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Vyasapuri, Bandlaguda, Post: Keshavgiri, Hyderabad- 500 005, Telangana, India.
https://www.mist.ac.in E-mail:principal.mahaveer@gmail.com, Mobile: 8978380692

ESTD : 2001

Department of Aeronautical Engineering

(R18)

PRACTICAL NON-DESTRUCTIVE TESTING

Lecture Notes

B. Tech IV YEAR – II SEM

Prepared by

Mr.D.NAVEEN
(Assistant Professor)
Dept.Aero

AE822PE: PRACTICAL NON-DESTRUCTIVE TESTING (PE – VI)

B.Tech. IV Year AE II Sem. **L T/P/D C**
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Pre-Requisites: Nil

Course Objectives:

- Understanding the basic principles of various non-destructive testing methods, fundamentals, discontinuities in different product forms.
- Differentiate various defect types and select the appropriate non-destructive testing methods for better evaluation of the specimen.
- Implement and document a written procedure paving the way for further training in specific techniques of non-destructive inspection of the experimental subject.
- Recognize the principles and operational techniques of the radiographic testing followed by its interpretation and evaluation.

Course Outcomes:

- Different type of testing
- Principles of electronic measurement devices

UNIT - I

Overview of Non-Destructive Testing: NDT versus mechanical testing, overview of the nondestructive testing methods for the detection of manufacturing defects as well as material characterization; Relative merits and limitations, various physical characteristics of materials and their applications in NDT, visual inspection, v unaided and aided.

UNIT - II

Surface Non-Destructive Examination Methods:

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

UNIT - III

Thermography and Eddy Current Testing (ET):

Thermography: Principles, contact and non-contact inspection methods, Techniques for applying liquid crystals. Advantages and limitation, infrared radiation and infrared detectors, instrumentations and methods, applications;
Eddy Current Testing: Generation of eddy currents, properties of eddy currents, Eddy current sensing elements, probes, instrumentation, types of arrangement, applications, advantages, limitations, interpretation/evaluation.

UNIT - IV

Ultrasonic Testing (UT) and Acoustic Emission (AE):

Ultrasonic Testing: Principle, transducers, transmission and pulse-echo method, straight beam and angle beam, instrumentation, data representation, A-scan, B-scan, C-scan; Phased array ultrasound, time of flight diffraction; Acoustic emission technique, V principle, AE parameters, applications.

UNIT - V

Experimental Methods: Principle, interaction of X-Ray with matter, imaging, film and film less techniques, types and use of filters and screens, geometric factors, inverse square, law, characteristics of films, graininess, density, speed, contrast, characteristic curves, pentameters, exposure charts, radiographic equivalence. Fluoroscopy; Xerox; Radiography, computed radiography, computed

tomography.

TEXT BOOKS:

1. Baldev Raj, T. Jayakumar, M. Thavasimuthu ―Practical Non-Destructive Testing, Narosa Publishing House, 2009.

2. Ravi Prakash, ―Non-Destructive Testing Techniques, 1st revised edition, New Age International Publishers, 2010.

REFERENCE BOOKS:

1. Paul E Mix, ―Introduction to Non-destructive testing: a training guide, Wiley, 2nd Edition New Jersey, 2005.

2. Charles, J. Hellier, ―Handbook of Non-destructive evaluation‖, McGraw Hill, New York 2001.

UNIT-I

NDT versus mechanical testing:

Non-destructive testing (NDT) and mechanical testing are two different approaches used in assessing the properties and integrity of materials, components, and structures. Each method has its own advantages, limitations, and areas of application. Here's a comparison between NDT and mechanical testing:

1.Purpose:

NDT: The primary purpose of NDT is to evaluate the material or component without causing damage. It aims to detect flaws, defects, inconsistencies, or irregularities within the material or structure.

Mechanical Testing: Mechanical testing involves subjecting a material or component to controlled loading conditions to measure mechanical properties such as strength, elasticity, ductility, toughness, and hardness.

2.Destructiveness:

NDT: Non-destructive testing methods do not cause damage to the material or structure being examined. They are designed to inspect without altering the integrity of the object under test.

Mechanical Testing: Mechanical testing, particularly destructive testing, involves subjecting the material to loads until it fails. While some tests might be non-destructive, many are designed to push the material to its limits, leading to deformation or fracture.

3.Types:

NDT: NDT encompasses various techniques such as ultrasonic testing, radiographic testing, eddy current testing, magnetic particle testing, dye penetrant testing, visual testing, etc.

Mechanical Testing: Mechanical testing includes tension testing, compression testing, flexural testing, hardness testing, impact testing, fatigue testing, etc.

4.Information Obtained:

NDT: NDT provides information regarding the presence, location, size, shape, and nature of defects or irregularities within the material or structure.

Mechanical Testing: Mechanical testing provides quantitative data regarding the material's response to applied loads, including its strength, stiffness, ductility, toughness, etc.

5.Applications:

NDT: NDT is widely used in industries such as aerospace, automotive, construction, manufacturing, oil and gas, power generation, and transportation for inspecting welds, castings, forgings, pipelines, structures, and other components.

Mechanical Testing: Mechanical testing is used in materials research, quality control, product development, and failure analysis across various industries to assess the mechanical properties of materials and components.

6.Cost and Time:

NDT: NDT methods are often quicker and less expensive compared to mechanical testing, especially when assessing large or complex structures where destructive testing is not feasible.

Mechanical Testing: Mechanical testing can be more time-consuming and costly, particularly if destructive testing is involved, as it requires the preparation of samples and may necessitate specialized equipment.

overview of the nondestructive testing methods:

Non-destructive testing (NDT) methods play a crucial role in detecting manufacturing defects and characterizing materials without causing damage to the tested components. These methods are widely used across industries to ensure product quality, safety, and reliability. Here's an overview of some common NDT methods used for the detection of manufacturing defects as well as material characterization:

1. Ultrasonic Testing (UT):

Principle: UT utilizes high-frequency sound waves to penetrate materials. When encountering interfaces or defects, the sound waves are reflected or refracted, providing information about the internal structure of the material.

Applications: UT is used for detecting flaws such as cracks, voids, inclusions, and delaminations in materials like metals, composites, and plastics.

2.Radiographic Testing (RT):

Principle: RT involves passing X-rays or gamma rays through a material. The radiation is absorbed differently by the various materials within the object, creating a shadow image on a film or digital detector.

Applications: RT is effective in detecting internal defects such as porosity, inclusions, cracks, and voids in materials like metals, welds, and composites.

3.Eddy Current Testing (ECT):

Principle: ECT relies on electromagnetic induction to detect surface and near-surface defects in conductive materials. A coil carrying an alternating current generates eddy currents in the material, and changes in the eddy current flow due to defects are measured.

Applications: ECT is commonly used for inspecting conductive materials, detecting surface cracks, corrosion, and material thickness variations.

4.Magnetic Particle Testing (MPT):

Principle: MPT is based on the principle of magnetic flux leakage. Ferromagnetic materials are magnetized, and discontinuities such as cracks or laps disrupt the magnetic field, causing magnetic particles to gather at these locations, indicating the presence of defects.

Applications: MPT is used for detecting surface and near-surface defects in ferromagnetic materials such as steel and iron.

5.Dye Penetrant Testing (PT):

Principle: PT involves applying a penetrating liquid (dye) to the surface of a material. The liquid penetrates into surface-breaking defects, and after excess dye is removed, a developer is applied to draw out the trapped dye, making the defects visible.

Applications: PT is effective for detecting surface cracks, pores, laps, and seams in materials like metals, ceramics, and plastics.

6.Visual Testing (VT):

Principle: VT is the simplest form of NDT, involving direct visual examination of the material or component. It may be supplemented with magnification, illumination, or other aids.

Applications: VT is used for detecting surface defects, irregularities, corrosion, and other visible abnormalities in various materials.

These NDT methods are often used in combination or sequentially to provide comprehensive inspection coverage. They are essential tools for ensuring the quality and integrity of materials and components in manufacturing processes, maintenance, and safety inspections across a wide range of industries.

Relative merits and limitations:

1.Ultrasonic Testing (UT):

Merits:

- High sensitivity to both surface and subsurface defects.
- Depth penetration capability, making it suitable for thick materials.
- Quantitative measurements possible for flaw sizing and material characterization.

Limitations:

- Requires access to both sides of the test piece for full inspection.
- Skilled personnel needed for interpretation of results.
- Limited effectiveness in highly attenuative or coarse-grained materials.

2.Radiographic Testing (RT):

Merits:

- High sensitivity to internal defects.
- Provides a permanent record of inspection.
- Suitable for a wide range of material types and thicknesses.

Limitations:

- Potential radiation hazards, requiring safety precautions and trained personnel.
- Limited sensitivity to surface defects.
- Limited in application to materials that are sufficiently dense to produce detectable contrast.

3.Eddy Current Testing (ECT):

Merits:

- High sensitivity to surface and near-surface defects.
- Rapid inspection speeds possible, making it suitable for production environments.
- Can be automated for continuous inspection.

Limitations:

- Limited penetration depth, typically only suitable for thin materials.
- Sensitivity decreases with increasing material conductivity.
- Complex geometry and surface roughness can affect accuracy.

4.Magnetic Particle Testing (MPT):

Merits:

- High sensitivity to surface and near-surface defects in ferromagnetic materials.
- Simple and relatively inexpensive equipment.
- Immediate indication of defect location.

Limitations:

- Requires the material to be magnetizable.
- Surface preparation needed to remove coatings and contaminants.
- Limited to ferromagnetic materials.

5.Dye Penetrant Testing (PT):

Merits:

- High sensitivity to surface-breaking defects.
- Simple and low-cost method.
- Suitable for irregularly shaped components and complex geometries.

Limitations:

- Limited to surface defects only.
- Requires adequate cleaning of the surface for accurate results.
- Not suitable for porous materials or materials with high surface roughness.

6.Visual Testing (VT):

Merits:

- Direct and immediate indication of surface defects.
- Low cost and simplicity.
- Can be used in combination with other NDT methods.

Limitations:

- Limited to surface defects and visible abnormalities.

- Subject to human error and interpretation.
- Requires adequate lighting and access to the test area.

various physical characteristics of materials and their applications in NDT:

1.Density:

Applications: Density is used in radiographic testing (RT) where X-rays or gamma rays are passed through a material. Different materials absorb radiation differently based on their density, allowing defects or variations in density to be detected.

2.Electrical Conductivity:

Applications: Eddy current testing (ECT) utilizes variations in electrical conductivity to detect surface and near-surface defects in conductive materials. Changes in electrical conductivity due to defects cause variations in the eddy currents induced in the material, which can be detected by the ECT equipment.

