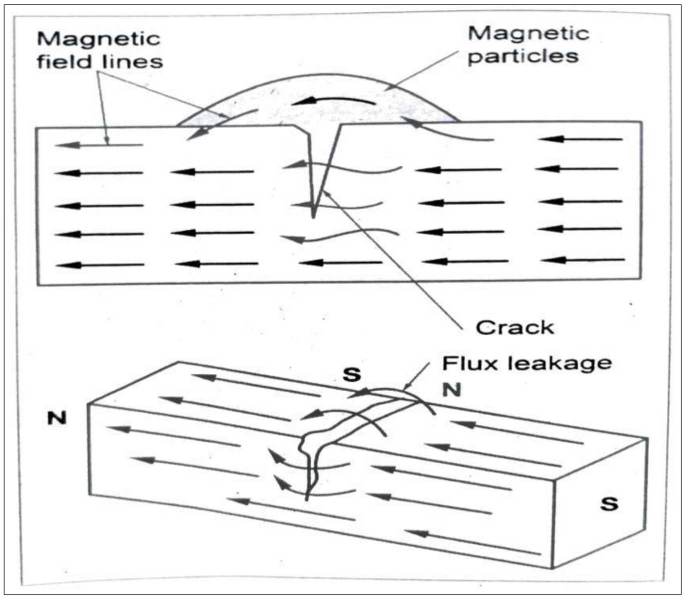

Figure. Basic Principle of magnetic particle testing

- In a magnetic material, there will be magnetic field in and around the material and the magnetic line of force exits the magnet from north pole and enters the south pole. When the magnetic field encounters a break in the magnetic field due to crack or inclusion, magnetic field disturbances are produced.
- This variation in the magnetic field can be identified by sprinkling magnetic particles on the surface of the part to be inspected. The particles will be attracted at the edges of crack. Critical investigation will reveal the pattern of defect in the Surface or subsurface of the part.

Advantages of Magnetic Particle Testing

Some of the advantages of magnetic particle testing are as follows:

(i) High sensitive and complex parts can be inspected rapidly.
(ii) Elaborate surface preparation is not required.
(iii) Low cost testing method and equipment are relatively inexpensive.
(iv) Portable (can be adapted for site or workshop).
(v) Large or small objects can be examined.

Limitations of Magnetic Particle Testing

Some of the limitations of magnetic particle testing are given below:

(i) Only ferromagnetic materials such as iron, steel, cobalt, nickel can be inspected.
(ii) Proper alignment of magnetic field is important to achieve good results.
(iii) Large currents are needed for very large parts
(iv) Only surface and near surface defects can be detected.
(v) This method cannot be used if a thick paint coating is present.

MAGNETIC PARTICLE TESTING PROCESS (Procedure of Magnetic Particle Testing)

To ensure satisfactory identification of surface and subsurface defects, following steps are essential in magnetic particle testing

Step 1: Cleaning,
Step 2: Demagnetization,
Step 3: Magnetizing,
Step 4: Addition of magnetic particles,
Step 5: Illumination,
Step 6: Interpretation, and
Step 7: Documentation and reporting.

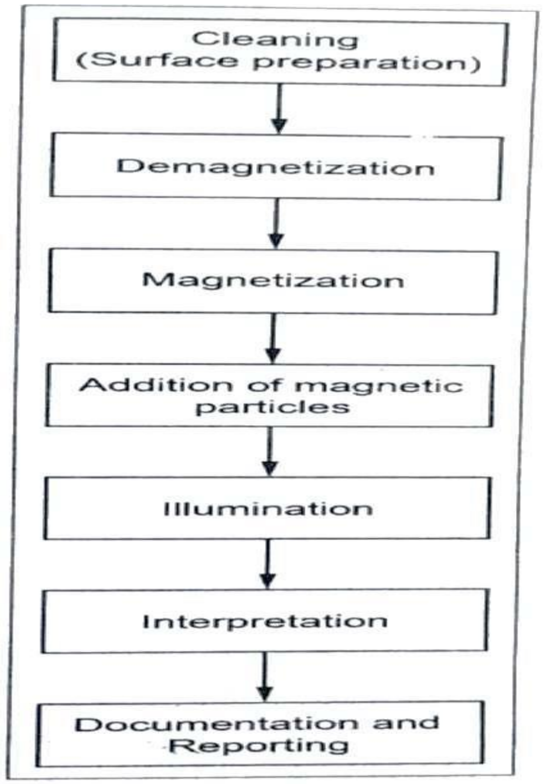

Figure. Various steps involved in magnetic particle testing

Step 1: Cleaning/Surface Preparation

- In order to identify the defects, it is necessary to remove rust Flakes and grease from the surface of inspection.
- If the surface is not cleaned thoroughly, it will restrict the free movement of the magnetic particles and being captured at the leakage area.
- Mechanical cleaning is carried out by using wire brushes of Sand blasting and degreasing is possible by using solvents.

Step 2: Demagnetization

- The parts used in magnetic field are susceptible to magnetize by continuous usage, then it is necessary to demagnetize it to eliminate poles.
- If it is not demagnetized, the residual magnetism in the part may mislead the .

