بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Study

Determination of Length, Thickness and Elements of Some Samples defects By Using magnetic particles and Ultrasound testing

تعين الطول والسمك والعناصر لبعض العيوب في العينات بإستخدام الإختبارات بالجسيمات الممغنطه والموجات فوق السمعيه

Thesis Submitted In Partial fulfillment of Requirements for Msc in Physics

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الايـه

(اللَّهُ نُورُ السَّمَاوَاتِ وَالْأَرْضِ ۚ مَثَلُ نُورِهِ كَمِشْكَاةٍ فِيهَا مِصْبَاحٌ ۖ الْمِصْبَاحُ فِي زُجَاجَةٍ ۖ الزُّجَاجَةُ كَأَنَّهَا كَوْكَبٌ دُرِّيٌّ يُوقَدُ مِن شَجَرَةٍ مُّبَارَكَةٍ زَيْتُونَةٍ لَّا شَرْقِيَّةٍ وَلَا غَرْبِيَّةٍ يَكَادُ زَيْتُهَا يُضِيءُ وَلَوْ لَمْ تَمْسَسْهُ نَارٌ ۚ نُّورٌ عَلَىٰ نُورٍ ۗ يَهْدِي اللَّهُ لِنُورِهِ مَن يَشَاءُ ۚ وَيَضْرِبُ اللَّهُ الْأَمْثَالَ لِلنَّاسِ ۗ وَاللَّهُ بِكُلِّ شَيْءٍ عَلِيمٌ)

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Finally, all thanks to the people who supported me to complete this search

Dedication

To my mother

To my father

To my brothers

To my friends

مستخلص البحث

تستخدم الاختبارات على نطاق واسع في الصناعه والتكنولوجيا وذللك للتاكد من سلامه وآمان الاجهزة والمعدات.

في هذا العمل تم تعريض ثلاثة عينات من الاستيل,الكربون -استيل والالومينيوم لقوة متساويه وتم اختبار العيوب الناتجه باستخدام كشفي الموجات فوق الصوتيه والجسيمات الممغنطة. تم قياس طول العيوب الناتجة باستخدام كشف الجسيمات الممغنطة و هي مطابقه للاطوال التي كشف عنها با ستخدام الموجات فوق الصوتيه حيث بلغ طول العيب في الالومينيوم والاستيل والكربون-استيل 8.3,cm13.6cm و4.3cm على التوالي. وقد اجريت تجارب اخرى لتحديد عمق العيوب باستخدام الموجات فوق الصوتيه فقط ووجد ان العمق في العينات الثلاثه هو 5 cm, 8 cm و3 cm على التوالي.

اجريت تجربه اخرى لتحجيد سمك مكعب وقرص معدنين . بعد اجراء التجربه تم التوصل الى السمك 9.3cm و3cm على التوالي. تم استخدام هذه السماكات لحساب السرعه الاصليه للصوت في القرص والمكعب ووجد ان سرعه الصوت هي4430m/s و4470m/s وهي سرعه الصوت في النيكل.

Abstract

Nondestructive testing methods are that used widely in industry and technology so to test material and equipment to make sure that they are proper and secure.

In this work three samples from steel, carbon steel and aluminum were subjected to same fraction force. The damages produced were tested by ultrasound and magnetic particles. The fraction length obtained by magnetic particle and ultrasound give the same result. Where the length in the aluminum, steel and carbon steel defects are 13.6cm, 8.3cm and 4.3cm respectively. Whoever the depth of the defect was detected by ultrasound only and have results 8cm, 5cm and 2cm respectively. Other experiments were done to determine the thicknesses of disc and cube. The tests give apparent thickness of 3.9cm and 3.0cm respectively. These apparent thicknesses were used to find the real speed of sound for the disc and cube. The calculation shows that the speed is 4431m/s and 4470m/s which are the speed of sound for nickel.

Chapter One

1.1Introduction

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.

In recent years industries have recognized the importance of NDT to their own product and quality. Critical damages are placed on NDT inspectors and the techniques on which they rely on for which Training and Hands on experience in NDT has gained importance.

2.1Problems of the research

The use of ultrasonic detection to identify the material thickness and describe defects that can arise there in.

3.1The aims of the Research

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

4.1 The Research layout

The Research contain the five chapter, chapter one explain the importance of NDT, chapter two the methods NDT, chapter three for ultrasonic test, chapter four for detecting the magnetic particles and the last chapter for the results, discussion and conclusion.

Chapter Two

Destructive and Nondestructive Testing

2.1 Destructive testing

Destructive testing is a form of mechanical test of materials whereby certain specific characteristics of the material can be evaluated quantitatively. In some cases, the test elements being tested are subjected to controlled conditions that simulate service. The information that 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 can be used for other purpose beyond the mechanical test. Such destructive testing provides 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.

The key benefits of destructive testing are to related to the fact that it is reliable and accurate data from the test specimen.The information can be used to establish standard and specification. Also data achieved through destructive testing is usually quantitative. Typically, various service conditions are capable of being measured.Useful life can generally be predicted.

Despite these successes the destructive test suffers from certain limitations. In these test data applies only to the specimen being examined. Also most destructive test specimens cannot be used once the test is complete. Beside the fact that 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 (1-1) below:

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 non destructive testing

- Quality control of pre-cast units or construction in situ.
- Removing uncertainties about the acceptability of the material supplied owing to apparent non-compliance with specification.
- Confirming or negating doubt concerning the workmanship involved in batching, mixing, placing, compacting or curing of concrete.
- Monitoring of strength development in relation to formwork removal, cessation of curing, prestressing, load application or similar purpose.
- 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

- determining the extent of concrete variability in order to help in the selection of sample locations representative of the quality to be assessed
- 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.
- Assessing the potential durability of the concrete.
- Monitoring long term changes in concrete properties.
- Providing information for any proposed change of use of a structure for insurance or for change of ownership.

