UNIT V DESIGN OF WELD JOINTS, WELDABILITY AND TESTING OF WELDMENTS

TYPES OF WELDED JOINTS

Welding joints is an edge or point where two or more metal pieces or plastic pieces are joined together. The two or more workpieces (either metal or plastic) are joined with the help of a suitable welding process to form a strong joint.

There are five different types of welded joints for bringing two parts together for joining.

Five types of welded joints are butt joint, corner joint, lap joint, tee-joint and edge joint.

1. Butt joint:

The joint which is formed by placing the ends of two parts together is called butt joint. In butt joint the two parts are lie on the same plane or side by side. It is the most simplest type of joint used to join metal or plastic parts together.

The different weld types in butt welding are

(i) Square Butt weld

(ii) Bevel groove weld

(iii) V-groove weld

(iv) J-groove weld

(v) U-groove weld

(vi) Flare-V-groove weld

(vii) Flare-bevel-groove butt weld

2. Corner joint:

The joint formed by placing the corner of two parts at right angle is called corner joint (see fig above). Two parts which is going to be weld with corner joint forms the shape of L.

The different weld types in corner joint are as follows

(i) Fillet weld

(ii) Spot weld

(iii) Square-groove weld or butt weld

(iv) V-groove weld

(v) Bevel-groove weld

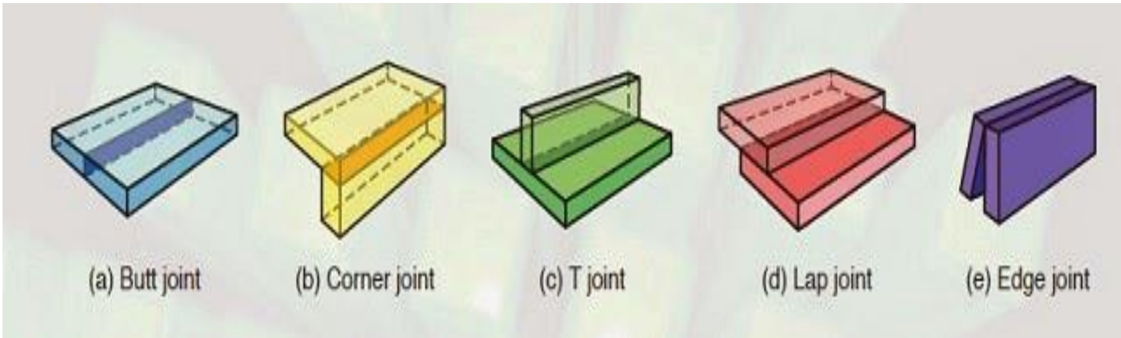
(vi) U-groove weld

(vii) J-groove weld

(viii) Flare-V-groove weld

(ix) Edge weld

(x) Corner-flange weld



3. Lap joint:

The lap joint is formed when the two parts are placed one over another and than welded (see fig above). It may one sided or double sided. This types of welding joints are mostly used to join two pieces with different thickness.

The Various weld types in lap joint are

(i) Fillet weld

(ii) Bevel-groove weld

(iii) J-groove weld

(iv) Plug weld

(v) Slot weld

(vi) Spot weld

(vii) Flare-bevel-groove weld

4. Tee-joint:

he joint which is made by intersecting two parts at right angle (i.e at 90 degree) and one part lie at the centre of the other. It is called as T joint as the two part welded look like english letter ‘T’.

The types of welds in T joint are as follows

i) Fillet weld

(ii) Plug weld

(iii) Slot weld

(iv) Bevel-groove weld(

v) J-groove weld

(vi) Flare-bevel groove

(vii) Melt-through weld

5. Edge joint:

The joint formed by welding the edges of two parts together are called edge joint. This joint is used where the edges of two sheets are adjacent and are approximately parallel planes at the point of welding. In this joint the weld does not penetrates completely the thickness of joint, so it cannot be used in stress and pressure application.

The various weld types in this welding joint are:

(i) Square-groove weld or butt weld

(ii) Bevel-groove weld

(iii) V-groove weld

(iv) J-groove weld

(v) U-groove weld

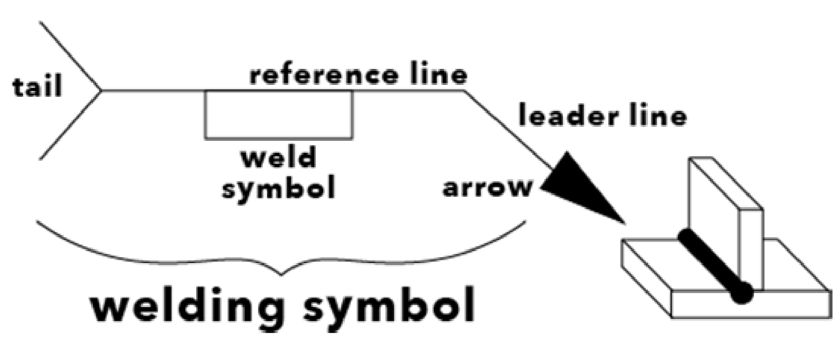
(vi) Edge-flange weld

(vii) Corner-flange weld

6.(b).(i) Draw neat sketches and explain the welding symbols and sectional representation form of weld

Welding symbols are used to communicate between the designer and the welder. Most blueprints for a welding project heavily peppered with them. The skeleton of a welding symbol has an arrow, a leader line (attached to the arrow), a horizontal reference line, a tail, and a weld symbol (not to be confused with *welding symbol*, which refers to the whole thing.

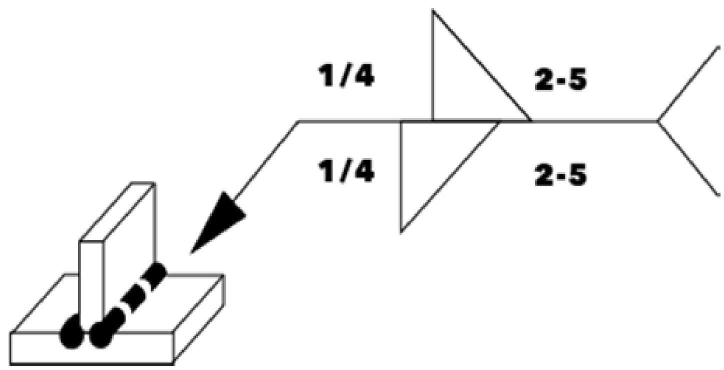
1



The arrow and leader line point to the joint in question, while the weld symbol tells you what type of weld to do. If the weld symbol is below the reference line (such as in symbol 1), the weld should be made on the same side as the arrow. If the weld symbol is above the reference line, the weld should go on the side opposite the arrow.