Step 3: Magnetization

- To identify defects, the part to be examined must magnetized.
- Two different forms of magnetization methods are followed reveal the defects in the best possible manner. The method are:
  - (a) Longitudinal magnetization, and
  - (b) Circumferential magnetization.
- The magnetization is ensured by selection of current strength There are no precise rules to select current strength during magnetic particle inspection, but generic guidelines are followed.
- To inspect cylindrical objects, the current required is given by

l = 20 D

Where I = Current in amperes, and
D= External diameter of the cylindrical objects in millimetres.

- To inspect large surfaces by local electrode magnetization, about 4 amperes/centimetre electrode spacing is required.

Step 4: Addition of Magnetic Particles

- After magnetizing the part, magnetic particles are applied on the surface of inspection.
- The magnetic particles to be used must be available in powder Form, hence called as magnetic powder.
- **Two types of magnetic particles powder carrier agent as:**
  - (a) Dry powder (particles are carried by jet of air), and
  - (b) Wet powder (particles are suspended in liquid).

Step 5: Illumination

- To identify magnetic particles attracted near the defects illumination is necessary.
- Ordinary day light is sufficient, but it is possible to manage with artificial light like strong lamp which can be moved around to illuminate the surface of the object.
- When coloured or fluorescent powder is used, a sufficiently Strong ultraviolet light is used to achieve maximum sensitivity During inspection.

Step 6: Interpretation

- After magnetization and spreading of powder, indications are appeared on the surface of inspection due to piling up of magnetic powders at the defective area. It is the task of the examiner to evaluate the cause of the indications.
- A crack which is open to surface is easy to detect but in questionable situations, light polishing and magnifying glass can be helpful to determine the existence and type of defects.

Step 7: Documentation and Reporting

- Photographs are useful as a permanent record of the appearance of the defect.
- Another way of permanent record is taking tape impressions.
- When making tape impressions the defects are transferred to a report sheet by means of tape which is pressed against the top of each defective indication.
- A magnetic particle examination is of no value without a written report.

DRY AND WET PARTICLE INSPECTION TECHNIQUES

- Based on the types of magnetic particles used, magnetic particle testing techniques can be of two types:
  1. **Dry particle inspection technique, and**
  2. **Wet particle inspection techniques**

Dry Particle Inspection (or Dry Magnetic Particle Testing)

- In this technique, dry particles are applied onto the surface of the test object as the item is magnetized.
- Dry particle inspection is well suited for the inspections Conducted or rough surface.

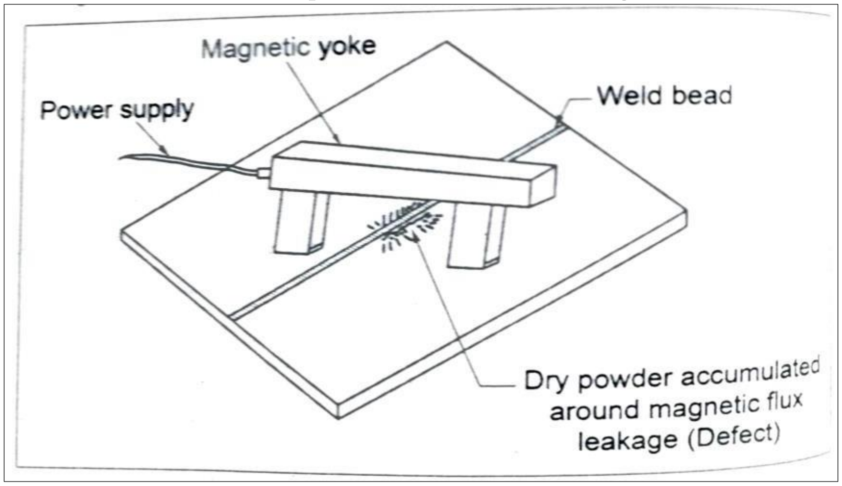

Figure. Dry powder inspection

Steps involved in dry particle inspection are as follows:

Step 1: Cleaning/surface preparation
Step 2: Demagnetization
Step 3: Magnetization
Step 4: Application of dry magnetic particles
Step 5: Blowing off excess powder
Step 6: Terminating the magnetizing force
Step 7: Inspection/interpretation

- The steps such as Cleaning, Demagnetization, Magnetization, Application and Inspection/Interpretation consist of exactly the same procedure as that of magnetic particle testing presented.
- In step 5 (i.e., blowing off excess powder), the excess powder is removed from the surface with a jet of air when the part is in magnetized condition.
- In step 6 (i.e., terminating the magnetizing force), the electromagnetic field used to generate magnetic flux should be terminated. This is achieved by switching off the power supply. If permanent magnets are used, they can be lifted from the surface of the part to terminate the magnetizing force**.**

Advantages:

Some of the advantaged of dry particle testing are as follows:

(i) Superior to the wet technique for detection of near surface discontinuities.

(ii) Highly suitable to inspect large objects when using portable equipment for local magnetization. (iii) Superior particle mobility is obtained for relatively deep seated flaws.

(iii) Easy to remove after inspection.

Disadvantages:

Some of the limitations of dry particle testing are given below:

(i) Cannot be used in confined areas considering safety.

(ii) Less accuracy in detection of fine surface discontinuities Compared to wet technique.

(iii) Difficult to use in overhead magnetizing positions.

(iv) Complete coverage of part surface is difficult as compared with wet technique.

Wet Particle Inspection (or Wet Magnetic Particle

- In wet particle inspection technique, the particles are applied while they are suspended in a liquid carrier.
- This technique is commonly performed using stationary, wet horizontal inspection unit.

