TESTING AND INSPECTION OF WELDS

ME 473 WELDING TECHNOLOGY

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Testing & Inspection Methods

- **Destructive Tests**
  - Tension test
  - Nick-Break test
  - Bend test
  - Hardness test
  - Fatigue test
  - Impact test

- **Nondestructive Tests (NDT)**
  - Visual examinations
  - Radiography testing
    - Gamma-ray
    - X-Ray
  - Magnetic testing
  - Ultrasonic inspection
  - Penetrant examinations
  - Stethoscope test
  - Eddy-Current Inspection
Testing & Inspection Methods

- Tests must be made to qualify the process(es) and the operators.
- Inspection usually involves the examination of completed welds to establish their quality and their confirmation to specifications.
- Thus, testing and inspection determines whether or not the quality standards of materials and workmanship are being met.
- In welded joints, the complexity is further increased by the nature of the joint which is far from homogeneous, metallurgically or chemically. In addition to the base metal, the welded joint consists of weld metal and a heat-affected-zone. A variety of properties are thus to be expected throughout the welded joint.

- Mechanical tests are used to qualify welding procedures, welders, and welding processes, and to determine if electrodes and filler metals meet the requirements of the specification.
- Welds in weldments are often tested for soundness, strength, and toughness by mechanical tests.
- Mechanical tests are destructive tests since the weld joint is destroyed in making the test. The test specimen (coupon) may be taken from a completed joint in a welded structure or from a test piece welded at the same conditions.
Weld Tension test

Welding results in metallurgical (and often compositional) differences in the weld joint, and it is important to know the effects of these changes on, mechanical properties.

The tension testing of welds is somewhat more involved than for base metal because the weld test section is heterogeneous in nature, composed of the deposited weld metal, the HAZ and the uneffected base metal.

Tensile test specimen can be either transverse or longitudinal depending on the loading on the welded joint.

In tension test, strength, elongation and reduction area are of primary importance.
Weld Tension test

- If the weld metal strength exceeds that of the base metal, most of the plastic strain occurs in the base metal, with resultant necking (local reduction in area of the cross-section by stretching) and failure outside of the area. In such a case, the test does not give an indication of the weld ductility.

- When the weld strength is considerably lower than that of the base metal, most of the plastic strain occurs in the weld.

- Transverse weld specimens may provide a measure of joint efficiency in terms of strength, but do not provide a good ductility measurement of the weld. But, however, transverse specimen is generally used.

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Weld Tension test

- Tension-shear tests may be used to evaluate the shear properties of fillet welds.
- Such tests are usually intended to represent completed joints in weldments and so are prepared using similar procedures.
- The tension-shear test is the most widely used method for determining the strength of resistance spot welds.
Weld Hardness test

- Brinell, Rockwell, Vickers and Knoop hardness tests can be applicable to welds.
- Hardness measurements can provide information about the metallurgical changes caused by welding. In construction steels, for example, rapid cooling from high HAZ temperature may cause the formation of martensite of much higher hardness than the base metal.
- Hardness values in a welded joint are usually sensitive to such conditions of welding, as the process used, heat input, preheat or interpass temp, electrode compositions, and plate thickness.
- Hardness testing of welds is performed on ground, polished, or polished and etched cross-section of the joint area.
- Indentations are made in the specific areas of interests, including the weld center line, face or root regions of the deposit, the HAZ, and the base metal.
Weld Hardness test

- Which hardness test is used depends primarily on the hardness or strength of the material, the size of the welded joint, and the type of information desired.
- The Brinell test produces a large indentation, typically 2 to 5.6 mm in diameter, and it is thus suited on for large welds.
- The Rockwell test produces a much smaller indentation more suited for hardness traverses.
- The Vickers and Knoop tests make relatively small indentations and thus are well-suited for hardness measurements of the various regions of the HAZ and for fine-scale traverses.
Weld Bend tests

- Various types of bend tests are used to evaluate the ductility and soundness of welded joints.
- Bend specimens may be longitudinal or transverse to the weld axis and may be bent in simple three- or four-point bending (free bend) or around a mandrel of specified diameter (guided bend).
- The top and bottom surfaces of a welded plate frequently designated as the face and root surfaces, respectively.
- Face bends have the weld face on the tension side of the bend specimen; with root bends, the weld root is on the convex side.
- In bend testing of thick plates, transverse slices are usually cut from the welded joint and bent so that one of the cut side surfaces becomes the convex side of the bend specimen, these are referred to as side bends.
Weld Bend tests