If the symbol appears on both sides the weld must be performed on both sides of the joint (see symbol 2).

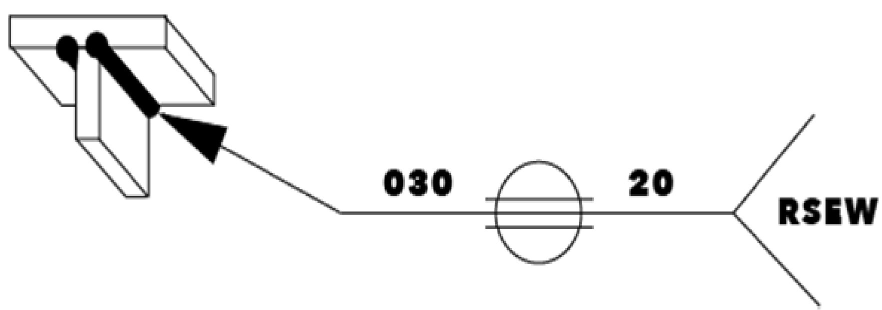
2



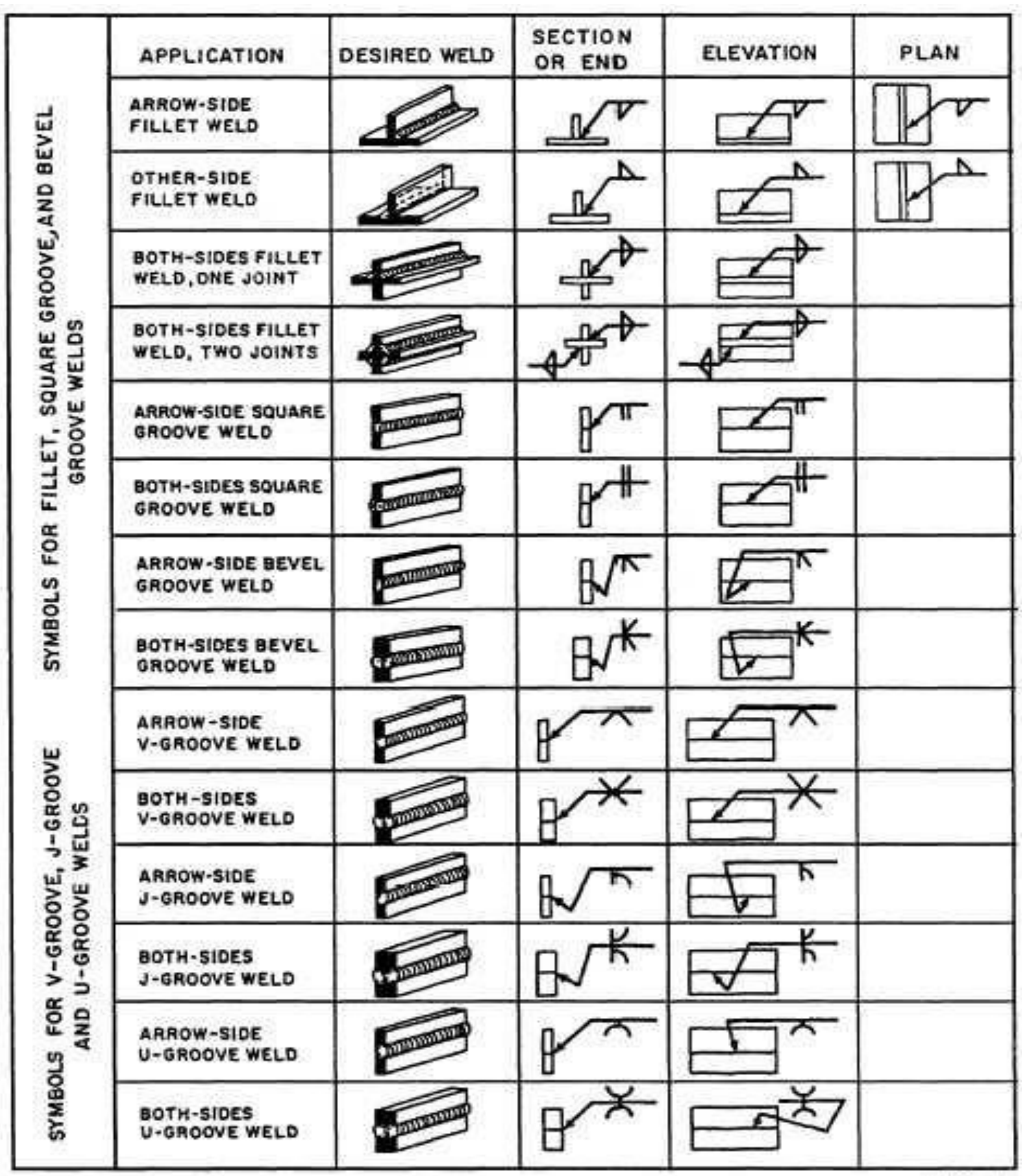
But if there are two weld symbols that are slightly offset (symbol 2)? This means you need to perform a weld that is actually a bunch of smaller welds. In this case, the welding symbol will include numbers to the left and right of the weld symbol (tricky, we know). The number to the left indicates the width of the weld (or diameter) while the number on the right indicates the length. In the case of symbol 2 above, the number to the right will give you the length of the increment first (which is 2), then the pitch (distance between centers of increments), which in this case is 5.

In the case of symbol 3, since the weld symbol is not offset, the numbers refer to the length of the whole weld. This means that the weld will not be completed in segments, but rather will be 20 units in length from start to finish.

3



There may be special instructions included in the tail of the welding symbol (see symbol 3). Generally this tells the welder to use a particular type of welding or to pay attention to a certain detail. If nothing is included in the tail, the tail is considered optional and can even be left off entirely.
The following table shows various types of welded joints and their symbols.