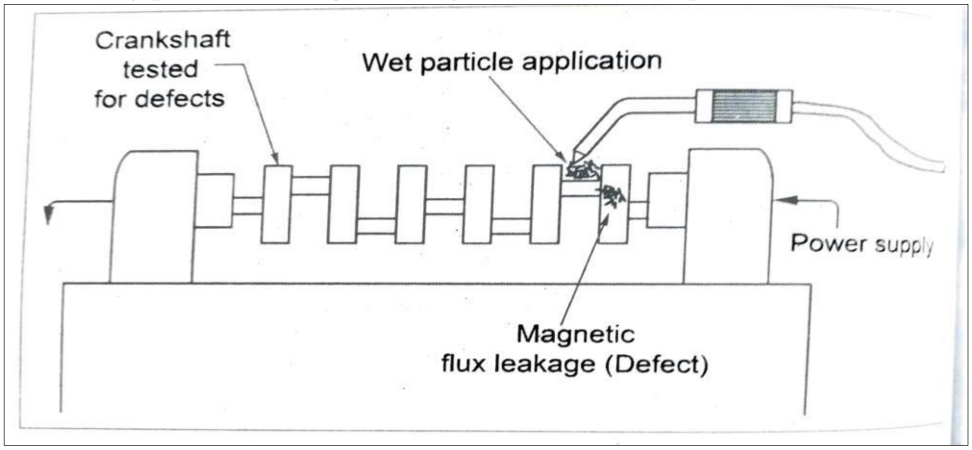

Figure. Wet Particle Inspection

- Suspension filled spray cans are also used with electromagnetic yokes.

The steps involved in wet particle inspection are as follows:

- Step 1: Cleaning/surface preparation
- Step 2: Demagnetization
- Step 3: Application of suspended magnetic particles
- Step 4: Magnetization
- Step 5: Inspection/interpretation

The above steps are already presented

- In step 3 (i.e., applications of suspended magnetic particles the suspension is gently sprayed or flowed over the surface the part. Normally, a stream of suspension is diverted from th part just before the magnetizing field is applied.

Advantages: Some of the advantages of wet particle testing are given below:

i. Surface of the part can be easily covered by the particle suspension.
ii. Liquid carrier provides mobility to the particles.
iii. Best results are possible in detection of very small cracks On smooth surfaces.

OVERVIEW OF MAGNETISM

Theory of Magnetism

- The material or object that produces a magnetic field is called magnets. The magnetic field can be described by imaginary lines and is responsible for the most important properties of magnet.

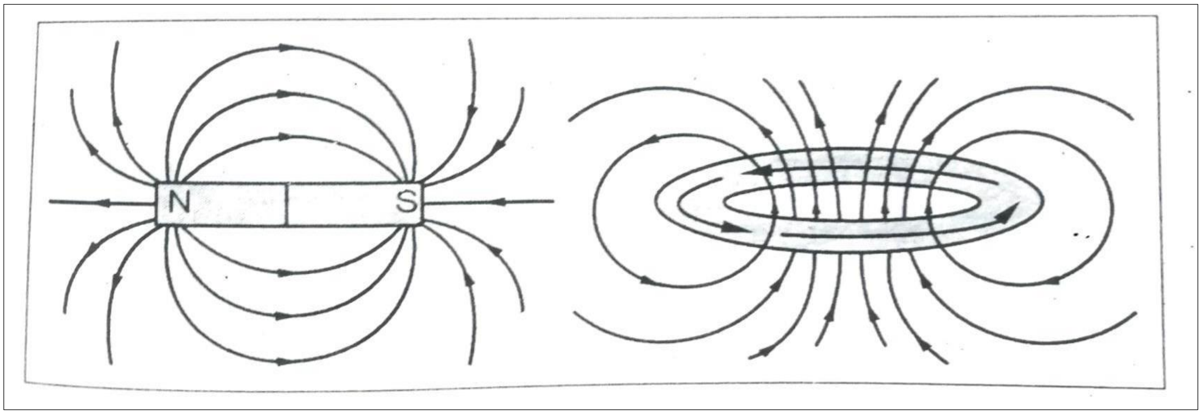

Figure. Magnetic lines of force and a current loop

- If a magnetic piece (ferromagnetic material) is cut into smaller pieces, each piece is a magnet with a north (N) or south (S) pole, Therefore a magnet can be said to be made of lots of 'tiny' magnets all lined up with their N poles pointing in the same direction.

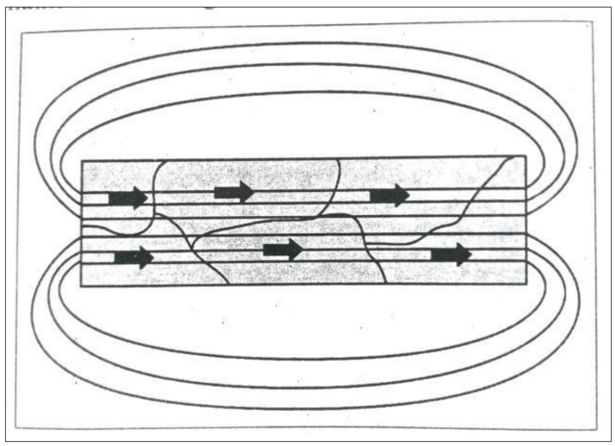

Figure. Aligned domains showing same direction of poles

<u>Magnetic Properties and Hysteresis Loop</u>

- When a ferromagnetic material is magnetized in one direction, it will not relax back to zero magnetization even after the imposed magnetizing field is removed.
- If an alternating magnetic field is applied to the material, its magnetization will trace out a loop called a hysteresis loop.
- The lack of retraceability of the magnetization curve is the Property called hysteresis and it is related to the existence of Magnetic domains in the material.
- The loop is generated by measuring the magnetic flux of a ferromagnetic material while the magnetizing force is changed.
- A hysteresis loop shows the relationship between the induced magnetic flux density (B) and the magnetizing force (H).