- Transverse bend tests are useful in qualifying welders and welding operators because they quite often reveal the presence of defects (lack of root fusion or penetration) that are not detected in tension tests.
- The transverse bend test is sensitive to the relative strengths of the weld metal, the HAZ, and the base metal.
- It is normal to machine or grind, flat the face and root of a weld bend test coupon to reduce the stress raising effect that these would have.
- Weld joints with non-uniform properties such as dissimilar metal joints or where the weld and parent metal strengths are substantially different can result in 'peaking' of the bend coupon. This is when the most of the deformation takes place in the weaker of the two materials which therefore experiences excessive localised deformation that may result in premature failure.
Visual inspection

- It is the most widely used nondestructive testing technique. It is extremely effective and is the least expensive inspection method.
- The welding inspector can utilize inspection visual inspection throughout the entire production cycle of a weldment.
- It is an effective quality control method that will ensure procedure conformity and will catch errors at early stages.
- Visual inspection methods can be divided into three sub-groups:
  - **Visual examinations prior to welding**: drawings, material specifications, edge preparation, dimensions, cleanliness of the welding joint etc.
  - **Visual examination during welding**: welding process, electrode selection, operating conditions, preheat requirements, welder performance etc.
  - **Visual examinations of the finished weldment**: weld size (using weld gauges), defects (surface cracks, creater cracks, surface porosity, incomplete root penetration, undercut, underfill), warpage, base metal defects etc.
Nondestructive testing (NDT)

- Nondestructive testing is also known as nondestructive examinations or evaluation (NDE) or inspection.
- These techniques use the application of physical principles from the detection of flaws or discontinuities in materials without impairing their usefulness.
- In the field of welding, four nondestructive tests are widely used:
  - Dye-penetrant testing and Fluorescent-penetrant testing
  - Magnetic particle testing
  - Ultrasonic testing
  - Radiographic testing
Liquid-penetrant examination is a highly sensitive, nondestructive method for detecting minute discontinuities (flaws) such as cracks, pores, and porosity, which are open to the surface of the material being inspected.

It may be applied to many materials, ferrous and nonferrous metals, glass and plastics.

The applied surface must be cleaned from dirt and film. So, discontinuities must be free from dirt, rust, grease, or paint to enable the penetrant to enter the surface opening.

A liquid penetrant is applied to the surface of the part to be inspected. The penetrant remains on the surface and seeps into any surface opening. The penetrant is drawn into the surface opening by capillary action. The parts may be in any position when tested. After sufficient penetration time elapsed, the surface is cleaned and excess penetrant is removed.

The penetrant is usually a red color; therefore, the indication shows up brilliantly against the white background. Even small defects may be located...
Weld Penetrant examination

Applications:
- Liquid-penetrant examination is used to detect surface defects in aluminium, magnesium, and stainless steel weldments when the magnetic particle examination method cannot be used.
- It is very useful for locating leaks in all types of welds. Welds in pressure and storage vessels and in piping for the petroleum industry are examined for surface cracks and for porosity.

Fluorescent-Penetrant Examination:
- The penetrant is fluorescent and when it is exposed to ultraviolet or black light it shows a glowing fluorescent type of read-out.
- It provides a greater contrast than the visible dye penetrants.
- Used for leak detection in magnetic and nonmagnetic weldments.
- A fluorescent penetrant is applied to one side of the joint and a portable ultraviolet light is then used on the reverse side of the joint to examine the weld for leaks.
- Inspect the root pass of highly critical pipe welds.

1. Section of material with a surface-breaking crack that is not visible to the naked eye.
2. Penetrant is applied to the surface.
3. Excess penetrant is removed.
4. Developer is applied, rendering the crack visible.
Radiographic examinations

- Radiography is a nondestructive examination method that uses invisible X-ray, or Gamma radiation to examine the interior of materials.
- It gives a permanent film record of defects that is relatively easy to interpret.
- Although this is a slow and expensive method of nondestructive examination, it is a positive method for detecting porosity, inclusions, cracks, and voids in the interior of castings, welds, other structures.
- X-ray generated by electron bombardment of tungsten, and gamma rays emitted by radioactive elements are penetrating radiation whose intensity is modified by passage through a material.
- The amount of energy absorbed by a material depends on its thickness and density. Energy not absorbed by the material will cause exposure of the radiographic film. Those area will be dark when the film is developed.
- Areas of material where the thickness has been changed by discontinuities, such as porosity or cracks, will appear as dark outlines on the film.
- All discontinuities are detected by viewing shape and variations in the density of the processed film.
Radiographic examinations