2.5Limitations of nondestructive testing

Benefits of nondestructive testing appear in many advantages. The first of all, 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. The materials can be examined for conditions internal and at the surface parts can be examined while in service. The NDT devices are portable and can be taken to the object to be examined.Nondestructive testing is cost effective, overall.

In spite these successes the non destructive test suffers from some limitations. It is usually quite operator dependent. Some methods do not provide permanent records of the examination. NDT methods do not generally provide quantitative data. Theorientation 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

Ultrasound Test

3.1 Sound and ultrasound nondestructive tests

Sound waves that have high frequency can be used in nondestructive testing. This needs understanding the physics of sound and ultrasound.

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.

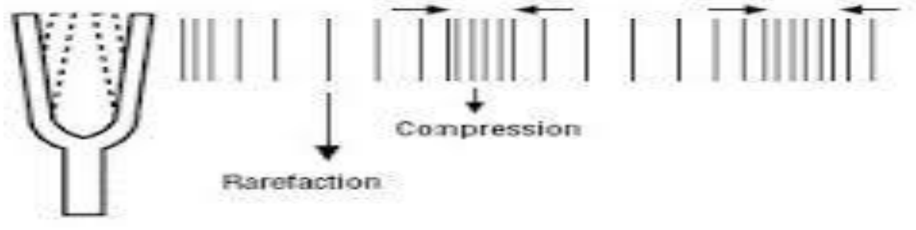


Fig (3.1) sound wave in the form of compressed and stretched successive layers.

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

$$C = f\lambda$$

The human higher than 20000 Hz are called ultrasound frequencies.

3.3 speed of sound in a media

Consider a fluid o density ρ in a tube of cross sectional area A under a pressure$P$, at rest. Let the piston and the tube move to the right with speed$v$. All portion of the fluid at the left of point $x$are moving with speed$v$, where as all at right of $x$are still at rest. The boundary between the moving and stationary portion travel to the right with speed.The piston has moved a distancevt, while the boundary a distance advancedut. The quantity of the fluid that moves occupy volume

$$V = utA \qquad (3.3.1)$$

Thus it mass is given by

$$m = \rho uAt \qquad (3.3.2)$$

The momentum is this given by

$$M_o = mv = \rho uAvt \qquad (3.3.3)$$

The change of pressure $\triangle$p causes the volume change by an a mount

$$\triangle v = Avt$$

From the definition of the Bulk modules

$$B = \frac{\triangle p}{(\triangle v/v)} = \frac{\triangle p}{((Avt)/Aut)} = \frac{u \triangle p}{v}$$

Thus

$$\triangle p = \frac{Bv}{u} \qquad (3.3.4)$$

The force is related to the pressure according to the relation

$$F = \triangle pA \qquad (3.3.5)$$

The momentum is related to the force according to the Newton's second low according to the relation

$$F = \frac{dM_o}{dt}$$

$$M_o = \int f dt = Ft \qquad (3.3.6)$$

$$\rho Auvt = \frac{Bv}{u} At$$

$$u^2 = \frac{B}{\rho} \quad (3.3.7)$$

Thus the speed of sound in fluid is given by

$$u = \sqrt{\frac{B}{\rho}} \qquad (3.3.8)$$

This means that the sound speed depends on the density as well as Bulk modules.

3.4 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.

3.5 Energy, Power and Intense

Transmission of sound waves when processed through medium transfer to energy to the molecules of the medium which oscillate as a result of this absorption of energy. The one assumes the existence of a particular layer of the living tissue having a mass Δm, thickness Δx, and wave of sound passes through this tissue with amplitude A, frequency f, the total energy ΔE given by:

$$\Delta E = {}^{1}/_{2}\,(\Delta m)\omega^2 A^2$$

$$\Delta E = {}^{1}/_{2}\,\rho a \Delta x(\omega A)^2 \qquad (3.5.1)$$

Where:

P: density of the medium.

ω= 2 π f: angular frequency.

a :area of sector.

$$\Delta E = {}^{1}/_{2}\,\rho a \Delta x(2\pi f A)^2.\ \text{Joule} \qquad (3.5.2)$$

The power of sound waves P is defined as the energy transfer rate (per unite time) for each part of living tissue.

$$P = \Delta E/\Delta t = 1/2\,\rho a \upsilon(\omega A)^2.\ \ \text{watt} \qquad (3.5.3)$$

The intensity I of sound waves is defined as the power per unite area, and measured by watt/cm^2

$$I = 1/2\,\rho\upsilon(\omega A)^2 = 1/2\,\rho Z(2\pi f A)^2 \qquad (3.5.3)$$

The intensity I is related to the pressure $P_r$through the relation:

$$I = P_r\upsilon \qquad (3.5.5)$$

$$Z = \rho\upsilon\ . \qquad \text{(acoustic impedance)} \qquad (3.5.6)$$

The relationship between intensity and maximum change in pressure inside the living tissue P_r when sound waves passes through it given by P^2/Z .