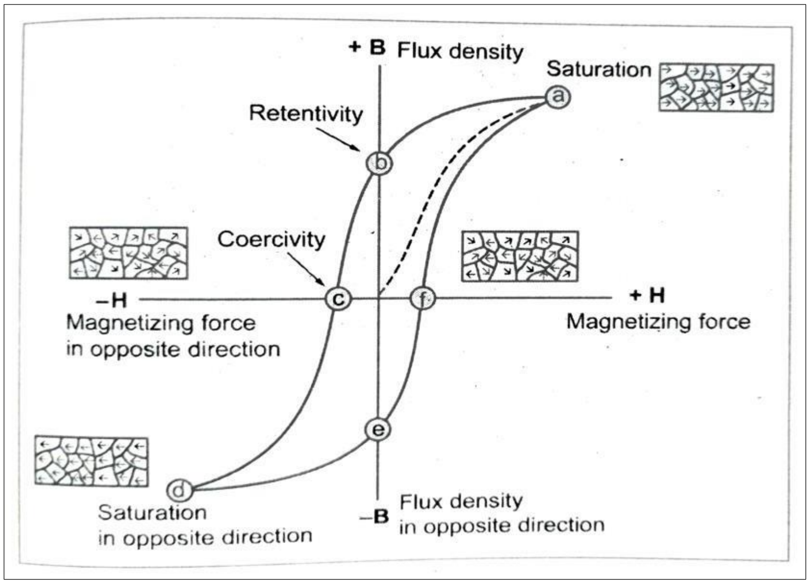

Figure. Hysteresis loop

From the hysteresis loop following observation can be made:

- The dashed line will follow a non-linear magnetization curve as H is increased. (As the line demonstrates, the greater the amount of current applied (H+), the stronger the magnetic field in the component (B+).
- At point 'a' the material is magnetized to saturation by alignment of domains.
- When applied current (H) is reduced to zero, the curve will move from point 'a' to 'b'. (At point 'b' some magnetic flux remains in the material even though the magnetizing force is zero; some residual magnetism present in the material).
- As the magnetizing force is reversed, the curve move to point 'c'. The magnetic flux has been reduced to zero and the point is called **point of coercivity** on the curve.
- As the magnetizing force is increased in negative direction, the material will again become magnetically saturated but in opposite direction at point 'd'.
- Reducing applied current (H) to zero brings the curve at point 'e'. Some residual magnetic present in the material but in opposite direction.
- Increasing applied current (H) in the positive direction Will return B to zero.
- From the curve it is evident that, the curve will take different path from the original because some force is required to remove residual magnetism.

Primary magnetic properties determined from the hysteresis loop are given below:

(i) **Retensivity:** It is a material's ability to retain a certain Amount of residual magnetic field, when a magnetizing Force is removed.

(ii) **Residual magnetism**: The magnetic flux density that remains in a material when the magnetizing force is zero.

(iii) **Coercive force:** The amount of reverse magnetic field which must be applied to a magnetic material to make the magnetic flux return to zero.

(iv) **Permeability:** A property of a material that describes The ease with which a magnetic flux is established in the component.

(v) **Reluctance:** It is the resistance in the establishment of magnetic field in ferromagnetic material.

MAGNETIC FIELD ORIENTATION IN MAGNETIC PARTICLE TESTING

- In magnetic particle testing, the orientation of magnetic line of force is important in detection of cracks or other defects
- There are two general types of magnetic fields that can be established within a component. They are:
  1. Longitudinal magnetic field, and
  2. Circular magnetic field.

Longitudinal Magnetic Field

- A longitudinal magnetic field has magnetic lines of force that run parallel to the long axis of the part.
- Longitudinal magnetization of a component can be accomplished using the longitudinal field set up by a coil or solenoid. It can also be established by permanent magnets or electromagnets.

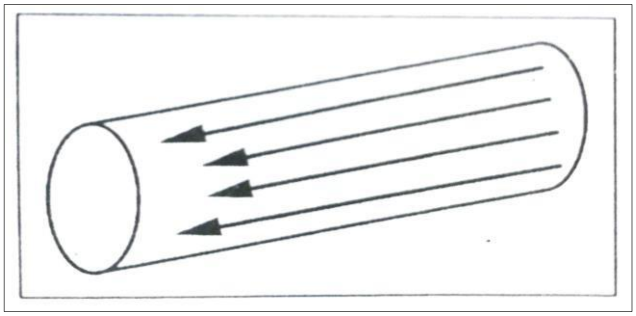

Figure. Longitudinal magnetic field

Circular Magnetic Field

- A circular magnetic field has magnetic lines of force that run circumferentially around the perimeter of a part.
- A circular magnetic field is induced in the component by either passing current through the component or by passing current through a conductor surrounded by the component.