Applications:

- It is used for examination of weldments in all types of materials.
- Pipeline industry to ensure proper weld quality.
Ultrasonic examinations

- It is a nondestructive examination method that employs mechanical vibrations similar to sound waves but of a higher frequency.
- A beam of ultrasonic energy is directed into the specimen to be examined. This beam travels through a material with only a small loss, except when it is intercepted and reflected by a discontinuity or by a change in material.
- Ultrasonic examination is capable of finding surface and subsurface discontinuities.
- The system uses a transducer, which changes electrical energy into mechanical energy. The transducer is excited by a high-frequency voltage that causes a crystal to vibrate mechanically. The crystal probe becomes the source of ultrasonic mechanical vibrations.
- These vibrations are transmitted into the test piece through a coupling fluid, usually a film of oil, called a couplant.
- When the pulse of ultrasonic waves strikes a discontinuity in the test piece, it is reflected back to its point of origin.
- The transducer serves as a receiver for the reflected energy.
- The initial signal or main bang, the returned echoes from the discontinuities, and the echo of the rear surface of the test material are all displayed by a trace on the screen of a cathode-ray oscilloscope.
Ultrasonic examinations

Equipment:
- Transducer, pulse rate generator, amplifier, timer, and cathode ray oscilloscope (all are portable).

Applications:
- Practically any metal or material
- Restricted only very complex weldments and joining of plates with thicknesses of 10mm to 12mm or more
- Cracks, gas pockets, and slag
<table>
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<th>Examination technique</th>
<th>Equipment</th>
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<th>Advantages</th>
<th>Disadvantages</th>
<th>Other Considerations</th>
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<tr>
<td>Visual: VT</td>
<td>Pocket magnifier, welding viewer, flashlight, weld gauge, scale</td>
<td>Weld penetration, fitup, cleanliness, roughness, spatter, undercuts, overlaps, weld contour and size, welding procedure</td>
<td>Easy to use, fast, inexpensive, usable at all stages of production</td>
<td>For surface conditions only, dependent on subjective opinion inspector</td>
<td>Most universally used examinations method</td>
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<tr>
<td>Dye penetrant or fluorescent: DP, FPT</td>
<td>Fluorescent or visible penetrating liquids and developers; ultraviolet light for the fluorescent type</td>
<td>Defects open to the surface only; good for leak detection</td>
<td>Detects very small, tight, surface imperfections, easy to apply and to interpret; inexpensive; use on magnetic or nonmagnetic materials</td>
<td>Time consuming in the various steps of the process; normally no permanent record</td>
<td>Often used on root pass of highly critical gas welds if material improperly cleaned; some indications may be misleading</td>
</tr>
<tr>
<td>Magnetic particle: MT</td>
<td>Iron particles, wet or dry, or fluorescent; special power source; ultraviolet light for the fluorescent type</td>
<td>Surface and near-surface discontinuities, cracks, etc.; porosity, slag</td>
<td>Indicates discontinuities not visible to the naked eye; useful in checking edges prior to welding, also, repairs; no size restriction</td>
<td>Used on magnetic materials only; surface roughness may distort magnetic field; normally no permanent record</td>
<td>Examination should be from two perpendicular directions to catch discontinuities that may be parallel to one set of magnetic lines of force</td>
</tr>
<tr>
<td>Radiographic: RT</td>
<td>X-ray or gamma ray; source: film processing equipment, film viewing equipment, penetrameters</td>
<td>Most internal discontinuities and flaws; limited by direction of discontinuity</td>
<td>Provides permanent record; indicates both surface and internal flaws; applicable on all materials</td>
<td>Usually no suitable for fillet weld inspection; film exposure and processing critical; slow and expensive</td>
<td>Most popular technique for subsurface inspection; required by some codes and specifications</td>
</tr>
<tr>
<td>Ultrasonic: UT</td>
<td>Ultrasonic units and probes; reference and comparison patterns</td>
<td>Can locate all internal flaws located by other methods with the addition of exceptionally small flaws</td>
<td>Extremely sensitive; use restricted only by very complex weldments; can be used on all materials</td>
<td>Demands highly developed interpretation skill</td>
<td>Required by some codes and specifications</td>
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End of the chapter

Thank you…