WELDABILTY

The weldability, also known as joinability, of a material refers to its ability to be welded. Many metals and thermoplastics can be welded, but some are easier to weld than others

Weldabilty and general guidelines to weld stainless steel and aluminum materials.

Stainless steels are chosen because of their enhanced corrosion resistance, high temperature oxidation resistance or their strength. The various types of stainless steel are identified and guidance given on welding processes and techniques which can be employed in fabricating stainless steel components without impairing the corrosion, oxidation and mechanical properties of the material or introducing defects into the weld.

Material types

The unique properties of the stainless steels are derived from the addition of alloying elements, principally chromium and nickel, to steel. Typically, more than 10% chromium is required to produce a stainless iron. The four grades of stainless steel have been classified according to their material properties and welding requirements:

- Austenitic
- Ferritic
- Martensitic
- Austenitic-ferritic (duplex)

The alloy groups are designated largely according to their microstructure. The first three consist of a single phase but the fourth group contains both ferrite and austenite in the microstructure.

As nickel (plus carbon, manganese and nitrogen) promotes austenite and chromium (plus silicon, molybdenum and niobium) encourages ferrite formation, the structure of welds in commercially available stainless steels can be largely predicted on the basis of their chemical composition. The predicted weld metal structure is shown in the Schaeffler diagram in which austenite and ferrite promoting elements are plotted in terms of the nickel and chromium equivalents.

Because of the different microstructures, the alloy groups have both different welding characteristics and susceptibility to defects.

Austenitic stainless steel

Austenitic stainless steels typically have a composition within the range 16-26% chromium (Cr) and 8-22% nickel (Ni). A commonly used alloy for welded fabrications is Type 304 which contains approximately 18%Cr and 10%Ni. These alloys can be readily welded using any of the arc welding processes (TIG, MIG, MMA and SA). As they are non-hardenable on cooling, they exhibit good toughness and there is no need for pre- or post-weld heat treatment.

Avoiding weld imperfections

Although austenitic stainless steel is readily welded, weld metal and HAZ cracking can occur. Weld metal solidification cracking is more likely in fully austenitic structures which are more crack sensitive than those containing a small amount of ferrite. The beneficial effect of ferrite has been attributed largely to its capacity to dissolve harmful impurities which would otherwise form low melting point segregates and interdendritic cracks.

As the presence of 5-10% ferrite in the microstructure is extremely beneficial, the choice of filler material composition is crucial in suppressing the risk of cracking. An indication of the ferrite-austenite balance for different compositions is provided by the Schaeffler diagram. For example, when welding Type 304 stainless steel, a Type 308 filler material which has a slightly different alloy content, is used.

Ferritic stainless steel

Ferritic stainless steels have a Cr content typically within the range 11-28%. Commonly used alloys include the 430 grade, having 16-18% Cr and 407 grade having 10-12% Cr. As these alloys can be considered to be predominantly single phase and non-hardenable, they can be readily fusion welded. However, a coarse grained HAZ will have poor toughness.

Avoiding weld imperfections

The main problem when welding this type of stainless steel is poor HAZ toughness. Excessive grain coarsening can lead to cracking in highly restrained joints and thick section material. When welding thin section material, (less than 6mm) no special precautions are necessary.

In thicker material, it is necessary to employ a low heat input to minimise the width of the grain coarsened zone and an austenitic filler to produce a tougher weld metal. Although preheating will not reduce the grain size, it will reduce the HAZ cooling rate, maintain the weld metal above the ductile-brittle transition temperature and may reduce residual stresses. Preheat temperature should be within the range 50-250 deg. C depending on material composition.

Martensitic stainless steel

The most common martensitic alloys e.g. type 410, have a moderate chromium content, 12-18% Cr, with low Ni but more importantly have a relatively high carbon content. The principal difference compared with welding the austenitic and ferritic grades of stainless steel is the potentially hard HAZ martensitic structure and the matching composition weld metal. The material can be successfully welded providing precautions are taken to avoid cracking in the HAZ, especially in thick section components and highly restrained joints.

Avoiding weld imperfections

High hardness in the HAZ makes this type of stainless steel very prone to hydrogen cracking. The risk of cracking generally increases with the carbon content. Precautions which must be taken to minimise the risk, include:using low hydrogen process (TIG or MIG) and ensure the flux or flux coated consumable are dried (MMA and SAW) according to the manufacturer's instructions;

preheating to around 200 to 300 deg. C. Actual temperature will depend on welding procedure, chemical composition (especially Cr and C content), section thickness and the amount of hydrogen entering the weld metal;maintaining the recommended minimum interpass temperature.carrying out post-weld heat treatment, e.g. at 650-750 deg. C. The time and temperature will be determined by chemical composition.Thin section, low carbon material, typically less than 3mm, can often be welded without preheat, providing that a low hydrogen process is used, the joints have low restraint and attention is paid to cleaning the joint area. Thicker section and higher carbon (> 0.1%) material will probably need preheat and post-weld heat treatment. The post-weld heat treatment should be carried out immediately after welding not only to temper (toughen) the structure but also to enable the hydrogen to diffuse away from the weld metal and HAZ.

Duplex stainless steels

Duplex stainless steels have a two phase structure of almost equal proportions of austenite and ferrite. The composition of the most common duplex steels lies within the range 22-26% Cr, 4-7% Ni and 0-3% Mo normally with a small amount of nitrogen (0.1-0.3%) to stabilise the austenite. Modern duplex steels are readily weldable but the procedure, especially maintaining the heat input range, must be strictly followed to obtain the correct weld metalstructure.

Avoiding weld imperfections

Although most welding processes can be used, low heat input welding procedures are usually avoided. Preheat is not normally required and the maximum interpass temperature must be controlled. Choice of filler is important as it is designed to produce a weld metal structure with a ferrite-austenite balance to match the parent metal. To compensate for nitrogen loss, the filler may be overalloyed with nitrogen or the shielding gas itself may contain a small amount of nitrogen.

various welding defects its causes and remedies with neat sketches.

Welding defects are the irregularities that are formed due to the wrong welding process or due to inexperienced welders. Even if irregularities are very minimal but if the shape, size and quality of the weld are way different than what is expected, it is also called welding defects.Some amount of weld defects are acceptable if that is under the tolerable limit and does not impact the product function and performance.

Causes of welding defects?

