Introduction to Welding and Non-Destructive Testing (NDT)

An Online Continuing Education Course for Engineers

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Introduction to Welding and Non-Destructive Testing (NDT)

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Welding is one of the most common types of joining methods used in the industry. Welded components are subjected to thermal stress, which results in microscopic cracking, deformation, and hardening of the metal. Depending on the materials and the welding process, the consequences of heat input on the material surrounding the weld can compromise the material's integrity or suitability for service.

Welded materials are subjected to destructive and/or non-destructive tests to ascertain these to be fit for purpose. Destructive testing has the drawback of destroying the test object in the process. Non-destructive tests, on the other hand, permit evaluation of the material or component without destroying it. To appropriately apply these inspection procedures, a certain level of skill is required. These tests aren't simply for screening out bad products; they're also for assuring that what appears to be good is actually good.

This course provides a quick rundown of non-destructive and destructive testing methods that are used in the evaluation of welds. This includes understanding the basic principles of various testing methods, as well as details of typical applications, principles, advantages, and limitations.

Learning Objectives:

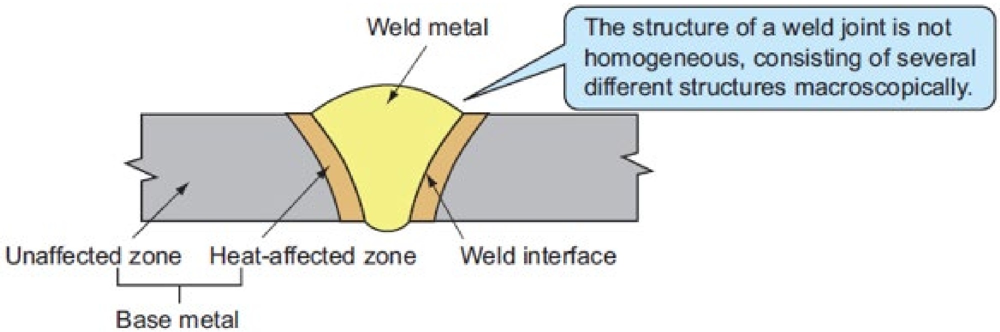
Understand the basic principles pertaining to weld design with emphasis on the following:

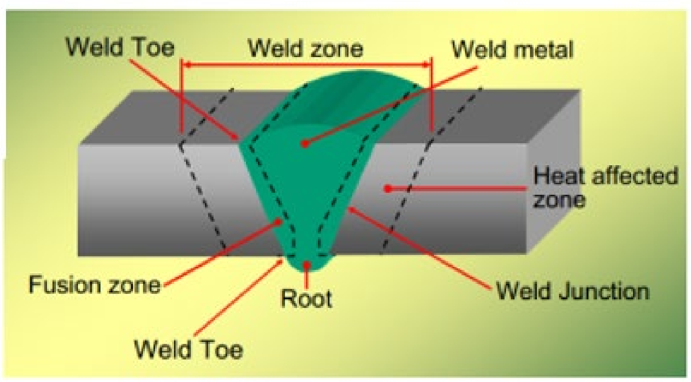
- Characteristics and properties of materials and steel alloys
- The basic types of weld joints and their symbols
- Welding defects and discontinuities - their causes and interpretation
- Review of commonly used welding processes
- Introduction to common mechanical destructive tests for establishing tensile strength, hardness, toughness, and impact resistance
- An overview of common non-destructive testing (NDT) methods, including visual testing, penetrant testing, magnetic particle testing, eddy current testing, radiographic testing, and ultrasonic testing
- Types of equipment used for each non-destructive and destructive examination
- Describe the advantages and limitations of various test methods
  Acceptance criteria of weld defects

Chapter 1: Characteristics of Materials

Welding is the process of uniting two metal parts by melting the materials at their interface. Usually, a filler material is added to form a pool of molten material (the weld pool) that solidifies to become a strong joint. The parts being joined are referred to as base metal, and the filler is referred to as weld metal.

A welded joint made by fusion welding exhibits a fusion zone containing the weld metal, a heat-affected zone (HAZ), and a zone where the properties of the base metal remain unchanged. The HAZ is not melted, but the properties are altered by the welding process. The quality of weld is highly dependent on several factors, such as the nature of the base metals, the weld metal used to join them, and the heat input of the welding process used.





Weld Zone Terminology

In most cases, problems arise when the heat input is too low or too high. Heat input that is too high, either through excessive voltage, excessive amperage, or slow travel speed, can slow your solidification rate, promoting grain growth in the weld metal and HAZ. This excessive grain growth shows up in changed mechanical properties, mainly a decrease in the material's cold weather toughness. As a rule, when the weld is made correctly, with the proper filler metal and with controlled welding parameters, it should meet or exceed the strength of the base material.