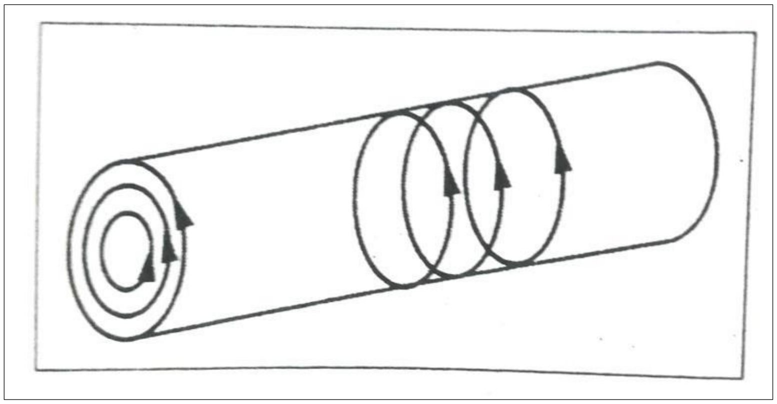

Figure. Circular Magnetic Field

Flaw Detectability

- Magnetizing 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.
- The orientation creates the largest disruption of the magnetic field within the part and the greater flux leakage at the surface of the part.
- Defects may occur in various and unknown directions. Each Part is normally magnetized in two directions at right angles to each other.

<u>EQUIPMENT USED IN MAGNETIC PARTICLE TESTING</u>

The main categories of equipment used in magnetic particle Testing are:

1. Magnetization equipment,
2. Portable power supplies, and
3. Lighting equipment.

Magnetization Equipment in Magnetic Particle Testing

- The primary requirement for detecting a defect in a ferromagnetic material is that the magnetic field induced in the part must intercept the defect at 45 to 90degree angle.
- Flaws that are 90 degrees to the magnetic field will produce the strongest indications because they disrupt more of the magnetic flux.
- Magnetic particle testing equipments are broadly classified on the basis of portability as:
    1. Portable magnetization equipment, and
    2. Stationary magnetization equipment.

Portable Magnetization Equipment

- Portable magnetization equipment are suitable for inspection in the field.
- Typical portable magnetization equipment used are:
    (i) Permanent magnet,
    (ii) Electromagnetic yokes,
    (iii) Prods, and
    (iv) Portable coils.

Permanent magnet

- Permanent magnets, like bar magnets or horse shoe magnets, can be used for magnetic particle inspection as the source of magnetism
- Permanent magnets can be made small enough to fit into the tight areas where electromagnets might not fit.
- Permanent magnets are sometimes used by divers for inspection in underwater environments or other areas, where electromagnets cannot be used for safety considerations.

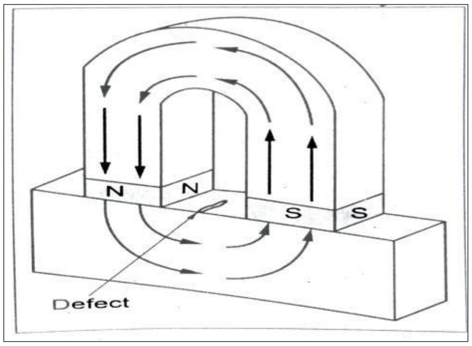

Figure. Permanent magnet producing magnetic field

(ii) Electromagnetic Yokes

- Higher portability can be achieved by using electromagnetic yokes. This unit can be used with AC and is also available in DC from a battery pack.
- This type of magnets generates a very strong magnetic field in a local area where the poles of the magnet touch the part being inspected.
- Many yokes have adjustable legs to facilitate various inspection area profiles.
- Figure shows the AC yoke used in inspection of part by producing longitudinal magnetic field to detect transverse crack.

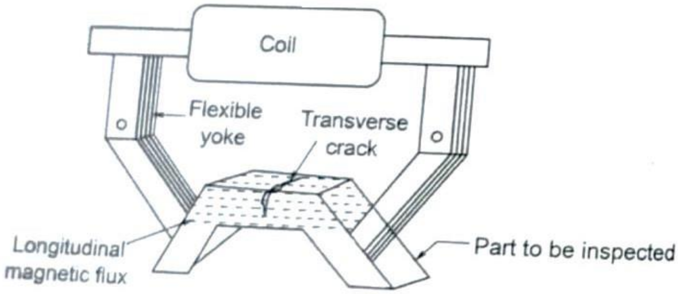

Figure. Portable electromagnetic yoke in detection of transverses crack

(iii) Prods

- Prods are handheld electrodes that are pressed against the surface of the component to be tested. The current passing between the prods creates a circular magnetic field around the prods, which is used to detect the defects.
- Prods are typically made from copper and have an insulated handle to help protect the operator.
- Prods are provided with a trigger switch to control the current supplied. If two prods are connected by an insulator, then the device is called dual prod and is extensively used for weld inspection.
- While using prods, caution is required to avoid electric arcing to prevent damage to the surface of the component.

