Chapter one

1.1Introduction

A general definition of nondestructive test (NDT) is an examination, test or evaluation performed on any type of test object without changing or altering that object in any way, in order to determine the absence or presence of conditions or discontinuities that may have an effect on the usefulness or serviceability of that object .Nondestructive tests may also be conducted to measure other test object characteristics such as size, dimension, configuration or structure.

Non - destructive testing (NDT) plays a very significant role in the preventive protection of our environment. The importance of NDT methods is reflected in preventing major damages by early identification and detection of critical failures in production, during service and in construction. In this way NDT joins the activities of the "greens" providing efficient protection of human lives and the environment [1].

1.2Problems of the research

Using the ultrasonic detection to describe defects that can arise in the materials.

1.3The aims of the Research

This work aims to study the effectiveness of detection using ultrasound compared with other nondestructive detection methods, especially penetrant test.

1.4 Methodology

We effect on two samples with a certain force which resulted in effect differed depending on the structure of samples placement experience. The defects were detected using liquid penetrant test (for surface defects) and ultrasound test (for surface and subsurface defect).

1.5 The Research layout

The research contain five chapters, chapter one explain the Proposal of the research, chapter two the methods of NDT, chapter three ultrasonic testing, chapter four penetrant testing ,and the last chapter for the results, discussion and conclusion.

Chapter Two

Nondestructive versus Destructive Tests

2.1 Destructive testing

Destructive testing has been defined as a form of mechanical test of materials whereby certain specific characteristics of the material can be evaluated quantitatively. The information that is obtained through destructive testing is quite precise, but it only applies to the specimen being examined. Since the specimen is destroyed or mechanically changed, it is unlikely that it can be used for other purposes beyond the mechanical test. Such destructive tests can provide very useful information, especially relating to the material's design consideration and useful life.

Destructive testing may be a dynamic or static and can provide data relative to the materials properties like ultimate material strength, bending, Yield point, ductility, elongation, fatigue life, hardness and impact resistance.

Other than the fact that the specimen being examined typically cannot be used after destructive testing for any useful purpose, it must also be stressed that data achieved through destructive testing are specific to the test specimen.

Another destructive test commonly used to measures materials resistance to impact is the charpy test. In this test, a specimen that is usually notched is supported at one end is broken as a pendulum is released and impacts in the region of the notch. The measure of the material’s resistance to impact is determined by the subsequent rise of the pendulum.

Hardness is also an important material characteristic. The hardness test measures the material’s resistance to plastic deformation. There has always been a minor dispute as to whether this test was nondestructive or destructive, since there usually is an indentation made on the surface of the material. If the hardness test made is made without indentation, it can be considered truly “nondestructive”.

Although it is assumed in many cases that the test specimen is representative of the material from which it has been taken, it cannot be said with 100% reliability that the balance of the material will exactly the same characteristics as that test specimen [1].

Benefits of destructive testing:

- Reliable and accurate data from the test specimen.
- Extremely useful data for design purposes.
- Information can be used to establish standards and specifications.
- Data achieved through destructive testing is usually quantitative.
- Typically, various service conditions are capable of being measured.
- Useful life can be predicated.

Limitations of destructive testing:

- In these test data applies only to the specimen being examined.
- Also most destructive test specimens cannot be used once the test is complete.
- Many destructive tests require large, expensive equipment in laboratory environment.

2.2 Nondestructive Testing

A general definition of nondestructive testing (NDT) is an examination, test, or evaluation performed on any type of test object without changing or altering that object in any way, in order to determine the absence or presence of conditions or discontinuities that may have an effect on the usefulness or serviceability of that object. Nondestructive tests may also be conducted to measure other test object characteristics, such as size; dimension; configuration; or structure, including alloy content, hardness, grain size, etc. The simplest of all definitions is basically an examination that performed on an object of any type, size, shape or material to determine presence or absence of discontinuities, or to evaluate other materials characteristic.

Nondestructive examination (NDE), nondestructive inspection (NDI) or nondestructive evaluation (NDE) is also expressions commonly used to describe this technology. Although this technology has been effectively for used to decades, it is still generally unknown by the average person, who takes it for granted that buildings will not collapse, plan will not crash, and product will not fail. Although NDT cannot guarantee that failures will not occur, it plays a significant role in minimizing the possibilities of failure. Other variables, such as inadequate design and improper application the object, may contribute to failure even when NDT is appropriately applied.

2.3Common methods of NDT

Some common methods of NDT with their principles, applications, advantages and limitations are listed in the table (2-1) below [1]:

Method	Principles	Application	Advantages	Limitation
Visual Testing (VT)	Uses reflected or transmitted light from test object that imaged with the human eye or other light sensing device.	Many applications in many industries ranging from row material to finished products and service inspection.	Can be inexpensive and simple with minimal training required. Broad scope of uses and benefits.	Only surface conditions can be evaluated. Effective source of illumination required. Access necessary.
Magnetic particle Testing (MT)	Test part is magnetized and fine ferromagnetic particles applied to surface, aligning at discontinuity.	All ferromagnetic materials for surface, for surface and slightly subsurface discontinuities ; large and small parts.	Relatively easy to use. Equipment/material usually inexpensive. Highly sensitive and fast compared to PT.	Only surface and a few subsurface discontinuities can be detected. Ferromagnetic materials only.
Penetrate testing (PT)	A Liquid containing visible or fluorescent dye is applied to surface and enters discontinuities by capillary action.	Virtually any solid nonabsorbent material having uncoated surfaces that are not contaminated.	Relatively easy to use and materials are inexpensive. Extremely sensitive, very versatile. Minimal training.	Discontinuities open to the surface only. Surface condition must be relatively smooth and free contaminations.

Radiographic Testing (RT)	Radiographic film is exposed when radiation passes through the test object. Discontinuities affect exposure.	Most materials, shapes, and structures. Examples include welds, castings, composites, etc. as manufactured or in-service.	Provides a permanent record and high sensitivity. Most widely used and accepted volumetric examination.	Limited thickness based on material density. Orientation of planar discontinuities is critical. Radiation hazard.
Ultrasonic Testing (UT)	High-frequency sound pulses from a transducer propagate through the test material, reflecting at interfaces.	Most materials can be examined if sound transmission and surface finish are good and shape is not complex.	Provides precise, high-sensitivity result quickly. Thickness information, depth, and type of flaw can be obtained from one side of the component.	No permanent record(usually) 0 Material attenuation, surface finish, and contour. Requires couplant.
Eddy current Testing (ET)	Localized electrical fields are induced into conductive test specimen by electromagnetic induction.	Virtually all conductive materials can be examined for flaws, metallurgical conditions, thinning and conductivity.	Quick, versatile, sensitive to; can be no contacting; easily adaptable to automation and in-situ examinations.	Variables must be understood and controlled. Shallow by depth of penetration lift-off effects and surface condition.

Thermal infrared Testing (TIR)	Temperature variations at the test surface are measured/detected using thermal sensors/detectors instruments/cameras	Most materials and component where temperature changes are related to part conditions/thermal conductivity.	Extremely sensitive to slight temperature changes in small parts or large areas. Provides permanent record.	Not effective for detection flows in thick parts. Surface only is evaluated. Evaluation requires high skill level.
Acoustic emission testing(AE)	As discontinuities propagate, energy is released and travels as stress waves through materials. These are detected by means of sensors.	Welds, pressure vessels, rotating equipment, some composites and other structures subject to stress or loading.	Large areas can be monitored to detect deteriorating conditions. Can possibly predict failure.	Sensors must contact test surface. Multiple sensors required for flow location. Signal interpretation.

