NON-DESTRUCTIVE TESTING AND INSPECTION

by

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Introduction

Non-destructive testing may be defined as the science of examination of materials or manufactured articles, in order to determine their fitness for certain purposes, without impairment of their desirable properties.

One of the main applications of non-destructive testing is the provision of information about that which is hidden or is inaccessible: for example, the soundness of the center of a foot cube of metal or the freedom from corrosion of the tubes in a power-station condenser. If metals were transparent to ordinary light, cavities might be as visible as bubbles in cast glass and small surface cracks might show up on account of total reflection. Ordinary light carries evidence directly to our eyes; in the absence of light transmission, therefore, we have to rely on indirect evidence, and the development of non-destructive testing has been bound up with the discovery of methods – such as the use of x-rays – whereby such indirect evidence is made available and understandable.

Liquid Penetrant Inspection

Liquid penetrant processes are non-destructive testing methods for detecting discontinuities that are open to the surface. They can be effectively used in the inspection of non porous, metallic materials, both ferrous and nonferrous. Surface discontinuities such as cracks, seams, laps, cold shuts, laminations, or lack of bond are indicated by these methods. They are applicable to in-process, final and maintenance inspection. The inspection materials used shall not adversely affect the parts tested by any chemical action.

Penetrant inspection is basically a simple process. First a liquid penetrant is applied to the surface of the part. It is permitted to remain on the surface for a period of time, during which it penetrates into defects open at the surface. After the penetrating period, the excess penetrants that remain on the surface are removed. Then an absorbent, light-colored, powdered material called a developer is applied to the surface. This developer acts as a blotter and draws out a portion of the penetrant which had previously seeped into the surface openings. As the penetrant is drawn out, it diffuses into the coating of the developer, forming indications that are much wider than the surface openings with which they are associated. The inspector then views the part and looks for these colored indications against the background of the developing powder.

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Magnetic Particle Inspection

Magnetic particle inspection is a non-destructive method of detecting the presence of cracks, laps, burst, tears, splits, seams, inclusions, segregations, laminations, shrinks, cold shuts, porosity, lack of fusion and similar discontinuities in ferromagnetic materials, such as iron and steel. This method will detect discontinuities that are open to the surface, but too fine to be seen with the naked eye. Magnetic particle inspection will readily detect discontinuities that are more deeply seated. The location of the discontinuity is indicated and the approximate size and shape are outlined. The method is applicable to billet bars, tubes, forgings, comparatively thick sheets, and bodies that are irregular in shape, such as machine parts and structural members. It is not applicable to non-magnetic materials.

The work piece to be inspected is magnetized and then covered with fine magnetic particles, or the magnetization and application of the particles may occur simultaneously. The magnetic particles may be held in suspension in a liquid that is flushed over the piece, the piece may be immersed in the suspension, or the particles in the form of dry powder, may be dusted over the surface of the object. The presence of a discontinuity is disclosed by the formation and adherence of a particle pattern on the surface of the work piece over the discontinuity. This pattern, known as a "indication", assumes the approximate shape of the surface projection of the discontinuity.

Eddy-Current Inspection

Eddy-current inspection consists of observing the interaction between electromagnetic fields and metals. In a basic system, currents are induced to flow in the test piece by a coil of wire that carries an alternating current. As the part enters the coil, or as the coil in the form of a probe or yoke is placed in the test piece, electromagnetic energy produced by the coil is partly absorbed and converted into heat by the effects of resistivity and hysteresis. Part of the remaining energy is reflected back to the test coil, its electrical characteristics having been changed in a manner determined by the properties of the test piece. Consequently, the currents flowing through the probe coil are the source of information describing characteristics of the test piece. These currents may be analyzed and compared with currents flowing through a reference specimen.

Eddy-current methods of inspection are effective with both ferromagnetic and nonferromagnetic materials may be obscurred by changes in magnetic permeability of the test piece. Changes in temperature must be avoided to prevent erroneous results if electrical conductivity or other properties are being determined.

Applications of eddy-current and electromagnetic methods of inspection to castings can be divided into the following three categories:

1. Detecting near-surface flaws such as cracks, voids, inclusions, blowholes and pinholes (eddy-current inspection).

2. Sorting according to alloy, temper, electrical conductivity, hardness and other metallurgical factors (primarily electromagnetic inspection).

3. Gaging according to size, shape, plating thickness or insulation thickness (eddy-current or electromagnetic inspection).

Radiographic Inspection

Radiography plays an important part in non-destructive testing and inspection. Without damage to the material, radiography provides a visible permanent record of internal conditions of the product through a film, furnishing thereby the basic information through which its soundness can be determined. With the film record, which is known as a radiograph, improvements in the process of the product's manufacture may be made by eliminating or lessening the irregularities found. The elimination of the defective articles from the production line naturally increases the efficiency of production. The economic value of radiography becomes obvious in such processes as the radiographic examination of castings before machining thereby eliminating the unnecessary machining of internally defective castings.

In castings, certain sections that are thinner because of the design, and intentional cavities such as cored holes, are regions of low density and are revealed as darkened areas. Specimens containing variations in thickness caused by the unintentional absence of metal are also more transparent, resulting in darkening of the film. Excess metal and inclusions more dense than the base metal appear as light regions. The common casting discontinuities may be recognized on the negative by the following characteristics.