3.Magnetic Permeability:

Applications: Magnetic particle testing (MPT) relies on variations in magnetic permeability to detect surface and near-surface defects in ferromagnetic materials. Discontinuities disrupt the magnetic field, causing magnetic particles to gather at the defect location, making it visible to inspectors.

4.Sound Attenuation and Velocity:

Applications: Ultrasonic testing (UT) utilizes sound waves to inspect materials. The speed of sound and its attenuation within a material can provide information about material properties and the presence of defects such as voids, cracks, or inclusions.

5.Surface Tension and Wetting Properties:

Applications: Dye penetrant testing (PT) relies on the surface tension and wetting properties of liquids to detect surface-breaking defects. The liquid penetrates into the defects due to capillary action, and excess liquid is removed before a developer is applied to visualize the defects.

6.Nuclear Properties (e.g., Atomic Number, Neutron Absorption):

Applications: In addition to density, radiographic testing (RT) can exploit the atomic number and neutron absorption properties of materials to detect defects and variations. Different materials with distinct nuclear properties exhibit varying levels of radiation absorption, aiding in defect detection.

7.Reflectivity and Absorption of Electromagnetic Waves:

Applications: Electromagnetic testing methods such as microwave testing utilize the reflectivity and absorption properties of materials to detect defects or anomalies. Changes in electromagnetic wave behavior can indicate the presence of defects or material variations.

8.Thermal Conductivity:

Applications: Thermographic testing utilizes variations in thermal conductivity to detect defects or anomalies in materials. Differences in thermal conductivity lead to variations in heat flow, which can be visualized using infrared cameras or thermal imaging systems.

visual inspection:

Visual inspection is a fundamental method used across various industries for evaluating the quality, integrity, and condition of materials, components, and structures through direct observation by human inspectors. It involves visually examining the surface or external features of an object to detect defects, irregularities, anomalies, or other visible abnormalities. Visual inspection is often the first step in non-destructive testing (NDT) processes and is also widely used in quality control, maintenance, and safety assessments. Here are some key aspects of visual inspection:

1.Objectives:

- Identify Surface Defects: Visual inspection aims to detect surface imperfections such as cracks, scratches, dents, pits, corrosion, porosity, inclusions, and discontinuities.
- Evaluate Workmanship: It assesses the quality of manufacturing processes, including welds, joints, seals, finishes, coatings, and assembly.
- Monitor Condition: Visual inspection helps monitor the condition of materials, components, or structures over time to detect signs of wear, damage, or degradation.
- Ensure Compliance: Inspections may be conducted to verify compliance with specifications, standards, regulations, or customer requirements.

2.Methodology:

- Direct Observation: Inspectors visually examine the surface of the object under natural or artificial lighting conditions.
- Systematic Approach: Inspection may follow predefined procedures, checklists, or criteria to ensure thorough coverage and consistency.

- Documentation: Findings, observations, and measurements may be recorded using written reports, photographs, sketches, or digital imaging systems.

3.Equipment and Tools:

- Basic Tools: Inspection may be performed using the naked eye or handheld tools such as magnifying lenses, mirrors, rulers, or gauges.
- Aids and Accessories: Specialized equipment such as magnifiers, microscopes, borescopes, endoscopes, cameras, lighting devices, or remote imaging systems may be used to enhance visibility or access hard-to-reach areas.

4.Applications:

- Manufacturing: Visual inspection is employed in production processes to ensure product quality, detect defects, and maintain consistency in manufacturing operations.
- Maintenance: It is used for routine inspections, preventive maintenance, troubleshooting, and condition monitoring of machinery, equipment, infrastructure, or facilities.
- Construction: Inspections are conducted during construction activities to verify adherence to design specifications, identify construction defects, and ensure structural integrity and safety.
- Aerospace, Automotive, Electronics, Healthcare, Oil & Gas, Power Generation, Transportation, and various other industries utilize visual inspection for quality assurance, safety compliance, and regulatory requirements.

Advantages and Limitations:

Advantages: Visual inspection is simple, cost-effective, and versatile. It provides immediate feedback, does not require complex equipment, and can be performed by trained personnel.

Limitations: It is subjective and relies on the inspector's experience, expertise, and visual acuity. It may be limited in detecting subsurface defects or defects in inaccessible areas.

unaided and aided:

Unaided Visual Inspection:

Definition: Unaided visual inspection involves the direct examination of materials or components by human inspectors without the assistance of specialized equipment.

Merits:

- Simplicity: Unaided visual inspection is straightforward and requires minimal equipment or training.
- Versatility: It can be applied to a wide range of materials, components, and structures.
- Immediate Feedback: Inspectors can quickly identify surface defects, irregularities, or anomalies and make decisions on the spot.

Limitations:

- Subjectivity: Interpretation of visual cues can vary among inspectors, leading to inconsistencies.
- Limited Detection Capabilities: Unaided visual inspection may miss defects that are subtle or located in hard-to-reach areas.
- Environmental Constraints: Visibility may be compromised in low-light conditions or environments with restricted access.

Aided Visual Inspection:

Definition: Aided visual inspection involves the use of specialized equipment or tools to enhance the inspector's ability to detect defects or anomalies.

Merits:

- Enhanced Detection: Aided inspection methods can provide magnification, illumination, or other enhancements to improve defect detection capabilities.
- Consistency: Standardized equipment and procedures can help reduce variability among inspectors and ensure more reliable results.
- Documentation: Aided inspection methods often allow for the capture of visual data, providing a record of the inspection process and results.

Limitations:

- Equipment Cost and Complexity: Specialized equipment may be expensive to procure and maintain, and training may be required to use it effectively.
- Accessibility: Some inspection tools may not be suitable for inspecting certain materials or components with complex geometries.
- Calibration and Verification: Aided inspection equipment may require regular calibration and verification to ensure accuracy and reliability.

Examples of tools used in aided visual inspection include:

- Magnifying Lenses or Microscopes: Used to magnify small features or defects for better visibility.
- Borescopes or Endoscopes: Flexible or rigid optical devices used to inspect internal surfaces or areas that are difficult to access.
- Remote Cameras: Cameras mounted on robotic arms or drones to inspect large or hazardous structures from a safe distance.
- Lighting Devices: Specialized lighting sources such as UV lamps or strobe lights to enhance visibility of defects or surface irregularities.
- Digital Imaging Systems: High-resolution cameras and image processing software for capturing, analyzing, and documenting visual inspection data.

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AE822PE: PRACTICAL NON-DESTRUCTIVE TESTING (PE – VI)

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Pre-Requisites: Nil

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- Understanding the basic principles of various non-destructive testing methods, fundamentals, discontinuities in different product forms.
- Differentiate various defect types and select the appropriate non-destructive testing methods for better evaluation of the specimen.
- Implement and document a written procedure paving the way for further training in specific techniques of non-destructive inspection of the experimental subject.
- Recognize the principles and operational techniques of the radiographic testing followed by its interpretation and evaluation.

Course Outcomes:

- Different type of testing
- Principles of electronic measurement devices

UNIT - I

Overview of Non-Destructive Testing: NDT versus mechanical testing, overview of the nondestructive testing methods for the detection of manufacturing defects as well as material characterization; Relative merits and limitations, various physical characteristics of materials and their applications in NDT, visual inspection, v unaided and aided.

UNIT - II

Surface Non-Destructive Examination Methods:

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

UNIT - III

Thermography and Eddy Current Testing (ET):

Thermography: Principles, contact and non-contact inspection methods, Techniques for applying liquid crystals. Advantages and limitation, infrared radiation and infrared detectors, instrumentations and methods, applications;
Eddy Current Testing: Generation of eddy currents, properties of eddy currents, Eddy current sensing elements, probes, instrumentation, types of arrangement, applications, advantages, limitations, interpretation/evaluation.

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UNIT - V

Experimental Methods: Principle, interaction of X-Ray with matter, imaging, film and film less techniques, types and use of filters and screens, geometric factors, inverse square, law, characteristics of films, graininess, density, speed, contrast, characteristic curves, pentameters, exposure charts, radiographic equivalence. Fluoroscopy; Xerox; Radiography, computed radiography, computed

tomography.

TEXT BOOKS:

1. Baldev Raj, T. Jayakumar, M. Thavasimuthu ―Practical Non-Destructive Testing, Narosa Publishing House, 2009.

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2. Charles, J. Hellier, ―Handbook of Non-destructive evaluation‖, McGraw Hill, New York 2001.

UNIT-II

Liquid Penetrant Testing:

Liquid Penetrant Testing (LPT), also known as Dye Penetrant Testing (DPT) or Penetrant Inspection (PI), is a widely used non-destructive testing (NDT) method for detecting surface-breaking defects in materials. The principle of liquid penetrant testing involves the capillary action of a penetrating liquid to reveal discontinuities or defects that may not be visible to the naked eye. Here's an overview of the principles of liquid penetrant testing:

1.Capillary Action:

- The fundamental principle behind liquid penetrant testing is capillary action. When a liquid penetrant is applied to the surface of a material, it flows into surface-breaking defects or discontinuities due to capillary action.
- Capillary action occurs because of the cohesive forces between the liquid molecules and the adhesive forces between the liquid and the surface of the material. This allows the penetrant to seep into fine cracks, pores, voids, or other surface imperfections.

2.Surface Preparation:

- Before applying the penetrant, the surface of the material must be thoroughly cleaned to remove any contaminants, dirt, grease, or other substances that could interfere with the inspection process.
- Cleaning may involve degreasing, solvent wiping, alkaline cleaning, or other methods to ensure the surface is free from debris and contaminants.

3.Penetrant Application:

- The penetrant is applied to the cleaned surface of the material by spraying, brushing, dipping, or immersion methods. The penetrant is allowed to dwell on the surface for a specified period to ensure adequate penetration into any surface defects.
- The penetrant used in liquid penetrant testing is typically a highly visible colored dye or fluorescent dye, depending on whether visible or fluorescent inspection methods are employed.

4.Dwell Time:

- Dwell time refers to the duration for which the penetrant is allowed to remain in contact with the surface. The dwell time may vary depending on factors such as the type of penetrant, the material being inspected, and the size of defects being targeted.
- During the dwell time, the penetrant infiltrates and fills any surface defects, allowing it to be effectively detected during the subsequent inspection stage.