2.4 The benefits of nondestructive testing

- Location and determination of the extent of cracks, voids, honeycombing and similar defects within a concrete structure.
- Determining the concrete uniformity, possibly preliminary to core load testing or other more expensive or disruptive tests.
- Determining the position, quantity or condition of reinforcement.
- Increasing the confidence level of a smaller number of destructive tests.
- Confirming or locating suspected deterioration of concrete resulting from such factors as overloading, fatigue, external or internal chemical attack or change, fire, explosion, environmental effects.
- Monitoring long term changes in concrete properties.
- The part is not changed or altered and can be used after examination.
- Every item or a large portion of the material can be examined with no adverse consequences.
- Materials can be examined for conditions internal and at the surface parts can be examined while in service.
- Many NDT devices are portable and can be taken to the object to be examined.
- Nondestructive testing is cost effective, overall.

2.5Limitations of nondestructive testing

- It is usually quite operator dependent.
- Some methods do not provide permanent records of the examination.
- NDT methods do not generally provide quantitative data.
- Orientation of discontinuities must be considered.
- Evaluation of some test results is subjective and subject to dispute.
- While most methods are cost effective, some, such as radiography, can be expensive.
- Defined procedures that have been qualified are essential.

Chapter Three

Ultra sonic Testing

3.1Nature of Sound waves

Sound waves are simply vibrations of the particles making up a solid, liquid, or gas. As an energy form they are therefore an example of mechanical energy, and it follows that, since there must be something to vibrate, sound waves cannot exist in a vacuum.

The only human sense that can detect sound waves is hearing, and that sense is restricted to a relatively narrow range of vibration frequencies called "the audible range" .it follows that there will be vibration frequencies that are so low or so high that they cannot be detected by the human ear.

The transducers are devices that will change sound waves into electrical energy that can be displayed as visual signals on a cathode ray tube (CRT) or liquid crystal display (LCD) screen. This allows all sounds, including those outside the audible range, to be detected and studied. Materials exhibiting the piezoelectric effect are commonly used to both generate and detect sound waves [1].

3.2 Sound waves

Sound waves are transverse mechanical waves since they are generated due to the vibration of molecules of any material in direction parallel to the direction propagation.

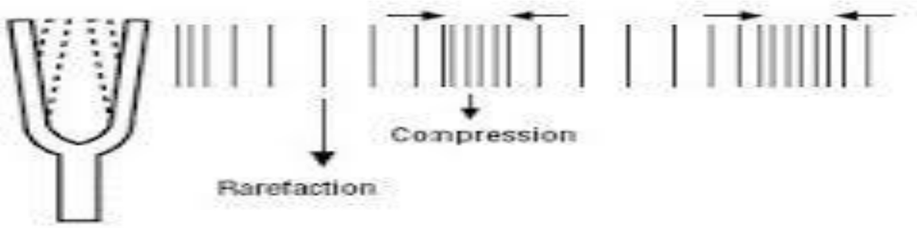


Figure (3.1)

Sound wave in the form of compressed and stretched successive layers.

Each layer is periodically compressed and stretched. The frequency f of the sound waves is defined as the number of complete oscillations per second, while the wavelength λ is defined as a distance between two successive condensed layers verified layers. The speed of the sound c is given by [1].

$$C = f\lambda$$

Human hearing higher than (20000) Hz are called ultrasound frequencies.

3.3 Ultrasound generation

Ultrasound is mechanically produced waves frequency above the range of human hearing (above 20000Hz). The ultrasound waves depend on the phenomenon of piezoelectric effect. In this effect certain crystals subject can produced ultrasound mechanical wave when they are subjected to electrical potential. The reverse effect also occurs when these crystal are subjected to mechanical pressure (echo), where electrical potential is produced.

The piezoelectric effect was described in1880 by Pierre and Jacques Curie. Lead or PZT, the piezoelectric material used in nearly all medical ultrasound transducer, it is the ceramic ferroelectric crystal exhibiting a strong piezoelectric effect and can be manufactured in nearly any shape. The most common transducer shapes are the circle for single crystal transducer assemblies, and the rectangle for multiple transducer assemblies, such as those found liner and phased arrays [3].

3.4 Reflection and Refraction of sound for two different tissues

Upon passage of ultrasound in living tissue, the energy of these waves is absorbed into the various body tissues. When waves pass through different tissues reflected and transmitted.

The amount of received echo depends on two acoustic impedance for two different tissuesz_1 and $z_2$where:

$$A_r/A_i = (z_2 - z_1)/(z_2 + z_1) \qquad (3.4.1)$$

Where:

A_r: Amplitude of the reflected wave.

A_i: Amplitude of the incident wave.

z_1Andz_2: acoustic impedance for two different tissues.

As the sound intensity is proportional to the square of the amplitude of the wave, it follows that$I\alpha A^2$.

$$I_r/I_i = [A_r/A_i]^2 \qquad (3.4.2)$$

I_r/I_i: are called the reflectivity coefficient and is defined as the reflected relative intensity at the interface between two different living tissues.

$$R = [A_r/A_i]^2 = [(z_2 - z_1)/(z_2 + z_1)]^2 \qquad (3.4.3)$$

3.5Snell's low

The general law that, for a certain incident ultrasonic wave on a boundary, determines the directions of the reflected and refracted waves is known as Snell's Law. According to this law the ratio of the sine of the angle of incidence to the since of the angle of reflection or refraction equals the ratio of the corresponding velocities of the incident, and reflected or refracted waves [1].

Mathematically Snell's Law is expressed as

$$\frac{\sin \theta_1}{\sin \theta_2} = \frac{V_{L1}}{V_{L2}} \qquad (3.5.1)$$

θ_1 =The angle of incidence

θ_2 =The angle of reflection or refraction

$V_{L1} =$ Velocity of incident wave

$V_{L2} =$ Velocity of reflected or refracted waves

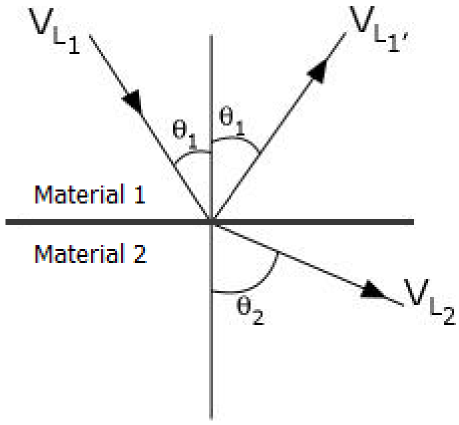


Figure (3-2) Snell's low

3.6Mode conversion

When sound travels in a solid material, one form of wave energy can be transformed into another form. For example, when a longitudinal wave hits an interface at an angle, some of the energy can cause particle movement in the transverse direction to start a shear wave. Mode conversion occurs when a wave encounters an interface between materials of different acoustic impedances and the incident angle is not normal to the interface. Itshould be noted that mode conversion occurs "every time" a wave encounters an interface at an angle. This mode conversion occurs for both the portion of the wave that passes through the interface and the portion that reflects off the interface.

