Section 1: THE TEST CERTIFICATE

The objective of Section 1 is to explain the Metallurgical makeup of the Material Test Certificate.

Introduction

A material test certificate is used to report the chemical and physical properties of a specified heat.
Depending on the type of material being tested a test certificate can report the following:

Chemical composition
Tensile test results
- Ultimate Tensile Strength
- 0.2% Proof Stress and
- Elongation

Hardness Test results
Impact test Results

Additional information may include:
Ultrasonic test results
Macro etch test results

What is Tensile Testing?

A tensile test, also known as a tension test, is probably the most fundamental type of mechanical test you can perform on material. Tensile tests are simple, relatively inexpensive, and fully standardized. By pulling on something, you will very quickly determine how the material will react to forces being applied in tension. As the material is being pulled, you will find its strength along with how much it will elongate.

Tensile Test Procedure

In practice, a test piece of known cross sectional area is gripped in the jaws of a testing machine and subjected to a tensile force which is increased by suitable increments. For each increment of force the amount by which the length of a predetermined “gauge length” on the test piece increases is measured by some device. The test piece is extended in this way to destruction.

The Test Piece

In general the relevant standard will specify the procedure for obtaining the test piece. Test pieces are standardized in order that results are reproducible. In Australia, Tensile Tests are conducted in accordance with AS 1391. A typical test piece is pictured below.

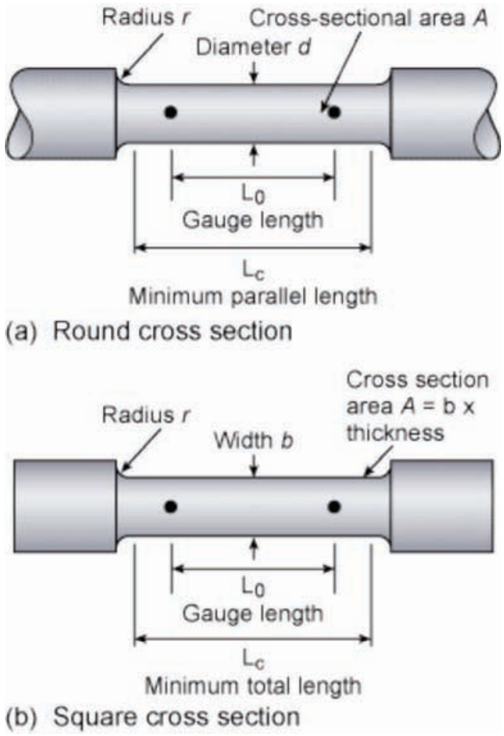


Figure 1: Typical Test piece

Why Perform a Tensile Test or Tension Test?

You can learn a lot about a substance from tensile testing. As you continue to pull on the material until it breaks, you will obtain a good, complete tensile profile. A curve will result showing how it reacted to the forces being applied.