5.Penetrant Removal:

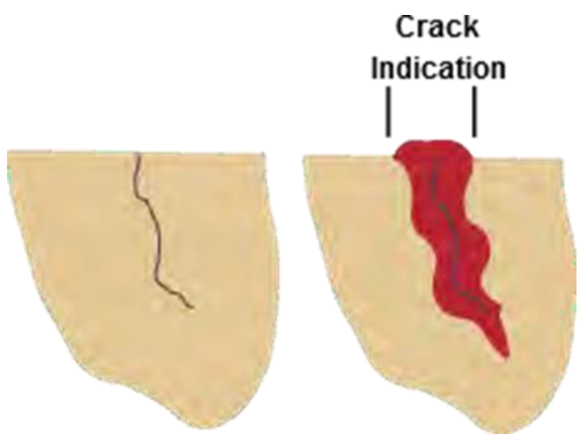
- After the dwell time has elapsed, excess penetrant is removed from the surface using a solvent cleaner or emulsifier. The cleaning process removes surface penetrant while leaving penetrant trapped within defects.
- Care must be taken during this step to avoid removing penetrant from defects, which could lead to false-negative results.

6.Developer Application:

- Following penetrant removal, a developer is applied to the surface of the material. The developer acts as a blotter, drawing the trapped penetrant out of defects and spreading it across the surface.
- The developer enhances the visibility of defects by providing a contrasting background against which the penetrant indications can be easily observed.

7.Indication Interpretation:

- The surface is then inspected visually under appropriate lighting conditions to detect indications or indications of defects revealed by the penetrant. Indications appear as distinct colored or fluorescent markings against the contrasting background provided by the developer.
- The inspector evaluates the size, shape, location, and intensity of indications to determine the nature and significance of detected defects.



types and properties of liquid penetrants:

Liquid penetrants used in liquid penetrant testing (LPT) are specifically formulated substances designed to penetrate into surface-breaking defects and reveal them during the inspection process. There are several types of liquid penetrants available, each with its own properties and suitability for different applications. Here are the common types and their properties:

Type I - Fluorescent Penetrants:

- Fluorescent penetrants contain fluorescent dyes that emit visible light when exposed to ultraviolet (UV) or black light.

- The fluorescent properties make indications highly visible under UV or black light, even in low-light conditions.
- These penetrants provide enhanced sensitivity for detecting smaller defects compared to visible penetrants.
- Suitable for inspections where high sensitivity is required, such as aerospace and critical component inspections.

Type II - Visible Penetrants:

- Visible penetrants contain colored dyes that provide visible indications under normal lighting conditions.
- Indications appear as brightly colored marks against the background of the material being inspected.
- Visible penetrants are less sensitive compared to fluorescent penetrants but are still effective for detecting larger defects.
- They are often preferred for inspections conducted in environments where UV or black light is not readily available.

Water-Washable Penetrants:

- Water-washable penetrants are formulated to be easily removed from the surface with water after the penetration and dwell time.
- They are typically used in situations where water-based cleaning is preferred over solvent-based cleaners.
- Water-washable penetrants are suitable for inspections where environmental concerns or regulations restrict the use of solvent-based cleaners.

Post-emulsifiable Penetrants:

- Post-emulsifiable penetrants contain a special emulsifier that allows the penetrant to be removed from the surface by a water rinse followed by a developer application.
- They are versatile and can be used with both visible and fluorescent penetrants.
- Post-emulsifiable penetrants are effective for inspecting a wide range of materials and surface conditions.

Solvent-Removable Penetrants:

- Solvent-removable penetrants are designed to be removed from the surface using solvent-based cleaners.
- They offer rapid removal of excess penetrant and are suitable for applications where fast turnaround times are required.
- Solvent-removable penetrants may be used with both visible and fluorescent penetrants.

Low-Sensitivity Penetrants:

- Low-sensitivity penetrants are formulated for applications where high sensitivity is not required.
- They are often used for routine inspections or in situations where the probability of defects is low.
- Low-sensitivity penetrants may offer faster inspection times and reduced processing steps compared to high-sensitivity penetrants.

High-Sensitivity Penetrants:

- High-sensitivity penetrants are formulated to provide enhanced sensitivity for detecting very small defects.
- They are commonly used in critical applications where the detection of minute defects is essential for safety and reliability.
- High-sensitivity penetrants may require longer dwell times and additional processing steps compared to low-sensitivity penetrants.

Developers:

Developers are an essential component in liquid penetrant testing (LPT) processes. After the penetrant has been applied, allowed to dwell, and excess penetrant has been removed, a developer is applied to the surface of the material being inspected. Developers serve several crucial functions in the LPT process, enhancing the visibility of indications and aiding in defect detection. Here are the key aspects of developers:

1. Purpose: Developers are applied to the surface of the material after the penetrant has penetrated into surface-breaking defects and excess penetrant has been removed. They serve to draw the trapped penetrant out of defects and spread it across the surface, making indications visible for inspection.
2. Enhanced Contrast: Developers create a contrasting background against which penetrant indications become more visible. By absorbing penetrant from defects and dispersing it over the surface, developers increase the contrast between indications and the surrounding material, making defects easier to detect.
3. Absorbent Properties: Developers are typically formulated with highly absorbent materials such as chalk, talc, or diatomaceous earth. These materials effectively absorb penetrant from defects, allowing indications to stand out against the developer-coated surface.
4. Uniform Coating: Developers are applied evenly and uniformly over the entire surface of the material being inspected. This ensures consistent coverage and enhances the visibility of indications across the entire inspection area.
5. Application Methods: Developers can be applied using various methods, including spraying, dusting, brushing, or dipping, depending on the form of the developer (liquid, powder, or aerosol) and the requirements of the inspection.

Powder developers are often applied using handheld dispensers or spray guns, while liquid developers may be applied using sprayers or brush-on techniques.

Types:

- Developers come in different forms, including dry powder, wet suspension, and aerosol formulations. Each type offers specific advantages and is selected based on factors such as the material being inspected, the size and type of defects, and environmental conditions.
- Dry powder developers are commonly used for their ease of application and effectiveness in creating a uniform, matte-white coating on the surface.

- Wet suspension developers are mixed with water to form a slurry and are applied as a thin layer over the surface.
- Aerosol developers provide convenience and ease of application, particularly for overhead or difficult-to-reach areas.

Environmental Considerations: Developers should be selected based on environmental considerations such as temperature, humidity, and cleanliness requirements. Some developers may be sensitive to environmental conditions and may require specific storage or application conditions to ensure optimal performance.

advantages and limitations of various methods:

Advantages:

- Detects Surface Defects: LPT is highly effective in detecting surface-breaking defects such as cracks, porosity, laps, seams, and other discontinuities that are open to the surface.
- Versatile: Liquid penetrant testing can be applied to a wide range of materials, including metals, plastics, ceramics, and composites, making it suitable for various industries such as aerospace, automotive, manufacturing, and construction.
- Simple and Cost-effective: LPT is relatively simple to perform and does not require expensive equipment. It is a cost-effective method for inspecting large quantities of components or structures.
- High Sensitivity: Liquid penetrants have high sensitivity, capable of detecting very small defects that may not be visible to the naked eye.
- Adaptable to Different Surfaces: Liquid penetrants can be applied to a variety of surface finishes, including rough, smooth, porous, and non-porous surfaces.
- Portable: LPT equipment is portable and can be used in the field for on-site inspections, providing flexibility in inspection locations.

Limitations:

- Limited to Surface Defects: Liquid penetrant testing is only capable of detecting surface-breaking defects. It cannot detect internal defects or flaws located below the surface of the material.
- Surface Preparation Required: Effective surface preparation is essential for the success of liquid penetrant testing. The surface must be thoroughly cleaned to remove dirt, grease, oil, or other contaminants that could interfere with the inspection process.
- Environmental Impact: Some penetrants and developers used in liquid penetrant testing may contain hazardous chemicals, posing environmental and safety concerns. Proper handling, storage, and disposal practices are necessary to mitigate risks.
- Subjectivity in Interpretation: Interpretation of inspection results may be subjective and rely on the experience and expertise of the inspector. Indications may vary in visibility depending on lighting conditions and background contrast.

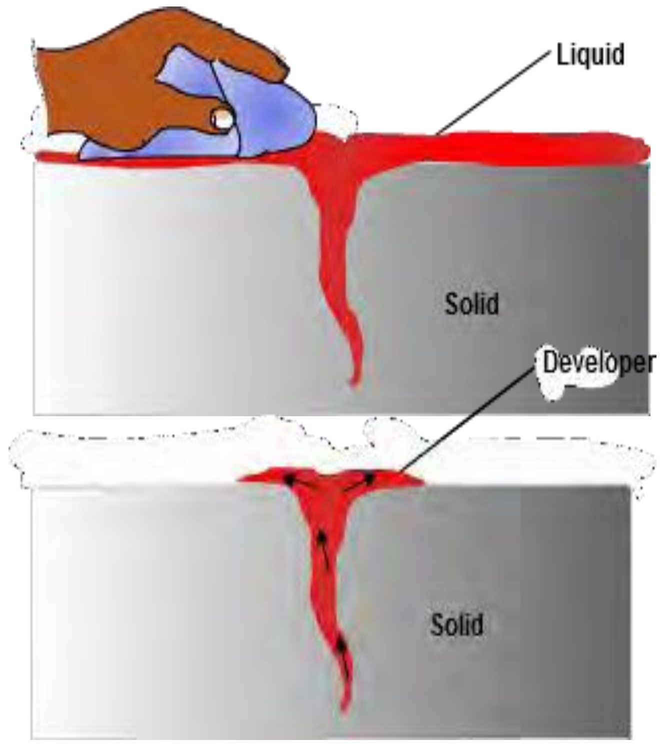
- Limited to Non-porous Materials: Liquid penetrant testing is not suitable for inspecting porous materials where penetrant may be absorbed, leading to false indications or difficulties in interpretation.
- Dwell Time: Proper dwell time is required to allow the penetrant to seep into defects adequately. Insufficient dwell time may result in missed defects, while excessive dwell time may lead to overpenetrating and false indications.

Testing Procedure, Interpretation of results:

1. **Surface Preparation:** One of the most critical steps of a liquid penetrant inspection is the surface preparation. The surface must be free of oil, grease, water, or other contaminants that may prevent penetrant from entering flaws. The sample may also require etching if mechanical operations such asmachining, sanding, or grit blasting have been performed. These and other mechanical operations can smear metal over the flaw opening and prevent the penetrant from entering.
2. **Penetrant Application:** Once the surface has been thoroughly cleaned and dried, the penetrant material is applied by spraying, brushing, or immersing the part in a penetrant bath.

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

while removing as little penetrant as possible from defects. Depending on the penetrant system used, this step may involve cleaning with a solvent, direct rinsing with water, or first treating the part with an emulsifier and then rinsing with water.