1. Surface roughness appears as irregular white or dark areas with a smooth contour. The coloration depends on whether the surface protrudes or is depressed. The surface irregularities of the actual casting must be compared carefully with the radiograph and identified before an attempt is made to interpret the internal discontinuities.

2. Gas cavities, blowholes and minute gas porosity appear as well defined, spherical or rounded darkened areas. Hydrogen or other gas porosity in aluminum alloys is represented by round, dark spots and is generally distributed through the section or entire casting. In coarse-grained aluminum alloy castings, these voids tend to be curved or elongated.

3. Inclusions such as foreign material, slag, oxide or sand, appear as regular or irregular areas. The areas may vary in intensity and are either lighter or darker than the background, depending on the relative densities.

4. Segregation may be well-defined or may appear as mottled areas, either regular or irregular in shape and lighter or darker than the background.

5. Shrinkage cavities and shrinkage porosity (pipe or sponge) are represented by filamentary or dendritic dark regions of irregular dimensions and indistinct outline. These voids are localized. Shrinkage porosity is lacy or honeycombed and not a continuous cavity.

6. Microshrinkage in magnesium alloys appears on a radiograph as dark, feathery streaks or irregular dark patches caused by shrinkage in the grain boundaries.

7. Misruns appear as very prominent darkened areas of variable dimensions with definite smooth outlines where the metal failed to fill the section.

8. Cold shuts are represented by dark lines or bands with variable lengths and definite smooth outlines that tend to be curved (meniscold). Cold shuts occur where the metal has come together but has failed to unite and the contact surfaces are oxidized.

9. Hot cracks are represented by darkened lines of variable width and often possess numerous branches that follow the outlines of the dendrite. A cold crack, originating from residual or external stresses, is a straight dark line usually continuous throughout its length.

The origin and identification of flaws in steel welds have been studied exhaustively. The discontinuities in order of prevalence of occurrence are: (1) slag inclusions, (2) porosity, (3) cracks, (4) incomplete fusion between the weld and base metal or between two layers of weld metal. All these imperfections are less dense than steel itself and are recorded as darkened regions on the radiograph. With the exception of incomplete fusion, which is represented by a dark line of variable width parallel to the scarf.

In the metal industries, radiography has been used primarily for the inspection of castings and welded products. The examination of wrought metal, such as forged, rolled or drawn sections, is very limited because of the uniformly dense structure and the unlikely existence of flaws large enough to be detected by the radiographic method. Therefore, the commercial value of radiography depends on the nature of the material to be tested. The most extensive applications of radiography to steel, aluminum and magnesium are:

1. For welds.

(a) An aid in the development of welding procedures; (b) routine inspection of pressure vessels, boilers and such, according to specification; (c) intermittent checking of the quality of less critical products; (d) determining the quality of repaired areas.

2. For castings.

(a) An aid in the development of casting technique; (b) routine inspection of critical castings; (c) percentage or spot examination of less critical castings; (d) determining the quality of areas salvaged by welding, (e) locating core wires, chaplets and the like in complex castings.

3. For forgings.

(a) An aid in the development of forging practices; (b) routine inspection of critical parts. Used only to a limited extent for forgings, because of the very infrequent occurrence of discontinuities of a size detectable by radiography.

4. For assemblies.

(a) Determining location and dimensions of internal components; (b) inspecting quality of soldered or brazed joints; (c) locating foreign materials, drills and such in complicated assemblies.

5. For plastic and other non-metallic parts.

(a) In the development of operating procedures; (b) routine inspection.

Ultrasonic Inspection

Ultrasonic inspection is a non-destructive method in which beams of high-frequency sound waves that are introduced into the material being inspected are used to detect surface and subsurface flaws. The sound waves travel through the material with some attendant loss of energy (attenuation) and are reflected at interfaces.

The reflected beam is detected and analyzed to define the presence and location of flaws.

The degree of reflection depends largely on the physical state of matter on the opposite side of the interface, and to a lesser extent on specific physical properties of that matter. For instance, sound waves are almost completely reflected at metal-gas interfaces.

Cracks, laminations, shrinkage cavities, burst, flakes, pores, bonding faults and other discontinuities that act as metal-gas interfaces can be easily detected. Inclusions and other inhomogenuities that act as metal-gas interfaces can be easily detected (even though they may not act as metal-gas interfaces) by causing partial reflection or scattering of the ultrasonic waves, or by producing some other detectable effect on the ultrasonic waves.

The determination of the type of defect from the oscilloscope trace depends to a very large extent on the experience of the operator. In many cases different types of defects may produce similar traces. The various kinds of traces, corresponding to particular defects, can be characterized as follows:

a) **Blow-holes.** The echo from a single flaw, having dimensions greater than some set value, is sharp and clear. A collection of blow-holes gives rise to an echo representing a number of reflections superimposed on one another and the trace appears jagged.

b) **Slag inclusions.** Slag inclusions frequently gives rise to an echo trace which is normally forked and sometimes, where the resolution of the apparatus is insufficient, broadened. When the probe is rotated around the defect, the echo does not disappear; one can even observe a number of maxima. For a single blow-hole, the echo does not disappear when the probe is moved round the defect.

c) **Cracks.** Cracks also give sharp and clear signals. The amplitude can vary when the probe is moved around the defect. For long cracks, the amplitude decays when the probe moves in a circular path having the flaw as its centre.