- Wrong welding procedure
- Inexperienced welders
- Metal compatibility
- Environmental issues

Welding defects are classified into the following two types

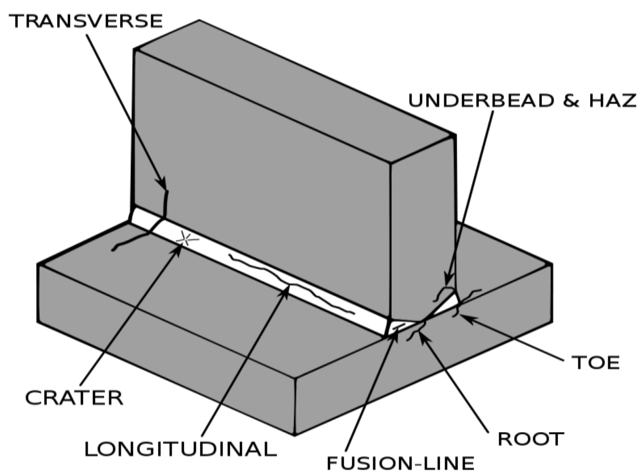
1. Internal welding defects
2. External welding defects

INTERNAL WELDING DEFECTS

- Weld cracks
- Inclusions
- Blowholes
- Insufficient fusion

Weld Cracks

Weld cracks are serious defects in welding and by any means, it is not accepted. Cracks can be internal as well as external. Weld cracks are formed due to the excessive stress formed by metal because if temperature different and insufficient cooling. A good welder should always consider the amount of shrinkage metals might have or else crack will form.



Causes of Weld Crack

- Foreign metal contamination
- Use of hydrogen when welding ferrous alloys
- High welding speed with low current
- Poor weld joint design

Remedies for Weld Crack

- Use proper welding speed
- Remove foreign material from metals
- Check metal compatibility before welding.
- Consider shrinkage of weld metal before welding
- Preheat the metal as required.

Inclusions

Inclusions or slag inclusion us a serious defect in welding. These are foreign material which does get trapped inside the weld or on the top of weld thus weakening the structure. Slug is basically solidified flux after the weld cools

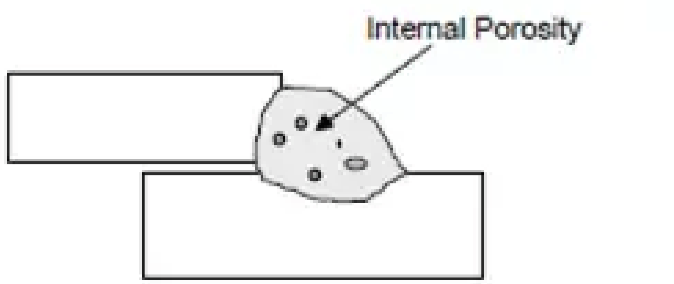
Reason for Slag Inclusion

- Improper cleaning
- Too high welding speed

- Incorrect welding angle
- Use proper speed during welding
- Adjust the angle if required
- Remove slag from the previous weld.
- Adjust the current

Blowholes

Blowholes are basically voids or pockets formed by entrapped gas during welding. Some amount of voids are accepted but it compromises with the weld strength.



Causes of blowholes

- Excessive fast arc travel speed
- Improper electrode
- Too low or too high current
- Dirty weld surface

Remedies of Blowholes

- Clean weld surface before welding
- Use proper electrode
- Adjust welding speed
- Preheat the weld metal

Insufficient Fusion

This type of weld defects occurs when there is an insufficient fusion between the base metal and the weld metal. This creates a gap under the joint or in between adjoining weld beads. Due to the insufficient fusion, molten metal can not reach toall areas of the weld and thus creates the gap. This kind of weld defects weakens the structure.

Remedies of Insufficient Fusion

- Adjust the electrode angle so that molten metal reaches every corner
- Reduce welding speed

- Clean the metal before welding
- Reduce the disposition rate

EXTERNAL WELDING DEFECTS

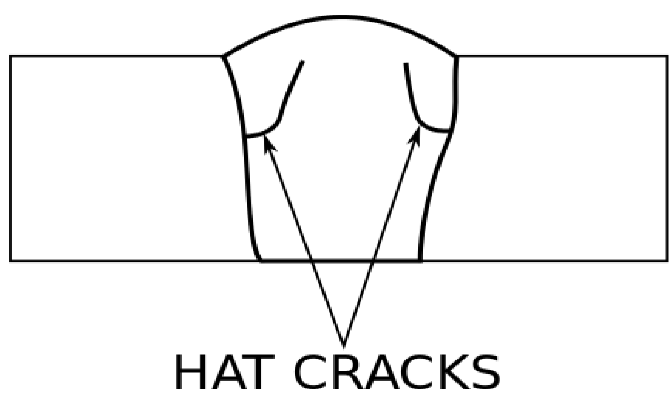
External welding defects can be discovered by open eyes. Often external welding defects are acceptable up to some extent unless it is affecting the strength of materials.

Below are a few external welding defects.

- Crater
- Undercut
- Spatter
- Distortion
- Hot Tearing
- Surface cracks

Crater

The crater is kind of crack which occurs when the welding arc is broken and molten metal is not available to fill the cavity. Crater occurs due to residual stress imposed by the lack of metal in the cavity.



Reasons For Crater

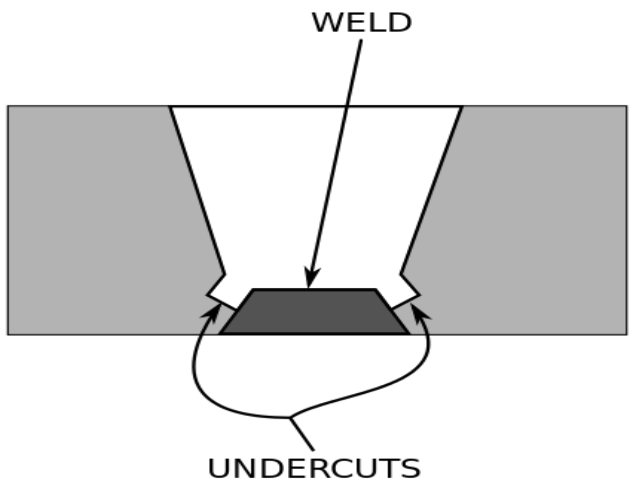
- High welding speed
- Low current
- Metal contamination
- Poor weld joint design

Remedies of Crater

- Reduce weld speed
- Preheat the metal
- Reduce impurities
- Good weld joint design

Undercut

The undercut is kind of groove formation around the weld reducing the cross-sectional thickness of the weld. Due to less cross-sectional thickness, the weld becomes weak and not accepted.