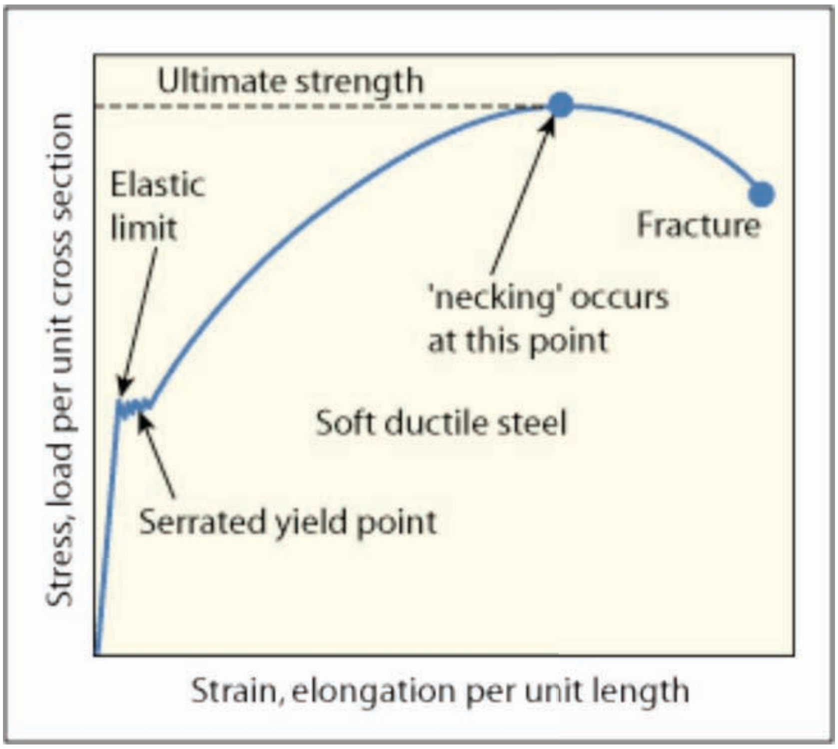


Figure 2: Typical Stress vs. Strain Curve for a Low-Carbon Steel

Hooke's Law

For most tensile testing of materials, you will notice that in the initial portion of the test, the relationship between the applied force, or load, and the elongation the specimen exhibits is linear. In this linear region, the line obeys the relationship defined as "Hooke's Law" where the ratio of stress to strain is a constant, or $\frac{\sigma}{\varepsilon} = E$. E is the slope of the line in this region where stress (σ) is proportional to strain (ε) and is called the "Modulus of Elasticity" or "Young's Modulus".

Modulus of Elasticity

The modulus of elasticity is a measure of the stiffness of the material, but it only applies in the linear region of the curve. If a specimen is loaded within this linear region, the material will return to its exact same condition if the load is removed. At the point that the curve is no longer linear and deviates from the straight-line relationship, Hooke's Law no longer applies and some permanent deformation occurs in the specimen. This point is called the "elastic, or proportional, limit". From this point on in the tensile test, the material reacts plastically to any further increase in load or stress. It will not return to its original, unstressed condition if the load were removed.

Yield Strength

A value called “yield strength” of a material is defined as the stress applied to the material at which plastic deformation starts to occur while the material is loaded.

Offset Method

For some materials (e.g., metals and plastics), the departure from the linear elastic region cannot be easily identified. Therefore, an offset method to determine the yield strength of the material tested is allowed. An offset is specified as a % of strain (for metals, usually 0.2% is used). The stress that is determined from the intersection point "r" (below) when the line of the linear elastic region (with slope equal to Modulus of Elasticity) is drawn from the offset and becomes the Yield Strength by the offset method.

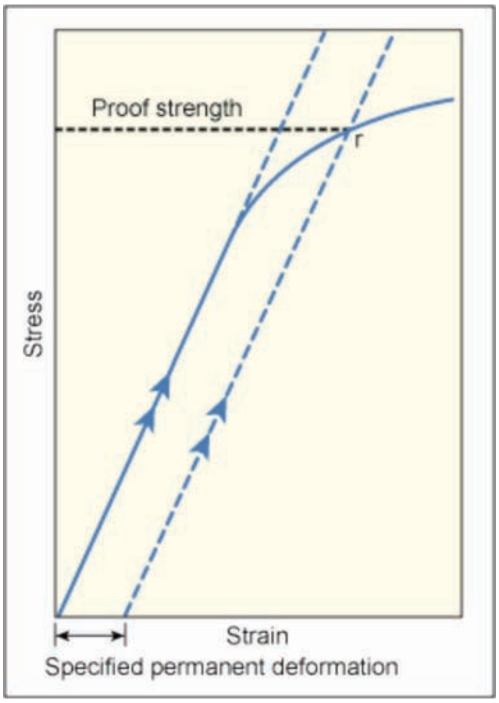


Figure 3: Determination of the 0.2% Proof Stress

Elongation

You will also be able to find the amount of stretch or elongation the specimen undergoes during tensile testing. This can be expressed as an absolute measurement in the change in length or as a relative measurement called "strain". Strain itself can be expressed in two different ways, as "engineering strain" and "true strain". Engineering strain is probably the easiest and the most common expression of strain used. It is the ratio of the change in length to the original length, $e = \frac{L - L_0}{L_0} = \frac{\Delta L}{L_0}$. Whereas, the true strain is similar but based on the instantaneous length of the specimen as the test progresses, $\varepsilon = \ln(\frac{L_i}{L_0})$, where L_i is the instantaneous length and L_0 the initial length.

