7AN6-60.2: Non-Destructive Testing

Introduction and Visual Testing

Dr. Manoj Kumar Sain, PhD
Associate Professor
Department of Mechanical Engineering, SKIT

Course Details

- **Credit: 3 Max.**
- **Marks: 150 (IA: 30, ETE: 120)**
- **3L+0T+0P**
- **End Term Exam: 3 Hours**

Syllabus

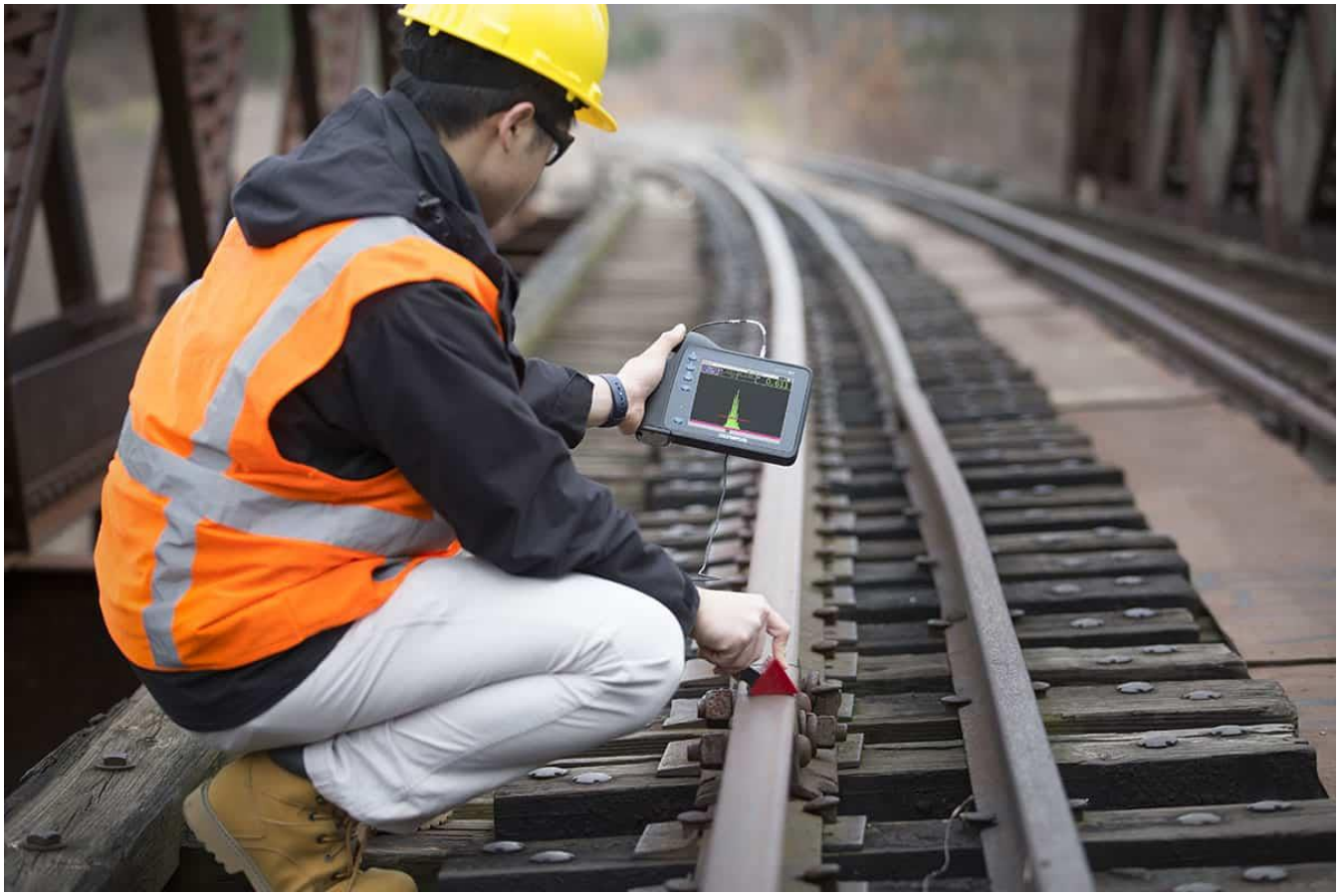
SN	CONTENTS	Hours
1	**Introduction:** Objective, scope and outcome of the course.	1
2	**Overview of NDT:** NDT Versus Mechanical testing, Overview of the Non Destructive Testing Methods for the detection of manufacturing defects as well as material characterization. Relative merits and limitations, Various physical characteristics of materials and their applications in NDT, Visual inspection, Unaided and aided.	7
3	**Surface Non Destructive Evaluation (NDE) Methods:** Liquid Penetrant Testing, Principles, types and properties of liquid penetrants, developers, advantages and limitations of various methods. Testing Procedure, Magnetic Particle Testing, Theory of magnetism, inspection materials. Magnetization methods, Interpretation and evaluation, Principles and methods of demagnetization, Residual magnetism.	8
4	**Thermography and Eddy Current Testing (ET):** Thermography, Principles, Contact and non contact inspection methods, Advantages and limitation, Instrumentations and methods, applications. Eddy Current Testing, Generation of eddy currents, Properties of eddy currents, Eddy current sensing elements, Types of arrangement, Applications, advantages, Limitations, Interpretation/Evaluation.	6
5	**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. Acoustic Emission Technique, Principle, AE parameters, Applications.	6
6	**Radiography (RT):** 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, Interpretation/ Evaluation, Fluoroscopy, Xero Radiography, Computed Radiography, Computed Tomography.	7
7	**Special Techniques and Applications:** Phased array ultrasonics time of flight diffractions, Automated and remote ultrasonic testing, Acoustic pulse reflectometry, Alternative current field method, Case studies on NDT techniques used in aircrafts.	5