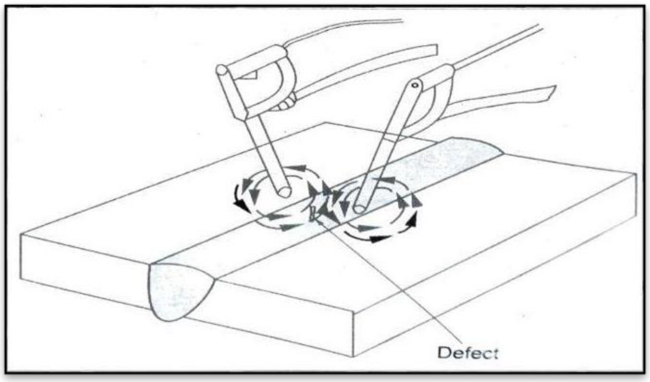

Figure. Prod used in detection of defects

(iii) Portable Coils

- Portable coils are used to establish a longitudinal magnetic field within a component.
- The magnetic field in parallel to the axis of the component. When a preformed coil is used, the component is placed inside the surface of the coil. The component becomes the core of Electromagnet and is magnetized by induction from the magnetic field created in the coil.
- Coils are normally have three to five turns of copper cable within the moulded frame. A control switch is used to energize the coil.

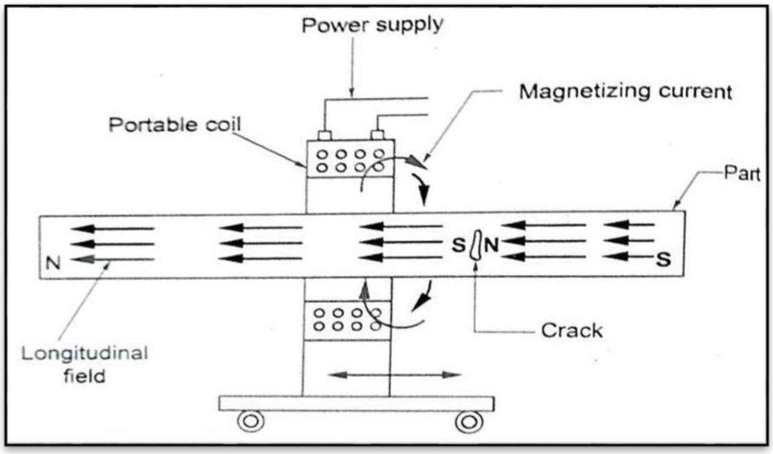

Figure. Portable coil in detection of cracks

2. Stationary Magnetization Equipment

- Stationary magnetic particle inspection equipment is designed for use in laboratory or production environment.
- The most common stationary system is the wet horizontal unit. This unit is provided with a fixed head-stock and a sliding tail-stock.
- The part is placed between the head-stock and tail-stock and Gripped by pneumatic chuck to permit current to flow, thereby producing a circular magnetic field.

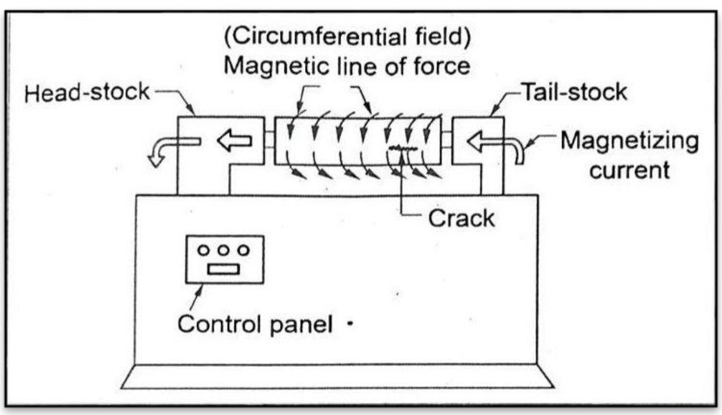

Figure. Stationary unit

- The wet magnetic particle solution is collected and held in a tank. A pump and hose system is used to apply the particle solution to the component being inspected.
- To inspect a part, the part is clamped between head-stock and tail-stock with the help of electrical contact pads. The magnetic solution, called bath, is then flowed over the surface of the part.
- The bath is then interrupted and a magnetizing current is applied to the part for a short duration (0.5 to 1.5 seconds). A circular field flowing around the circumference of the part is created.
- Magnetic particles attracted around the leakage field area Indicate defects on the surface.
- Some of the units are capable of producing longitudinal fields and demagnetization of the parts.

Portable Power Supplies

- Portable equipment like prods, coils and cables need Supply to energize it during inspection of components.
- Power supplies are available in different sizes according to the requirement
- Small power supplies generally provide upto 1500 A. The Power supplies can be operated both AC and DC.
- When higher power is required, mobile power supplies are used. These are capable of operating with 120 V or 240 V can provide upto 6000 A.

Lights in Magnetic Particle Inspection

- Magnetic particle inspection is basically a visual inspection Method after magnetizing and application of metal powder Therefore, sufficient lighting is important to identify the defects.
- The lighting requirements are different for inspection with Colored or fluorescent particles.

i. Lighting for visible coloured particles

- ➢ When coloured particles are used, ordinary day lighting is Enough. But natural day lighting changes from time to time, the use of artificial lighting is recommended results get better result.
- ➢ To manage with artificial light, a strong hand lamp which can be moved around by hand to illuminate the object. Halogen lamps are widely used to produce white light.

ii. Lighting for fluorescent particles

- ➢ When magnetic particle testing is carried out with fluorescent Particles, sufficiently strong ultraviolet light must be available. Mercury vapour lamps with filters are used to fluoresce the particles.
- ➢ A filter is used to filter the unwanted white light and harmful UV radiation and allows the harmless portion ultraviolet spectrum with a wavelength of 365 nanometers (nm). The condition of the filter must be regularly checked to ensure filtration of harmful UV and white light.

