

DESTRUCTIVE TESTING METHODS

Training Workbook



HOBART INSTITUTE OF WELDING TECHNOLOGY

An explanation of destructive testing
and results obtained.

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DESTRUCTIVE TESTING METHODS

Training Workbook

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the Staff of Hobart Institute
of Welding Technology

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TABLE OF CONTENTS

TOPIC	PAGE
Glossary of Welding Terms	iii
Introduction to Destructive Testing Methods	1
Tension Testing	6
Impact Testing	16
Guided Bend Testing	22
Nick Break Testing	29
Fillet Weld Break Testing	34
Etch Testing	40

GLOSSARY OF WELDING TERMS

All-Weld Metal Test Specimen – A test specimen with the reduced section composed wholly of weld metal.

Axis of a Weld – A line through the length of a weld, perpendicular to and at the geometric center of its cross section.

Base Metal Test Specimen – A test specimen composed wholly of base metal.

Complete Fusion – Fusion which has occurred over the entire base material surfaces intended for welding and between all layers and weld beads.

Complete Joint Penetration – Joint penetration in which the weld metal completely fills the groove and is fused to the base metal throughout its total thickness.

Crack – A fracture type discontinuity characterized by a sharp tip and high ratio of length and width to opening displacement.

Defect – A discontinuity or discontinuities that, by nature or accumulated effect, render a part or product unable to meet minimum applicable acceptance standards or specifications. This term designates rejectability.

Depth of Fusion – The distance that fusion extends into the base metal or previous pass from the surface melted during welding.

Discontinuity – An interruption of the typical structure of a material, such as a lack of homogeneity in its mechanical, metallurgical, or physical characteristics. A discontinuity is not necessarily a defect.

Electrogas Welding (EGW) – An arc welding process which produces coalescence of metals by heating them with an arc between a continuous filler metal (consumable) electrode and the work.

Molding shoe(s) are used to confine the molten weld metal for vertical position welding. The electrodes may be either flux cored or solid. Shielding may or may not be obtained from an externally supplied gas or mixture.

Electroslag Welding (ESW) – A welding process producing coalescence of metals with molten slag which melts the filler metal and the surfaces of the work to be welded. The molten weld pool is shielded by this slag which moves along the full cross section of the joint as welding progresses. The process is initiated by an arc which heats the slag. The arc is then extinguished and the conductive slag is maintained in a molten condition by its resistance to electric current passing between the electrode and the work.

Ferrite Number – An arbitrary, standardized value designating the ferrite content of an austenitic stainless steel weld metal. It should be used in place of percent ferrite or volume percent ferrite on a direct one-to-one replacement basis. See the latest edition of AWS A4.2 *Standard Procedure for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*.

Fusion Zone – The area of base metal melted as determined on the cross section of a weld.

Heat-Affected Zone – That portion of the base metal which has not been melted, but whose mechanical properties or microstructure have been altered by the heat of welding, brazing, soldering or cutting.

Joint Penetration – The minimum depth a groove or flange weld extends from its face into a joint, exclusive of reinforcement. Joint penetration may include root penetration.

Leg of Fillet Weld – The shortest distance from the root of the joint to the toe of the fillet weld.

Overlap – In fusion welding, the protrusion of weld metal beyond the weld toe or weld root; In resistance seam welding, the portion of the preceding weld nugget remelted by the succeeding weld.

Peel Test – A destructive method of inspection which mechanically separates a lap joint by peeling.

Porosity – Cavity-type discontinuities formed by gas entrapment during solidification.

Procedure Qualification – The demonstration that welds made by a specific procedure can meet prescribed standards.

Procedure Qualification Record (PQR) – A record of welding variables used to produce an acceptable test weldment and the results of tests conducted on the weldment to qualify a welding procedure specification.

Reinforcement of Weld – Weld metal in excess of the quantity required to fill a joint.

Size of Weld:

Groove Weld – The joint penetration (depth of bevel plus the root penetration when specified.)

Fillet Weld – For equal leg fillet welds, the leg lengths of the largest isosceles right triangle which can be inscribed within the fillet weld cross section. For unequal leg fillet welds, the leg lengths of the largest right triangle which can be inscribed within the fillet weld cross section.