Course Outcomes

After completion of this course, students will be able to –

7AN6-60.2.1	Explain the scope, objectives, outcomes, overview, merits and limitations of Non Destructive Methods (NDT) compared to mechanical testing.
7AN6-60.2.2	Enlist various NDT methods and, elaborate visual inspection and surface non destructive testing methods: liquid penetrant testing and magnetic particle testing with the help of schematic diagrams.
7AN6-60.2.3	Describe the principles, instrumentations, methods, advantages, limitations, and applications of thermography and eddy current testing.
7AN6-60.2.4	Explain the principles, instrumentations, methods, advantages, limitations, and applications of ultrasonic testing, acoustic emission testing and radiography testing.
7AN6-60.2.5	Describe the phased array ultrasonic time of flight diffractions, automated and remote ultrasonic testing, acoustic pulse reflectometry, alternative current field method, and case studies on NDT techniques used in aircrafts.

Non-destructive Testing



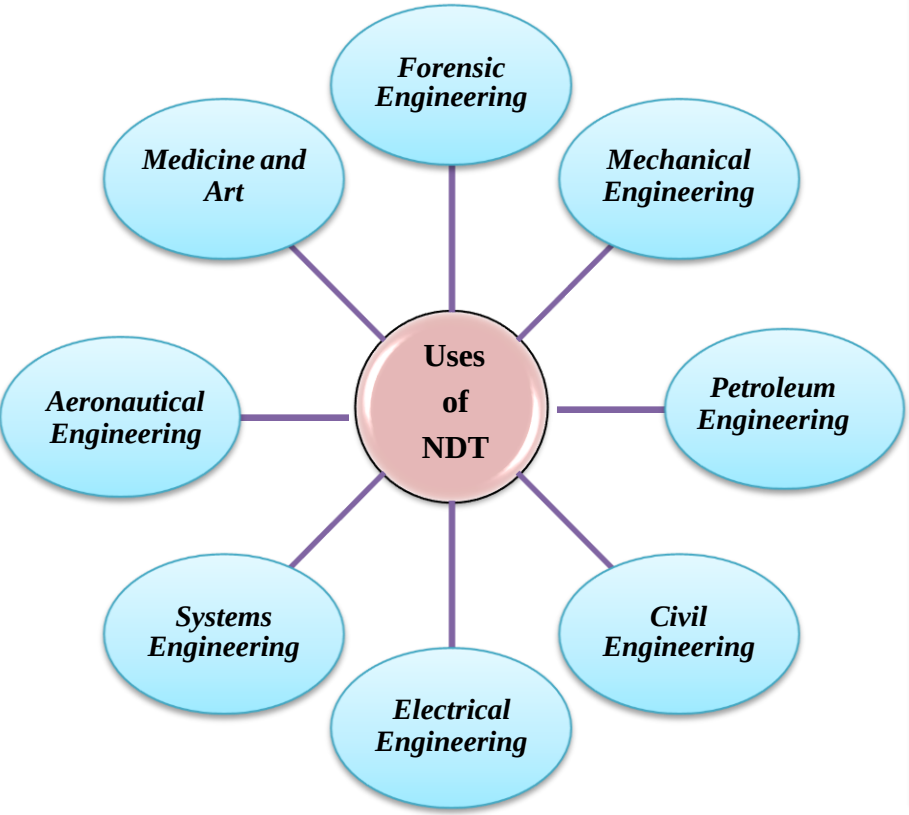
Nondestructive Testing: Introduction

- **Non-destructive testing (NDT)** is the process of inspecting, testing, or evaluating materials, components or assemblies for discontinuities, or differences in characteristics without destroying the serviceability of the part or system.
- Terms non-destructive examination (NDE), non-destructive inspection (NDI), and non-destructive evaluation (NDE)
  are also commonly used to describe this technology.
- It is a highly valuable technique that can save both money and time in product evaluation, troubleshooting, and research.

Nondestructive Testing...

- Because it allows inspection without interfering with a product's final use, NDT provides an excellent balance between quality control and cost-effectiveness.
- Non-destructive tests are used in manufacturing, fabrication and in-service inspections to ensure product integrity and reliability, to control manufacturing processes, lower production costs and to maintain a uniform quality level.
- During construction, NDT is used to ensure the quality of materials and joining processes during the fabrication and erection phases, and in-service NDT inspections are used to ensure that the products in use continue to have the integrity necessary to ensure their usefulness and the safety of the public.

Uses of NDT



Non-destructive evaluation can be conveniently divided into nine distinct areas:

1. Flaw detection and evaluation.
2. Leak detection.
3. Metrology (measurement of dimension).
4. Location determination.
5. Structure or microstructure characterization.
6. Estimation of mechanical and physical properties.
7. Stress (strain) and dynamic response determination.
8. Signature analysis.
9. Chemical composition determination.

Selection of an NDT Method

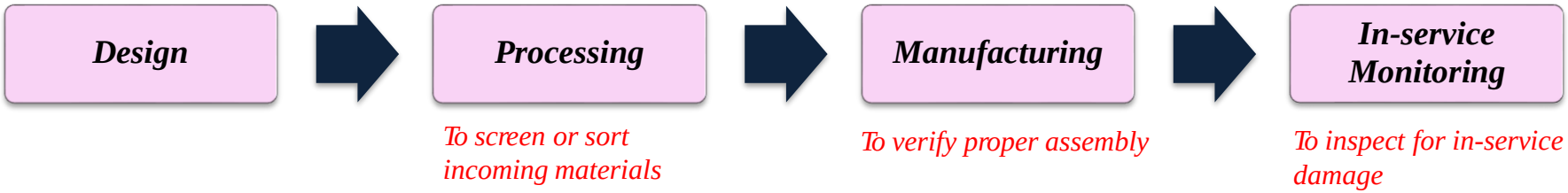
- Each NDT method has its own set of advantages and disadvantages and, therefore, some are better suited than others for a particular application.
- The NDT technician or engineer must select the method that will detect the defect or make the measurement with the highest sensitivity and reliability.
- The cost effectiveness of the technique must also be taken into consideration.