Snell's Law holds true for shear waves as well as longitudinal waves and can be written as follows [1].

$$\frac{\sin\theta_1}{V_{L2}} = \frac{\sin\theta_2}{V_{L2}} = \frac{\sin\theta_3}{V_{S1}} = \frac{\sin\theta_4}{V_{S2}} \qquad (3.6.1)$$

Where

V_{L1}&V_{L2} The longitudinal wave velocities in the first and second materials respectively

V_{S1}&V_{S2} The shear wave velocities in the first and second materials respectively

θ_1&θ_2 The angles of incident and refracted longitudinal waves respectively

V_3&θ_4 The angles of the converted reflected and refracted shear waves respectively

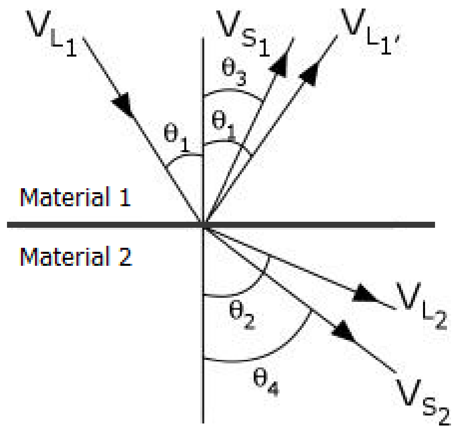


Figure (3-3) mode conversion

3.7The equipment for ultrasonic application

3.7.1 Piezoelectric Transducers

A transducer is a device which converts one form of energy into another. Ultrasonic transducers convert electrical energy into ultrasonic energy and vice versa by utilizing a phenomenon known as the piezoelectric effect.

TheMaterials which exhibit this property are known as piezoelectric materials.

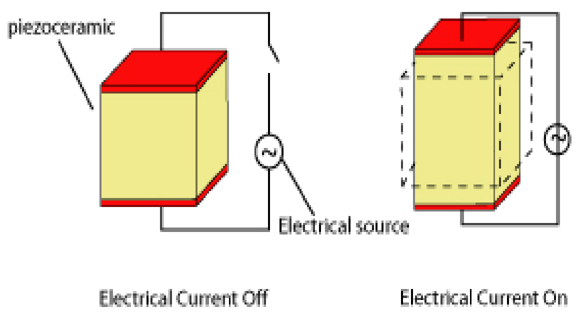


Figure (3-4) piezoelectric effect

Types of Piezoelectric Transducers

Piezoelectric transducers can be classified into two groups based on the type of piezoelectric material which is used in the manufacture of the transducer.

If the transducers are made from single crystal materials in which the piezoelectric effect occurs naturally, they are classified as piezoelectric crystal transducers. On the other hand the transducers which are made from polycrystalline materials.

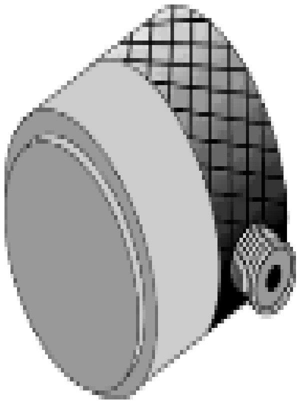
Transducer Types

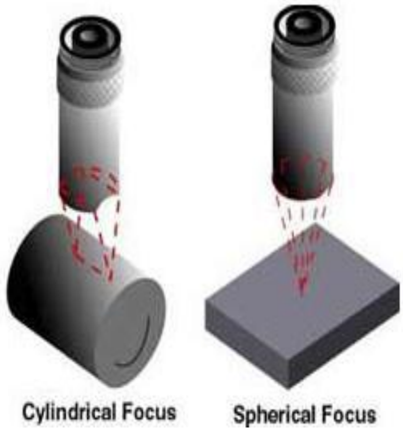
Ultrasonic transducers are manufactured for a variety of applications and can be custom fabricated when necessary. It is important to choose transducers that have the desired frequency, bandwidth, and focusing to optimize inspection capability. Most often the transducer is chosen either to enhance the sensitivity or resolution of the system.

Transducers are classified into two major groups according to the application.

Contact transducers are used for direct contact inspections, and are generally hand manipulated.

Immersion transducers do not contact the component. These transducers are designed to operate in a liquid environment and all connections are watertight. Immersion transducers usually have an impedance matching layer that helps to get more sound energy into the water and, in turn, into the component being inspected [1].





Contact transducers **Immersion transducer**

Figure (3-5) Type of transducer

3.7.2Couplant

A couplant is a material (*usually liquid*) that facilitates the transmission of ultrasonic energy from the transducer into the test specimen. Couplant is generally necessary because the acoustic impedance mismatch between air and solids is large.

In contact ultrasonic testing a thin film of oil, glycerin or water is typically used between the transducer and the test surface.

There are many suitable substances that can be used as couplants, the main criteria being the best possible match and no adverse chemical reaction between the couplant and the metal. Most couplants only allow limited matching because liquids in general have low acoustic impedance. In immersion testing, the couplant is usually water, which only allows about 12% of the energy into steel, and, of course only 12% of any echoes to pass back across the interface and back to the receiving transducer. Most couplants permit between 10% and 15% sound transmission. The best of these is glycerin at around 15%.

Commonly used couplants are:

- Water
- Kerosene
- Oil
- Grease
- Wallpaper paste
- Glycerin
- Special gels designed for the purpose

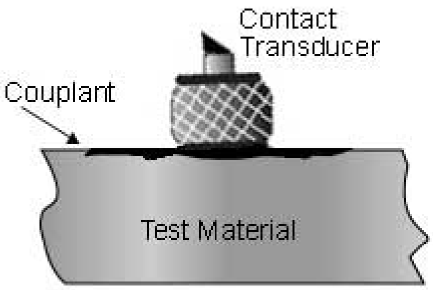


Figure (3-6) Couplant

3.7.3Pulser-Receivers

Ultrasonic pulser-receivers are well suited to general purpose ultrasonic testing. Along with appropriate transducers and an oscilloscope, they can be used for flaw detection and thickness gauging in a wide variety of metals, plastics, ceramics, and composites. Ultrasonic pulser-receivers provide a unique, low-cost ultrasonic measurement.

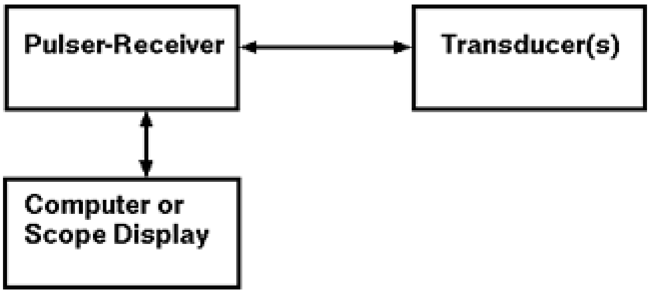


Figure (3-7) pluser-receiver

3.7.4 Test Procedure

Pulse-echo ultrasonic measurements can determine the location of a discontinuity in a part or structure by accurately measuring the time required for a short ultrasonic pulse generated by a transducer to travel through a thickness of material, reflect from the back or the surface of a discontinuity, and be returned to the transducer. In most applications, this time interval is a few microseconds or less. The two-way transit time measured is divided by two to account for the down-and-back travel path and multiplied by the velocity of sound in the test material. The result is expressed in the well-known relationship:

$$d = \frac{Vt}{2} \qquad (3.7.4.1)$$

Where

$d =$ The distance from the surface to the discontinuity in the test piece

$V =$The velocity of sound waves in the material

$t =$ The measured round-trip transit time

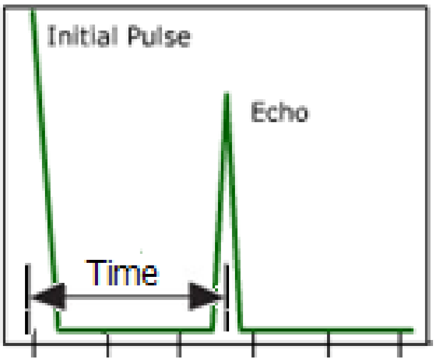


Figure (3-8)