Note: When one member makes an angle with the other member greater than 105 degrees, the leg length (size) is of less significance than the effective throat, which is the controlling factor for the strength of a weld.

Slag inclusion – A discontinuity consisting of slag entrapped in weld metal or at the weld interface.

Spatter – The metal particles expelled during welding and which do not form a part of the weld.

Tack Weld – A weld made to hold parts of a weldment in proper alignment until the final welds are made.

Undercut – A groove melted into the base metal adjacent to the toe or root of a weld and left unfilled by weld metal.

Underfill – A depression on the face of the weld or root surface extending below the surface of the adjacent base metal.

Weldability – The capacity of a material to be welded under the fabrication conditions imposed into a specific, suitably designed structure and to perform satisfactorily in the intended service.

Welder – One who performs a manual or semiautomatic welding operation.

Welder Performance Qualification – The demonstration of a welder's ability to produce welds meeting prescribed standards.

Welding Operator – One who operates machine or automatic welding equipment.

Welding Procedure – The detailed methods and practices including all welding procedure specifications involved in the production of a weldment.

Welding Procedure Specification (WPS) – A document providing in detail the required variables for a specific application to assure repeatability by properly trained welders and welding operators.

Based on Standard Welding Terms and Definitions, AWS 3.0. American Welding Society.

TOPIC 1

INTRODUCTION TO DESTRUCTIVE TESTING METHODS

OBJECTIVE

To know the mechanical properties of metals and welds and the type of tests used to evaluate these properties.

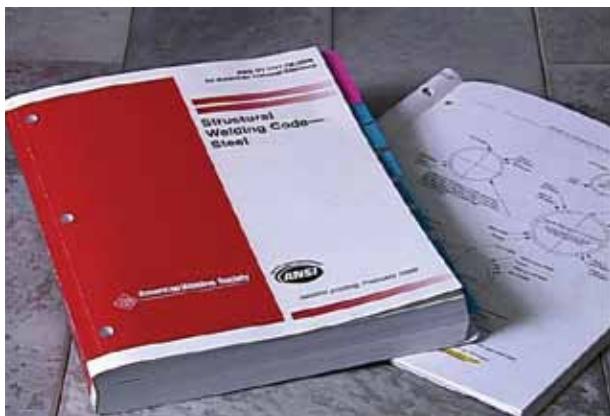


INTRODUCTION

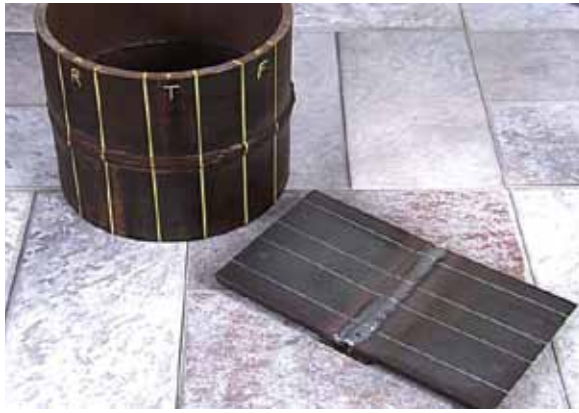
Destructive testing is an evaluation process of a weld or base metal specimen. Evaluation takes place during and/or after the destruction of the specimen. It is a function performed by quality control to measure properties of metals and welds.



The term weld soundness is commonly used to describe the degree of freedom from discontinuities contained within a weld. Cracks, inclusions, porosity and lack of fusion reduce weld soundness, which may prevent the weld from performing in service. In addition to weld soundness, the mechanical, chemical and metallurgical properties of the welded joint are important to insure reliability of the weldment in service.



In design, materials are selected to provide these properties. The process of welding must enable the materials to maintain these properties through development and use of a proven procedure. Welding codes use a variety of destructive testing methods to evaluate materials so that design performance requirements can be met.



Destructive testing processes are also specified to evaluate the results of welding procedures. Procedure and welders are qualified by destructive tests.



Destructive testing can also be used to spot check the quality of production weldments. This is commonly known as work sampling.