When planning NDT testing one should take into account a number of factors such as:

- Requirements regarding reliable and safe operation.
- Quality assurance level achieved.
- Characteristics of manufacturing processes, properties of materials used.
- Feasibility of NDT methods available.
- Economic criteria.

Need of NDT

- There are NDT application at almost any stage in the production or life cycle of a component.
  - ✓ To assist in product development.
  - ✓ To screen or sort incoming materials.
  - ✓ To monitor, improve or control manufacturing processes.
  - ✓ To verify proper processing such as heat treating.
  - ✓ To verify proper assembly.
  - ✓ To inspect for in-service damage.



Benefits of Using NDT in Manufacturing

- Use of NDT during all stages of manufacturing results in the following benefits:

a) It increases the safety and reliability of the product during operation.

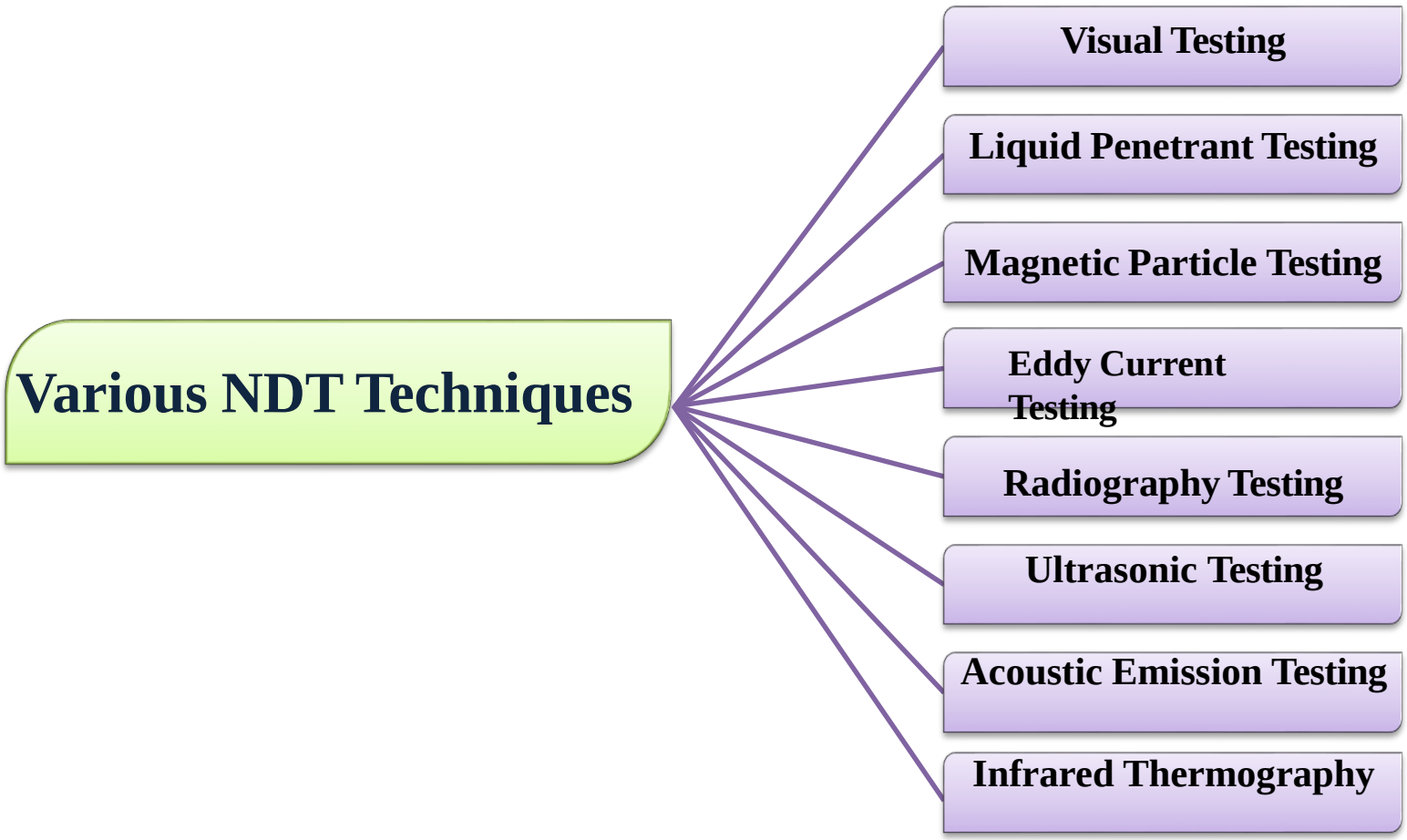
b) It decreases the cost of the product by reducing scrap and conserving materials, labour and energy.

c) It enhances the reputation of the manufacturer as producer of quality goods.

d) It enables design of new products.