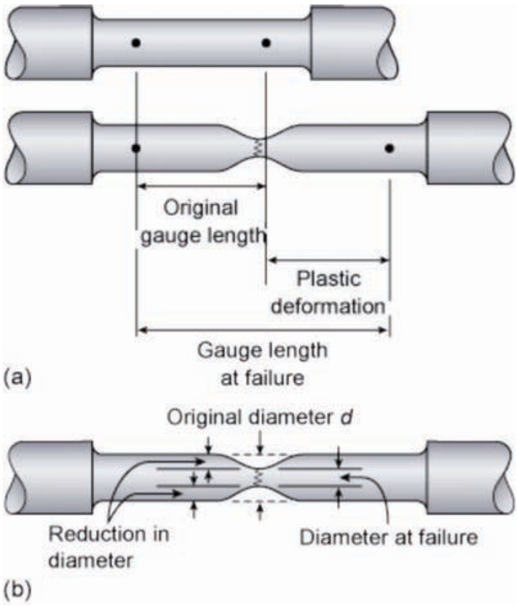


Figure 4: Measuring Elongation and Reduction of Area

Ultimate Tensile Strength

One of the properties you can determine about a material is its Ultimate Tensile Strength (UTS). This is the maximum load the specimen sustains during the test. The UTS may or may not equate to the strength at break. This all depends on what type of material you are testing ie. brittle, ductile, or a substance that even exhibits both properties. And sometimes a material may be ductile when tested in a lab, but, when placed in service and exposed to extremely cold temperatures, it may transition to brittle behavior.

The Brinell Hardness Test

Dr. J. A. Brinell invented the Brinell test in Sweden in 1900. The oldest of the hardness test methods in common use today, the Brinell test is frequently used to determine the hardness of forgings and castings that have a grain structure too course for Rockwell or Vickers testing. Therefore, Brinell tests are frequently done on large parts. By varying the test force and ball size, nearly all metals can be tested using a Brinell test. Brinell values are considered test force independent as long as the ball size/test force relationship is the same.

Brinell testing is typically done on iron and steel castings using a 3000Kg test force and a 10mm diameter carbide ball. Aluminum and other softer alloys are frequently tested using a 500Kg test force and a 10 or 5mm carbide ball. Although rare, it is possible to perform Brinell tests on small parts using a 1mm carbide ball and a test force as low as 1kg.

Brinell Test Method

All Brinell tests use a carbide ball indenter. The test procedure is as follows:

The indenter is pressed into the sample by an accurately controlled test force.
The force is maintained for a specific dwell time, normally 10 - 15 seconds.
After the dwell time is complete, the indenter is removed leaving a round indent in the sample.
The size of the indent is determined optically by measuring two diagonals of the round indent using either a portable microscope or one that is integrated with the load application device.

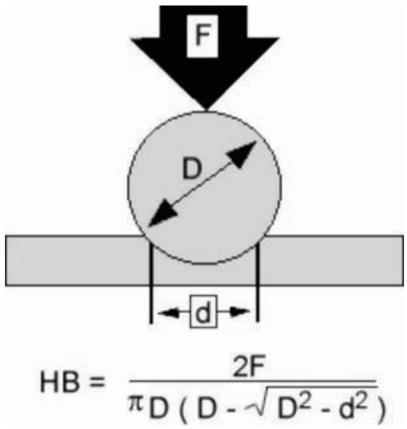


Figure 5: Calculating Brinell Hardness

The Brinell hardness number is a function of the test force divided by the curved surface area of the indent. The indentation is considered to be spherical with a radius equal to half the diameter of the ball. The average of the two diagonals is used in the following formula to calculate the Brinell hardness.
The Brinell number, which normally ranges from HB 50 to HB 750 for metals, will increase as the sample gets harder. Tables are available to make the calculation simple.

Strengths of the Brinell Test

1) One scale covers the entire hardness range, although comparable results can only be obtained if the ball size and test force relationship is the same.
2) A wide range of test forces and ball sizes to suit every application.
3) Nondestructive, sample can normally be reused.

Weaknesses of the Brinell Test

1) The main drawback of the Brinell test is the need to optically measure the indent size. This requires that the test point be finished well enough to make an accurate measurement.