5. **Developer Application:** A thin layer of developer is then applied to the sample to draw penetrant trapped in flaws back to the surface where it will be visible. Developers come in a variety of forms that may be applied by dusting (dry powdered), dipping, or spraying (wet developers).

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

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

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

Magnetic particle testing: Theory of magnetism

Magnetic Field:

- A magnetic field is an invisible force field produced by magnetic materials or moving electric charges.
- Magnetic fields have both magnitude (strength) and direction and can exert forces on other magnetic materials or charged particles.

Magnetic Materials:

- Materials that can be magnetized and exhibit magnetic properties are classified into three main categories: ferromagnetic, paramagnetic, and diamagnetic.
- Ferromagnetic materials, such as iron, nickel, cobalt, and their alloys, are strongly attracted to magnets and can retain magnetic properties after exposure to a magnetic field. They are most commonly used in MPT.
- Paramagnetic materials are weakly attracted to magnets, while diamagnetic materials are weakly repelled by magnets.

Magnetic Domains:

- Inside ferromagnetic materials, magnetic moments of individual atoms align to form regions called magnetic domains.
- Within each domain, magnetic moments are aligned in the same direction, resulting in a net magnetic moment for the domain.
- In an unmagnetized state, magnetic domains are randomly oriented, resulting in no overall magnetic field.

Magnetization:

- Magnetization occurs when an external magnetic field is applied to a material, causing the magnetic moments within the domains to align in the direction of the applied field.
- When a ferromagnetic material is magnetized, the number and size of aligned domains increase, resulting in an overall magnetic field within the material.

Magnetic Flux:

- Magnetic flux is a measure of the total magnetic field passing through a given area.
- In MPT, magnetic flux lines are used to visualize the magnetic field and its behavior around defects or irregularities in ferromagnetic materials.

Magnetic Field Strength:

- The strength of a magnetic field is determined by the magnitude of the magnetic flux density, typically measured in units of tesla (T) or gauss (G).
- In MPT, the strength of the magnetic field is crucial for achieving adequate magnetization of the test specimen and detecting defects.

Magnetic Flux Leakage:

- Discontinuities or defects in a ferromagnetic material disrupt the magnetic field, causing magnetic flux leakage.
- Magnetic particle indications are formed when magnetic particles collect at defect sites due to the magnetic flux leakage, making defects visible during inspection.

Inspection Materials:

- Magnetic Particles: These are typically small, finely divided ferromagnetic particles, commonly iron or iron oxide-based. They come in dry form (powder) or suspended in a liquid carrier (wet form). These particles are applied to the surface of the test specimen and adhere to magnetic flux leakage at defect sites, forming visible indications.
- Carrier Fluid: In wet method MPT, the magnetic particles are suspended in a carrier fluid, usually a light oil or water-based solution. The carrier fluid helps in the application of the particles to the test surface and aids in the removal of excess particles during cleaning.

Magnetization Methods:

- Continuous Magnetization: In continuous magnetization, a magnetic field is continuously applied to the test specimen during the inspection process. This can be achieved using permanent magnets, electromagnets, or electromagnetic yokes. The test piece is inspected while under the influence of the magnetic field.

- Residual Magnetization: Residual magnetization involves the initial magnetization of the test specimen using an external magnetic field, followed by demagnetization to remove residual magnetism. Residual magnetization can be beneficial for enhancing the visibility of indications during inspection.

Interpretation and Evaluation of Test Indications:

1. Indications observed during MPT appear as accumulations or clusters of magnetic particles at defect sites.
2. The size, shape, location, and density of indications are evaluated to determine the nature and significance of defects.
3. Acceptance criteria, often provided by applicable standards or specifications, are used to classify indications as acceptable or rejectable.
4. Principles and Methods of Demagnetization:
5. Alternating Current (AC) Demagnetization: AC demagnetization involves subjecting the test specimen to an alternating magnetic field, gradually reducing and eliminating residual magnetism.
6. Coil Demagnetization: In this method, the test specimen is passed through a coil carrying alternating current, inducing an alternating magnetic field in the material.
7. Stationary Demagnetization Units: These units consist of stationary coils or electromagnets surrounding the test specimen. The specimen is placed within the demagnetization unit, and the residual magnetism is gradually reduced by applying alternating current.

Residual Magnetism:

- Residual magnetism refers to the magnetization that remains in a material after the removal of an external magnetic field.
- Proper demagnetization procedures are essential to reduce residual magnetism to acceptable levels, as residual magnetism can interfere with subsequent processes or operations and lead to false indications during future inspections.

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Vyasapuri, Bandlaguda, Post: Keshavgiri, Hyderabad- 500 005, Telangana, India.
https://www.mist.ac.in E-mail:principal.mahaveer@gmail.com, Mobile: 8978380692

ESTD : 2001

Department of Aeronautical Engineering

(R18)

PRACTICAL NON-DESTRUCTIVE TESTING

Lecture Notes

B. Tech IV YEAR – II SEM

Prepared by

Mr.D.NAVEEN
(Assistant Professor)
Dept.Aero

AE822PE: PRACTICAL NON-DESTRUCTIVE TESTING (PE – VI)

B.Tech. IV Year AE II Sem. **L T/P/D C**
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Pre-Requisites: Nil

Course Objectives:

- Understanding the basic principles of various non-destructive testing methods, fundamentals, discontinuities in different product forms.
- Differentiate various defect types and select the appropriate non-destructive testing methods for better evaluation of the specimen.
- Implement and document a written procedure paving the way for further training in specific techniques of non-destructive inspection of the experimental subject.
- Recognize the principles and operational techniques of the radiographic testing followed by its interpretation and evaluation.

Course Outcomes:

- Different type of testing
- Principles of electronic measurement devices

UNIT - I

Overview of Non-Destructive Testing: NDT versus mechanical testing, overview of the nondestructive testing methods for the detection of manufacturing defects as well as material characterization; Relative merits and limitations, various physical characteristics of materials and their applications in NDT, visual inspection, v unaided and aided.

UNIT - II

Surface Non-Destructive Examination Methods:

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

UNIT - III

Thermography and Eddy Current Testing (ET):

Thermography: Principles, contact and non-contact inspection methods, Techniques for applying liquid crystals. Advantages and limitation, infrared radiation and infrared detectors, instrumentations and methods, applications;
Eddy Current Testing: Generation of eddy currents, properties of eddy currents, Eddy current sensing elements, probes, instrumentation, types of arrangement, applications, advantages, limitations, interpretation/evaluation.

UNIT - IV

Ultrasonic Testing (UT) and Acoustic Emission (AE):

Ultrasonic Testing: Principle, transducers, transmission and pulse-echo method, straight beam and angle beam, instrumentation, data representation, A-scan, B-scan, C-scan; Phased array ultrasound, time of flight diffraction; Acoustic emission technique, V principle, AE parameters, applications.

UNIT - V

Experimental Methods: Principle, interaction of X-Ray with matter, imaging, film and film less techniques, types and use of filters and screens, geometric factors, inverse square, law, characteristics of films, graininess, density, speed, contrast, characteristic curves, pentameters, exposure charts, radiographic equivalence. Fluoroscopy; Xerox; Radiography, computed radiography, computed

tomography.

TEXT BOOKS:

1. Baldev Raj, T. Jayakumar, M. Thavasimuthu ―Practical Non-Destructive Testing, Narosa Publishing House, 2009.
2. Ravi Prakash, ―Non-Destructive Testing Techniques, 1st revised edition, New Age International Publishers, 2010.

REFERENCE BOOKS:

1. Paul E Mix, ―Introduction to Non-destructive testing: a training guide, Wiley, 2nd Edition New Jersey, 2005.
2. Charles, J. Hellier, ―Handbook of Non-destructive evaluation‖, McGraw Hill, New York 2001.

UNIT-III

Thermography: Principles

Infrared Radiation:

- All objects with a temperature above absolute zero (-273.15°C or 0 Kelvin) emit infrared radiation, which is electromagnetic radiation with wavelengths longer than visible light.
- The intensity and wavelength distribution of infrared radiation emitted by an object depend on its temperature and emissivity (the ability to emit radiation).

Thermal Contrast:

- Thermography relies on detecting differences in temperature (thermal contrast) between the surface of the object being inspected and its surroundings or between different areas of the object itself.
- Variations in temperature can be indicative of defects, anomalies, or thermal gradients within the material or structure.

Heat Transfer Mechanisms:

- Heat transfer mechanisms such as conduction, convection, and radiation influence temperature distributions within objects.
- Defects or abnormalities can affect heat transfer patterns, resulting in localized temperature variations that can be detected using thermography.

Infrared Camera:

- Thermographic inspections are performed using infrared cameras (also known as thermal imaging cameras or thermographic cameras) capable of detecting and measuring infrared radiation.
- Infrared cameras contain infrared sensors that convert the detected infrared radiation into electrical signals, which are then processed to generate thermal images.

Thermal Imaging:

- Thermal imaging involves capturing thermal images of the object's surface, where each pixel in the image represents a specific temperature.
- Thermal images are displayed in false color or grayscale, where warmer temperatures are typically represented by brighter colors (such as red or yellow) and cooler temperatures by darker colors (such as blue or purple).

Data Analysis:

- During thermographic inspections, captured thermal images are analyzed to identify temperature anomalies or patterns that may indicate defects or abnormalities.
- Advanced image processing techniques, such as image subtraction, temporal averaging, and spatial filtering, may be employed to enhance defect visibility and reduce noise.

Applications:

- Thermography is used in a wide range of industries for various applications, including:
- Non-destructive testing (e.g., detecting cracks, delaminations, voids, and corrosion in materials).
- Condition monitoring and predictive maintenance of mechanical systems, electrical equipment, and infrastructure.
- Building diagnostics, energy auditing, and moisture detection in construction.
- Medical diagnostics, such as identifying inflammation, circulatory abnormalities, or tumors.

contact and non-contact inspection methods

Contact and non-contact inspection methods are two broad categories of techniques used in various industries for assessing the condition, quality, and integrity of materials, components, and structures. Each method offers distinct advantages and limitations, and the choice between them depends on factors such as the type of material, the nature of the inspection task, accessibility, accuracy requirements, and safety considerations. Here's an overview of contact and non-contact inspection methods:

Contact Inspection Methods:

Visual Inspection:

- Visual inspection involves direct observation of the surface or external features of an object by human inspectors.
- It can be performed with or without the aid of magnifying tools, such as magnifying lenses or microscopes.
- Contact with the surface is typically required for close examination of defects, anomalies, or features.