All of the above factors bring profitability to the manufacturer

Non-destructive Inspection Techniques



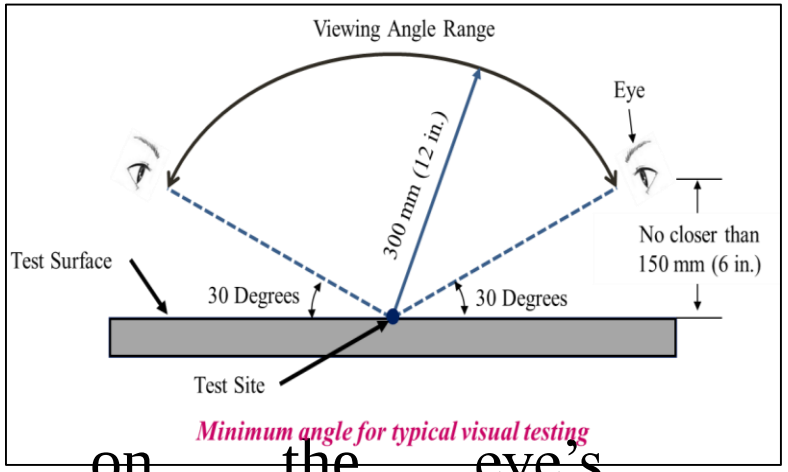
Visual Inspection

Visual Inspection is a non-destructive testing technique that provides a means of detecting and examining a variety of surface flaws, such as corrosion, contamination, surface finish, and surface discontinuities on joints (e.g., welds, seals, solder connections, and adhesive bonds).

- It is the most cost effective method of detecting common defects in welding and castings.
- As it can be implemented easily throughout the progression of a job it is easy to eliminate simple
  errors and problems preventing the follow on effect.
- It is also the most widely used method for detecting and examining surface cracks, which are particularly important because of their relationship to structural failure mechanism.
- Even when other non-destructive techniques are used to detect surface cracks, visual inspection often provides a useful supplement.

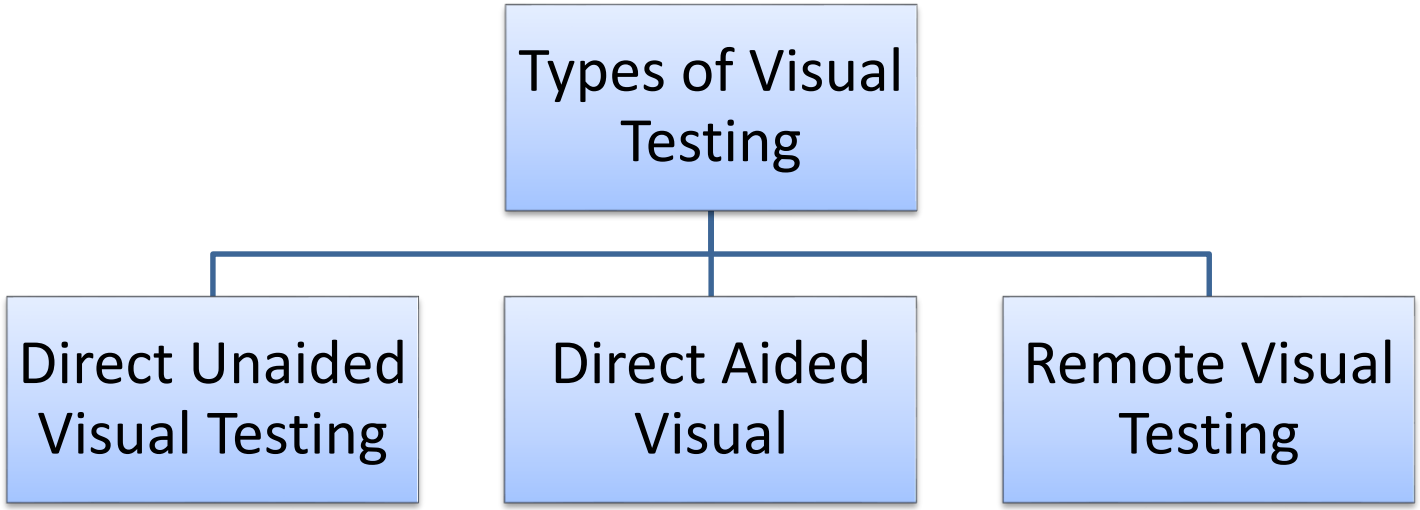
Visual Angle and Distance

- It is general recommendation for operator to be placed at a distance for his eye to be within 600 mm of the test surface at an angle not less than 30 degrees.



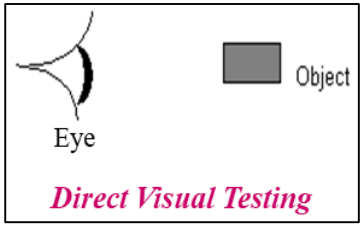
- The criterion set above is based on the eye's resolving power.
- Natural or artificial lighting of sufficient intensity and placement is needed to illuminate the test areas and to allow proper reading of weld gauges and other equipment.
- The visual test resolution is considered adequate when the examiner, by combination of lenses, access, lighting and angle of vision, can resolve a 0.8 mm wide black line or an artificial flaw located on the surface to be examined.

Types of Visual Testing



Direct Visual Testing:

- Direct visual examination is the type of examination made in situations where there is an access to the area of interest without any possibility of injury to the inspectors.
- There is no interruption between the eye and the object.
- Defects can be detected are: cracks, corrosion layer, physical damage, surface porosity, misalignment of mated parts, etc.