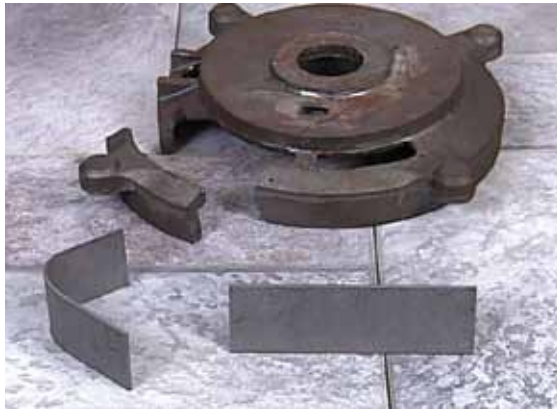


MECHANICAL PROPERTIES

The most important mechanical properties of welded joints include strength, ductility, toughness and hardness.



One important measure of strength is the material's ultimate tensile strength. This is determined by subjecting weld metal or a weld joint to a pulling load until it fails. The maximum stress developed is a good indication of the amount of load the material can sustain. Yield strength is another important measurement of the material's load carrying capacity. The yield strength is the stress at which the material will change permanently in dimension, usually length, and cross sectional area.



Ductility is the property of a metal which allows it to be drawn or stretched without fracture. A ductile material can be bent. A material which is not ductile is referred to as brittle.



Toughness is the ability of a material to sustain sudden shock loading at various temperatures without failure. The energy absorbed by the specimen will vary depending on temperature. For example, steel will possess lower toughness properties as the temperature is reduced.



The property of hardness is defined as the metal's resistance to indentation from the force of a hardened substance. Hardness of metals is measured by forcing a hardened steel ball or a diamond into the surface of a metal. The Brinell, Rockwell and Vickers tests are commonly used to evaluate this property.



CHEMICAL PROPERTIES

Destructive testing also includes chemical tests. Welded joints may be cut to remove sections for analysis of alloying elements.



Specialized equipment in laboratory conditions is used to evaluate chemical composition. For example, spectrographic analysis could be used. Chemical composition is important to weldments which require corrosion resistance. Chromium and nickel contents and carbide formations are analyzed to determine the weldment's ability to perform in service.



One method of determining metallurgical structures is through etching the welded joint. This method consists of cutting a specimen, polishing the cut surface, applying an etching acid, and visually inspecting the etched surface.



Variations of the process include viewing the etched surface with different degrees of magnification. This form of examination is known as macro or micro examination, depending upon the magnification used.

DESTRUCTIVE TESTING

ESTABLISH PROCEDURE

SELECT AND PREPARE SPECIMENS

EVALUATE RESULTS

CONCLUSION

Destructive testing can be a very effective tool to determine weld quality if:

- 1) The destructive testing procedure is established.
- 2) Specimens are properly selected and prepared.
- 3) Results are evaluated in accordance with prescribed standards.

TOPIC 1

REVIEW QUESTIONS

1. List the three major groups of properties evaluated by destructive testing:

2. Name three functions of destructive testing:

3. Name the four most common mechanical properties related to welding:

4. The process of selecting production weldments for test is called:

TOPIC 2

TENSION TESTING

OBJECTIVE

To know the procedure used to perform tensile tests and the results derived from the test.



INTRODUCTION

The tension test is used to determine the behavior of a material as it is pulled gradually beyond the breaking point. It is one of the most valuable destructive tests because it provides data on strength, ductility and soundness of base metal and weld metal.

ALL WELD METAL TENSION TEST

All weld metal and all base metal specimens are used to determine the strength and ductility properties of material.

These tests are commonly used to classify base metal and weld metal to national standards. For example, filler metals must meet minimum mechanical properties to be classified to the American Welding Society filler metal identification system.



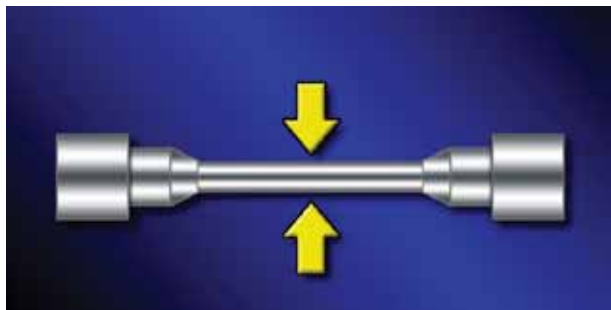
All weld metal specimens are machined from the center portion of a weld test coupon.