EQUIPMENT USED IN DETERMINATION OF MAGNETIC FIELD STRENGTH AND DIRECTION

- ➢ The strength of the magnetic field and direction is important in magnetic particle testing.
- ➢ To check the adequacy of field strength and direction various equipment are used.
- ➢ Some of the main equipment used in determination of Magnetic field strength and direction are:

1. Hall-effect (or Gauss meter),
2. Pie gauge,
3. Quantitative quality indicator (QQI), and
4. Slotted strips.

(1) Hall-Effect meter (Gauss Meter)

Gauss meter is generally used to measure the tangential field strength on the surface of the part.

Most commonly used Hall-effect meters are:

(1) Transverse probe, and

(2) Axial probes.

Transverse probes: Transverse probes have the Hall. Effect element mounted on a thin, flat stem and they are used to make measurements between two magnetic poles.

Axial probes: Axial Hall-effect probes have the sensing element mounted such that the magnetic flux in the direction of the long axis of the probe is measured.

- ➢ The Hall-effect voltage is a function of the angle which the magnetic lines of flux pass through the sensing element.
- ➢ When the line of flux pass perpendicularly (90 degrees) through the sensing element, highest Hall-effect voltage can be recorded.

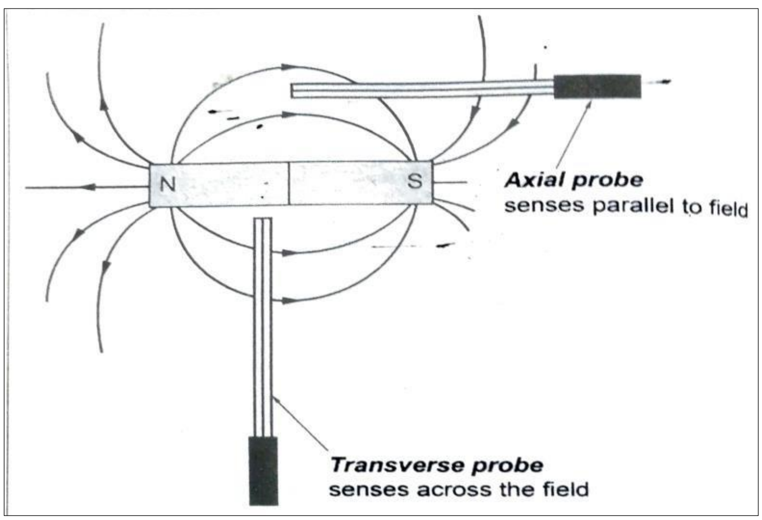

Figure. Hall effect gauss meter with probes

(2) Pie Gauge

- ➢ The pie gauge is octagonal shaped disk made by highly permeable low certain speed segments, joined together by brazing. One side of the octagonal flat plate is plated with copper to hide the joint lines.
- ➢ The gauge is placed on the test specimen during magnetization, with its copper face up.

- The particles are applied to this face and the orientation of the resultant field is displayed by the indications produced at the Joint lines.
- Pie gauges are widely used on flat surfaces like steel casings and weldments where dry powder is used with yoke or prods.

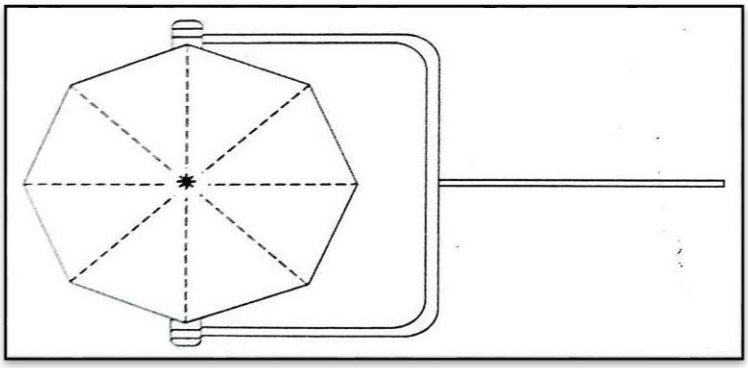

Figure. Pie Gauge

(3) Quantitative Quality Indicator (QQI)

- The quantitative quality indicator (QQI) is an artificial flat standard used for calibration of magnetic field strength direction.
- It is made up of thin steel strip with a thickness of 0.05 to 0.1 mm and specific patterns are etched on the surface.
- To ensure intimate contact with the part being inspected, the QQI is taped or glued with etched side down.
- By spreading magnetic particles over the component, the particles get adhered on the part surface provides information about the Field direction.
- For better results, the part surface must be clean and dry.