According to (3.4.1) and (3.4.6):

$$P_{rm} = \sqrt{2P_r} = \sqrt{2\,I\,Z} \qquad (3.5.7)$$

3.6 pressure and Acoustic Impedance

If a sound wave having velocityυ, moves through a medium of acoustic impedance z, the pressure P is given by:

$$P_r = z\upsilon \qquad (3.6.1)$$

The pressure and sound velocity changes when sound travel through different media. If the sound travel from one media of impedancez_1 to another one of impedancez_2. The velocity, pressure relation for incident, reflected and transmitted pressureP_i, P_r and P_t satisfies the relation:

$$P_i = z_1\upsilon_i P_r = -z_1\upsilon_r P_t = z_2\upsilon_t$$

$$P_r = ([z_2 - z_1]/[z_2 + z_1])P_i \qquad (3.6.2)$$

$$P_t = ([2z_2]/[z_2 + z_1])\,P_i \qquad (3.6.3)$$

Fig (3.2) refraction transmitted sound waves.

3.7 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 tissues z_1 and $z_2$where:

$$A_r/A_i = (z_2 - z_1)/(z_2 + z_1) \qquad (3.7.1)$$

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 $I \alpha A^2$.

$$I_r/I_i = [A_r/A_i]^2 \qquad (3.7.2)$$

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.

$$R = [A_r/A_i]^2 = [(z_2 - z_1)/(z_2 + z_1)]^2 \qquad (3.7.3)$$

3.8Snell'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. Mathematically Snell's Law is expressed as

$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{V_{L1}}{V_{L2}} \qquad (3.8.1)$$

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

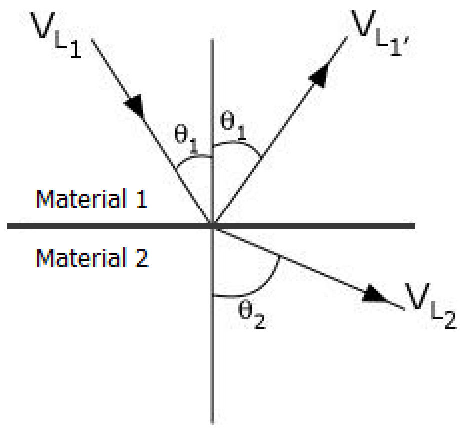


Figure (3-3) Snell's low

3.9Mode 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 conversionoccurs when a wave encounters an interface between materials of different acoustic impedances and the incident angle is not normal to the interface.It should 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

$$\frac{\sin\theta_1}{V_{L2}} = \frac{\sin\theta_2}{V_{L2}} = \frac{\sin\theta_3}{V_{S1}} = \frac{\sin\theta_4}{V_{S2}} \qquad (3.9.1)$$

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

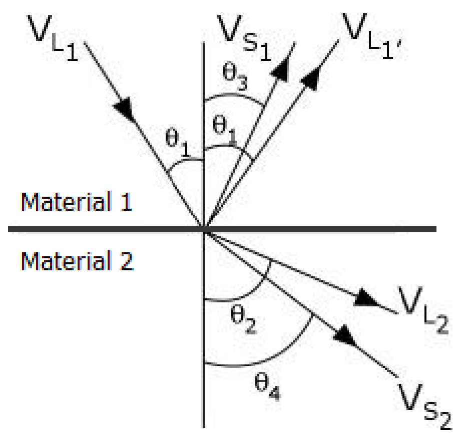


Figure (3-4) mode conversion

3.10The equipment for ultrasonic application

3.10.1 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. The Materials which exhibit this property are known as piezoelectric materials.

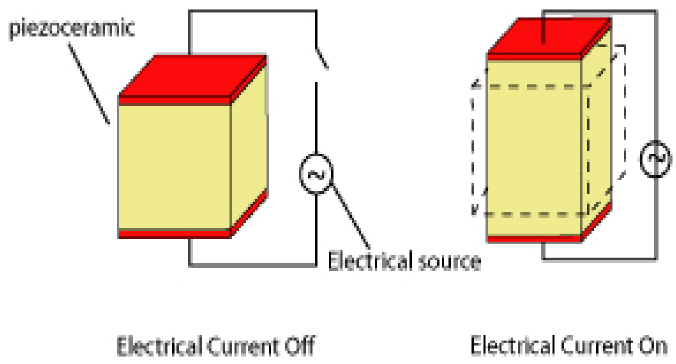


Figure (3-5) piezoelectric effect

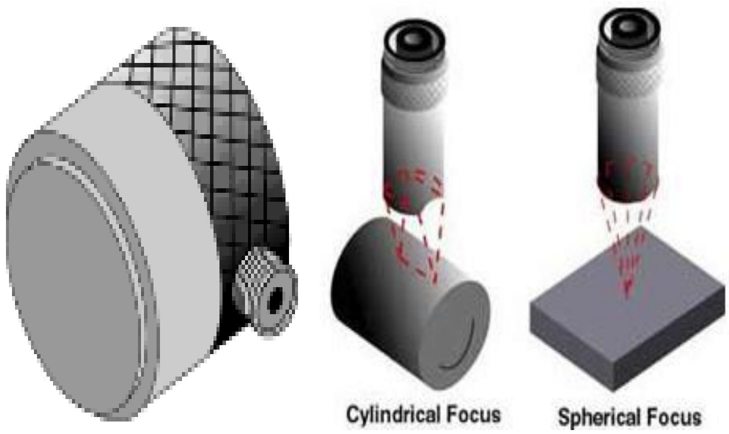
3.10.2 Types of Piezoelectric Transducers

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.

3.9.3Transducer 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 transducersdo 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.



Contact transducers Immersion transducer

Figure (3-6) Type of transducer

3.11 Couplant

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.