2) Slow. Testing can take 30 seconds not counting the sample preparation time.

As mentioned above, other Hardness Tests include The Rockwell Hardness Test and The Vickers Hardness Test

Impact Testing

Impact testing is testing an object's ability to resist high-rate loading. An impact test is a test for determining the energy absorbed in fracturing a test piece at high velocity. Most of us think of it as one object striking another object at a relatively high speed.

Why is Impact Testing Important?

Impact resistance is one of the most important properties for a part designer to consider, and without question, the most difficult to quantify. The impact resistance of a part is, in many applications, a critical measure of service life. More importantly these days, it involves the perplexing problem of product safety and liability.
Impact Tests also indicate the behaviour of a material under conditions of mechanical shock and to some extent measure its toughness. Brittleness and consequent lack of reliability, resulting from incorrect heat treatment or other causes may not be revealed during a tensile test but will usually be evident in an impact test.

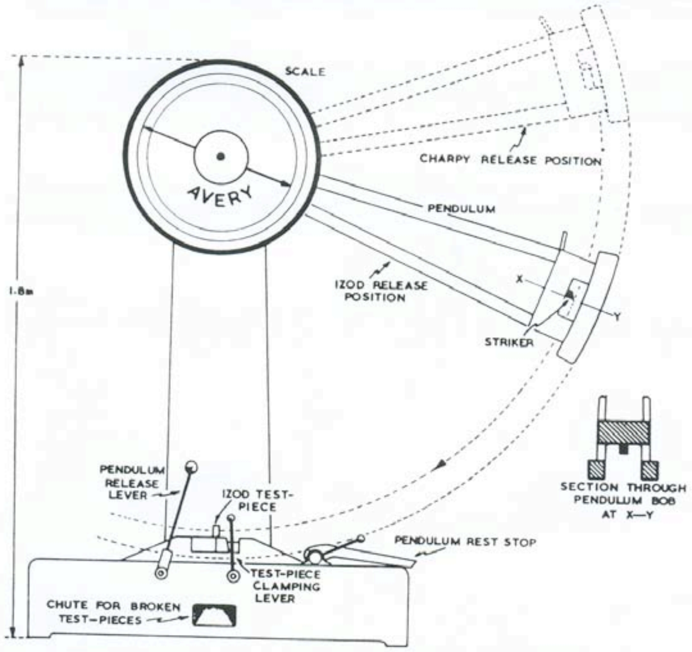
The Izod Impact Test

In this test a standard notched specimen is held in a vice and a heavy pendulum, mounted on ball bearings, is allowed to strike the specimen after swinging from a fixed height. The striking energy of 167 J is partially absorbed in breaking the specimen and, as the pendulum swings past, it carries a pointer to its highest point of swing, thus indicating the amount of energy used in fracturing the test piece.

The Charpy Test

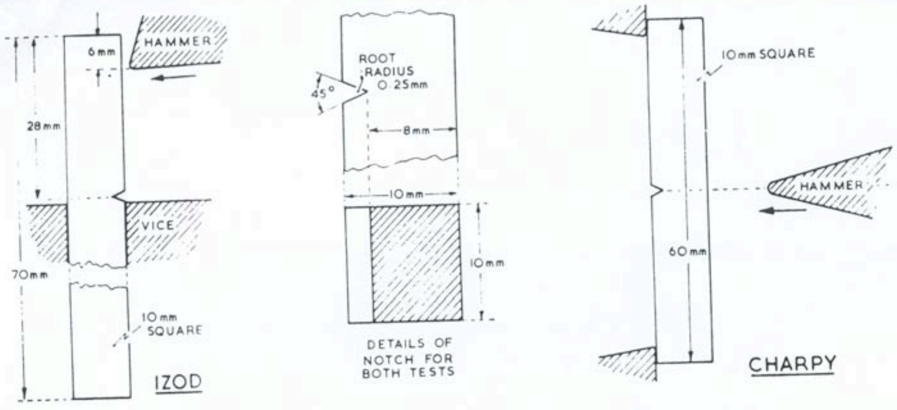
This test employs a test piece mounted as a simply supported beam instead of in the cantilever form used in the Izod test. The striking energy is 300 J

To set up stress concentrations which ensure that fracture does occur, test pieces are notched. It is essential that notches always be standard, for which reason a standard gauge is used to test the dimensional accuracy of the notch.