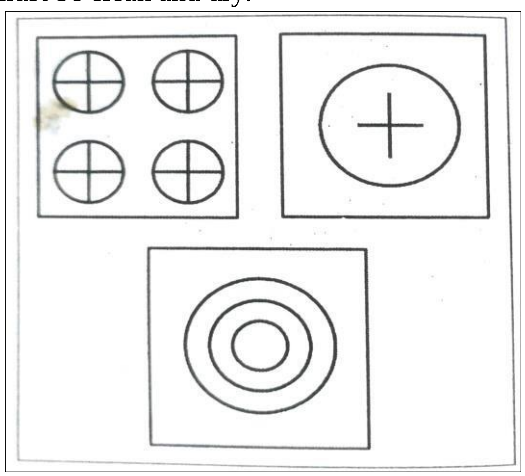

Figure. Quantitative quality indicators

(4) Slotted Strips

- Slotted strips, also known as **Burmah-castrol strips**, are pieces of highly permeable ferromagnetic material with slots of different widths. They are placed on the object and magnetic field is established.
- The indicators produced on the strips give the idea of the field strength. These strips can be used with wet or dry method.

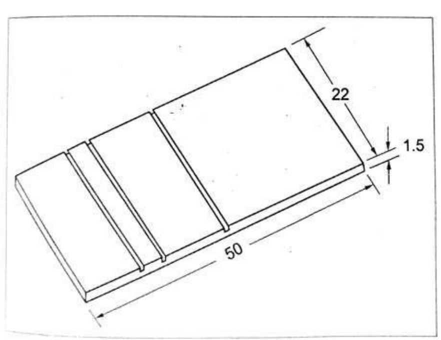

Figure. Slotted strips

MAGNETIC PARTICLES

- Magnetic particle testing is performed by inducing magnetic field in ferromagnetic material and covering the surface with magnetic particles. Hence magnetic particles are key ingredient in magnetic particle testing and shows the defects on the surface when the flux leakage is occurred.

Characteristics Magnetic particles must possess the following characteristics:

1. High permeability (maximum response in flux leakage field).
2. Low retentivity (will not be remain magnetized when the magnetic field is removed).
3. Shape should be smooth and have high degree of mobility.
4. Non-toxic, free from rust, grease and dirt.
5. No hazard potential with regard to flammability and Toxicity.

Types: The three types of magnetic particles are:

1. Iron oxide particles,
2. Pure iron particles, and
3. Fluorescent particles.

1. Iron Oxide Particles

- Iron oxide particles are finer and lighter and can be used to detect small and critical discontinuities.
- Shape of the iron oxide particles can be controlled by the oxidation and reduction process.
- The iron oxide will remain in the discontinuity more effectively than pure iron particles and stay in suspension with Simple agitation.
- Iron oxide particles are highly suitable for wet particle inspection method.

2. Pure Iron Particles

- The pure iron particles are larger in particle size and can be used to detect medium to large discontinuities.
- These particles are made by milling process and reduced to required size in various stages of machining processes.
- The geometry and size of these particles will render a much brighter particle than the iron oxide particle.
- A coloring agent like paint also bonded to the surface of the particles for better visibility during inspection.
- These pure iron particles will migrate quicker to the discontinuity than the iron oxide and they are suitable for dry particle inspection technique.
- The iron particles will not stay in suspension as easy as the iron oxides and requires a more aggressive constant, agitation, if it is used in wet particle inspection.

3. Fluorescent Magnetic Particles

- Fluorescent magnetic particles are used when higher possible sensitivity is required during inspection.
- It is actually just ordinary magnetic powder where thin layer of fluorescent material has been applied to the individual particle.
- When the object is observed under suitable lighting, the defects will be visible as bright indicators.

DEMAGNETIZATION

- When ferromagnetic materials are subjected to magnetic particle testing, there will be a certain amount of magnetism retained with the part even after removal of magnetic current. This magnetic is called as "residual magnetism".
- The residual magnetic field is considered harmful when it interferes with subsequent machining operations due to attracted magnetic particles on the surface which will increase friction and wear.
- Demagnetization can be accomplished by several ways. Two methods of demagnetizations that are being generally followed are:
  1. Reversing the polarity with lower level field strength, and
  2. Heating the material above curie temperature.

Reversing the Polarity

- Demagnetization can be achieved by reversing the current application i.c., opposite direction to the previously applied force and will be at lower level. It should be below the saturation point, but must be above that required to produce a higher flux field than the retained magnetism.
- The most satisfactory method of demagnetization using AC is to gradually reduce the applied current to zero. AC demagnetization is preferred, due to its inherent reversing nature.

Heating the Material

- Complete demagnetization is possible by heating the part to a temperature above its curie point and allowing it to cool without any magnetizing force acting upon it.
- Curie point is the temperature at which steels lose their permanent magnetic properties.

- If this can be accomplished, the residual field will be totally removed and the part will be totally demagnetized. The curie point for steels various from 720°C to 800°C.
- But this method is not convenient to heat the material above its curie temperature by considering the size of the part and subsequent production stages.

APPLICATIONS OF MAGNETIC PARTICLE INSPECTION

- The magnetic particle test method is effective for the detection of surface and subsurface defects on ferromagnetic parts.
- Using magnetic particle testing, surface defects can be detected safely even along complex geometries of the casting, forging and welded parts.
- Due to simplicity, the magnetic particle testing shows a very high potential to inspect
  parts during production and in service.
- Magnetic particle inspection found wide applications during manufacture of parts. Discontinuities detectable during manufacturing are:

1. In metal forming:

- Forging bursts (cracks)
- Rolling seams
- Casting hot tears

2. In heat measurement:

- Quenched and heat cracks

3. In machining:

- Grinding cracks Machining tears

4. In welding:

- Longitudinal and transverse crack in welding
- Lack of fusion
- Incomplete penetration
- Inclusions
- Entrapped slag