Precision ultrasonic thickness gages usually operate at frequencies between 500 kHz and 100 MHz, by means of piezoelectric transducers that generate bursts of sound waves when excited by electrical pulses. Typically, lower frequencies are used to optimize penetration when measuring thick, highly attenuating or highly scattering materials, while higher frequencies will be recommended to optimize resolution in thinner, non-attenuating, non-scattering materials [1].

3-8 the advantages of Ultrasonic examination are:

- Inspection can be accomplished from one surface
- Small discontinuities can be detected
- High-temperature examination is possible with the correct equipment
- Examination of thick or long parts
- Discontinuity depth information
- Surface and subsurface discontinuities can be detected
- High speed scanning is possible with electronic signal gating and alarm system
- Test repeatability
- Equipment is light and portable

3.9 The limitation of ultrasonic testing

- Discontinuities that are oriented parallel with the beam energy will usually not be detected.
- Orientation of the discontinuity (reflector) is the most important factor in detecting discontinuities.
- Discontinuities that are similar to or smaller than the material's grain structure may not be detected.
- Thin sections may present resolution problems or require the implementation of special techniques.
- Uneven scanning surfaces can reduce the effectiveness of the test.
- In general, this method requires a high level of skill and training.
- Permanent record of the examination results is not typical. The records are limited to physical documentation rather than an actual reproduction of the test.

Chapter Four

Penetrant Test

4-1 Introduction

Penetrant testing (PT) is one of the most widely used nondestructive testing methods for the detection of surface discontinuities in nonporous solid materials. It's almost certainly the most commonly used surface NDT method today because it can be applied to virtually any magnetic or nonmagnetic material.

This method is very appropriate in a production type environment where many smaller parts can be processed in relatively short period of time [1].

4-2 penetrant process

The materials used in the Penetrant process are classified into four groups. The characteristics for each will be presented in detail. The first groups of materials that are essential for a penetrant test are precleaners. The second group of materials, which has the greatest influence on sensitivity, is penetranrs. The third group comprises the emulsifiers and solvent removers, and the forth group the developers.

4-2-1 precleaners

Precleaning is an essential first step in penetrant process. The surface must be thoroughly cleaned to assure that all contaminants and other materials that may prohibit or restrict the entry of the penetrant into surface openings are removed. Thorough cleaning is essential if the examination results are to be reliable. Not only does the surface have to be thoroughly cleaned, but openings must be free from contaminants such as oil and water, oxides of any kind, paint or other foreign material which can greatly reduce the penetrant sensitivity.

Typical cleaners include the following:

Solventsare probably the most widely used liquids for precleaning parts in penetrant test. There are a variety of solvents that can be effective in dissolving oil, films, grease, and other contaminants. These solvents should be free of any residues that would remain on the surface. Solvents cannot be used for the removal of spatter, rust, or similar materials on the surface. This must be removed by some type of a mechanical cleaning process.

Ultrasonic cleaning of all the precleaner materials and processes, ultrasonic cleaning is probably the most effective. Not only will contaminants be removed from the surface, but also if there are entrapped contaminants in discontinuities and other surface openings, the power that is generated in the ultrasonic cleaning process will usually be effective in breaking up and removing them.

Alkaline cleaning it's used for precleaning are nonflammable water solutions that, typically, contain specially selected detergents that are capable of removing various types of contamination.

Steam cleaningin some rare instances, steam may be used to remove contaminants from the surface. Although very effective in removing oil-based contaminants, this is not a widely used technique.

Water and etergent cleaning there are various devices that utilize hot water and detergents to clean part surfaces. This technique depends largely upon the type of contamination that is present on the test surfaces. Usually, if parts are covered with oil or grease, the contaminants will not be satisfactorily removed from the surface with this cleaning technique.

Chemical cleaning Chemical cleaning techniques usually involve etchants, acids, or alkaline baths. This precleaning approach is primarily confined to softer materials, such as aluminum and titanium, where prior mechanical surface treatments, such as machining or grinding, could possibly have smeared metal over discontinuity openings. Both acid oralkaline liquids are usually effective in the removal of rust and surface scale; however, a slight amount of the surface material is also removed, so this process must be very carefully controlled. Steps must be taken to assure the complete removal of these liquids from all surface openings.

4-2-2 penetrants

The most important characteristic that affects the ability of a penetrant to penetrate an opening is that of **"wetability."** Wetability is a characteristic of a liquid and its response to a surface. If a drop of water is placed on a very smooth, flat surface, a droplet with a very pronounced contour will result, as shown in Figure 4-1(c). Although water is a liquid and is **"wet"**it's wetting characteristics are not good enough to make it an effective penetrant.

The contact angle **Ɵ** is measured from a line drawn in an arc from its junction point with the surface to the opposite surface (see Figure 4-1). If that same droplet of liquid is emulsified, such as would be the case with the addition of a small amount of liquid soap, the droplet will tend to flatten out and the contact angle will be somewhat decreased, see Figure 4-1(b). In the case of a liquid penetrant, its wetting properties are so great that it will, essentially, lie almost flat on a smooth surface and the contact angle **Ɵ** will be very low, as in Figure 4-1(a). Therefore, the penetrants with the lowest contact angles will have the best wetability and provide good penetrability for a given material. Two other important characteristics of the penetrant are the dye concentrate and the viscosity. Dye concentrate has a major and direct influence on the "seeability" or sensitivity of the penetrant material, assuming that the wetting properties and the penetrability are of a very high level. The dye concentrate makes the penetrant more visible to the human eye. In some early penetrants, different colored dyes were tried, including blue, yellow, and green, but it seemed that the red dye resulted in the best response to visible observation. In fact, the term "**contrast ratio**" is generally used to express the seeability of a penetrant. If a white penetrant were used on a white developed background, the contrast ratio would be one-to -one. In other words, there would be no contrast between the penetrant and the background. In the case of a red penetrant, the contrast ratio is said to be six-to-one, making that contrast very noticeable on a white background surface. The dye concentrate is also important in a fluorescent penetrant. The contrast ratio of a fluorescent penetrant is said by many references to be forty-to-one, compared to the six-to-one of a visible red dye. In reality, the contrast ratio of the fluorescent penetrant being viewed under a black light in a virtually dark room would essentially be the same as would exist if there were a single candle in a perfectly pitch-black room. The contrast ratio in this case would be exceptional and, for this reason, the fluorescent penetrant produces a much higher degree of seeability or sensitivity as compared to the visible dye penetrants.

