The Basics of Metallurgy

In this white paper Element engaged expert, John Tartaglia PhD, will guide you through the process of metallurgical testing, beginning with material identification and walking you through each type of analysis available when you test with Element.

What is a metal?

Bonding in metals exists between large numbers of atoms and metal atoms can hold their electrons loosely. When metal atoms bond with other atoms to make pure metals or alloys the electrons are more or less free to travel through the solid. Because of this most metals are shiny, soft, and easy to bend, as well as being good conductors of electricity.

Materials are often classified in these three classifications:

Pure metal or alloyed combinations of metallic elements
(1) Ductile
(2) Strong
(3) Electrically and thermally conductive

Polymers-plastics and rubber that are compounds of carbon, hydrogen and selected other elements
(1) Flexible
(2) Low strength
(3) Low hardness
(4) Electrical insulators

Ceramics-compounds between metallic and nonmetallic elements
(1) Brittle
(2) Hard
(3) Electrical insulators or semiconductors
(4) More resistant to high temperatures and harsh environments than the other two categories

What is metallurgy?

Metallurgy is the science and technology of extracting metals from their ores, refining them and preparing them for end use.

Metallurgy examines the microstructure of a metal, the structural features that are subject to observation under a microscope. Microstructure determines the mechanical properties of a metal, including its elastic and plastic behavior when force is applied.

Chemical composition is the relative content of a particular element within an alloy, and is usually expressed in weight percent. Composition, as well as mechanical and thermal processing, determine microstructure.

Types of metallurgical testing:

Chemical analysis

(1) Conducted in a solid state: Glow discharge optical emission spectroscopy (GD-OES)
(2) Conducted in a liquid state: Inductively Couples (Argon) Plasma Emission Spectroscopy (ICP)
(3) Conducted in a gaseous state (combustion evolution): Measures Carbon, Sulfur, Nitrogen, Oxygen and Hydrogen contents

Hardness testing

(1) Hardness is the resistance of a material to deformation, particularly permanent deformation.
(2) In practical terms, hardness measures how difficult it is to scratch or indent a material.
(3) Each type of hardness test has its own arbitrarily defined scale of hardness. There's no absolute hardness scale.
(4) Types of hardness testing:

- Brinell
- Vickers macrohardness and microhardness
- Knoop microhardness
- Rockwell and superficial Rockwell

Types of metallurgical testing continued:

Tensile testing

(1) In practical terms, tensile properties determine how much applied load and deformation can be placed on a material before it will deform and ultimately break.
(2) Tensile testing pulls a machined sample to failure while measuring the instantaneous applied load and sample extension
- Strain rate is how fast the deformation is applied

(3) This testing determines the applied loads that will cause the material to yield and fracture
- Yield is defined as the onset of plastic deformation or when the metal is permanently deformed

Fatigue testing

(1) Fatigue
- is a process of progressive and localized permanent structural change
- occurs in a material subjected to conditions that produce fluctuating stresses and strains at some points
- May culminate in cracks or complete fracture after a sufficient number of fluctuations

Impact testing

(1) is a measure of the amount of energy absorbed by a material as it fractures after being impacted at high strain rates.
(2) This test places a notched specimen on an anvil, and a hammer is lifted to swing into the specimen at full force, causing it to fracture
(3) The lower the height that the hammer swings after impacting the specimen is a measurement of higher toughness in the metal

Microstructural analysis

(1) Samples are mounted in a plastic resin
(2) The mount is polished to a mirror finish and etched in acid
(3) The mount is examined and photographed in an optical microscope called a metallograph
(4) Qualitative microstructural descriptions and quantitative measurements describe the effects of processing and composition on structure that determine the mechanical properties of metals.