Causes Of Undercut

- Incorrect electrode angle
- Too high weld current
- Incorrect filler metal
- Poor weld technique

Remedies Of Undercut

- Adjust the electrode angle
- Reduce the arc length
- Reduce electrode travel speed
- Check filler metal compatibility before welding

Spatter

Spatter, as the name suggests are small particle from the weld that gets deposited on the surface of the weld joint. This is very common in gas welding and sometimes it's impossible to avoid spatter. However, with a better technique, you can mitigate the defects and create acceptable weld joints. In the below image you may notice small metal all around the surface. Those are spatters.

Cause Of Spatter

- Too long arc
- Surface contamination
- Incorrect polarity
- Too steep electrode angle

Remedies Of Spatter

- Adjust weld current
- Adjust the electrode angle
- Clean the surface before welding
- Use proper polarity

Distortion

Distortion is a result of molten metal shrinkage at the side of the weld joint. It’s notalways possible to only melt the area where weld joint supposed to take place.Right? Due to heat area next to weld joint also get melted and when it cools causesdistortion. The distortion can be of many types as shown below. Distortion can be asevere issue as it affects the part shape.

Types of Distortion

- Angular Distortion
- Longitudinal Distortion
- Fillet Distortion
- Neutral Axis distortion

Causes Of Distortion

- Slow arc speed
- Base metal and weld metal compatibility
- Improper welding methods
- Numerous travel with small electrodes

Remedies Of Distortion

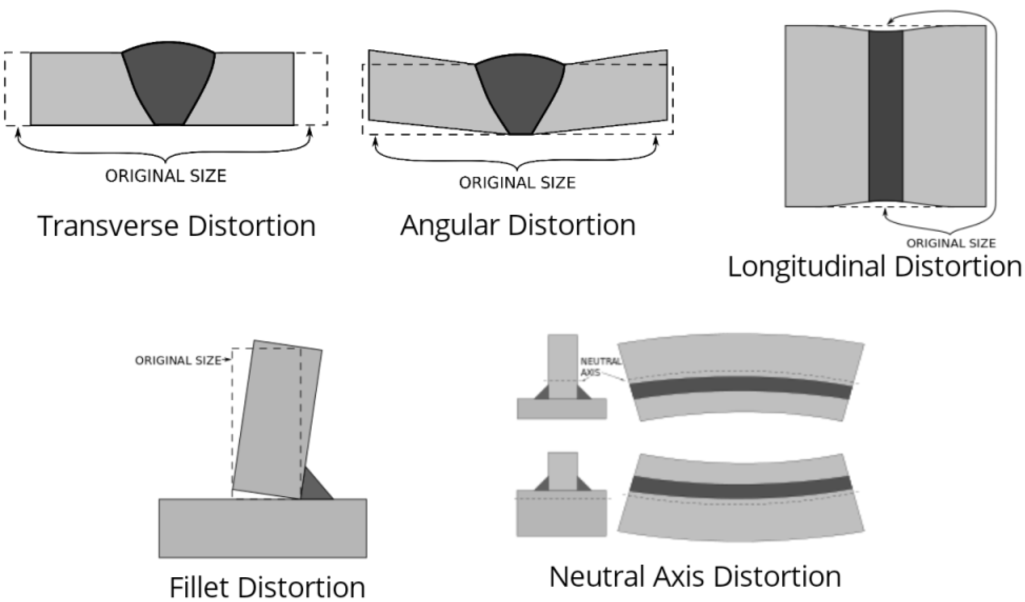
- Weld need to be placed near neutral axis
- Use proper welding sequence
- Reduce the number of electrode travel
- Use an exact amount of weld metal.

Hot Tearing

Hot tearing is similar to cracks but occurs at the edge of weld joints. It occurs due to the improper cooling at different areas of the weld joint. Some areas cool faster whereas some areas remain in the molten state thus inducing excessive stress at the edges forming tearing. Tearing is serious defects and parts are always rejected if this defect occurs.

Causes Of Hot Tearing

- Thermal Contraction
- Liquid pressure drop
- Improper electrode
- Weld metal and base metal is not compatible



Remedies of Hot Tearing

- Adjust the current as required to heat up base metals
- Use correct size electrodes
- Use proper electrode materials.

Surface Cracks

Surface cracks are different from other internal weld crack in the sense that surface crack occurs on the surface of the weld joint. Those can be easily diagnosed and fixed. The reason and remedies remain the same like any other intern welding cracks.

DESTRUCTIVE TESTING

Non destructive testing is a testing and analysis technique used by industry to evaluate the properties of a material, component, structure or system for welding defects and discontinuities by causing damage to the original part.

TYPES OF DESTRUCTIVE TESTING

The types of Destructive are as follows;

1.) Tensile Testing

2.) Bend Testing

3.) Impact Testing

4.) Nick Break Testing

5.) Hardness Testing

NON-DESTRUCTIVE TESTING

Non destructive testing is a testing and analysis technique used by industry to evaluate the properties of a material, component, structure or system for welding defects and discontinuities without causing damage to the original part. NDT also known as non-destructive examination (NDE), non-destructive inspection (NDI) and non-destructive evaluation (NDE).

Categories of Non-destructive Testing

The different types of non-destructive testing used to inspect welding are shown below:

1. **Radiographic Inspection (Graphs)**
2. **Magnetic Particle Inspection(MPI)**
3. **Ultrasonic Testing (UT)**
4. **Liquid Penetrant Testing(Lpt) Or Dye Penetrant Inspection (Dp)**

DESCRIPTION AND APPLICATION OF NON DESTRUCTIVE TESTING METHODS

Radiographic Inspection

This is carried out where the welded components require a very critical inspection technique due to their application. Shielding from x-ray and gamma-ray radiation is a strict requirement; this can be of a portable means or the components can be brought to a specialised building to be x-rayed. In my old offshore construction yard, radiography was carried out during the dead hours between shifts, when a visible and audio alarm would howl continuously to warn against entrance to the assembly buildings.

