Introduction

An industrial product is manufactured with an aim to perform a certain function and the user expects that it performs the assigned function well. However, the product may contain certain defects and imperfections, which impair its performance level. **Non Destructive Testing** (NDT) refers to the entire range of test methods that detect the harmful defects in the finished products without affecting their future usefulness.

Defects in a product can arise during manufacturing stage, or during assembly, installation, commissioning or during in-service. In the pre-service stage, the defects may be present in the raw material or may be introduced during machining, fabrication, heat treatment, assembling. The pre-service quality can be achieved essentially by good engineering practice i.e. by way of selecting suitable quality raw materials and by ensuring that harmful defects are not produced during the subsequent stages of fabrication and assembly, prior to putting the part/ component into service.

However, even with the highest quality of materials and workmanship, the occurrence of some form of imperfections during manufacture is inevitable and there will be a typical distribution of imperfection sizes associated with a particular manufacturing process and quality. In the in-service stage, defects will be generated due to deterioration of the component/structure as a result of one or combination of the operating conditions like elevated temperature, pressure, stress, hostile chemical environment etc. **The goal of NDT is to detect the defects and give information about their distribution**. Therefore, NDT plays a vital role in modern engineering practice for achieving the required standards of quality in manufacturing.

37.3 METHODS OF NDT

There are a large number of nondestructive tests in use. We study here are some of the most common methods. The common methods are

1. Visual Inspection
2. Liquid Penetrant Testing
3. Magnetic Particle Testing
4. Eddy Current Testing
5. Ultrasonic Testing
6. Radiography

Depending on the requirements, the above tests are used singly or in conjunction with one another.

37.4 VISUAL INSPECTION

Visual NDT is mainly used for examination and detection of surface defects. In this, the test component is first adequately cleaned. Then, it is illuminated with light and examined with unaided eye or with the help of optical devices. Visual inspection can reveal the information on

(*i*) general condition of the component
(*ii*) presence or absence of corrosive product on the surface
(*iii*) presence or absence of cracks
(*iv*) orientation and position of cracks, if present
(*v*) surface porosity etc.

In many cases, the results of visual examination will be of great assistance to other tests.

Magnifying devices or lighting aids are used wherever their necessity is felt. Microscopes, borescopes, endoscopes and flexiscopes are some of the optical aids used in the visual testing. A microscope detects minute defects and details of fine structure. A *borescope* is an instrument used to inspect the inside of a narrow tube, bore, or chamber. The *endoscope* is much like a borescope with a superior optical system and high intensity light source. The *flexiscope* is a flexible fibre-optic borescope that can be used to inspect inaccessible regions and through

passages with several bends. In recent times, holography is used to inspect surfaces of precision components.

37.5 LIQUID/DYE PENETRANT TESTING

This method is used for detecting minute discontinuities such as cracks and surface openings. **Liquid penetrant testing** can be applied to any non-porous clean material, metallic or non-metallic, but is unsuitable for dirty or very rough surfaces. Though it is applicable for both magnetic and non-magnetic materials, primarily it is applied for non-magnetic materials. It is simple to perform and relatively cheaper than other testing methods. Cracks, as narrow as 150 nanometers can be detected with this method.

37.5.1 Basic Principle

The basic principle of penetrant inspection is that when a liquid penetrant is applied over a clean surface to be inspected, the penetrant seeps into defect by the combined action of surface tension and capillary action; when developed, by the blotting action of the developer powder, gives a recognizable indication of the defect (a crack or surface opening etc).

In this method, a liquid penetrant is applied to the surface of a component for a certain predetermined time. The penetrant seeps through any surface opening defect by capillary action. Subsequently, the excess penetrant is removed from the surface. The surface is then dried and a developer is applied to it. The developer absorbs the penetrant that remained in the discontinuity and indicates the presence as well as the location, size and nature of the discontinuity.

37.5.2 Basic Processing Steps of Liquid Penetrant Inspection

The following are the basic stages of liquid penetrant method:

1. Surface Preparation: One of the most important steps of a liquid penetrant inspection is the initial cleaning and drying of the surface area of the test component. The surface must be free of oil, grease, water, or other contaminants that may prevent penetrant from entering flaws.