Direct Visual Testing

Examples:

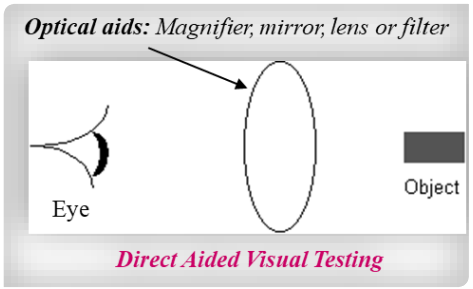

Visual inspection for surface cracks


Inspection of car after assembly


Direct visual inspection of welded parts

Direct Aided Visual Testing

- The nature of the image is not modified.
- Modification of the image is only allowed by:
  - ✓ *Magnification with for example a mirror, a lens, an endoscope;*
  - ✓ *Spectral or density filtering by a filter lens.*



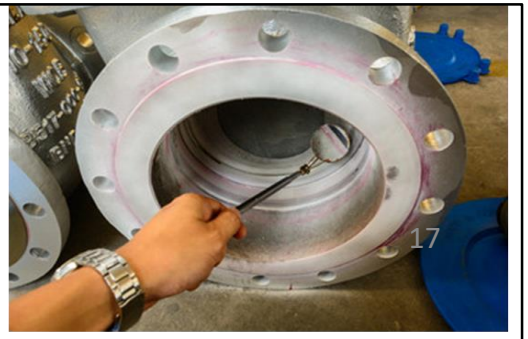
Direct Aided Visual Testing


Visual testing of the inner surface of welded parts

e


Underbody inspection of automobile chassis

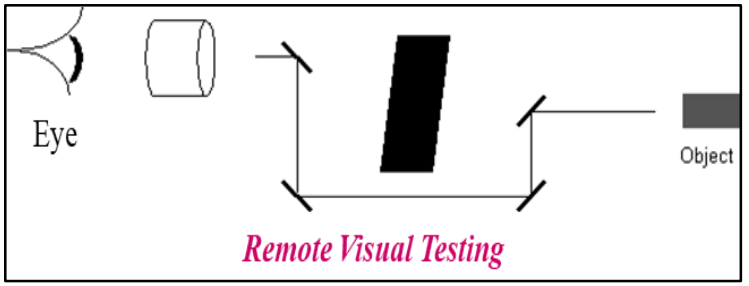

Inspection of weldment by magnifying glass


Inspection after liquid penetrant testing

Remote Visual Testing:

- The nature of the image is modified.
  - ✓ **For example:**

    The optical image is converted into an electronic image by a camera.



Remote Visual Testing

- **Equipment used:** Camera, robotic devices, fiber optics, portable video probes, etc.

Examples:


Robotic pipeline inspection crawler


Inspection of Aircraft using Fiberscope


Visual Inspection Microscope

Basic Procedure for Visual Inspection

- It generally comprises of three steps as:

1) Clean the inspection surface properly.

   - (Contaminants such as oil, grease, scale, sand (on casting surface), etc. may interfere with interpretation of results).

2) Adequately illuminate the specimen with light.

   - (Human eye is most sensitive to yellow-green light, with a wave length of 5560 Å).

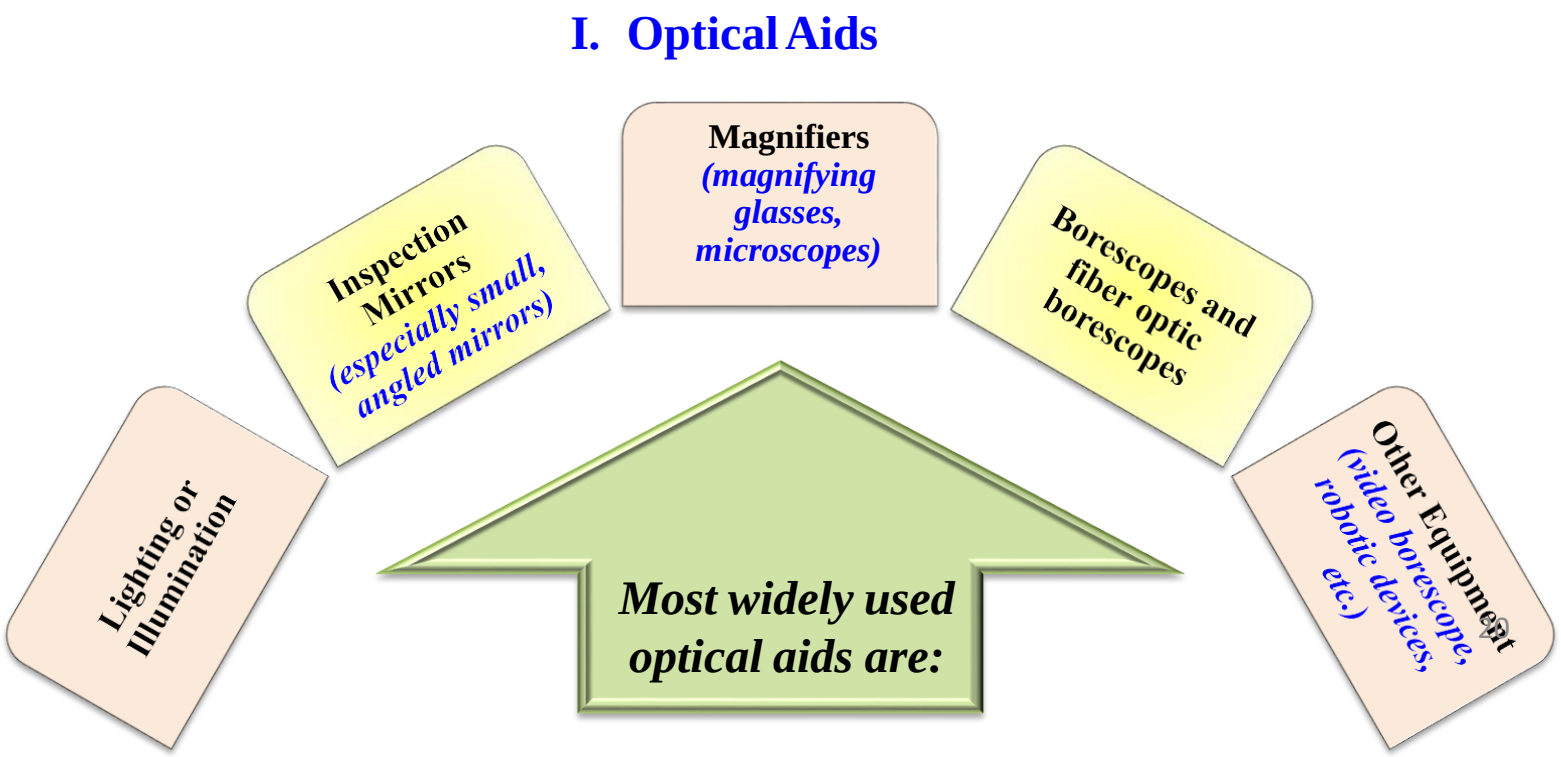
3) Examine the specimen with eyes or take the assistance of light sensitive devices such as photocells.