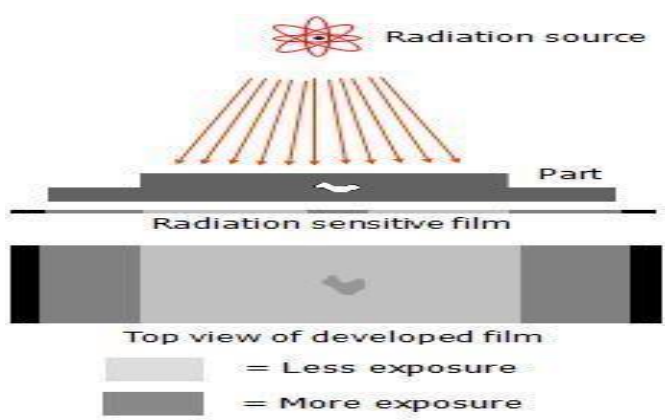
Anyway, the relative components are exposed to the radioactive source from which a radiograph is produced. This will show any irregularities in the welding when checked by an experienced radiograph interpret

Radiography is used in a very wide range of applications including medicine, engineering, forensics, security, etc. In NDT, radiography is one of the most important and widely used methods. Radiographic testing (RT) offers a number of advantages over other NDT methods, however, one of its major disadvantages is the health risk associated with the radiation.

In general, RT is method of inspecting materials for hidden flaws by using the ability of short wavelength electromagnetic radiation (high energy photons) to penetrate various materials. The intensity of the radiation that penetrates and passes through the material is either captured by a radiation sensitive film (*Film Radiography*) or by a planer array of radiation sensitive sensors (*Real-time Radiography*). Film radiography is the oldest approach, yet it is still the most widely used in NDT.

Basic Principles

In radiographic testing, the part to be inspected is placed between the radiation source and a piece of radiation sensitive film. The radiation source can either be an Xray machine or a radioactive source (Ir-192, Co-60, or in rare cases Cs-137). The part will stop some of the radiation where thicker and denser areas will stop more of the radiation. The radiation that passes through the part will expose the film and forms a shadow graph of the part. The film darkness (density) will vary with the amount of radiation reaching the film through the test object where darker areas indicate more exposure (higher radiation intensity) and lighter areas indicate less exposure (lower radiation intensity).This variation in the image darkness can be used to determine thickness or composition of material and would also reveal the presence of any flaws or discontinuities inside the material.



Advantages

- Both surface and internal discontinuities can be detected.
- Significant variations in composition can be detected. It has a very few material limitations.
- Can be used for inspecting hidden areas (direct access to surface is not required)
- Very minimal or no part preparation is required.
- Permanent test record is obtained.
- Good portability especially for gamma-ray sources.

Disadvantages

- Hazardous to operators and other nearby personnel.
- High degree of skill and experience is required for exposure and interpretation.
- The equipment is relatively expensive (*especially for x-ray sources*).
- The process is generally slow.
- Highly directional (*sensitive to flaw orientation*).
- Depth of discontinuity is not indicated.
- It requires a two-sided access to the component.

Applications

- Industrial radiography is used in the inspection of new products and welds
- New pipelines (including bends and joints), storage containers and even insulated materials are routinely inspected using radiography.
- detection and measurement of internal flaws in existing plant.
- The early detection of internal flaws in pipelines and plant in the oil and gas sector,
- Detection of Corrosion Under Insulation (CUI), is another common application for radiography.
- NDT radiography is also used in security.

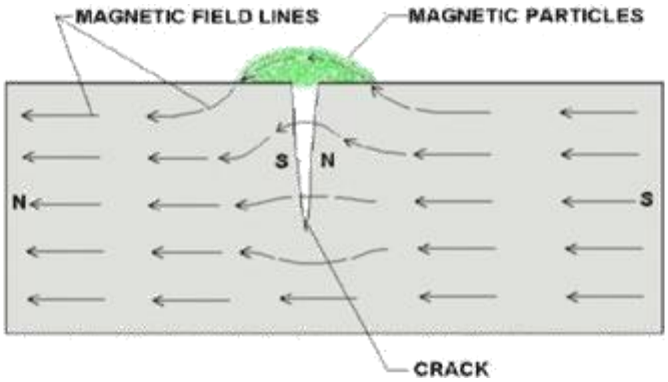
MAGNETIC PARTICLE INSPECTION (MPI)

Magnetic Particle Testing (MPT), also referred to as Magnetic Particle Inspection, is a nondestructive examination (NDE) technique used to detect surface and slightly subsurface flaws in most ferromagnetic materials such as iron, nickel, and cobalt, and some of their alloys.

Working Principle

The welded area is coated with a magnetic flux containing iron ferrous particles. An electric yoke magnet is placed across the flux producing a visible magnetic field. Any surface cracks or weld irregularities will become evident by the accumulation of the flux due to the forming of a new magnetic pole each side of the crack. This is a very inexpensive and quick method of weld inspection, however it is only used to check fillet welds for surface imperfections, and of course can only be used on ferrous metals.

This method can detect surface and internal irregularities in ferrous and non-ferrous metal welding.The first step in a magnetic particle inspection is to magnetize the component that is to be inspected. If any defects on or near the surface are present, the defects will create a leakage field. After the component has been magnetized, iron particles, either in a dry or wet suspended form, are applied to the surface of the magnetized part. The particles will be attracted and cluster at the flux leakage fields, thus forming a visible indication that the inspector can detect



It operates by transmitting high frequency pulsing sound waves through the weld, the results being transmitted to a monitor as a trace. If the pulse comes in contact with an irregularity in the weld, the waves are sent back to the transmitter and show up on the monitor screen. The defect can be placed very accurately, but it requires an experienced operator to interpret the tracings on the monitor.

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

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 renters at the south pole.

The magnetic field spreads out when it encounters the small air gap created by the crack because the air cannot support as much magnetic field per unit volume as the magnet can. When the field spreads out, it appears to leak out of the material and, thus is called a flux leakage field.

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.