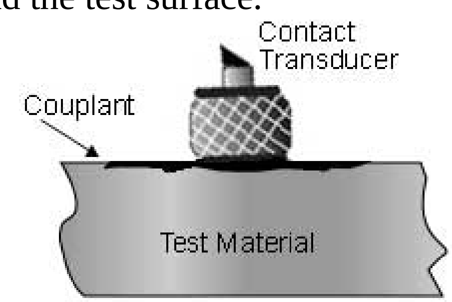


Figure (3-7) Couplant

3.12Pulser-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.

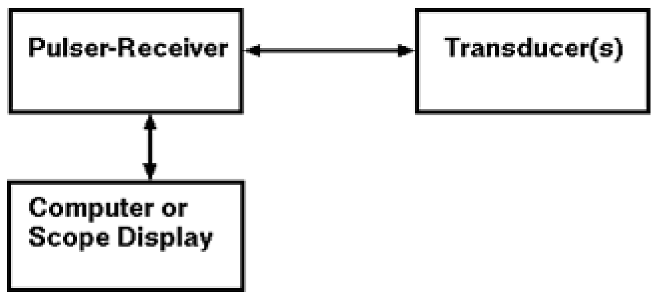


Figure (3-8) pluser-receiver

3.13 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:

$$d = \frac{Vt}{2} \tag{3.13.1}$$

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

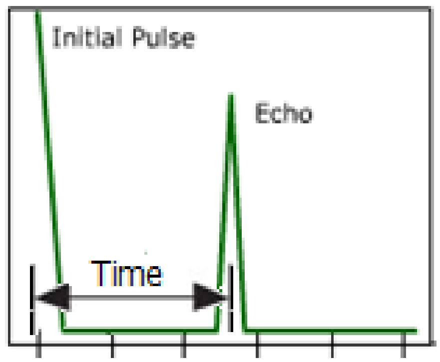


Figure (3-9)

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.

3.14 Advantages of ultrasonic testing

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

3.14 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

The Magnetic Particles Testing

4.1 Introduction

Magnetic fields play an important role in physics. It is used in many applications. Here one exhibits the applications in nondestructive testing.

4.2Diamagnetic, Paramagnetic and ferromagnetic materials

Diamagnetic: metals have a very week and negative susceptibility to magnetic fields. Diamagnetic materials are slightly repelled by a magnetic field and the material does not retain the magnetic properties when the external field is removed. Most elements in periodic table, including cooper, silver and gold, are diamagnetic.

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

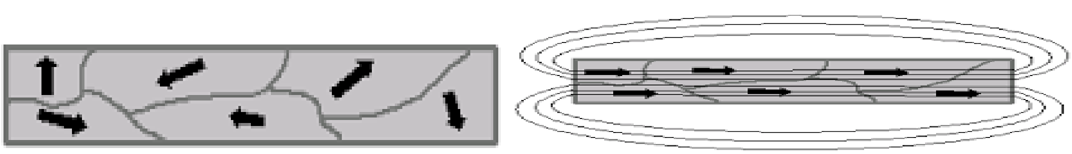
Paramagnetic materials include magnesium, molybdenum, lithium, and tantalum.

Ferromagnetic:materials have a large and positive susceptibility to an external magnetic field. They exhibit a strong attraction to magnetic field and are able to retain the magnetic properties after the external field has been removed. Iron, nickel, and cobalt are examples of ferromagnetic materials. Components with these materials are commonly inspected using the magnetic particle method.

4.3Magnetic Domains

Ferromagnetic materials get their magnetic properties not only because their atom carry a magnetic moment but also because the material is made up of small region known as magnetic domains. In each domain, all of the atomic dipoles are coupled together in a preferential direction. This alignment develops as the material develops its crystalline structure during solidification from the molten state.

Ferromagnetic materials become magnetized when the magnetic domain within the material are aligned. This can be done by placing the material in a strong external magnetic field or by passing electrical current through the material. Some or all the domains can become aligned. The mo re domains that are aligned, the more domains that are aligned, and the stronger the magnetic field in the material. When all of the domains are aligned, the material is said to be magnetically saturated. When a material is magnetically saturated, no additional amount of external magnetization force will cause an increase in its internal level of magnetization.



Unmagnitized material magnitized material

Fig (4-1) Un-magnetized material& magnetized material

4.4General Properties of Magnetic Lines of force

Magnetic lines of force have a number of important properties, which include:

- They seek the path of least resistance between opposite magnetic poles. In a single bar magnet, they attempt to form closed loops from pole to pole.
- They never cross one another.
- They all have a same strength.
- Their density decrease (the spread out) when they move from the area of higher permeability to an area of lower permeability.
- Their density decreases with increasing from the poles.
- They are considered to have direction ass is flowing, though no actual movement occurs.
- They flow from the South Pole to the North Pole within a material and North Pole to South Pole in air.

4.5 magnetization Of Ferromagnetic Material

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

4.6Circular Magnetization

A circular magnetic field is induced into a specimen by either direct magnetization that is, passing current directly through the part, by passing current through a conductor surrounded by a hollow part.

4.7 Direct Induction

Direct induction of a circular field into an article is accomplished by passing a current through the article as shown in Figure (). This method is called a head shot. Another direct method of inducing a circular field into a specimen is by use of prods. Prod magnetization is used where the size of location of an article does not permit the use of a head shot. This method provides the most sensitivity because all the lines of force generated by the current flow are contained within the material being magnetized. Current flow and field distribution are shown in Figure ().