Dimensional Measurement:

- Contact-based dimensional measurement methods involve physical contact between measurement instruments (e.g., calipers, micrometers, gauges) and the object being measured.
- These methods provide accurate measurements of dimensions, tolerances, and geometric features.
- Examples include coordinate measuring machines (CMMs) and profilometers.

Ultrasonic Testing (UT):

- UT involves the transmission of high-frequency sound waves into the material being inspected.
- Contact is typically required between the ultrasonic transducer and the surface of the test specimen to ensure efficient transmission and reception of ultrasonic waves.

Eddy Current Testing (ECT):

- ECT utilizes electromagnetic induction to detect surface and near-surface defects in conductive materials.
- Contact is established between the test probe or coil and the surface of the material to induce eddy currents and detect changes in electrical conductivity.

Non-contact Inspection Methods:

Remote Visual Inspection (RVI):

- RVI involves the use of remote inspection tools, such as borescopes, fiberscopes, or robotic cameras, to visually inspect areas that are difficult to access.
- No direct contact with the surface is required, making it suitable for inspecting confined spaces, complex geometries, or hazardous environments.

Thermography:

- Thermography utilizes infrared cameras to detect temperature variations across the surface of an object.
- No physical contact with the surface is necessary, allowing for non-destructive detection of defects, anomalies, or thermal patterns.

Laser Scanning:

- Laser scanning involves the use of laser beams to rapidly capture three-dimensional (3D) geometry of objects or surfaces.
- No contact with the object is required, and high-resolution 3D models can be generated for dimensional analysis or reverse engineering.

X-ray and Gamma-ray Inspection:

- X-ray and gamma-ray inspection techniques use penetrating radiation to detect internal defects or structures within objects.
- No direct contact with the material is necessary, making it suitable for inspecting complex assemblies or enclosed components.

Non-contact Dimensional Measurement:

- Non-contact dimensional measurement methods, such as optical or laser-based systems, use light or laser beams to measure dimensions, profiles, or surface roughness.
- These methods eliminate the need for physical contact with the object, reducing the risk of damage or deformation.

Techniques for applying liquid crystals:

Liquid crystals are materials that exhibit properties of both liquids and solids, and they are commonly used in various applications, including temperature measurement, displays, and optical devices. Here are some techniques for applying liquid crystals:

Spin Coating:

- Spin coating is a common technique used to apply thin films of liquid crystals onto substrates.
- In this method, a small amount of liquid crystal material is dispensed onto the center of a rotating substrate.
- Centrifugal force spreads the liquid crystal across the surface of the substrate, forming a uniform thin film.
- Spin coating is suitable for producing thin, uniform layers of liquid crystals for applications such as temperature-sensitive coatings or displays.

Drop Casting:

- Drop casting involves dispensing droplets of liquid crystal material onto a substrate surface.
- The liquid crystal droplets can be applied manually using a pipette or automated dispensing system.
- After dispensing, the liquid crystal droplets spread and form a thin film through surface tension and capillary action.
- Drop casting is a simple and versatile method suitable for applying liquid crystals to various substrates, including glass, plastic, and metal.

Brush Coating:

- Brush coating is a manual method for applying liquid crystals using a brush or applicator.
- The liquid crystal material is loaded onto the brush, and then the brush is used to spread the material evenly across the substrate surface.
- Brush coating allows for precise control over the thickness and coverage of the liquid crystal layer and is suitable for small-scale applications or research purposes.

Spray Coating:

- Spray coating involves spraying liquid crystal material onto a substrate surface using a spray gun or airbrush.
- The liquid crystal material is atomized into fine droplets and deposited onto the substrate, forming a thin film.
- Spray coating can be used to apply liquid crystals to large areas or irregularly shaped surfaces and is suitable for industrial-scale production.

Printing Techniques:

- Printing techniques such as inkjet printing, screen printing, or flexographic printing can be used to deposit liquid crystal material onto substrates.
- In inkjet printing, liquid crystal droplets are ejected from a print head onto the substrate in a controlled manner.
- Screen printing involves forcing liquid crystal material through a mesh screen onto the substrate surface.
- Flexographic printing utilizes a flexible printing plate to transfer liquid crystal material onto the substrate.

Langmuir-Blodgett (LB) Technique:

- The Langmuir-Blodgett technique involves transferring monolayers of liquid crystal molecules from the air-water interface onto a solid substrate.
- The liquid crystal molecules are first spread as a monolayer on the surface of a water subphase in a Langmuir trough.
- The substrate is then vertically lifted or dipped through the monolayer, transferring the liquid crystal molecules onto its surface in a controlled manner.

Advantages and limitation:

Advantages:

Uniformity: Many of the techniques mentioned, such as spin coating, drop casting, and Langmuir-Blodgett technique, can produce uniform and controlled layers of liquid crystals. This uniformity is crucial for applications such as displays and sensors, where consistent performance is required.

Versatility: Liquid crystals can be applied to a wide range of substrates, including glass, plastic, metal, and flexible materials. This versatility allows for the integration of liquid crystals into various devices and applications.

Control: Depending on the application and the chosen technique, there is often a high degree of control over the thickness, coverage, and distribution of the liquid crystal layer. This control ensures that the liquid crystals perform optimally for their intended purpose.

Scalability: Some techniques, such as spray coating and printing methods, are suitable for large-scale production and can be easily scaled up to accommodate high-volume manufacturing processes. This scalability is essential for industrial applications where efficiency and cost-effectiveness are paramount.

Cost-effectiveness: Many of the techniques for applying liquid crystals are relatively inexpensive compared to more complex deposition methods. Techniques like drop casting, brush coating, and printing methods require minimal equipment and resources, making them cost-effective options for research and development as well as large-scale production.

Limitations:

Thickness Control: Achieving precise control over the thickness of the liquid crystal layer can be challenging, particularly with techniques like drop casting and spray coating. Variations in thickness can affect the optical and electrical properties of the liquid crystal material, leading to inconsistent performance.

Surface Morphology: The surface morphology of the substrate can impact the adhesion and uniformity of the liquid crystal layer. Rough or uneven surfaces may result in non-uniform coatings and decreased performance of the liquid crystal material.

Substrate Compatibility: Some liquid crystal deposition techniques may be limited by the compatibility of the liquid crystal material with the substrate. Certain substrates may interact chemically with the liquid crystal material or may not provide sufficient adhesion, leading to delamination or other issues.

Complexity: Techniques such as Langmuir-Blodgett deposition require specialized equipment and expertise, making them less accessible and more complex compared to simpler methods like spin coating or drop casting. This complexity can increase the cost and difficulty of implementation.

Environmental Considerations: Some deposition techniques, particularly those involving solvents or aerosols, may pose environmental and health risks due to the release of volatile organic compounds (VOCs) or other hazardous materials. Proper ventilation and safety measures are necessary to mitigate these risks.

infrared radiation and infrared detectors:

Infrared radiation (IR) is a type of electromagnetic radiation with wavelengths longer than those of visible light, but shorter than those of radio waves. It is commonly associated with heat radiation emitted by objects due to their temperature. Here's an overview of infrared radiation and infrared detectors:

Infrared Radiation:

Source:

Infrared radiation is emitted by all objects with a temperature above absolute zero (-273.15°C or 0 Kelvin). The intensity and wavelength distribution of infrared radiation emitted by an object depend on its temperature and emissivity.

Wavelength Range:

Infrared radiation spans wavelengths ranging from approximately 0.7 micrometers (near-infrared) to over 1 millimeter (far-infrared).

It is often divided into three main categories based on wavelength:

Near-infrared (NIR): 0.7 to 1.5 micrometers

Mid-infrared (MIR): 1.5 to 6 micrometers

Far-infrared (FIR): 6 to 1000 micrometers

Characteristics:

Infrared radiation is invisible to the human eye but can be detected and measured using specialized equipment such as infrared cameras or sensors.

It interacts with materials differently depending on their properties. For example, materials that absorb infrared radiation readily become warm, while materials that reflect or transmit infrared radiation remain cooler.

Applications:

- Infrared radiation has diverse applications across various fields, including:
- Thermal imaging and thermography for detecting temperature variations in objects and environments.
- Remote sensing for environmental monitoring, agriculture, and geological surveys.
- Infrared spectroscopy for chemical analysis and material characterization.
- Infrared communication (IR communication) for remote control devices and data transmission.
- Infrared heating for industrial processes, cooking, and warming applications.

Infrared Detectors:

Types:

- There are several types of infrared detectors, each with its own operating principles and applications. Some common types include:
- Thermal detectors (thermopiles, bolometers): Measure changes in temperature caused by absorbed infrared radiation.
- Photodetectors (photodiodes, photovoltaic cells): Convert incident infrared radiation into an electrical signal via the photoelectric effect.
- Quantum detectors (quantum well infrared photodetectors, quantum-dot infrared photodetectors): Exploit quantum mechanical processes to detect infrared radiation with high sensitivity.

Operating Principles:

- Thermal detectors operate based on changes in temperature induced by absorbed infrared radiation. They typically consist of temperature-sensitive materials or structures that undergo measurable changes in electrical resistance, voltage, or current in response to temperature changes.

- Photodetectors operate based on the absorption of infrared radiation by semiconductor materials, resulting in the generation of electron-hole pairs. This generates a photocurrent or voltage proportional to the incident radiation intensity.
- Quantum detectors utilize quantum confinement effects to create discrete energy levels within semiconductor materials, allowing for efficient absorption of infrared radiation and high sensitivity detection.

Applications:

- Infrared detectors are used in various applications, including:
- Infrared cameras and thermal imaging systems for night vision, security surveillance, medical imaging, and industrial inspections.
- Infrared spectroscopy for chemical analysis, materials characterization, and environmental monitoring.
- Infrared sensors for proximity sensing, motion detection, gas detection, and temperature measurement.
- Infrared communication devices for remote control systems, data transmission, and infrared sensing.

instrumentations and methods:

Infrared Cameras:

- Infrared cameras, also known as thermal imaging cameras, are the primary instrumentation used to detect and visualize infrared radiation.
- These cameras consist of an infrared detector array, optics, and electronics to capture and process infrared images.
- Different types of infrared detectors, such as microbolometers or photodetectors, are used based on the desired sensitivity and wavelength range.
- Thermal imaging cameras may utilize various imaging techniques, including:
  1. Uncooled detectors: Operate at room temperature and do not require cryogenic cooling.
  2. Cooled detectors: Employ cryogenic cooling to improve sensitivity and reduce noise.
  3. Multispectral imaging: Capture infrared images at multiple wavelength bands for enhanced analysis.