It must consist entirely of weld metal in the reduced section of the specimen.

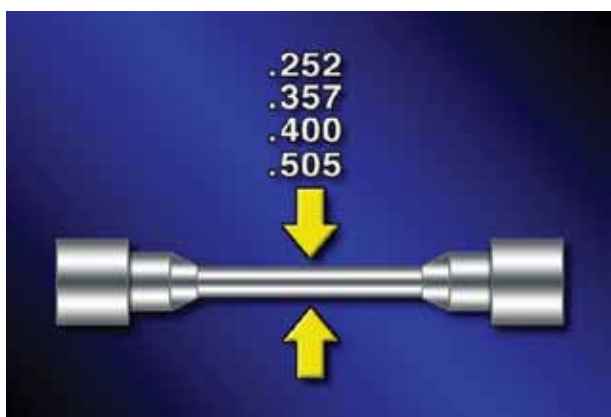




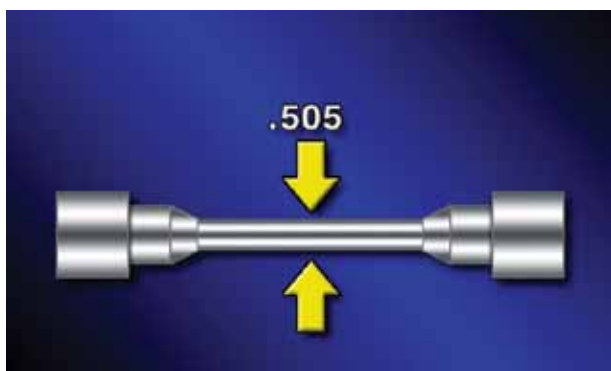
The ends of the specimen are shaped to fit the jaws of the testing equipment in use. Published codes provide requirements regarding preparation of test specimens which must be considered.



The reduced section of the specimen is normally tapered about .005-inch from the ends to the center. This allows the fracture to occur approximately in the center of the specimen where it is the thinnest.



The diameter at the center of the tensile specimen will vary depending on material thickness and code requirements. The finished surface should be smooth enough to prevent premature failure. A rough surface could initiate a fracture in an undesirable location.



The procedure for testing all weld metal or base metal tensile specimens will be discussed first. It is essential that the applicable specification be reviewed to determine the exact procedure. A .505-inch specimen will be used for illustration.



The five-o-five specimen is marked with a centerpunch at two points, two inches apart. This is known as gage length. The original gage length of two inches is recorded for use later to calculate ductility.



The specimen is secured in the jaws of the tension machine. A strain gage is attached to the specimen to detect changes in length when force is applied.



The equipment operator begins the pulling process by allowing the machine to apply pounds of force (load) to the specimen.

$$\frac{\text{Force (lbs)}}{\text{Area (in.}^2\text{)}} = \text{Stress (PSI)}$$

As the force is applied, stress develops in the specimen. The stress is equal to the force applied divided by the cross sectional area of the specimen.

$$\frac{\pi (d)^2}{4} = A$$

$$\frac{3.14 (.505)^2}{4} = .2 \text{ Square Inch Area}$$

The area of a five-o-five diameter specimen is determined by squaring the diameter and then multiplying by π or 3.14. This value is divided by four. The answer is .2 square inches.

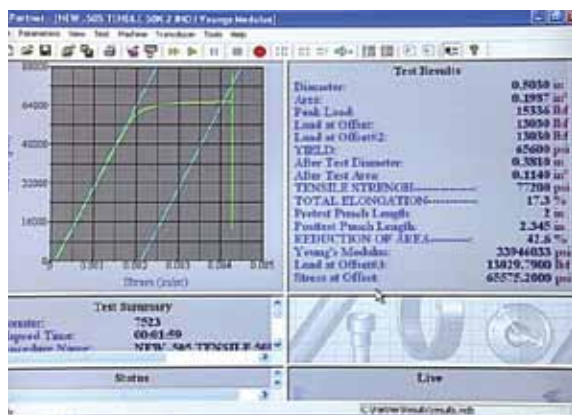
$$\frac{\text{Force (lbs)}}{\text{Area (in.}^2\text{)}} = \text{Stress (PSI)}$$

$$\frac{5,000 \text{ (lbs)}}{.2 \text{ (in.}^2\text{)}} = 25,000 \text{ Stress (PSI)}$$