2. Penetrant Application: Once the surface has been thoroughly cleaned and dried, the penetrant material is applied by spraying, brushing, etc methods. The liquid should spread uniformly over the surface and seep into the crack.

3. Penetrant Dwell: The penetrant is left on the surface for a sufficient time to allow as much penetrant as possible to seep into a defect. Penetrant dwell time is the total time that the penetrant is in contact with the part surface. The penetrant producers usually recommend dwell times. The times vary depending on the application, penetrant materials used, the component being inspected, and the type of defect being inspected. Minimum dwell times typically range from 5 to 60 minutes.

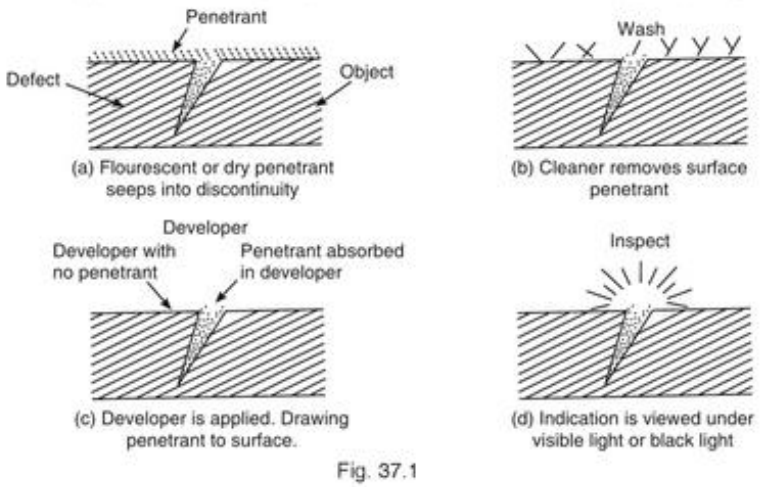

Fig. 37.1

4. Removal of Excess Penetrant: The excess penetrant is then carefully removed from the surface of the sample. Insufficient cleaning leaves penetrant on the surface and leads to overlooking of the defect. On the other hand over cleaning may remove penetrant from defects. Therefore, both insufficient cleaning and over cleaning must be avoided. The cleaning of the surface is carried out using a solvent and then rinsing with water, or first treating with an emulsifier and then rinsing with water.

5. Developer Application: In the next step, a thin layer of developer is applied to the surface. The developer acts as a blotter and draws trapped penetrant out of imperfections open to the surface and makes them 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 and 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.

The sequence of steps in liquid penetrant testing is shown in Fig. 37.1.

37.5.3 Materials used in Penetrant Testing

A variety of materials are used in penetrant testing method. They are penetrant materials, cleaners, emulsifiers and developer materials.

Penetrants

The penetrant materials are light, oil-like liquids, which have dissolved coloured dyes and may be classified as fluorescent, visible dye or dual-purpose materials. The role of the dye is to give colour contrast with respect to the surrounding background under white light or UV light illumination so that the defect becomes clearly visible. The penetrant materials may also be classified as (i) water-washable, (ii) solvent removable, and (iii) post-emulsifiable. Penetrants that are water washable can be removed from the surface by ordinary tap water. Other penetrants are removed with special solvents. For petroleum-based penetrants, an emulsifier is used that reacts with the oil-based penetrant to form a water-soluble substance, which is then washed away by water washing. The penetrant must be chemically stable, have low viscosity, chemical inertness, ease of removal, and sufficient brightness of colour.

Developers

The developer is required to enhance the conspicuity of the indication. Two types of developer materials are used in the technique: (i) dry developers and (ii) wet developers. Dry developers are dry light coloured powdery materials such as amorphous silica powder. Wet developers consist of a powdered material suspended in a suitable liquid. The developer must be highly absorptive to draw penetrant from the defect, provide a contrast background to indicate the location of the defect, and must be easy to apply.

37.5.4 Advantages and Limitations

The advantages of liquid penetrant testing method are as follows.

- No elaborate setup is required.
- It is simple to apply and cheaper in cost.
- It is portable and fast.
- Results are easy to interpret.
- It can be used to inspect any non-porous material.
- Defects of any size, shape and orientation can be detected using this method.

The limitations are that

- It can be used to detect surface-breaking defects only.
- Surfaces must be clean
- It cannot be applied to porous materials.