Infrared Spectrometers:

- Infrared spectrometers are instruments used to analyze the absorption, transmission, and emission of infrared radiation by materials.
- Fourier Transform Infrared (FTIR) spectrometers and dispersive spectrometers are two common types.
  1. FTIR spectrometers measure the interferogram resulting from the interference of infrared radiation passing through a sample and a reference.
  2. Dispersive spectrometers use diffraction grating or prism to separate infrared radiation into its component wavelengths for analysis.

Infrared Thermometers:

- Infrared thermometers, also known as pyrometers or infrared temperature guns, measure the surface temperature of objects without contact.
- They work based on the principle of detecting the emitted infrared radiation from the object's surface and converting it into a temperature reading.
- Infrared thermometers find applications in industries such as manufacturing, HVAC, automotive, and food processing for non-contact temperature measurement.

Infrared Sensors and Detectors:

- Infrared sensors and detectors are used for various purposes, including motion detection, proximity sensing, gas detection, and flame detection.
- They utilize photodetectors, thermopiles, or other technologies to detect and measure infrared radiation.

Applications:

Thermal Imaging and Thermography:

- Thermal imaging and thermography are used for non-contact temperature measurement and analysis in various fields.
- Applications include building diagnostics, predictive maintenance, electrical inspections, firefighting, medical diagnostics, and wildlife monitoring.

Remote Sensing and Environmental Monitoring:

- Infrared remote sensing techniques are employed for environmental monitoring, agriculture, forestry, and geological surveys.

- They provide valuable data on land surface temperature, vegetation health, soil moisture, and geological features.

Material Analysis and Characterization:

- Infrared spectroscopy is widely used for chemical analysis, material characterization, and quality control in pharmaceuticals, polymers, food, and other industries.
- It provides information about molecular structure, composition, and bonding within materials.

Security and Surveillance:

- Infrared cameras and sensors are used for security surveillance, border monitoring, perimeter protection, and intrusion detection.
- They can detect human presence, identify thermal anomalies, and enhance night vision capabilities.

Medical Imaging and Diagnosis:

Infrared imaging techniques, such as thermal imaging and near-infrared spectroscopy, are utilized in medical diagnostics for detecting abnormalities, monitoring physiological functions, and imaging tissues.

Communication and Data Transmission:

Infrared communication devices, such as remote controls, IR data transceivers, and optical communication systems, are used for wireless data transmission in consumer electronics, telecommunications, and industrial automation.

Eddy Current Testing:

Eddy Current Testing (ECT) is a non-destructive testing (NDT) method that utilizes electromagnetic induction to detect surface and near-surface flaws in conductive materials. Here's an overview of the key aspects of Eddy Current Testing, including the generation and properties of eddy currents, sensing elements, probes, instrumentation, arrangements, applications, advantages, limitations, and interpretation/evaluation:

Generation of Eddy Currents:

- Eddy currents are induced electrical currents that circulate within a conductive material when it is exposed to a changing magnetic field.
- These currents are generated through electromagnetic induction according to Faraday's Law and Lenz's Law.
- When alternating current (AC) is passed through a coil or probe, it generates a varying magnetic field that interacts with the conductive material, inducing eddy currents within the material.

Properties of Eddy Currents:

- Eddy currents flow in circular paths within the conductive material, perpendicular to the direction of the magnetic field that induced them.
- The depth of penetration and distribution of eddy currents within the material depend on the frequency of the applied alternating current and the electrical conductivity of the material.
- Eddy currents create their own magnetic field, which interacts with the primary magnetic field, resulting in changes that can be detected and analyzed.

Eddy Current Sensing Elements and Probes:

- ECT probes typically consist of a coil or coils wound around a core made of a non-conductive material.
- Different probe designs are used for various applications, including surface probes, pencil probes, array probes, and rotating probes.
- Probes may contain single or multiple coils configured to produce specific eddy current patterns for optimal flaw detection.

Instrumentation:

- ECT instrumentation includes an alternating current (AC) power source to generate the primary magnetic field, as well as signal conditioning and detection circuits to analyze the response signals from the eddy currents.
- Advanced ECT systems may incorporate features such as frequency tuning, phase-sensitive detection, impedance matching, and data processing capabilities.

Types of Arrangements:

- ECT can be performed using different arrangements depending on the application and the geometry of the test specimen.

- Common arrangements include absolute, differential, bridge, and rotating probe configurations, each offering advantages for specific inspection scenarios.

Applications:

- Eddy Current Testing is used in various industries for the detection of surface and near-surface defects, dimensional measurements, material characterization, and sorting of conductive materials.
- Common applications include flaw detection in aerospace components, automotive parts, electrical conductors, tubes, pipes, welds, and heat exchangers.

Advantages:

- ECT is fast, non-destructive, and suitable for inspecting complex geometries and inaccessible areas.
- It can detect small surface and subsurface defects, including cracks, corrosion, voids, and material variations.
- ECT can be automated and integrated into production lines for high-speed inspection of manufactured components.

Limitations:

- Eddy Current Testing is limited to conductive materials, and its effectiveness may be reduced for materials with low electrical conductivity or high magnetic permeability.
- Interpretation of ECT signals can be complex and require skilled technicians with a good understanding of electromagnetic principles and material properties.
- Surface finish, material thickness, and environmental factors can affect the accuracy and reliability of ECT inspections.

Interpretation/Evaluation:

- Interpretation of ECT signals involves analyzing changes in amplitude, phase, frequency, and impedance caused by the interaction between eddy currents and flaws or material variations.
- Signal anomalies, such as amplitude drops, phase shifts, or impedance changes, are indicative of defects and can be used to determine the size, shape, and location of flaws.

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Vyasapuri, Bandlaguda, Post: Keshavgiri, Hyderabad- 500 005, Telangana, India.
https://www.mist.ac.in E-mail:principal.mahaveer@gmail.com, Mobile: 8978380692

ESTD : 2001

Department of Aeronautical Engineering

(R18)

PRACTICAL NON-DESTRUCTIVE TESTING

Lecture Notes

B. Tech IV YEAR – II SEM

Prepared by

Mr.D.NAVEEN
(Assistant Professor)
Dept.Aero

AE822PE: PRACTICAL NON-DESTRUCTIVE TESTING (PE – VI)

B.Tech. IV Year AE II Sem. **L T/P/D C**
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- Recognize the principles and operational techniques of the radiographic testing followed by its interpretation and evaluation.

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- Different type of testing
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Thermography and Eddy Current Testing (ET):

Thermography: Principles, contact and non-contact inspection methods, Techniques for applying liquid crystals. Advantages and limitation, infrared radiation and infrared detectors, instrumentations and methods, applications;

Eddy Current Testing: Generation of eddy currents, properties of eddy currents, Eddy current sensing elements, probes, instrumentation, types of arrangement, applications, advantages, limitations, interpretation/evaluation.

UNIT - IV

Ultrasonic Testing (UT) and Acoustic Emission (AE):

Ultrasonic Testing: Principle, transducers, transmission and pulse-echo method, straight beam and angle beam, instrumentation, data representation, A-scan, B-scan, C-scan; Phased array ultrasound, time of flight diffraction; Acoustic emission technique, V principle, AE parameters, applications.

UNIT - V

Experimental Methods: Principle, interaction of X-Ray with matter, imaging, film and film less techniques, types and use of filters and screens, geometric factors, inverse square, law, characteristics of films, graininess, density, speed, contrast, characteristic curves, pentameters, exposure charts, radiographic equivalence. Fluoroscopy; Xerox; Radiography, computed radiography, computed

tomography.

TEXT BOOKS:

1. Baldev Raj, T. Jayakumar, M. Thavasimuthu ―Practical Non-Destructive Testing, Narosa Publishing House, 2009.
2. Ravi Prakash, ―Non-Destructive Testing Techniques, 1st revised edition, New Age International Publishers, 2010.

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1. Paul E Mix, ―Introduction to Non-destructive testing: a training guide, Wiley, 2nd Edition New Jersey, 2005.
2. Charles, J. Hellier, ―Handbook of Non-destructive evaluation‖, McGraw Hill, New York 2001.

UNIT-IV

Ultrasonic Testing:

Introduction Ultrasonic Testing (UT) uses high frequency sound energy to conduct examinations and make measurements. Ultrasonic inspection can be used for flaw detection/evaluation, dimensional measurements, material characterization, and more.

Advantages: Ultrasonic Inspection is a very useful and versatile NDT method. Some of the advantages of ultrasonic inspection that are often cited include:

- It is sensitive to both surface and subsurface discontinuities.
- The depth of penetration for flaw detection or measurement is superior to other NDT methods.
- Only single-sided access is needed when the pulse-echo technique is used.
- It is highly accurate in determining reflector position and estimating size and shape.
- Minimal part preparation is required.
- Electronic equipment provides instantaneous results.
- Detailed images can be produced with automated systems.
- It has other uses, such as thickness measurement, in addition to flaw detection.

Limitations: As with all NDT methods, ultrasonic inspection also has its limitations, which include:

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

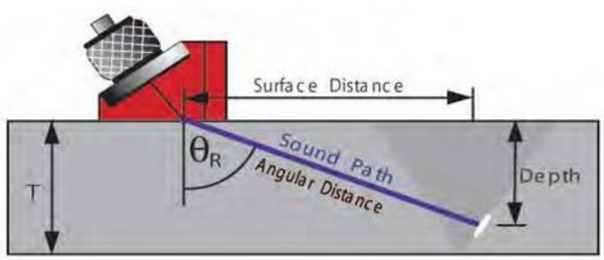
Applications: There are many applications of ultrasonic testing some of them are as follows:

- Forging Testing: Large forgings, e.g. generator shafts, undergo a 100% ultrasonic inspection, either manually or automatically on specific installations. The instrument setup requires the range calibration and sensitivity setting to be made according to given standards, using defined calibration blocks. Due to the fact that very small defects have to be detected, the instrument gain is set to a very high value causing increased noise indications on the screen.

- Tube testing: In high speed automatic tube testing the system is setup with test pieces having defined defects. The visualization of transversal/ longitudinal or inside/ outside defects at a scanning speed of up to 10 m/s or more is very difficult, as these defects are only hit with a few ultrasonic shots, nevertheless, when the system is set to automatic testing, the evaluation, is done with pulse repetition frequency.

- Rail Inspection: Both normal- and angle-beam techniques are used, as are both pulse-echo and pitch- catch techniques. The different transducer arrangements offer different inspection capabilities. Manual contact testing is done to evaluate small sections of rail but the ultrasonic inspection has been automated to allow inspection of large amounts of rail.