Visual Testing Equipment

- Different kinds of equipment are used to improve the inspection quality.
- These equipment can be classified into two parts:

I. Mechanical Aids

II. Optical Aids



a) Lighting

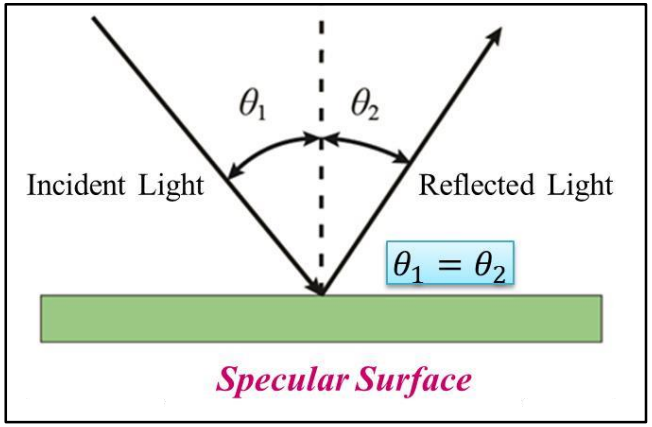
- The inspection surface illumination is of extreme importance.
- Adequate illumination levels should be established in order to ensure effective visual inspection.
- While designing lighting for an inspection system, we must consider what the inspection system should do:
  - ✓ Look for a defect in a part,
  - ✓ Measure a part's dimensions, or
  - ✓ Determine the presence or absence of a feature.
- While devising lighting for product's inspection, following things should be taken into account:
  - ✓ Optical properties of product's surface.
  - ✓ Inspection surface geometry.
  - ✓ Colour of product's surface.

Optical Properties of Product's Surface

- The surfaces of products have optical properties that fall into one of three general reflectance categories:

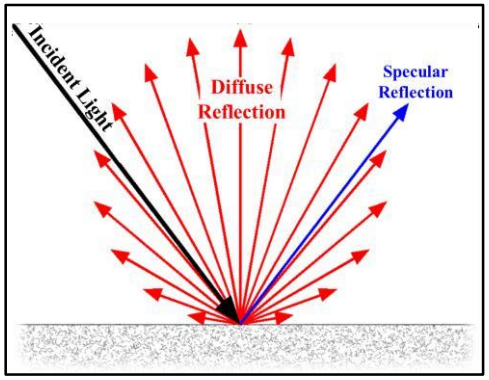
Specular Reflection:

- ❖ The specular reflection is a phenomenon where the incidence angle of light is equal to the angle of reflection.
- ❖ Specular surfaces are mirror like smooth and highly polished surfaces.



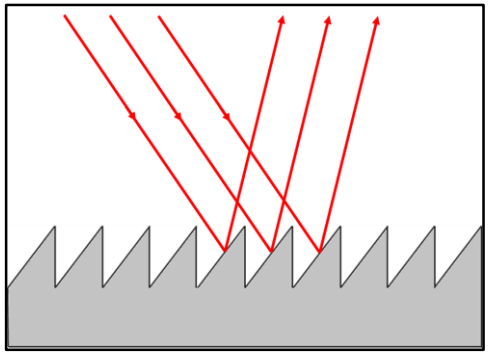
Diffused Reflection

- It is the reflection of light from a surface such that a ray incident on the surface is scattered at many angles rather than a just one angle as in the case of specular reflection.
- A surface built from a non-absorbing powder such as plaster, or from fibers such as paper, or from a polycrystalline material such as white marble, reflects light diffusely with great efficiency.
- Diffuse surfaces are rough and have a dull lustre.
- Many common materials exhibit a mixture of specular and diffuse reflection.



Directional Reflection:

- Directionally reflective surfaces typically contain fine grooves that reflect light generally in a preferred direction depending on the incidence angle.



Surface Geometry of Inspection Surface

- In addition to a part's reflective properties, the surface's geometry must also be considered.
  - ✓ ***Flat Surface:*** Flat surface is self-explanatory, and achieving uniform illumination across it is typically easier than other geometries.
  - ✓ ***Curved Surface:*** The changing slope of a curved part can often pose a lighting problem that manifests itself as uneven illumination across the part. If the curved surface is specular or directionally reflective, glinting can occur, too.
  - ✓ ***Prismatic Surface:*** Prismatic parts contain sharp edges or steep slopes, and such parts can be
    difficult to illuminate because lighting can produce shadows or glints.

