Mechanical & Non-Destructive Testing

Training Objective

After watching the program and reviewing this printed material, the viewer will gain an understanding and become familiar with the various methods, equipment, and applications of mechanical and non-destructive materials testing.

- Mechanical testing methods are clearly shown
- Non-destructive testing methods are shown in detail
- Advantages and limitations of the various tests are detailed

Materials Testing

Prior to manufacturing, many material, design, and production decisions are made to ensure product reliability and proper performance. To validate these decisions, a variety of testing methods are employed. The methods are grouped into two major categories:

- Mechanical Testing
- Non-Destructive Testing (NDT)

Mechanical testing, which is also known as destructive testing, is accomplished by forcing a part to fail by the application of various load factors. In contrast, non-destructive testing does not affect the part's future usefulness and leaves the part and its component materials in tact.

Mechanical Testing

Mechanical testing specifications have been developed by the American Society for Testing and Materials (ASTM) and many of these specifications have been adopted by the American National Standards Institute (ANSI).

Typically mechanical testing involves such attributes as hardness, strength, and impact toughness. Additionally, materials can be subjected to various types of loads such as tension or compression. Mechanical testing can occur at room temperatures or in either high or low temperature extremes.

Hardness – The resistance to indentation and to scratching or abrasion. The two most common hardness tests are the Brinell test and the Rockwell test.
In the Brinell hardness test, a known load is applied for a given period of time to a specimen surface using a hardened steel or tungsten-carbide ball, causing a permanent indentation. Standard ball diameter is 10 millimeters, or approximately four-tenths of an inch. The diameter of the resulting permanent indentation is then measured and converted to a Brinell hardness number.
The Rockwell hardness test involves the use of an indentor for penetrating the surface of a material first by applying a minor, or initial load, and then applying a major, or final load under specific conditions. The difference between the minor and major penetration depths is then noted as a hardness value directly from a dial or digital readout. The harder the material the higher the number.

Mechanical & Non-Destructive Testing

Tensile – Force is applied perpendicular to the cross sectional area of the test item. Two of the primary material properties that tensile tests determine are:

- Yield Strength, which is the stress required to permanently elongate, or deform, a material a specific amount, commonly 0.2% of total elongation.
- Ultimate Tensile Strength, which is the maximum stress a material can withstand just prior to fracturing.

Compression – Compressive loads are applied to a point just beyond the yield strength of the material and measured at that point or continued to the point of failure if required.

Impact – Impact tests measure resistance to shock loading or impact by determining the amount of energy absorbed by the test specimen. There are two basic types of impact tests:

- Pendulum
- Drop Weight

Most common pendulum impact tests are the Charpy notched-bar impact test and the Izod notched-bar impact test. In both tests, the specimen is fractured and the energy absorbed is documented. The chief differences between these two impact tests are the way the test specimen is held and in the pendulum hammer design.
In the dropped weight test, a known weight is dropped from a specified height. Such tests have advantages in that the impact is unidirectional with failure beginning at the weakest point and propagating from there. A principle advantage over the pendulum impact tests is that the drop weight impact test can define failure by either deformation, crack initiation, or complete failure of the specimen.

Fracture Toughness - Measures a material's resistance to brittle fracture and can be quantified by linear elastic fracture mechanics.

Fatigue – Measures material failure under repeated loading below the yield strength. Stresses measured below failure is referred to as the 'endurance limit' while the number of repeating cycles the material can withstand above this limit is known as 'fatigue life.'

Creep – Measures a material's continuing dimensional change while under timed stress load. Creep tests are usually performed at elevated temperatures and can last for a thousand hours or longer.

Non-Destructive Testing

All non-destructive tests include several basic elements:

- A source that distributes a probing medium
- A modification of the probing medium in reaction to discontinuities or variations in the material's properties
- A sensitive detector responsive to changes in the distribution of the probing medium
- A means of indicating or recording of the detector's signals
- An observer or devise capable of accurately interpreting the test object's material properties or discontinuities

Mechanical & Non-Destructive Testing

Non-Destructive Testing Methods

Non-destructive testing methods require a trained and competent inspector. Moreover, the inspector must be trained in the specific testing method involved. Some of the most common non-destructive testing methods include:

Visual – Most simple, quickly and easily performed method. Most often performed with special illuminations and magnification aids. Limited to detecting only surface defects.

Liquid Penetrant – Able to detect pits, porosity, and seams. A liquid penetrant dye is applied for a specific time. Later a developer is applied which causes the dye to be drawn out from the defect and mark the flaw's location.

Magnetic Particle – While dry or suspended in a liquid, magnetic particles are applied to a test surface area. When a magnetic field is created within a test part, a discontinuity, perpendicular to the induced magnetic field causes a leakage field to form on the parts surface and hold the rearranged particles in place at the flaw for inspection.

Eddy Currents – Using a testing coil, a small circulating current called an eddy current is applied to any electrically conductive part. Any change in the eddy current pattern results in a change in the coil signal. While sensitive and versatile, the process requires the use of accurate reference standards.

Ultrasonic – High frequency sound waves are sent by a transducer into an object. The energy of the ultrasonic waves is reflected back to the transducer by any discontinuities, indicating their presence and location. Ultrasonic testing can be accomplished using either:

- Immersion Testing
- Contact Testing

In immersion testing, sound waves are transmitted through a water path or column. In contact testing, the transducer is in direct contact with the test specimen. A thin liquid film couplant is required to ensure efficient transmission of the ultrasonic energy. All types of materials can be tested with ultrasonics, but complex shapes can prove problematic.

Radiographic – Based on the ability of x-rays and gamma rays to penetrate all materials and thicknesses differently. The radiation is directed through the part and imprints on a film stock or an electronic device. The resulting image reveals the internal characteristics of the part, with possible imperfections showing up as density changes in the image. This process is used primarily on welds and is difficult to use on complex shapes. The process is costly and involves certain health risks for process operators. Additionally, high interpretive skills in reading the x-ray images are required.

Mechanical & Non-Destructive Testing

Review Questions

1. Mechanical testing specifications have been developed by the:
   a. AWS
   b. ASTM
   c. GSA
   d. ANSI

2. In tensile strength tests, yield strength is a measure of:
   a. springback
   b. fracture point
   c. ultimate strength
   d. permanent elongation

3. Impact refers to:
   a. shock loading
   b. compressive loading
   c. fatigue loading
   d. torsion loading

4. A principle advantage of the 'dropped weight impact test' is:
   a. less costly
   b. applicable to all material
   c. part failure isn't required for a successful test
   d. can be done at room temperatures

5. 'Fatigue life' is a measure of the number of cycles:
   a. below the endurance limit
   b. above the endurance limit
   c. at the point of fracture
   d. at the point of permanent deformation

6. Visual non-destructive testing is limited to:
   a. small, easily handled parts
   b. non-ferrous materials
   c. dimensional defects
   d. surface defects

7. In magnetic particle inspection, a flaw is indicated by:
   a. it's lack of magnetism
   b. particles arranged in line
   c. particles arranged perpendicular to the discontinuity
   d. circular patterns

8. Eddy-current testing relies on:
   a. accurate reference standards
   b. coil strength
   c. electrolytic solution strength
   d. solid ground connections

9. X-ray testing is used most often on:
   a. complex shapes
   b. non-ferrous metals
   c. round objects
   d. welded joints

Mechanical & Non-Destructive Testing

Answer Key

1. b
2. d
3. a
4. c
5. b
6. d
7. c
8. a
9. d