- Weldments Inspection: Ultrasonic weld inspections are typically performed using a straight beam transducer in conjunction with an angle beam transducer and wedge. A straight beam transducer, producing a longitudinal wave at normal incidence into the test piece, is first used to locate any laminations in or near the heat-affected zone. This is important because an angle beam transducer may not be able to provide a return signal from a laminar flaw.

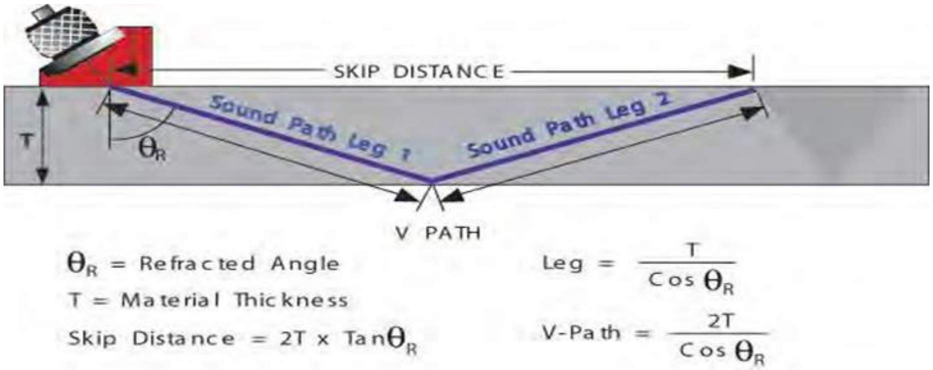


θ_R = Angle of Refraction

T = Material Thickness

Surface Distance = $\sin\theta_R$ x Sound Path

Depth (1st Leg) = $\cos\theta_R$ x Sound Path

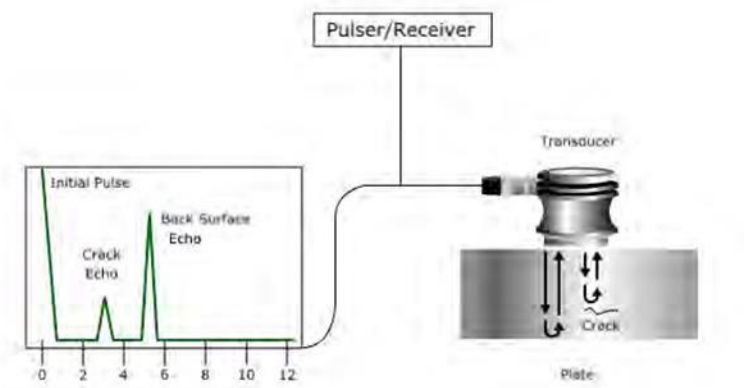


Generation of Ultrasonic Waves: In order to duplicate ultrasonic frequencies, humans have harnessed the electrical properties of materials. When an especially cut piezoelectric quartz crystal is compressed, the crystal becomes electrically charged and an electric current is generated: the greater the pressure, the greater the electric current. If the crystal is suddenly stretched rather than being compressed, the direction of the current will reverse itself. Alternately compressing and stretching the crystal has the effect of producing an alternating current. It follows that by applying an alternating current that matches the natural frequency of the crystal, the crystal can be made to expand and contract with the alternating current. When such a current is applied to the crystal, ultrasonic waves are produced.

Depending on which way the crystal is cut, the waves can be focused along the direction of ultrasound propagation or at right angles to the direction of propagation. Waves that travel along the direction of propagation are called longitudinal waves; as noted above, these waves travel in the direction in which molecules in the surrounding medium move back and forth. Waves that travel at right angles to the propagation direction are called transverse waves; the molecules in the surrounding medium move up and down with respect to the direction that the waves propagate. Ultrasound waves can also propagate as surface waves; in this case, molecules in the surrounding medium experience up-and-down motion as well as expanding and contracting motion.

In most applications, ultrasonic waves are generated by a transducer that includes a piezoelectric crystal that converts electrical energy (electric current) to mechanical energy (sound waves). These sound waves are reflected and return to the transducer as echoes and are converted back to electrical signals by the same transducer or by a separate one. Alternately, one can generate ultrasonic waves by means of magnetostriction (from magneto, meaning magnetic, and striction, meaning drawing together.) In this case an iron or nickel element is magnetized to change its dimensions, thereby producing ultrasonic waves. Ultrasound may also be produced by a whistle or siren-type generator. In this method, gas or liquid streams are passed through a resonant cavity or reflector with the result that ultrasonic vibrations characteristic of the particular gas or liquid are produced.

General characteristics of Ultrasonic Waves: A typical UT inspection system consists of several functional units, such as the pulser/receiver, transducer, and display devices. A pulser/receiver is an electronic device that can produce high voltage electrical pulses. Driven by the pulser, the transducer generates high frequency ultrasonic energy. The sound energy is introduced and propagates through the materials in the form of waves. When there is a discontinuity (such as a crack) in the wave path, part of the energy will be reflected back from the flaw surface.



The reflected wave signal is transformed into an electrical signal by the transducer and is displayed on a screen. In the applet below, the reflected signal strength is displayed versus the time from signal generation to when a echo was received. Signal travel time can be directly related to the distance that the signal traveled. From the signal, information about the reflector location, size, orientation and other features can sometimes be gained.

Methods and instruments for ultrasonic materials testing: Ultrasonic testing (UT) has been practiced for many decades. Initial rapid developments in instrumentation spurred by the technological advances from the 1950's continue today. Through the 1980's and continuing through the present, computers have provided technicians with smaller and more rugged instruments with greater capabilities.

Thickness gauging is an example application where instruments have been refined make data collection easier and better. Built-in data logging capabilities allow thousands of measurements to be recorded and eliminate the need for a "scribe." Some instruments have the capability to capture waveforms as well as thickness readings. The waveform option allows an operator to view or review the A-scan signal of thickness measurement long after the completion of an inspection. Also, some instruments are capable of modifying the measurement based on the surface conditions of the material. For example, the signal from a pitted or eroded inner surface of a pipe would be treated differently than a smooth surface. This has led to more accurate and repeatable field measurements.

Many ultrasonic flaw detectors have a trigonometric function that allows for fast and accurate location determination of flaws when performing shear wave inspections. Cathode ray tubes, for the most part, have been replaced with LED or LCD screens. These screens, in most cases, are extremely easy to view in a wide range of ambient lighting. Bright or low light working conditions encountered by technicians have little effect on the technician's ability to view the screen. Screens can be adjusted for brightness, contrast, and on some instruments even the color of the screen and signal can be selected. Transducers can be programmed with predetermined instrument settings. The operator only has to connect the transducer and the instrument will set variables such as frequency and probe drive.

Along with computers, motion control and robotics have contributed to the advancement of ultrasonic inspections. Early on, the advantage of a stationary platform was recognized and used in industry. Computers can be programmed to inspect large, complex shaped components, with one or multiple transducers collecting information. Automated systems typically consisted of an immersion tank, scanning system, and recording system for a printout of the scan. The immersion tank can be replaced with a squirter systems, which allows the sound to be transmitted through a water column. The resultant C-scan provides a plan or top view of the component. Scanning of components is considerably faster than contact hand scanning, the coupling is much more consistent. The scan information is collected by a computer for evaluation, transmission to a customer, and archiving.

Transducers:

- Transducers are the key components of UT systems and are used to generate and receive ultrasonic waves.
- Piezoelectric transducers are commonly used in UT, consisting of a piezoelectric crystal that converts electrical energy into mechanical vibrations and vice versa.

Transmission and Pulse-Echo Method:

- In the pulse-echo method, a short ultrasonic pulse is generated by the transducer and directed into the test material.
- The pulse travels through the material and is partially reflected back when it encounters an interface or defect.
- The time taken for the reflected pulse to return to the transducer is measured and used to determine the distance to the flaw or interface.

Straight Beam and Angle Beam:

- Straight beam testing involves sending ultrasonic waves perpendicular to the surface of the test material.
- Angle beam testing involves sending ultrasonic waves at an angle to the surface, allowing for detection of defects oriented parallel to the surface.

Instrumentation:

- UT instrumentation consists of a pulser-receiver, transducer, display unit, and data recording system.
- The pulser-receiver generates high-voltage electrical pulses to drive the transducer and amplifies the received signals for analysis.
- Display units may include A-scan, B-scan, and C-scan displays for visualizing and interpreting the test results.

Data Representation:

- A-scan displays amplitude versus time, showing the echoes received by the transducer.
- B-scan displays a two-dimensional cross-sectional view of the test material, showing the location and size of defects.
- C-scan displays a planar view of the test material, providing a top-down view of defects and their distribution.

Phased Array Ultrasound:

- Phased array ultrasound utilizes multiple elements in the transducer to generate and steer ultrasonic beams electronically.
- This allows for flexibility in beam angle, focus, and steering, improving defect detection and characterization capabilities.

Time of Flight Diffraction (TOFD):

- TOFD is a UT technique that utilizes the time difference between diffracted signals to detect and size defects accurately.
- It offers improved defect detection and sizing capabilities compared to traditional pulse-echo methods.

Acoustic Emission Technique:

- The Acoustic Emission (AE) technique involves monitoring the ultrasonic waves emitted by a material when subjected to stress or deformation.

- AE parameters such as amplitude, frequency, and duration are analyzed to detect and characterize defects, cracks, or structural changes in real-time.

Applications:

- Ultrasonic Testing is widely used in various industries, including aerospace, automotive, manufacturing, oil and gas, power generation, and construction.
- Applications include flaw detection, thickness measurement, weld inspection, corrosion assessment, material characterization, and structural health monitoring.

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https://www.mist.ac.in E-mail:principal.mahaveer@gmail.com, Mobile: 8978380692

ESTD : 2001

Department of Aeronautical Engineering

(R18)

PRACTICAL NON-DESTRUCTIVE TESTING

Lecture Notes

B. Tech IV YEAR – II SEM

Prepared by

Mr.D.NAVEEN
(Assistant Professor)
Dept.Aero

AE822PE: PRACTICAL NON-DESTRUCTIVE TESTING (PE – VI)

B.Tech. IV Year AE II Sem. **L T/P/D C**
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Pre-Requisites: Nil

Course Objectives:

- Understanding the basic principles of various non-destructive testing methods, fundamentals, discontinuities in different product forms.
- Differentiate various defect types and select the appropriate non-destructive testing methods for better evaluation of the specimen.
- Implement and document a written procedure paving the way for further training in specific techniques of non-destructive inspection of the experimental subject.
- Recognize the principles and operational techniques of the radiographic testing followed by its interpretation and evaluation.