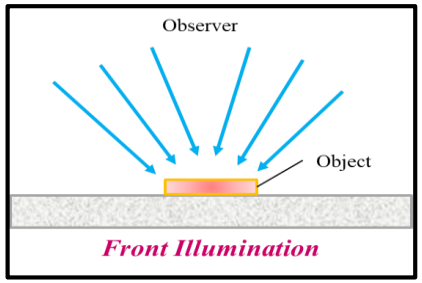
Colour of Inspection Surface:

- Contrasting colours may help your inspection system distinguish parts from backgrounds.
- If contrast differences are small, we can use colour filters or selective-wavelength illumination to enhance the contrast for our inspection system.

Illumination Techniques

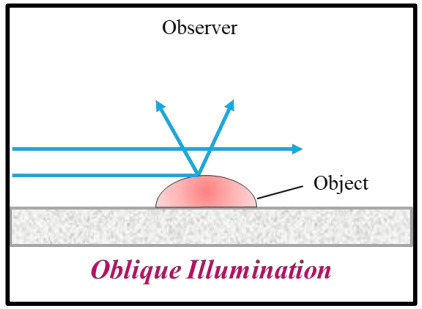
i. Front Illumination:

- Front illumination involves placing a light source and a camera/observer on the same side of a product to provide overall illumination.



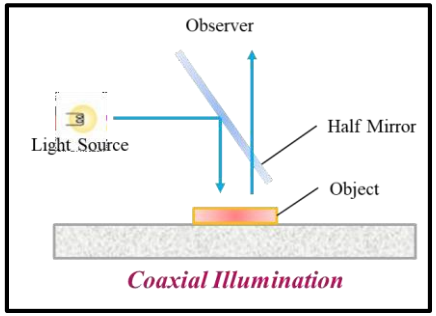
ii. Oblique Illumination:

- Placing a light source nearly perpendicular to a camera/observer provides oblique illumination.
- This technique is used to find surface irregularities such as burrs.



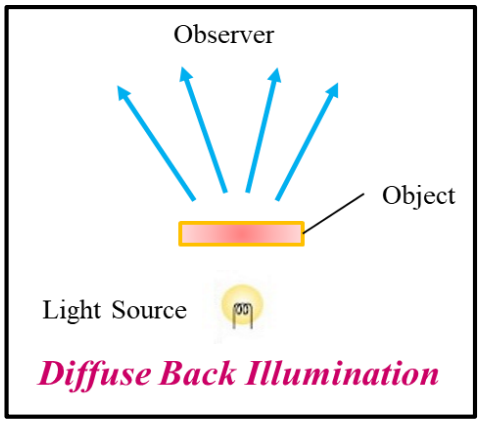
iii. Coaxial Illumination:

- It is another form of front lighting, which directs light down a camera's/observer's line of sight.
- Because this technique provides uniform illumination across your field of view, it can reduce shadows and some glinting.



iv. Diffuse Back Illumination:

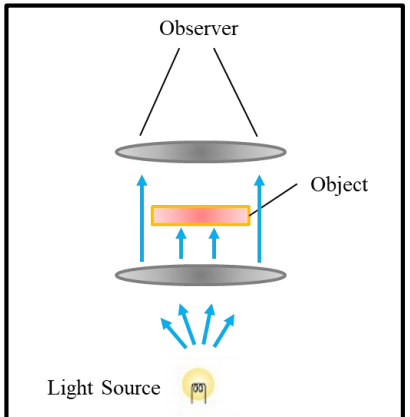
- The object is illuminated from the behind.
- It gives edge contrast to objects as well as aid in identifying defects or imperfections within translucent or opaque surfaces.



Diffuse Back Illumination

v. Collimated Back Illumination:

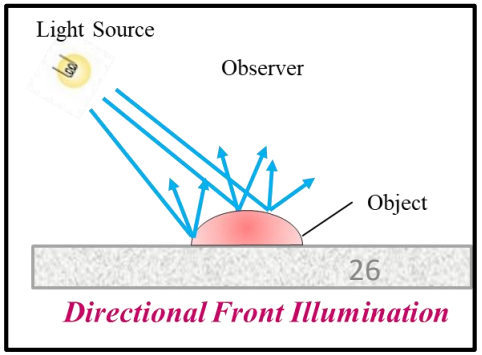
- It is a variation of back lighting, which uses collimated light to produce images with sharp edges, even for curved surfaces such as those on a cylinder or ball.



Collimated Back Illumination

vi. Directional Front Illumination:

- Directional lighting lets an inspection system measure shadows and calculate the heights of components.



Directional Front Illumination

b) Inspection Mirrors

- Inspection mirrors are used to improve the angle of vision.
- Inspection mirrors allow the inspectors to look inside piping, threaded and
  bored holes, inside castings, and other hardest to see places.