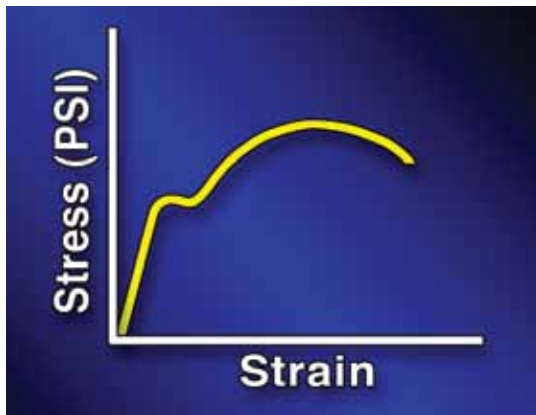
If the force applied to the specimen is five thousand pounds, the stress becomes 25,000 pounds per square inch (psi).



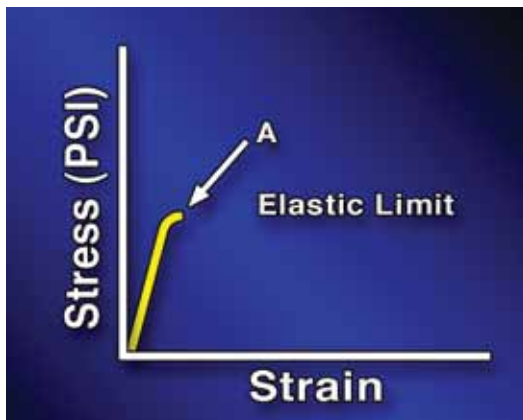
As the force is applied, the specimen begins to stretch or elongate. This is commonly referred to as strain. The units for strain are inch per inch. This is the amount of increase in length per inch of gage length.



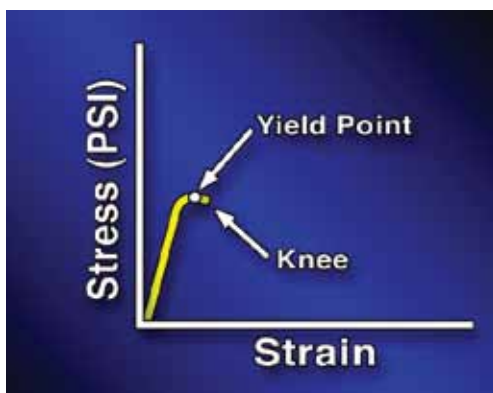
Some tensile equipment is designed with charts to plot the stress in relation to the strain. The gage attached to the specimen detects the elongation which is used by the equipment to plot the strain.



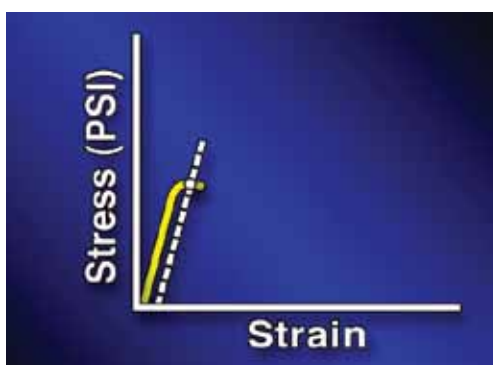
The curve which is plotted is called a stress-strain curve. In the lower part of the curve, the stress is proportional to the strain. Under these loading conditions, the material is in an elastic state. This means if the load is removed, the material will return to its original length.



As the load continues to increase, the material eventually reaches its elastic limit at point A. At point A, the material begins to yield. When the material yields, it will permanently elongate, sometimes referred to as plastic deformation. Under these loading conditions, the material is in a plastic state. If the load is removed now, the material will not return to its original length.



The point at which the material is permanently elongated is called the yield point. The yield point is defined as the load that causes a marked increase in strain without increase in stress.



In many cases, the yield point is difficult to determine. Because of this, yield strength is more commonly used to describe the point of yielding, or permanent deformation.

The yield strength is determined by drawing a straight line parallel to the straight portion of the curve.