Course Outcomes:

- Different type of testing
- Principles of electronic measurement devices

UNIT - I

Overview of Non-Destructive Testing: NDT versus mechanical testing, overview of the nondestructive testing methods for the detection of manufacturing defects as well as material characterization; Relative merits and limitations, various physical characteristics of materials and their applications in NDT, visual inspection, v unaided and aided.

UNIT - II

Surface Non-Destructive Examination Methods:

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

UNIT - III

Thermography and Eddy Current Testing (ET):

Thermography: Principles, contact and non-contact inspection methods, Techniques for applying liquid crystals. Advantages and limitation, infrared radiation and infrared detectors, instrumentations and methods, applications;
Eddy Current Testing: Generation of eddy currents, properties of eddy currents, Eddy current sensing elements, probes, instrumentation, types of arrangement, applications, advantages, limitations, interpretation/evaluation.

UNIT - IV

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Ultrasonic Testing: Principle, transducers, transmission and pulse-echo method, straight beam and angle beam, instrumentation, data representation, A-scan, B-scan, C-scan; Phased array ultrasound, time of flight diffraction; Acoustic emission technique, V principle, AE parameters, applications.

UNIT - V

Experimental Methods: Principle, interaction of X-Ray with matter, imaging, film and film less techniques, types and use of filters and screens, geometric factors, inverse square, law, characteristics of films, graininess, density, speed, contrast, characteristic curves, pentameters, exposure charts, radiographic equivalence. Fluoroscopy; Xerox; Radiography, computed radiography, computed

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UNIT-V

Experimental methods involving X-rays are fundamental in various fields, including medicine, industry, materials science, and research. Here's an overview of the principle of X-ray interaction with matter, imaging techniques, and the use of both film and filmless methods:

Principle of X-ray Interaction with Matter:

X-rays are a form of electromagnetic radiation with wavelengths shorter than visible light.

When X-rays pass through matter, they undergo several interactions, including:

- Photoelectric absorption: X-ray photon is absorbed by an inner shell electron, causing its ejection and the emission of characteristic X-rays.
- Compton scattering: X-ray photon interacts with an outer shell electron, resulting in the scattering of the photon and the ejection of the electron.
- Coherent scattering: X-ray photon interacts with an entire atom, causing it to vibrate and emit a scattered photon with the same energy.
- Pair production: High-energy X-ray photons produce an electron-positron pair in the presence of a nucleus.

The intensity of X-rays after passing through a material depends on its thickness, density, and composition.

Imaging Techniques:

Projection Radiography:

- In projection radiography, X-rays pass through the object and are detected by a receptor on the opposite side.
- The resulting image represents a 2D projection of the internal structure of the object.
- This technique is commonly used in medical diagnostics, industrial inspection, and security screening.

Computed Tomography (CT):

- CT involves rotating an X-ray source and detector around the object to acquire multiple projection images from different angles.
- Computer algorithms reconstruct these images to create cross-sectional slices (tomograms) of the object's internal structure.
- CT provides detailed 3D information and is widely used in medicine, industrial imaging, and research.

Fluoroscopy:

- Fluoroscopy involves continuous X-ray imaging in real-time, allowing for dynamic visualization of moving structures such as the heart or gastrointestinal tract.
- It is used in interventional procedures, surgery, and radiology.

Film Techniques:

- Traditional X-ray imaging uses photographic film as the receptor to capture the X-ray image.
- X-ray photons passing through the object expose the film, resulting in a latent image that can be developed using chemical processing.
- Film radiography provides high spatial resolution and is still used in many applications, but it requires chemical processing and has limited dynamic range.

Filmless Techniques:

- Digital X-ray imaging has largely replaced film-based techniques in many applications due to its numerous advantages:
- Immediate image acquisition and display
- Wide dynamic range and adjustable contrast
- Digital manipulation, enhancement, and storage
- Ability to electronically transmit images for remote interpretation and consultation
- Digital X-ray systems use digital detectors, such as amorphous silicon flat-panel detectors or charge-coupled devices (CCDs), to capture X-ray images directly.
- These detectors convert X-ray photons into electrical signals that are digitized and processed to generate the final image.

Types and Use of Filters and Screens:

Filters: Filters are used to selectively absorb certain wavelengths of radiation while allowing others to pass through. In radiography, filters are often used to remove unwanted radiation or enhance contrast. Common types include aluminum, copper, and lead filters.

Screens: Screens are used in conjunction with X-ray film to amplify the exposure. They consist of fluorescent materials that emit visible light when struck by X-rays, which in turn expose the film. Screens improve sensitivity and reduce radiation dose to the patient.

Geometric Factors:

- Source-to-Object Distance (SOD): The distance between the X-ray source and the object being imaged. Increasing SOD decreases radiation intensity and magnifies the image.
- Source-to-Image Distance (SID): The distance between the X-ray source and the image receptor (film or detector). Increasing SID reduces magnification and improves image sharpness.
- Object-to-Image Receptor Distance (OID): The distance between the object and the image receptor. Minimizing OID reduces geometric distortion.

Inverse Square Law:

- The inverse square law states that the intensity of radiation is inversely proportional to the square of the distance from the source. Mathematically, radiation intensity (I) is inversely proportional to the square of the distance (d): $I \propto 1/d^2$.
- This law governs the relationship between distance and radiation intensity, highlighting the importance of maintaining consistent source-to-object and source-to-image distances in radiography.

Characteristics of Films:

Graininess: Refers to the inherent granularity of the film caused by the presence of silver grains. Lower graininess results in higher image quality.

Density: The degree of blackening on the film, which corresponds to the amount of radiation exposure. Higher density indicates greater exposure.

Speed: The sensitivity of the film to radiation. Faster films require shorter exposure times but may have higher graininess.

Contrast: The difference in density between adjacent areas on the film. Higher contrast enhances image sharpness and clarity.

Characteristic Curves:

Characteristic curves represent the relationship between film density and radiation exposure. They illustrate the film's response to varying levels of radiation exposure, showing the range of densities produced at different exposure levels.

Penetrameters:

Penetrameters are calibration devices used to evaluate the quality of radiographic images. They consist of test objects with a series of steps or thicknesses that are radiographed alongside the object of interest. The steps provide a reference for assessing image quality, sensitivity, and contrast.

Exposure Charts:

Exposure charts provide guidelines for selecting exposure factors (e.g., kVp, mAs) based on the thickness and composition of the object being radiographed. They help optimize image quality while minimizing radiation dose.

Radiographic Equivalence:

Radiographic equivalence refers to the relationship between different exposure factors that produce the same image quality. It allows for the adjustment of exposure parameters when using different X-ray machines, techniques, or film/screen combinations while maintaining consistent image quality.

Fluoroscopy:

Fluoroscopy is a medical imaging technique that uses X-rays to obtain real-time moving images of the internal structures of a patient's body. Unlike traditional X-ray imaging, which produces static images, fluoroscopy allows for dynamic visualization of anatomical structures and physiological processes. Here's an overview of fluoroscopy, including its principle, equipment, uses, advantages, and considerations:

Principle:

- Fluoroscopy works on the same principles as conventional X-ray imaging. It involves the projection of X-ray photons through the patient's body onto a fluoroscopic screen or digital detector.
- The X-ray photons are attenuated to varying degrees by different tissues and structures within the body, resulting in differences in image contrast.
- The resulting image is viewed in real-time on a monitor, allowing for dynamic visualization of anatomical structures and the passage of contrast agents or other substances.

Equipment:

- Fluoroscopy equipment typically includes an X-ray tube, a fluoroscopic image intensifier or flat-panel detector, a collimator, and a display monitor.
- The X-ray tube emits a continuous X-ray beam, which is directed towards the patient.

- The fluoroscopic image intensifier or detector captures the attenuated X-rays and converts them into a visible image.
- The collimator shapes and limits the X-ray beam to the region of interest.
- The display monitor allows the radiologist or physician to view the fluoroscopic images in real-time.

Uses:

- Fluoroscopy is used in a variety of medical procedures and interventions, including:
- Gastrointestinal studies: Evaluating the function and anatomy of the digestive tract, including barium swallow studies, upper gastrointestinal (GI) series, and barium enemas.
- Orthopedic procedures: Guiding joint injections, arthrography, and spinal interventions such as epidural steroid injections and discography.
- Cardiac catheterization: Visualizing the heart and blood vessels during diagnostic and interventional procedures, including angiography and stent placement.
- Urological procedures: Assessing the urinary tract, including voiding cystourethrography (VCUG) and retrograde pyelography.
- Vascular procedures: Evaluating blood flow and vessel patency, including peripheral angiography and venography.

Advantages:

Real-time imaging: Provides dynamic visualization of anatomical structures and physiological processes.

Guidance for interventions: Allows for precise placement of catheters, needles, and medical devices during procedures.

Minimally invasive: Reduces the need for exploratory surgery by enabling diagnostic and therapeutic procedures to be performed with minimal trauma to the patient.

Considerations:

Radiation exposure: Fluoroscopy involves the use of ionizing radiation, so it is essential to minimize radiation dose to patients and healthcare providers through appropriate use of equipment and techniques.

Contrast agent use: Some fluoroscopic procedures require the administration of contrast agents to enhance visualization of certain structures or functions. Care must be taken to ensure patient safety and monitor for adverse reactions.

Image quality: Maintaining high-quality fluoroscopic images is crucial for accurate diagnosis and treatment. Regular equipment maintenance, calibration, and optimization of imaging parameters are necessary to achieve optimal image quality.

Radiography:

- Radiography is a medical imaging technique that uses X-rays to create static images of the internal structures of the body.
- In radiography, X-ray photons are passed through the body, and the resulting image is captured on a film or digital detector.
- Radiography is commonly used for diagnostic purposes, such as detecting fractures, tumors, and other abnormalities in bones and soft tissues.

Computed Radiography (CR):

- Computed radiography is a digital imaging technique that replaces traditional film-based radiography with a phosphor-based imaging plate.
- In CR, X-ray photons are absorbed by the phosphor material in the imaging plate, causing it to emit light.
- The emitted light is captured by a photomultiplier tube or a solid-state detector and converted into a digital image.
- CR offers advantages such as improved image quality, faster image acquisition, and digital storage and retrieval of images.

Computed Tomography (CT):

- Computed tomography is a medical imaging technique that uses X-rays to create detailed cross-sectional images (slices) of the body.
- In CT, an X-ray tube rotates around the patient, emitting X-ray beams from multiple angles.
- Detectors on the opposite side of the patient measure the intensity of the X-ray beams after they pass through the body.
- Computer algorithms reconstruct the measured data into detailed 3D images of the internal structures.
- CT is valuable for diagnosing a wide range of conditions, including tumors, vascular diseases, and trauma.