The Avery-Denison Universal impact-testing machine.
This machine can be used for either Charpy or Izod impact tests. For Izod tests, the pendulum is released from the lower position, to give a striking energy of 170 J; and for the Charpy test it is released from the upper position, to give a striking energy of 300 J. (The scale carries a set of graduations for each test.) The machine can also be used for impact-tension tests.

Figure 6: The Avery-Denison Universal impact-testing machine



Dimensions of standard test pieces for both Izod and Charpy tests.
In the Izod test piece, notches 28mm apart may be cut in three different faces so that a m
representative value is obtained.

Figure 7: Izod and Charpy Test Pieces

The results obtained from impact tests are not always easy to interpret, and some metals which are ductile under steady loads behave as brittle materials in an impact test. However, the impact test dives a good indication of how reliable the material is likely to

be under conditions of mechanical shock. These tests are most likely to be specified for constructional steels of medium carbon content.

Macro Etch Test

The Macro Etch Test is a test for visual evaluation of the homogeneity and soundness of an ingot, bloom, billet, or bar. It involves pickling a disc or cross section in strong acid until deep etching displays the steel's macro structure.

Macro examination may be carried out with the naked eye or by using a small magnifying glass

Test Procedure

A sample piece is obtained from the cross-section of material. This may be a finished part or directly from the rolled product.
Usually, medium grinding is sufficient to produce a satisfactory surface for examination. Polishing is not necessary, and for most specimens grinding can be finished at Grade 320 paper.
After being ground, the specimen should be washed to remove grit.
The structure of the steel can be revealed by deep etching the component in boiling 50% hydrochloric acid for up to fifteen minutes.

ASTM E381-01 is a standard which describes the Standard Method of Macroetch Testing Steel Bars, Billets, Blooms, and Forgings
The Contents of the Standard include:

1.1 Macroetching, which is the etching of specimens for macrostructural examination at low magnifications, is a frequently used technique for evaluating steel products such as bars, billets, blooms, and forgings.
1.2 Included in this method is a procedure for rating steel specimens by a graded series of photographs showing the incidence of certain conditions. The method is limited in application to bars, billets, blooms, and forgings of carbon and low alloy steels.
1.3 A number of different etching reagents may be used depending upon the type of examination to be made. Steels react differently to etching reagents because of variations in chemical composition, method of manufacture, heat treatment and many other variables. Establishment of general standards for acceptance or rejection for all conditions is impractical as some conditions must be considered relative to the part in which it occurs.

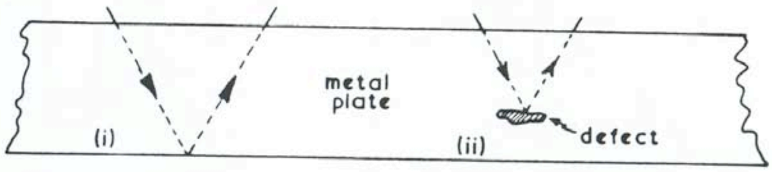
Ultrasonic Testing

This technique is relatively modern, is basically the same as radar, using energy at a frequency above that of sound, but below that of radio. The high frequency energy waves are fed to the surface and penetrate to the rear face. There they are reflected and collected by a receiver unit. The result is presented to an oscilloscope with a “pip” or peak at the

entry and exit. If no defect exists between the surfaces there will be a flat line. Any defect of significance will be shown as an intermediate pip on the oscilloscope line. This

description is of the simplest possible form but basically all ultrasonic methods work along these lines.

It should be noted that with the main signal and echo at the entry and exit to the sample this technique cannot be used for fine surface defects as these will be obliterated by the entry and exit pips. This technique therefore is for identifying subcutaneous defects and in general is used prior to machining in order to identify whether or not there are material defects which would appear at the surface after machining.



The detection of a fault in plate material by ultrasonics.
In (i) the impulse is reflected from the lower surface of the plate; whilst in (ii) it is reflected from a defect. Measurement of the time interval between transmission of the impulse and reflection of the echo determines the depth of the fault.

Figure 8: The detection of a fault by Ultrasonics