Viscosity is defined as the state or quality of being viscous. Liquids with higher viscosity values are thicker than those with lower ones. Although viscosity is an important characteristic of a penetrant, it is not as influential as the wetting characteristics and dye concentrate. If the penetrant has good wetting characteristics and exceptional dye concentration, it will still provide a meaningful examination, even if the viscosity is high. The difference in viscosity will influence the actual dwell time, or the amount of time that it will take for the liquid to effectively penetrate a given surface opening.

There are other characteristics that an effective penetrant should possess. In addition to being able to penetrate small surface openings

They must also:

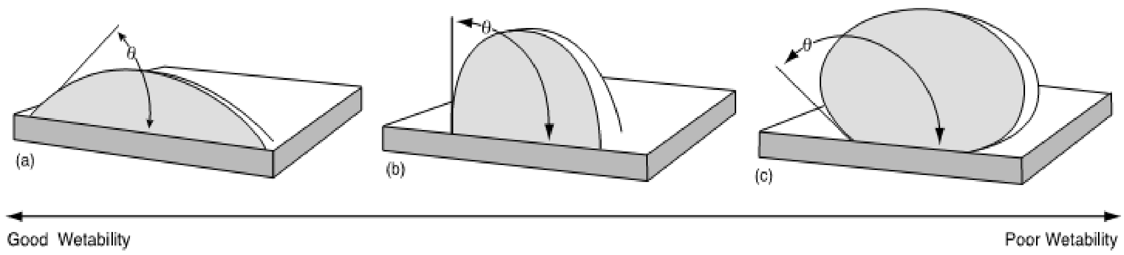
- Be relatively easy to remove from the surface during the removal step.
- Be able to remain in the discontinuities until they are withdrawn during the development step.

- Be able to bleed from the discontinuities when the developer interacts with it and have the ability to spread out in the developer layer.
- Have excellent color and the ability to be displayed as a contrasting indication in order to provide the sensitivity that is necessary.
- Exhibit no chemical reaction between the penetrant materials and the test specimen.
- Not evaporate or dry rapidly.
- In addition, they should be nonflammable, odorless, and nontoxic; possess stability under conditions of storage; and be cohesive, adhesive, and relatively low in cost.

In summary, the most important characteristics of a penetrant when performing a ***Penetrant test are:***

(1) Capillary action. (2) Wetting characteristics. (3) Dye

figure**4- 1**Wetability characteristics.



4-2-3 Emulsifiers/Removers

The purpose of the emulsifiers used in penetrant testing is to emulsify or break down the excess surface penetrant material. In order for these emulsifiers to be effective, they should also possess certain characteristics, including:

- The reaction of the emulsifier with any entrapped penetrant in a discontinuity should be minimal in order to assure that maximum sensitivity is achieved**.**
- The emulsifier must be compatible with the penetrant.
- The emulsifier must readily mix with and emulsify this excess surface penetrant.
- The emulsifier mixed with the surface penetrant should be readily removable from the surface with a water spray.

4-2-4 Solvent Removers

Solvent removers are used with the solvent removable technique and must be capable of effectively removing the excess surface penetrant. There are a number of commercially available solvents that make excellent removers. These solvents should readily mix with the penetrant residues and be capable of removing the final remnants from the surface.

They should also evaporate quickly and not leave any residue themselves. It is essential that the removers not be applied directly to the surface, since they are also good penetrants. Spraying or flushing the part with the solvent during the removal step is prohibited by many specifications. Even so, there are still users who insist on performing this unacceptable practice in order to “thoroughly” remove the surface penetrant. When using thevisible color contrast penetrants, a slight trace of pink on the cloth or paper towel will indicate that the removal is adequate. For fluorescent penetrants, slight traces of the fluorescent penetrant as observed under the black light will also indicate the proper level of removal.

4-2-5 Developers

There are four basic types of developers:

1. Dry developer
2. Solvent-based developers also referred to as “spirit” or nonaqueous

3. Wet developers suspended in water
4. Wet developers that are soluble in water

Developers have been described as “chalk” particles, primarily because of their white, chalk-like appearance.

In order for the developers to be effective in pulling or extracting the penetrant from entrapped discontinuities, thus presenting the penetrant bleed-out as an indication that can be evaluated; they should possess certain key characteristics. They should:

- Be able to uniformly cover the surface with a thin, smooth coating.
- Have good absorption characteristics to promote the maximum blotting of the penetrant that is entrapped in discontinuities.
- Be nonfluorescent if used with fluorescent penetrants.
- Provide a good contrast background that will result in an acceptable contrast ratio.
- Be easily applied to the test specimen.
- Be inert with respect to the test materials.
- Be nontoxic and compatible with the penetrant materials.
- Be easy to remove from the test specimen after the examination is complete.

There are other types of developers that are used on rare occasions. These are referred to as strippable, plastic film, or lacquer developers. They are typically nonaqueous suspensions containing a resin dissolved in the solvent carrier. This developer sets up after application and is then stripped off the surface, with the indications in place. It can then be stored and maintained as part of the inspection report[1].

4-3 The Penetrant procedures

Selecting the correct technique for penetrant testing is very important. Prior to performing the examination, a procedure should be developed and qualified. When preparing the procedure the following must be considered [1].

- ❖ **Prerequisites**

  Prior to any penetrant test, there are certain prerequisites that have to be addressed.

- ❖ **Temperature**

  Penetrant materials are influenced by temperature variations. Most codes and specifications require that the test part and the penetrant materials be within a specified temperature range, typically between 40 °F (4.4 °C) up to as high as 125 °F (51.6 °C). The part and the penetrant materials must fall within the specified temperature range. If the test part or the penetrant is extremely cold, the penetrant becomes very thick and viscous, which will affect the time it will take to penetrate the discontinuities. If the test surface or penetrants are high in temperature, some of the more volatile constituents may evaporate from the penetrant, leaving a thick residue that will not effectively penetrate the discontinuities.

- ❖ **Environmental Considerations**

  Since some of the solvent cleaners and removers used with penetrant testing can be somewhat flammable, it is essential that the penetrant test be performed in an area where there are no open flames or sparks that may tend to cause the penetrant materials to ignite. Typically, penetrant materials have relatively high flash points, but some of the cleaner/remover solvents could ignite when exposed to sparks or open flames. Also, some of the solvents may give off fumes. Therefore, penetrant testing should be performed in an area where there is adequate ventilation.

- **Lighting**

  there must be adequate lighting in the examination area, especially during the time when the evaluation is performed.