4. 8Indirect Induction

In the indirect method of inducing a circular field, the specimen to be magnetized is placed so that a current-carrying conductor induces a magnetic field into the specimen. This method is known as the central conductor technique and is illustrated in Figure (4-2)

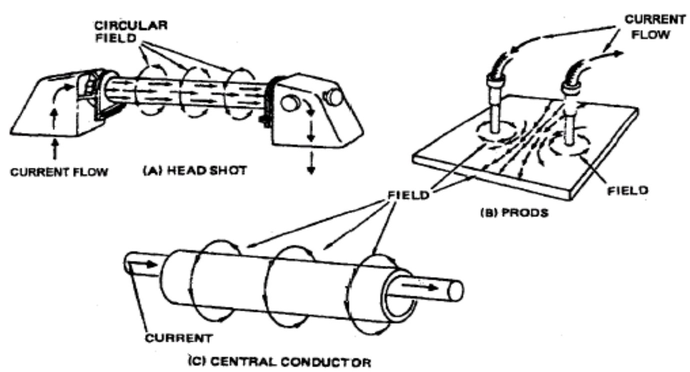


Fig (4-2).Circular magnetization

In a nonmagnetic material, the lines of force will not stay in the material. For example, when a copper bar is used, the magnetic field is established around the bar as shown below.

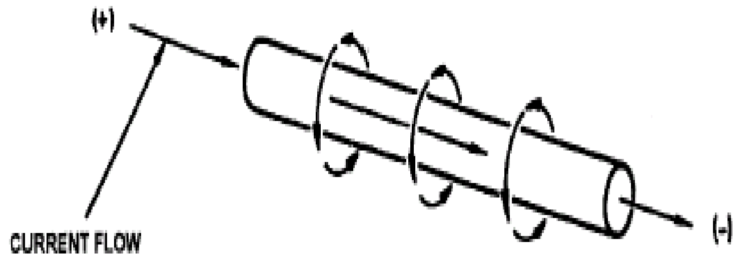


Fig (4-3) nonmagnetic material

In a magnetic material, the lines of force are established within the material. Iron, cobalt, nickel and steel are permeable and readily conduct the magnetic field as shown in Figure (2-5).

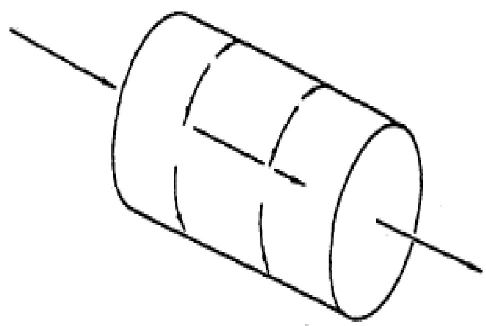


Fig (4-4) magnetic material

In both materials, the lines of force are at right angles (90 degrees) to the direction of current flow. Iron particles will not be attracted to a magnetized part except where a flux leakage exists. A crack in the part as shown in Figure () would cause a typical indication.

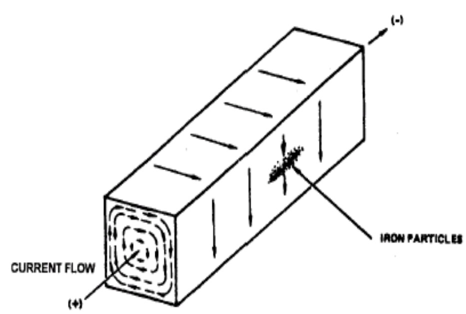


Figure (4-5) flux leakage

4.9LongitudinalMagnetization

A method of magnetization that produce magnetic lines parallel to the major axis of the component that using coil or Solenoid, permanent magnet or electromagnet.

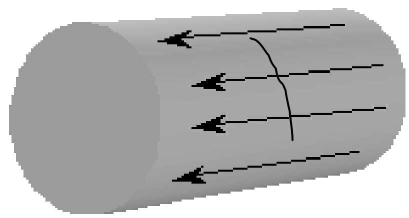


Fig (4-6) longitudinal magnetization

4.10Magnetic particle testing

Magnetic particle testing (MPT) is a method of NDT that detects and locate surface and near discontinuities in ferromagnetic materials utilizes the principle of magnetism. MPT is fast and relatively easy to apply, and part surface preparation is not as critical as it is for some other NDT methods. These characteristic makes MPT one of the most widely utilized nondestructive testing methods.

Magnetic particle testing (MPT) is relatively simple concept. Consider a bar magnet, every magnet is surrounded by magnetic line of force. Line of force enters and exits points called pole,Entry point is the South Pole and the exit point is the North Pole.

If a magnet is completely broken, it will become two bar magnets each with their own South and North Poles. If magnet is just cracked but not broken completely, a North and South Pole will form at each edge of the crack. Magnetic field exit at North and enter at South Pole, magnetic field spread out forming leakage field because air cannot contain magnetic in field as much as metal can. If magnetic particles sprinkled on the bar, it will be attracted and forming clusters at the poles (at the edge of the bar and at the edge of the crack). Cluster is easier to see than the crack

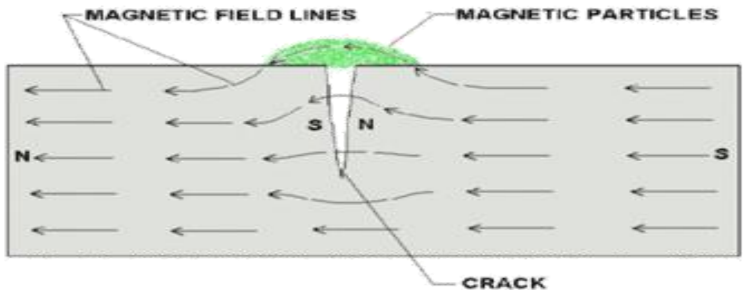


Fig (4-7) flux leakage field

4.11Magnetic particle equipment

The equipment used to process specimens for magnetic particle testing ranges from heavy duty, complex, stationary systems weighing several tons, to mobile units on wheels and small, light weight, hand carried, portable units.