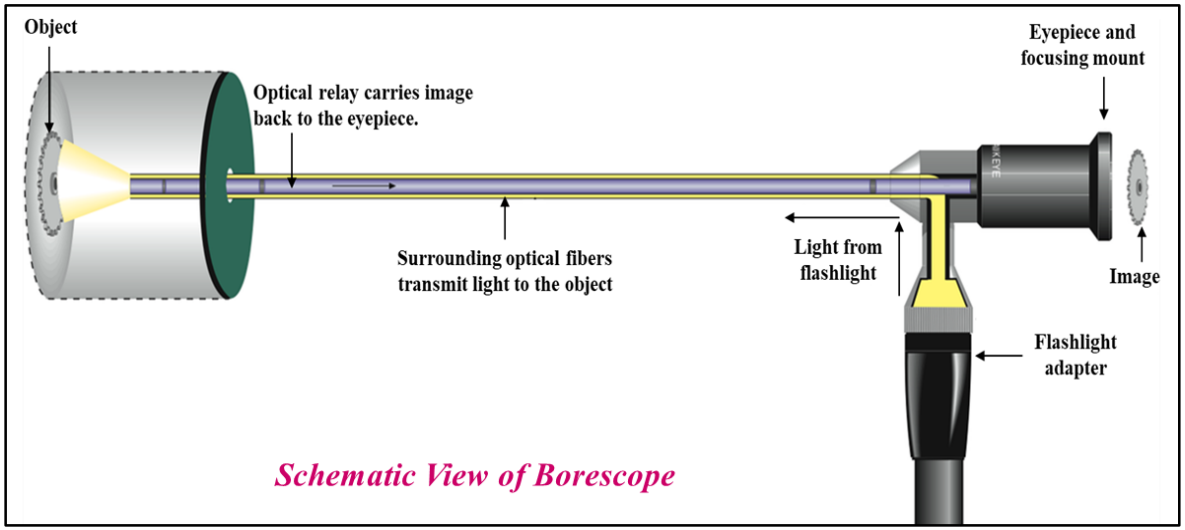

Inspection Mirrors

c) Magnifiers

- Magnifying systems are used for evaluating surface finish, surface shapes
  (profile and contour gauging), and surface microstructures.
- An inspector with eye fatigue is likely to miss defects that would otherwise be detected.
- Therefore, it is important to ensure that the possibility of eye fatigue is
  minimized by using appropriate levels of magnification for the job.
- The equipment should have proper ergonomic function such as adjustability and positionability.

d) Borescopes

- Borescopes are visual aids used for illuminating and observing internal, closed or otherwise inaccessible areas.
- They are designed for remote viewing in difficult to reach areas such as jet engines, cylinders,
  tanks, and various enclosed chambers.
- They are available in many different diameters and lengths, and are classified as ***rigid*** or ***flexible***.



e) Other Equipment

Portable Video Probes-

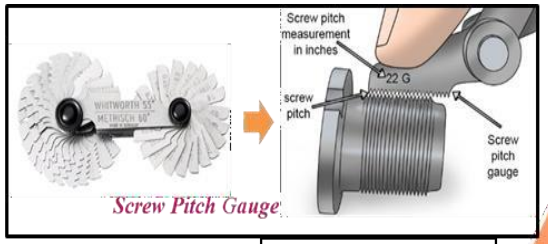
- Portable video probes allow inspectors to remotely perform examinations in closed chambers which are inaccessible by convention inspection means.
- Portable video inspection unit with zoom allows inspection of large tanks and vessels, railroad tank cars, sewer lines.

Robotic Devices-

- Robotics have been developed whereby cameras can be affixed to crawlers and submersibles.
- Robotic crawlers permit observation in hazardous or tight areas, such as air ducts, reactors, pipelines.
- Retrieval tools can be affixed to robotics to remove foreign objects.

II. Mechanical Aids

- Several mechanical gauges are also used to assist the visual inspection examinations.



For screw thread measurement.

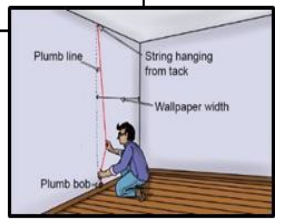
For angle measurement e.g. bend angle measurement in sheet metal working (bending).

Mechanical Aids Include:

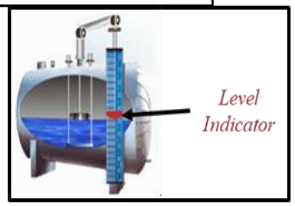
- Measuring Rules & Tapes
- Thread, Pitch & Thickness Gauges
- Plumb lines
- Angle Measuring Tools
- Lever Gauges
- Calipers & Micrometers

Used to measure distance.

To determine the vertical on an upright surface.



Used to measure level of fluids at various industrial applications.



To measure dimensions of product more precisely.

Mechanical Aid for Weldments:

❖ *Welding Gauges:*

- Welding fabrication uses fillet gauges to determine the width of the weld fillet, undercut gauges, angle gauges, skew fillet weld gauges, pit gauges, contour gauges, and a host of other specialty items to ensure product quality.

Examples

Universal Welding Gauge:

❖ It allows measuring of:

- ✓ Height of flat weld
- ✓ Height of fillet weld bead
- ✓ Thickness of fillet weld
- ✓ Bevel angle of weldment
- ✓ Undercut depth of weld seam
- ✓ Vertical misalignment

Universal Welding Gauge

Fillet Weld Gauge:

❖ It allows measuring of concavity or convexity of fillet weld.

Fillet Weld Gauge

Advantages of Visual Inspection

- ✓ It is a routine procedure.
- ✓ The cost of visual inspection is low.
- ✓ It can be very effective where examination is made before, during and after manufacturing process.
- ✓ Testing is simple and testing speed is high.
- ✓ Testing is possible while test object is being used.
- ✓ Permanent records are available when latest equipment are used.

Limitations of Visual Inspection:

- ✓ The scope is limited to surface defects, as internal and sub-surface defects can not be found.
- ✓ Limited to the visual acuity of the observer/inspector.
- ✓ Eye fatigue may cause the defects to remain undetected.

Summary:

- Non-destructive inspection is a wide group of analysis techniques used in science and technology industry to evaluate the properties of a material, component or system without causing damage.
- It is divided into various methods, each based on a particular scientific principle.
- Visual inspection is the most common and widely used non-destructive testing technique and it is normally the first step in the examination process.
- Various optical and non-optical equipment are used to further assist and improve the visual inspection examinations.

References

- C. G. K. Nair and J. Prasad “Non-Destructive Test and Evaluation of Materials”, TMH.
- R. Prakaskh “ Non-Destructive Testing Techniques”, New Age
- O. Lari and R. Kumar “ Basics of Non-Destructive Testing ”, Katsons

Thank You