- **Surface Condition Considerations**

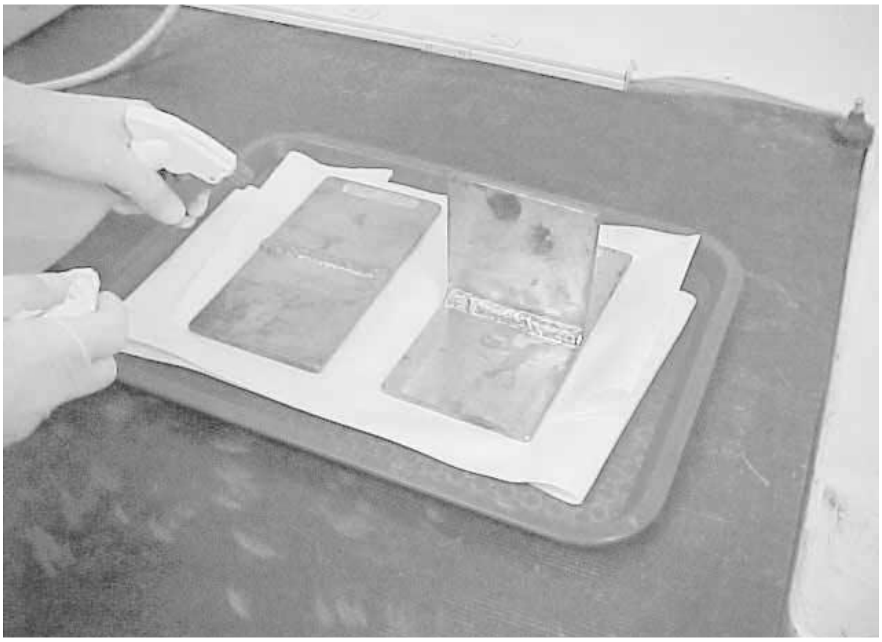
  Surfaces to be examined having coatings such as paint or plating, or extremely rough conditions, must be addressed. If the surface contains scale and rust, some type of strong mechanical cleaning process is required. Many codes and specifications do not permit the use of some mechanical cleaning techniques, such as shot-blasting, shot-peening, or sandblasting, since these processes tend to peen over the test surface, potentially closing a crack or other surface discontinuity. If wire brushing is used to remove scale or rust, it should be done with extreme care for the same reason. If extreme pressure is applied to a grinding wheel or power wire brush, it is possible to cause a smearing of the metal on the surface [4].

There are 7th steps when using the penetrant test

4-3-1 Precleaning

After addressing the prerequisites, it is necessary to remove all contaminants from the surface and, after the surface has been cleaned, all evidence of any residues that may remain.

(See Figure 4-2) After precleaning, it is essential that the precleaners evaporate and that the test surface be totally dry prior to application of the penetrant. This will prevent contamination or dilution of the penetrant in the event that it interacts and becomes mixed with the precleaner.



Figure(4-2)Precleaning of a weld surface.

4-3-2Penetrant Application

The penetrant can be applied to the surface of the test part in virtually any effective manner,including brushing (Figure 4-3), dipping the part into the penetrant, immersion,spraying, or just pouring it on the surface. (Figure 4-4) shows a water-removable fluorescentpenetrant being applied with an electrostatic sprayer. The key is to assure that thearea of interest is effectively wetted and that the penetrant liquid does not dry during thepenetration or **dwell time**,which is the period of time from when the penetrant is appliedto the surface until it is removed. The codes and specifications give detailed dwell timesthat must be followed. It is quite common to have a dwell time of 10 to 15 minutes formany applications.

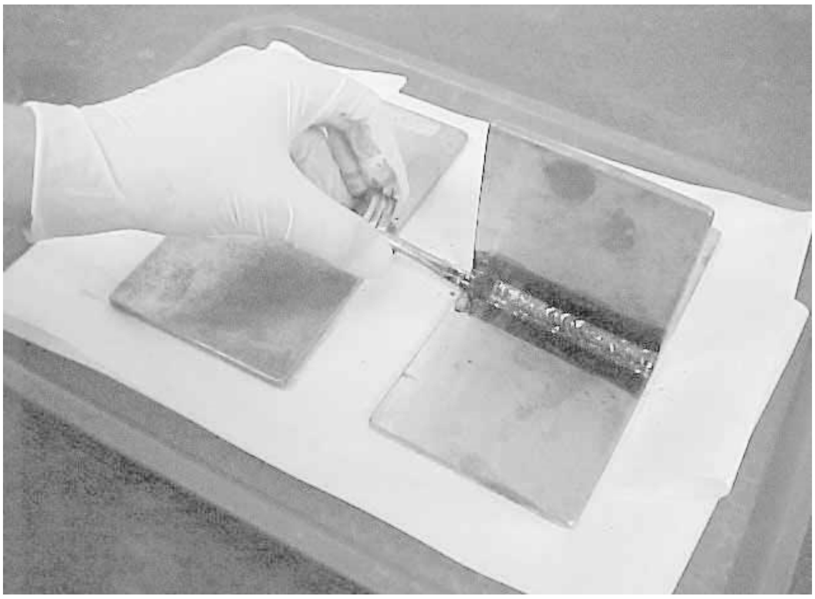


Figure (4-3)Application of a visible penetrant.

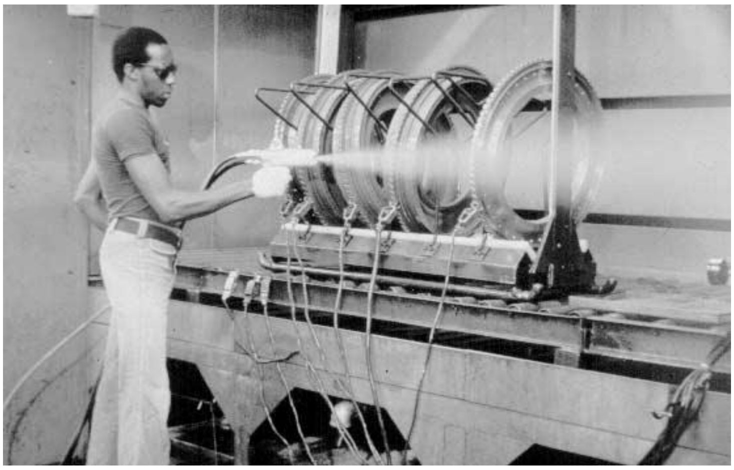


Figure (4-4)

Water-removable fluorescent penetrant being applied with electrostatic spray.

4-3-3Penetrant Removal

In this step the excess surface penetrant is removed from the test specimen surface; the method of removal depends on the type of penetrant that is being used. There are threetechniques for excess surface penetrant removal: **water, emulsifiers, and solvents**.(Figure4-5) illustrates excess surface visible contrast penetrant being removed with a solvent dampened cloth. Removal of fluorescent penetrants is usually accomplished under a black light. This provides a means of assuring complete removal of the excess surface penetrant while minimizing the possibility of over removal.

Figure (4-5) Removal of excess surface penetrant.

4-3-4Application of Developer

The type of developer to be used will be specified in the penetrant procedure. As mentioned above, the four types of developers are **dry, nonaqueous, aqueous suspendable,** and **aqueous soluble**. The entire test surface or area of interest must be properly developed, although there are rare applications where developers are not used. A nonaqueousdeveloper is applied by spraying (See Figure 4-6). It must be applied in a thin, uniform coating.

Thick layers of developer, whether nonaqueous, dry, or aqueous, can tend to mask a discontinuity bleed-out, especially if that discontinuity is small and tight.

Figure(4-6)Application of a nonaqueous developer.

4-3-5Development Time

The developer must be given ample time to draw the entrapped penetrant from the discontinuity out to the test surface. Many codes and specifications will require a development time from 7 to 30 minutes and, in some cases, as long as 60 minutes. **Development** is defined as the time it takes from the application of the developer until the actual evaluation commences. It is recommended that the surface be observed immediately after the application of the developer to assist in the characterizing and to determine the extent of the indication(s).

4-3-6 Interpretation

Upon completion of the development time, the indications from discontinuities or other sources that have formed must be interpreted. A visible contrast penetrant bleed out is illustrated in (Figure 4-7) and fluorescent penetrant indications are shown in (Figure 4-8). Bleed outs are interpreted based primarily on their **size, shape, and intensity.**

Figure(4-7)Indication of a bleedout.