Advantages

1. High sensitivity (small discontinuities can be detected).
1. Indications are produced directly on the surface of the part and constitute a visual representation of the flaw.
2. Minimal surface preparation (no need for paint removal)
3. Portable (materials are available in aerosol spray cans)
4. Low cost (materials and associated equipment are relatively inexpensive)
   Disadvantages
5. Only surface and near surface defects can be detected.
6. Only applicable to ferromagnetic materials
7. Relatively small area can be inspected at a time.Only materials with a relatively nonporous surface can be inspected.
8. The inspector must have direct access to the surface being inspected.

Disadvantages

1. The specimen must be ferromagnetic (e.g. steel, cast iron)
2. Paint thicker than about 0.005" must be removed before inspection
3. Post cleaning and post demagnetization is often necessary
4. Maximum depth sensitivity is typically quoted as 0.100" (deeper under perfect conditions)
5. Alignment between magnetic flux and defect is important

Applications

- Magnetic Particle Inspection (MPI) is a very effective method for location of surface breaking and slight sub-surface defects such as cracking, pores, cold lap, lack of sidewall fusion in welds etc in magnetic materials

ULTRASONIC TESTING (UT)

Ultrasonic nondestructive testing, also known as ultrasonic NDT or simply UT, is a method of characterizing the thickness or internal structure of a test piece through the use of high frequency sound waves.

This method can detect surface and internal irregularities in ferrous and non-ferrous metal welding.

It operates by transmitting high frequency pulsing sound waves through the weld, the results being transmitted to a monitor as a trace. If the pulse comes in contact with an irregularity in the weld, the waves are sent back to the transmitter and show up on the monitor screen.

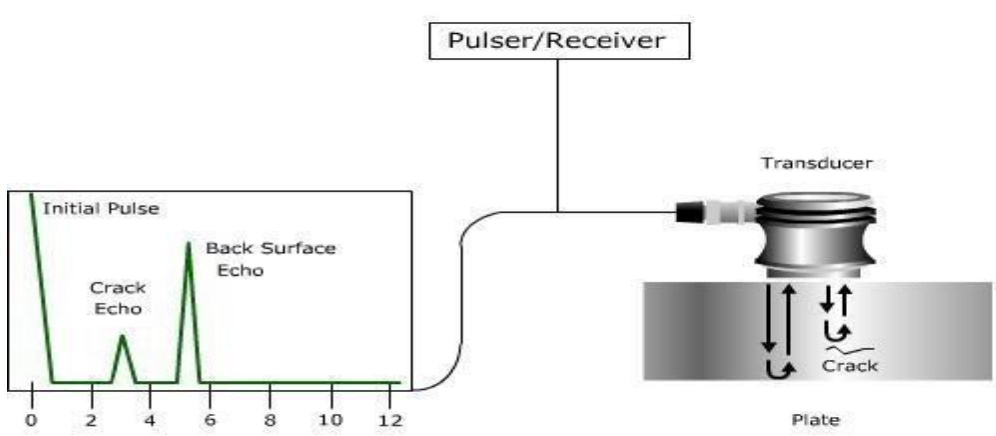
The defect can be placed very accurately, but it requires an experienced operator to interpret the tracings on the monitor.

Basic Principles

A typical pulse-echo UT inspection system consists of several functional units, such as the pulser/ receiver, transducer, and a display device. A pulser /receiver is an electronic device that can produce high voltage electrical pulses.

Driven by the pulser, the transducer generates high frequency ultrasonic energy. The sound energy is introduced and propagates through the materials in the form of waves. When there is a discontinuity (*such as a crack*) in the wave path, part of the energy will be reflected back from the flaw surface.

The reflected wave signal is transformed into an electrical signal by the transducer and is displayed on a screen. Knowing the velocity of the waves, travel time can be directly related to the distance that the signal travelled. From the signal, information about the reflector location, size, orientation and other features can sometimes be gained.



ADVANTAGES

1. It is sensitive to both surface and subsurface discontinuities.
2. The depth of penetration for flaw detection or measurement is superior to other NDT methods.
3. Only single-sided access is needed when the pulse-echo technique is used.
4. It is highly accurate in determining reflector position and estimating size and shape.
5. Minimal part preparation is required.
6. It provides instantaneous results.
7. Detailed images can be produced with automated systems.
8. It is nonhazardous to operators or nearby personnel and does not affect the material being tested.
9. It has other uses, such as thickness measurement, in addition to flaw detection. Its equipment can be highly portable or highly automated.

Disadvantages

1. Surface must be accessible to transmit ultrasound.
2. Skill and training is more extensive than with some other methods.
3. It normally requires a coupling medium to promote the transfer of sound energy into the test specimen.
4. Materials that are rough, irregular in shape, very small, exceptionally thin or not homogeneous are difficult to inspect.
5. Cast iron and other coarse grained materials are difficult to inspect due to low sound transmission and high signal noise.
6. Linear defects oriented parallel to the sound beam may go undetected. Reference standards are required for both equipment calibration and the characterization of flaws.

Applications

1. Ultrasonic flaw detectors are widely used for structural welds, steel beams,
2. Forgings, pipelines and tanks,
3. Aircraft engines and frames, automobile frames,
4. Railroad rails, power turbines and
5. Other heavy machinery, ship hulls, castings, .

LIQUID PENETRANT TESTING(LPT) OR DYE PENETRANT INSPECTION (DP)

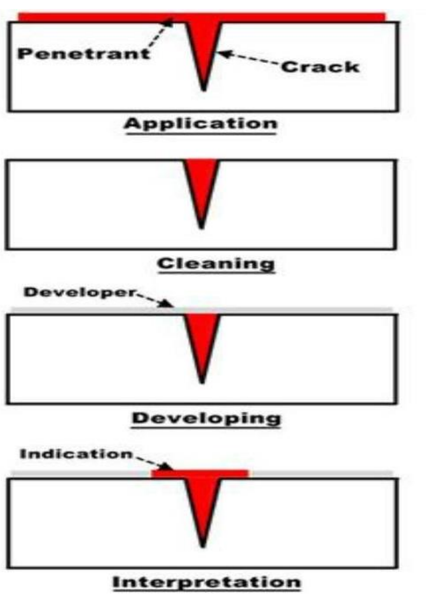
Dye penetrant inspection (DP), also called liquid penetrate inspection (LPI) or penetrant testing (PT), is a widely applied and low-cost inspection method used to check surface-breaking defects in all non-porous materials (metals, plastics, or ceramics).