Stationary equipment usually requires a 440 volts, 3-phase, AC electrical power source to power the: unit and is used in a fixed location figure (4.8.a). Mobile equipment is commonly used in refineries, power plants and shipyards where mobility is essential and the current requirements are slightly less. They usually require a 220-volt, single-phase, AC power source and are capable of up to 4000 amperes of current output figure (4.8.b), the lightweight yokes that can be powered by small 110-volt, AC generators. Theses portable units are needed for inspection where accessibility is a problem.

(a) (b)

(c)

Fig (4-8): Stationaryequipment. (b) Mobile equipment. (c) Portable equipment.

4.12 Magnetic Current Characteristic

Direct current, alternating current and half-wave rectified alternating current are usually used as magnetizing currents in magnetic particle testing. Only one type is required for a test. It is generally accepted that the best types of magnetizing current for magnetic particle testing are AC and DC (rectified alternating currents). AC is best suited for locating surface discontinuities (because of skin effect) and FWDC and HWDC are better for locating subsurface discontinuities.

Alternating Current (AC) is the most widely used power source for conducting magnetic particle testing. AC can be readily converted to the low voltages used in magnetic particle inspection by the use of transformers. AC has little penetrating power due to the skin effect and provides the best detection of surface discontinuities. It is not effective for subsurface discontinuities. Since AC is continuously reversing direction, the magnetic field has a tendency to agitate or make the iron particles more mobile. This causes the particles to be more responsive to the flux leakage. Current reversal is illustrated in Figure (4-7).

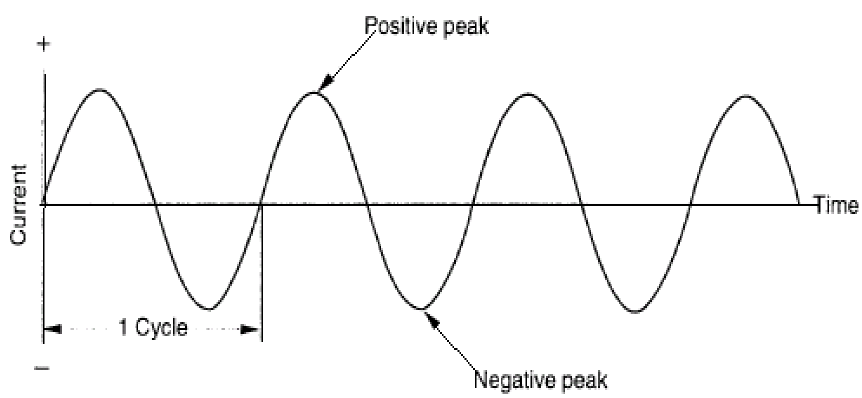


Fig (4-9).Single-phase AC waveform

Direct Current (DC). Single-phase AC can be rectified to produce half-wave direct current, which is commonly called half-wave direct current (HWDC). HWDC means that the reverse polarity or negative portion of the sine curve is eliminated as below. HWDC is superior for locating subsurface discontinuities and is the best choice for detecting both surface and subsurface discontinuities

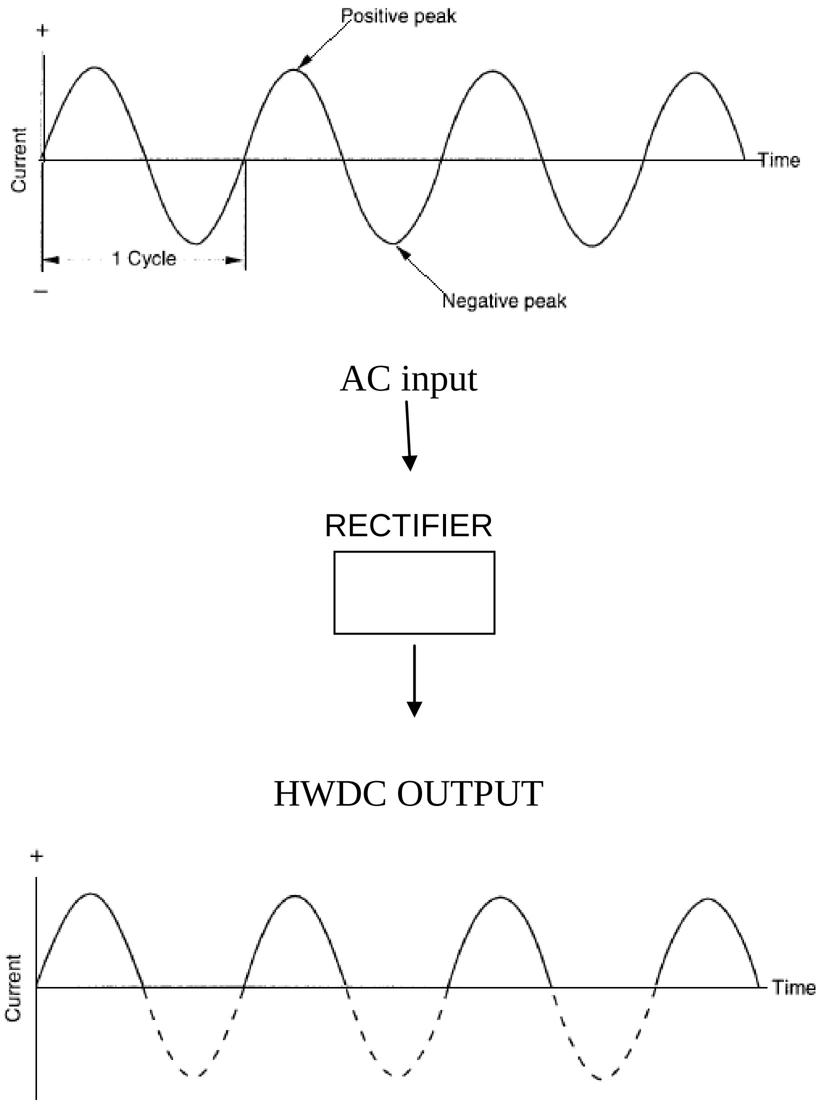


Fig (4-10).Rectification of AC to HWDC

4.13 Demagnetization

Process of removing magnetism from the inspected item. Demagnetization is required for the following reasons:

- A magnetization object can affect the accuracy of some instrumentation related to the object.
- Retained magnetism can affect subsequent operation such as machining and coating.

- Entrapped metal particles create serious imperfections in painted or plated materials.
- Residual magnetism can cause arc blow during the welding process.

4.14 The Yoke

A yoke is used to produce a longitudinal field. It induces the longitudinal field by using the part to complete a magnetic circuit. Yokes can be equipped to induce an AC or HWDC field in the component being inspected.

The yoke is basically a coil wrapped around the center of an iron core. The core is shaped like a square horseshoe. The two legs can be fixed but are usually flexible so they may be articulated or positioned to accommodate irregularly shaped parts. The coil induces a longitudinal field in the iron core.

The iron core is made of highly permeable material with extremely low receptivity so as not to become a permanent magnet. Therefore, the yoke only becomes magnetic when current is turned on. The yoke is then positioned on the test specimen with the legs touching the test surface and turned on. The part being inspected then completes the magnetic circuit and becomes magnetized.

Portable electrical power, such as a generator, will be required to operate the yoke in a remote location. Typical current draw is approximately 5 amps on the latest models. The latest models are also lightweight at less than 10 pounds, enhancing their portability. The AC mode of operation is usually fixed and the current is not adjustable. Some units are equipped with DC capability (AC rectified to HWDC) and the current is variable. The unit will have a current selector switch and a current adjustment knob.

Because a yoke induces a longitudinal field, defects which are 45 to 90 degrees to the yoke centerline are easily and instantly detected.

Two shots, perpendicular (90°) to each other, forming an "X" pattern will usually provide complete coverage of the area being tested as shown in figure ().

The area being tested includes 1" of adjacent area on either side of element. Spacing should be between a minimum of 3" and a maximum of 8".

Areas near the yoke legs cannot be adequately inspected because of the strength of the induced field at the poles.

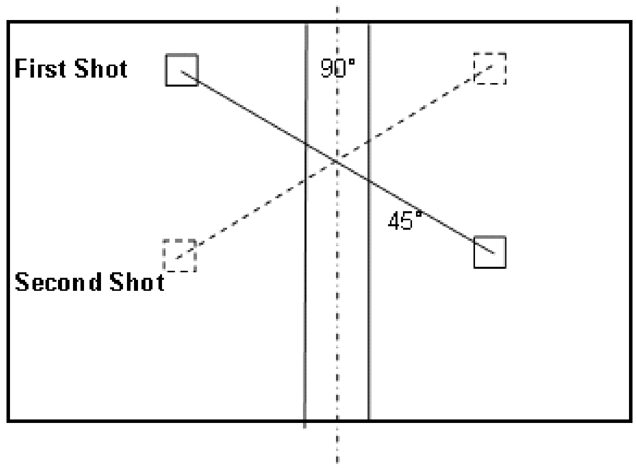


Fig (4-11).X-Pattern of yoke magnetization

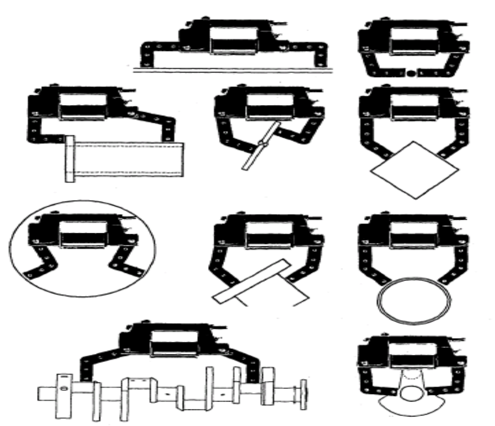


Fig (4-12).Different yoke leg positioning

- ## 4.15Test Procedures

The Five Basic Steps of MT Procedure

- Pre-clean and Pre-visual the test surface.
- Establish a magnetic field in the test specimen. Apply the magnetic particles, examine the test specimen.
- Repeat procedure at 90 degrees to the first test.
- Document and demagnetize.
- Post-clean and Post-visual the test surface.

4.16Advantage of magnetic particle testing

- Not applicable for no ferromagnetic materials.
- Magnetization must be in many directions to detect defects in all directions.
- Require demagnetizing.
- Sometimes require post cleaning.
- NOpermanent record.

4.17Limitation of magnetic particle test

The following are limitations of magnetic particle testing as compared to other NDT methods.

- It is only effective for the examination of ferromagnetic materials.
- Discontinuity detection is limited to those at or near the surface.
- Demagnetization may be required before, between, and after inspections.
- Discontinuities will only be detected when their major axis interrupts the primary flux lines. This necessitates inspection in more than one direction to assure discontinuity detection regardless of orientation.
- Some magnetic particle testing techniques may cause damage to the part as a result of arcing or localized overheating of the parts (for example, when using DC prods).
- Paint and/or coating removal is necessary from localized areas on the part to facilitate good electrical contact when using direct magnetization techniques.