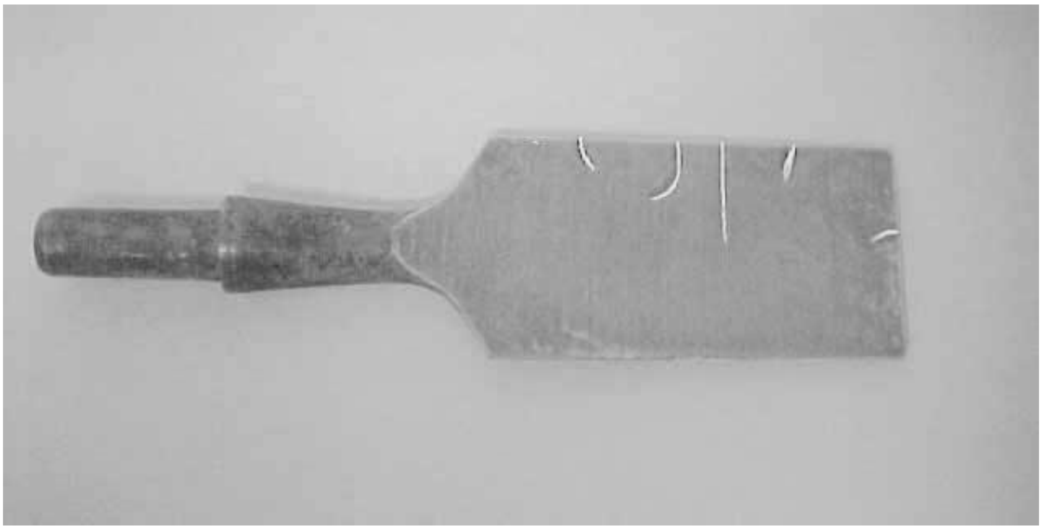


Figure (4-8) Fluorescent penetrant bleedouts.

4-3-7Post cleaning

After the part has been evaluated and the report completed, all traces of any remaining penetrant and developer must be thoroughly removed from the test surface prior to it being placed into service or returned for further processing[1].

4-4Techniques and variables

It should be apparent by now that there are a number of PT techniques that can be used with the different materials described. A summary of these techniques is listed in (Table4-1). A detailed description of two important techniques follows.

(*Note:* The technique and process designations in this section are for simplification and do not directly relate to code or specification classifications.)

TABLE 4-1 Penetrant Technique Classification

Technique	**Process**	**Materials**
I (Fluorescent)	**A** Figure(4-9)	Water-removable penetrant; dry, aqueous, or nonaqueous developer
	B	Postemulsifiablepenentrant; lipophilic emulsifier; dry, aqueous, or nonaqueous developer
	C	Solvent-removable penetrant; solvent cleaner/remover; dry or nonaqueous developer
	D	Same as I B except the emulsifier is hydrophilic
II (Visible,color contrast)	**A**	Water-removable penetrant; aqueous or nonaqueous developer
	B	Postemulsifiable penetrant, emulsifier, and aqueous or nonaqueous developer
	C Figure(4-10)	Solvent-removable penetrant; solvent cleaner/remover, aqueous or nonaqueous developer

4-4-1Technique I, Process A (I-A)

Technique I Process A uses a fluorescent water-removable penetrant that can be used with either dry, aqueous, or nonaqueous developers (see Figure 4-9). This technique is generally used for the following applications:

1. When a large number of parts or large surface areas are to be examined
2. When discontinuities that are not broad or shallow are anticipated

3. When parts to be examined have complex configurations such as threads, keyways, or other geometric variation

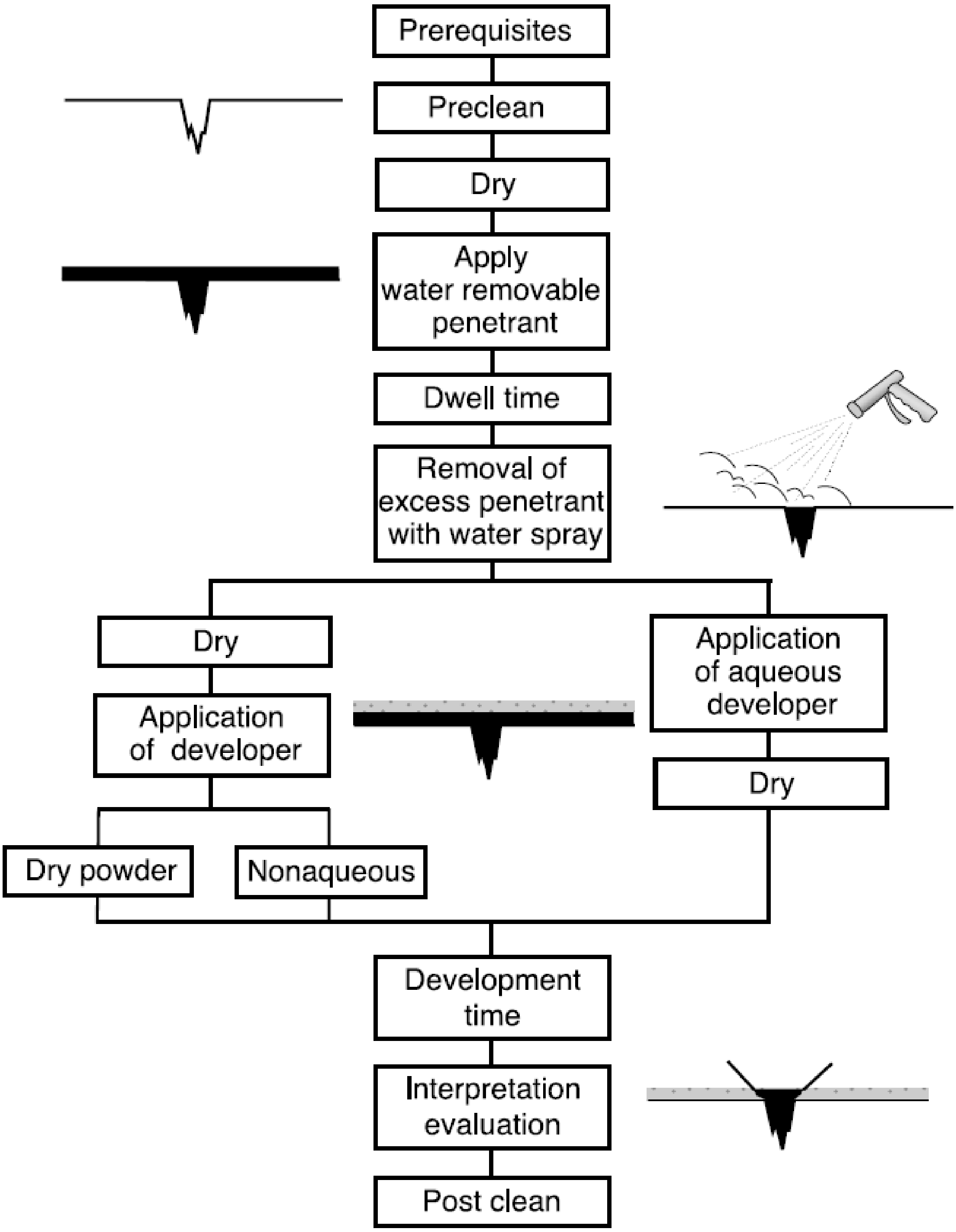
4. When the parts to be examined have surfaces that are rough, such as with sand castings or as-welded conditions

Advantages:

1. Higher sensitivity
2. Excess penetrant is easily removed with a coarse spray
3. Easily adaptable for large surfaces and large quantities of small parts
4. The cost is relatively low

Limitations:

1. A darkened area is required for evaluation
2. Under- or over removal of penetrant material is possible
3. Water contamination can degrade the effectiveness of the penetrant
4. Not effective for broad or shallow discontinuities
5. Dryers are required (usually) when using developers
6. This technique is usually not portable



Figure(4-9)Water-removable technique (Process I-A or II-A).