Material Properties

Each metal and metal alloy contains certain physical properties that can be altered or changed when welding occurs. Understanding what these properties are and how they may change will help us adjust our process when we encounter problems. While each material has many different physical properties that can change because of welding, we will focus on the ones that are most affected.

Strength

A metal's ability to resist deformation is known as its strength. Strength is quantified in four ways:

a. Tensile Strength: A metal's ability to resist forces attempting to pull it apart
b. Compressive Strength: The capability of a metal to withstand being crushed
c. Shear Strength: The capacity of a metal to tolerate forces trying to slice or cut it apart
d. Torsional strength: The ability of a metal to resist forces attempting to twist it

Strength can be altered drastically through welding.

If the weld is made with too little heat, little penetration will occur. If the weld is made with too much heat, the chemistry of the base material could be ruined. Welding can have a significant impact on a metal that has previously been heat treated. If the weld is done correctly and with the right filler metal, it should match or exceed the strength of the base material. The amount of heat the material sees will depend upon the welding process selected. For example, Gas Tungsten Arc Welding or TIG tends to put more heat into the material than a Gas Metal Arc Welding or MIG type process for the same size weld.

Ductility

Ductility is the capability of a metal to be permanently bent, twisted, stretched, or otherwise deformed without breaking or cracking. Ductility is also linked to the material's strength. In general, for the same cross-section, a stronger material will be more rigid than a weaker material. Adding a weld that cools quickly can reduce the ductility of some materials. On the other hand, many welds on a part that gets it really hot and keeps it hot for a sufficient amount of time can cause softening in the weld zone, especially something that had previously heat-treated to increase strength or hardness.

Any weld seam that will be bent or formed at a later stage requires special attention. For the same size weld, Gas Tungsten Arc Welding (TIG) tends to put more heat into the material than Gas Metal Arc Welding (GMAW) or Shielded Metal Arc Welding (SMAW).

Hardness

Hardness is the resistance to being scratched or indented by another material. Welding has a significant impact on a metal's hardness. If the metal was heat-treated to increase hardness prior to welding, the material becomes softer in general and loses the heat treatment in the weld heat-affected zone. Some alloys harden in the weld zone after welding and require a heat-treating technique to anneal, alleviate stress, or normalize the base material. Because a hard metal is typically a strong metal, anything that affects its hardness will also impact its strength.

Brittleness

Brittleness is the likelihood that a material will fail or fracture under a relatively small shock, force, or impact. Hardness and brittleness have a direct relationship, as when a metal's hardness is increased, so does its brittleness. A brittle material cracks in a way that it could be put back together without any deformation.

Toughness

Toughness is the ability of a metal to absorb energy without breaking, often when subjected to an impact load. In the event that a crack occurs, or if additional stress risers such as undercut, overlap, or incomplete penetration are overlooked during inspection, an excellent fracture toughness is desired.

The welding process can significantly change the toughness of a base metal. A thorough understanding of the toughness of the base metal, weld metal, and heat-affected zone allows inspectors and engineers to determine if a crack on a structure, for example, a bridge needs to be repaired or if it can be left alone for some time. Because of this, codes such as the AWS D1.5 require CVN (Charpy v-notch) testing of welding procedures. CVN testing provides values for toughness.

Corrosion Resistance

Corrosion resistance can be affected greatly by welding. Stainless steels are a great example of how welding can impact corrosion resistance. If we overheat stainless steel when welding, the alloy elements will separate and form carbide precipitation, what some people call "sugaring." Stainless becomes sensitized between about 800–1600 degrees Fahrenheit when the chromium combines with carbon to precipitate out in the form of black badness on the backside of our weld and heat-affected area.

Twenty Things a Welder Need to Know

It's important to get some basic knowledge of the mechanical properties of metals prior to welding training. This knowledge can allow a welder and inspector to determine the range of usefulness of a metal and the service that can be expected from it. It can also enable a welder to construct a safe, sound structure that meets engineering specifications.

1. The ability of a material to withstand a load pulling it apart is called its tensile strength
2. The ability of a material to be stretched out without breaking is called ductility
3. An Izod impact machine is used to give indication of the toughness of a material
4. The ability to withstand indentation is called hardness

5. Lack of ductility is called brittleness
6. The property of a metal to return to its original shape is called elasticity
7. Increase in carbon content causes an increase in strength and hardness
8. When carbon percentage increases, there is a decrease in ductility
9. Low carbon steel contains less than 0.2% carbon
10. Low ductility in a weld metal could result in cracking
11. Alloying is used to increase mechanical and physical pr
12. Sulfur and phosphorus are not all … impurities
13. Alloying all … ame strength
14. … ve resistance t
15. Q … and a de
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18. The … centage of carb
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