- Uniform, predictable flux flow through the parts being tested may not be possible due to complex shapes.
- No relevant indications due to abrupt changes in component profile or local changes in material properties may make interpretation difficult.

Chapter five

Results

5.1 Introduction

Two experiments were made. In the first one a certain force was applied on three different materials, Aluminum, steel and carbon steel. The image of the defect was found by ultrasound. In the second experiment two samples thickness were measured by using ultrasound.

5.2 Material and Methods

In this research two experiments were performed on different material. In the first was to effect on samples of aluminum, steel and carbon steel certain force which resulted in effect differed depending on the structure of samples placement experience. The defects were detected using magnetic particle (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, as the aluminum is not ferromagnetic material the magnetic particle test can be applied therefore the defects were detects only using ultrasound only. The defect has length13.6cm and depth 8mm (0.8cm) where the speed of sound in which is 3080m/s.

Steel has average structure and when the force is applied the resulting defect is detected using magnetic particles test for surface defects and found the length of 8cm , depth defects were detected using ultrasound and fount the depth is 5mm (0.5cm) where the speed of sound I which is 3220m/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 magnetic particle and found that the length of 4cm and the depthdefects were detected using ultrasound and found the depth is 2mm (0.2cm) where the speed of sound I which is 3220m/s.

The second experiments was performed on metallic disc and cube and then change the frequency form 2MHZ and 4MHZ and the study the relationship between the real thickness of the sample and the obtained after experiment.

In the metallic disc the ultrasound wave with speed 5960m/s is passed through the samples, the obtained thickness is 3.9cm while the real thickness is 2.9cm therefore the real speed of the ultrasound wave is 4431m/s.

In the cube sample a wave with speed 5960m/s is passed through specimen the obtained thickness is 2.25cm while the real thickness is3.0cm therefore the real speed of the ultrasound wave is 4470m/s.

The real speed of the ultrasound wave is calculation using the relationship

$$v_r = \left(\frac{da}{dt}\right) v_a (5.2.1)$$

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	13.6
2	Steel	3220	8.3
3	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 $\pm 0.1 cm$
1	Aluminum	3080	8
2	Steel	3220	5
3	Carbon steel	3235	2

(5.3.3): Relation between the apparent thickness of the defect and real speed of sound for frequency2MHZ (2×10^6HZ).

No	sample	Applied sound speed(m/s) v_a	Real thickness (d_r) $\pm 0.1cm$	Apparent thickness (d_a) $\pm 0.1cm$	Real sound speed(m/s) v_r	Material
1	Disc	5960	2.9	3.9	4431	Nickel
2	Cube	5960	2.25	3.0	4470	Nickel

The equation used for real speed of sound:

$$v_r = \frac{dr}{t} = \left(\frac{dr}{da/v_a}\right) = \left(\frac{dr}{da}\right) v_a \qquad (5.3.1)$$

Table (5.3.4): Relation apparent thickness of the defect and the defect and real speed of sound for frequency4MHZ (4×10^6HZ).

No	Sample	Applied sound speed(m/s) v_a	Real thickness(d_r) $\pm 0.1cm$	Apparent thickness(d_r) $\pm 0.1cm$	Real speed(m/s)	Material
1	Disc	5960	2.9	3.9	4431	Nickel
2	Cube	5960	2.25	3.0	4470	Nickel

5.4 Discussion

The ultrasound test made for some minerals like Aluminum, steel 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 three 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.

Another test was made on disc and cube having thickness of 2.9cm and 2.25cm for frequencies 2MHZ and 4MHZrespectively.

The sound speed applied is the same. The result shows that the measured length for both samples is larger than the real one. This is used to find the real speed and the material type of two samples.

5.5 Conclusion

From this work detecting defects in materials using waves ultrasound more comprehensive detection using the particle magnetic been reached that and because it gives an accurate description of the surface and subsurface of the reverse magnetic particles that operate on the surface only.
Ultrasound can be used to identify minerals by sending a sound wave with known frequency and speed on the metal thickness is known in advance and then the speed of sound in terms of the original thickness and thickness by the obtained after detecting and the speed-of the wave sending.
After the experiment found that each of the metallic cube and disk made of nickel, reaching a speed of sound in the disc 4431 m / s, and in 4470 cubic m / s while the speed of sound in the nickel 4800 m / s.

5.6 Refrens

[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.

[3] J.C.Drury, Ultrasonic Flaw Detection for technicians, Ninth Edition, OIS ple, Stockton-on-tees, Cleveland, U.K.,1997.

[4] Diederichs,Rolf and Ginzel, Ed, Nondestractive testing Encyclopedia, UT Formulae, NDT.net

[5] Introduction To Magnetic Particle Inspection, DR. ABD. NASSIR IBRAHIM

industrial technology division malaysian institute for nuclear tecnology (MINT)

[6]Krautkramer, Josef and Krautkramer, Herbert, Ultrasonic Testing of materials, 4th/revised edition, Springer Verlag, November 1990,ISBN: 0387512314.

[7]Ultrasonic Testing- Level I, ITC-NDT-103.

[8] Ultrasonic Testing -Level II, ITC-NDT-203.

[9]Magnetic Particle Testing-Level II, ITC-NDT-303.

[10]the Mark of traning Excllence Estableshed 1984 foundetion member.

[11] www.ndt-edu.org.

[12] www.ndtsupply.com.

[13] www.ijmr.net.

[14]www.rcafe.com