4-4-2Technique II, Process C (II-C)

Technique II Process C uses **a visible, color-contrast, solvent-removable penetrant, a solvent cleaner/remover, and an aqueous or nonaqueous developer**. (Figure 4-10) illustrates this technique. The excess penetrant is not water-removable and must be removed with a solvent remover. This technique is widely used for field applications when water removal is not feasible, or when examinations are to be
conductedin a remote location.

Advantages

1. This technique is very portable and can be used virtually anywhere.
2. It can be used when water removal is not possible.
3. Black lights or darkened evaluation areas are not required.
4. Evaluation is done in visible light.
5. It is very adaptable for a wide range of applications.

Limitations:

1. The use of solvent to remove excess surface penetrant limits the examinations tosmaller areas and parts without a complex geometry.
2. Sensitivity is reduced when an excessive amount of remover is used during the removal step.
3. Excess penetrant removal is difficult on rough surfaces, such as sand casting and as welded surfaces, and usually results in a "background."
4. This technique has a lower level of sensitivity compared to Technique I penetrants.
5. It is more "operator-dependent" due to the variables involved in the removal step.

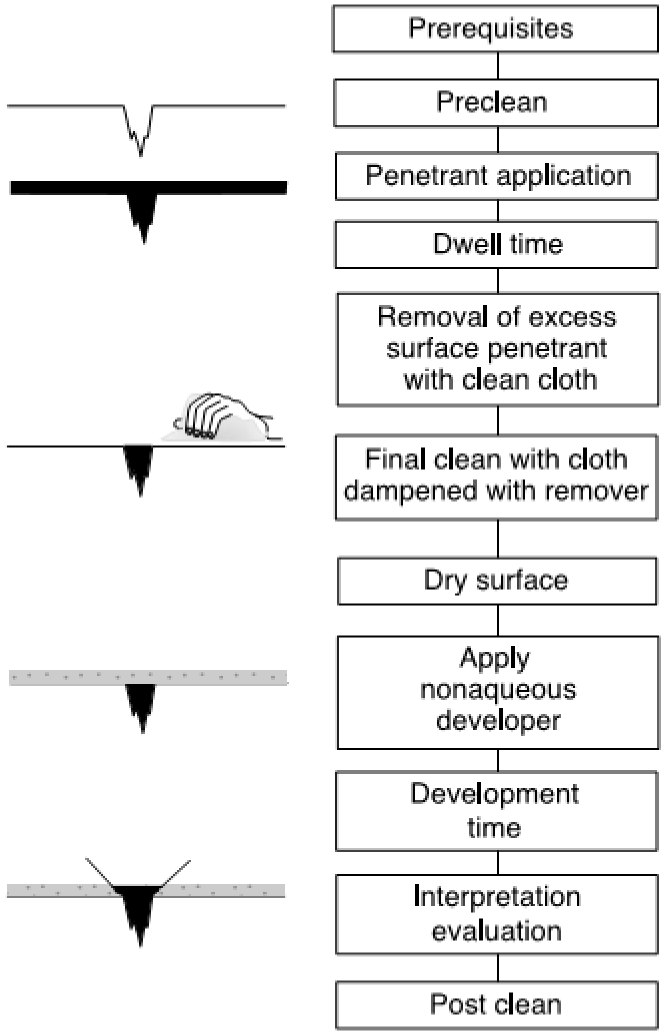


Figure (4-10) Solvent-removable technique (Process I-C or II-C).

Summary

Of all this techniques, the most widely used fluorescent penetrant technique is I-A (water-removable). Technique II-C is the most widely used visible color contrast penetrant.

4-5 Advantagesand limitations of penetrant testing

4-5-1 the major advantages of penetrant testing include:

1. Portability.
2. Cost (inexpensive).
3. Sensitivity.
4. Versatile—virtually any solid nonporous material can be inspected.

5. Effective for production inspection.

6. Nondestructiv.

4-5-2 The limitations include:

1. Only discontinuities open to the surface of the test specimen can be detected.

2. There are many processing variables that must be controlled.

3. Temperature variation effects.

4. Surface condition and configuration.

5. Surface preparation is necessary.

6. The process is usually messy.

Chapter five

Results

5.1 Introduction

One experiment was made. A certain force was applied on two different materials, Aluminum, and carbon steel. The image of the defect was found by ultrasound.

5.2 Material and Methods

In this research one experiment were performed on different materials. We effect on samples of aluminum, and carbon steel with a certain force which resulted in effect differed depending on the structure of samples placement experience. The defects were detected using liquid pentrant (for surface defects) test and ultrasound test (for surface and subsurface defect).

Aluminum has very weak structure, so the defect of applied force was very large,the defect is detected using liquid pentrant test for surface defects and found the length of **1.3cm**, and depth defects were detected using ultrasound and found the depth is 8mm **(0.8cm)** where the speed of sound in which is **3080m/s**.

Carbon steel has a very strong structure so the effect of the applied force is not being large. This defect detected for surface using liquid pentrant and found that the length of **0.4cm** and the depth defects were detected using ultrasound and found the depth is 2mm (**0.2cm**) where the speed of sound in which is **3220m/s**.

5.3 Results and tables

Table (5.3.1): Relation between the speed of sound in the material and the length defect.

No	Material type	Speed of sound (m/s)	Length of the defect image $\pm 0.1cm$
1	Aluminum	3080	13
2	Carbon steel	3235	4.0

Table (5.3.2): Relation between the speed of sound inside material and the depth of defect.

No	Material type	Speed of sound (m/s)	Depth of the defect image $\pm 0.1cm$
1	Aluminum	3080	8.0
2	Carbon steel	3235	2.0

5.4 Discussion

The ultrasound test made for some minerals like Aluminum, and carbon steel shows very interesting properties.

In view of tables (5.3.1) and (5.3.2) it is clear that, although the force excreted on the materials are the same for the two materials, the size of image are different.

The two figures show that the increase speed decreases the images sizes, including the length and the depth of the defect.

One can easily interpret this result as being resulting from the nature of the material and their response to the sound speed.

5.5 Conclusion

From this work detecting defects in materials using waves ultrasound more comprehensive detection using the liquid pentrant been reached that and because it gives an accurate description of the surface and subsurface of the reverse liquid pentrant that operate on the surface only.

5-6 References

[1] Charles J. Hellier, Handbook of Nondestructive Evaluation, McGraw-hill Companies.

[2] Cartz louis, Nondestructive testing : Radiography , Ultrasonics, Liquied penetrant, Magnatic particle, Edyy current, ASM Intl; ISBN: 0871705176.

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