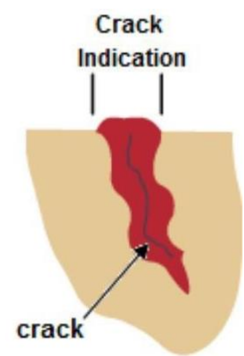
The penetrant may be applied to all non-ferrous materials and ferrous materials, although for ferrous components magnetic-particle inspection is often used instead for its subsurface detection capability. LPI is used to detect casting, forging and welding surface defects such as hairline cracks, surface porosity, leaks in new products, and fatigue cracks on in-service components.

It is one of the oldest and simplest NDT methods where its earliest versions (*using kerosene and oil mixture*) dates back to the 19th century. This method is used to reveal surface discontinuities by bleed out of a colored or fluorescent dye from the flaw.

The technique is based on the ability of a liquid to be drawn into a "clean" surface discontinuity by capillary action. After a period of time called the "dwell time", excess surface penetrant is removed and a developer applied. This acts as a blotter that draws the penetrant from the discontinuity to reveal its presence. The advantage that a liquid penetrant inspection offers over an unaided visual inspection is that it makes defects easier to see for the inspector where that is done in two ways: It produces a flaw indication that is much larger and easier for the eye to detect than the flaw itself. Many flaws are so small or narrow that they are undetectable by the unaided eye (*a person with a perfect vision cannot resolve features smaller than 0.08 mm*). It improves the detectability of a flaw due to the high level of contrast between the indication and the background which helps to make the indication more easily seen (*such as a red indication on a white background for visible penetrant or a penetrant that glows under ultraviolate light for flourecent penetrant*). Liquid penetrant testing is one of the most widely used NDT methods. Its popularity can be attributed to two main factors: its relative ease of use and its flexibility. It can be used to inspect almost any material provided that its surface is not extremely rough or porous. Materials that are commonly inspected using this method include; metals, glass, many ceramic materials, rubber and plastics. However, liquid penetrant testing can only be used to inspect for flaws that break the surface of the sample (*such as surface cracks, porosity, laps, seams, lack of fusion, etc.*). This system operates on a capillary action principle where a fluid in the form of a florescent or nonf lorescent dye is applied to a weld surface.

Once the fluid has been given time to penetrate the surface, (between 15 and 30 minutes) the excess is wiped away and a developing fluid applied. The developer draws fluid out from any flaws and when viewed under a UV or white light, imperfections in the weld become visible.





Steps of Liquid Penetrant Testing

The exact procedure for liquid penetrant testing can vary from case to case depending on several factors such as the penetrant system being used, the size and material of the component being inspected, the type of discontinuities being expected in the component and the condition and environment under which the inspection is performed. However, the general steps can be summarized as follows:

Surface Preparation: One of the most critical steps of a liquid penetrant testing is the surface preparation. The surface must be free of oil, grease, water, or other contaminants that may prevent penetrant from entering flaws. The sample may also require etching if mechanical operations such as machining, sanding, or grit blasting have been performed. These and other mechanical operations can smear metal over the flaw opening and prevent the penetrant from entering.

Penetrant Application: Once the surface has been thoroughly cleaned and dried, the penetrant material is applied by spraying, brushing, or immersing the part in a penetrant bath.

Penetrant Dwell: The penetrant is left on the surface for a sufficient time to allow as much penetrant as possible to be drawn from or to seep into a defect. Penetrant dwell time is the total time that the penetrant is in contact with the part surface. Dwell times are usually recommended by the penetrant producers or required by the specification being followed. The times vary depending on the application, penetrant materials used, the material, the form of the material being inspected, and the type of discontinuity being inspected for. Minimum dwell times typically range from five to 60 minutes. Generally, there is no harm in using a longer penetrant dwell time as long as the penetrant is not allowed to dry. The ideal dwell time is often determined by experimentation and may be very specific to a particular application.

Excess Penetrant Removal: This is the most delicate part of the inspection procedure because the excess penetrant must be removed from the surface of the sample while removing as little penetrant as possible from defects. Introduction to Non-Destructive Testing Techniques Liquid Penetrant Testing Page 3 of 20 Depending on the penetrant system used, this step may involve cleaning with a solvent, direct rinsing with water, or first treating the part with an emulsifier and then rinsing with water. 5. *Developer Application*: A thin layer of developer is then applied to the sample to draw penetrant trapped in flaws back to the surface where it will be visible. Developers come in a variety of forms that may be applied by dusting (*dry powders*), dipping, or spraying (*wet developers*).

Indication Development: The developer is allowed to stand on the part surface for a period of time sufficient to permit the extraction of the trapped penetrant out of any surface flaws. This development time is usually a minimum of 10 minutes. Significantly longer times may be necessary for tight cracks.

Inspection: Inspection is then performed under appropriate lighting to detect indications from any flaws which may be present.

Clean Surface: The final step in the process is to thoroughly clean the part surface to remove the developer from the parts that were found to be acceptable.

Advantages

1. High sensitivity (small discontinuities can be detected).
2. Few material limitations (metallic and nonmetallic, magnetic and nonmagnetic, and conductive and nonconductive materials may be inspected).
3. Rapid inspection of large areas and volumes.
4. Suitable for parts with complex shapes.
5. Indications are produced directly on the surface of the part and constitute a visual representation of the flaw.
6. Portable (materials are available in aerosol spray cans)
7. Low cost (materials and associated equipment are relatively inexpensive)

Disadvantages

1. Only surface breaking defects can be detected.
2. Only materials with a relatively nonporous surface can be inspected. Pre-cleaning is critical since contaminants can mask defects.
3. Metal smearing from machining, grinding, and grit or vapor blasting must be removed.
4. The inspector must have direct access to the surface being inspected. Surface finish

and roughness can affect inspection sensitivity.

5. Multiple process operations must be performed and controlled. Post cleaning of acceptable parts or materials is required.
6. Chemical handling and proper disposal is required.

Applications

1. It can be used to inspect almost any material provided that its surface is not extremely rough or porous.
2. Materials that are commonly inspected using this method include; metals, glass, many ceramic materials, rubber and plastics.
3. Liquid penetrant testing can be used to inspect for flaws that break the surface of the sample (such as surface cracks, porosity, laps, seams, lack of fusion, etc.).
4. Non-ferrous materials and ferrous materials can be tested