Impact Test

The tensile test is normally performed at a low strain rate, at which the specimen is very slowly loaded and elongated. When a material is subjected to a sudden, intense blow, in which the strain rate is extremely rapid, the material may behave in a much more brittle manner than is observed in the tensile test.

Impact testing techniques were established so as to determine the fracture characteristics of materials at high loading rates. It was realized that the results of laboratory tensile tests (at low loading rates) could not predict fracture behavior. For example, under some circumstances normally ductile metals fracture suddenly and with very little plastic deformation under high loading rates.

Impact tests are used to indicate the toughness of a material*, and particularly its capacity for resisting mechanical shock. Brittleness, resulting from a variety of causes, is often not revealed during a tensile test. For example, nickel – chromium constructional steels suffer from a defect known as temper brittleness. This is caused by faulty heat-treatment, yet a tensile test-piece derived from a satisfactorily treated material and one produced from a similar material but which has been incorrectly heat-treated might both show approximately the same tensile strengths and elongations. In an impact test, however, the difference would be apparent; the unsatisfactory material would prove to be extremely brittle as compared with the correctly treated one, which would be tough.

The energy absorbed at fracture is generally related to the area under the stress-strain curve which is termed as toughness in some references, Figure 1. Brittle materials have a small area under the stress-strain curve (due to its limited toughness) and as a result, little energy is absorbed during impact failure. As plastic deformation

*toughness is the ability of a material to absorb energy and plastically deform without fracturing or it is the amount of energy per unit volume that a material can absorb before rupturing capability of the materials (ductility) increases, the area under the curve also increases and absorbed energy and respectively toughness increase.

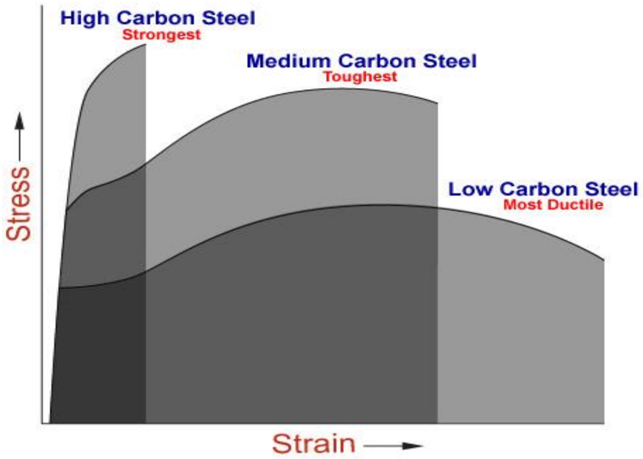
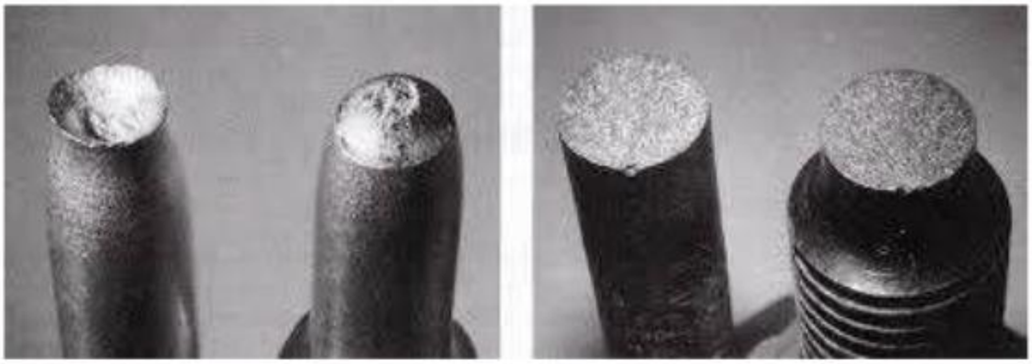


Figure 1: Toughness of Different Materials

Similar characteristics can be seen on the fracture surfaces of broken specimens. The fracture surfaces for low energy impact failures, indicating brittle behavior, are relatively smooth and have crystalline appearance in the metals. On the contrary, those for high energy fractures have regions of shear where the fracture surface and have rougher and more highly deformed appearance, called fibrous fracture, Figure 2.



(a). Cup & Cone Ductile Fracture; (b). Brittle fracture.

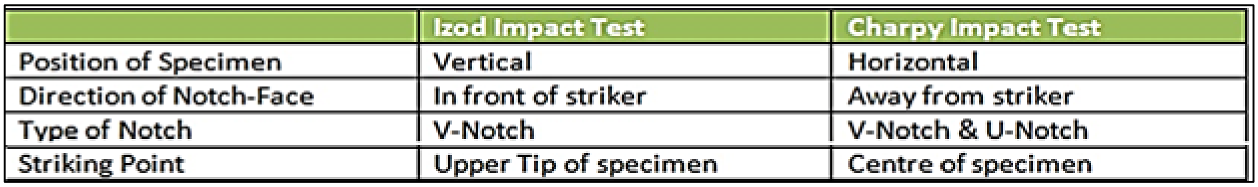
Figure 2: Ductile vs. brittle fracture

Types of Impact Tests

Two standardized tests, the **Charpy** and **Izod,** were designed and are still used to measure the impact energy (sometimes also termed notch toughness). For both Charpy and Izod, the specimen is in the shape of a bar of square cross section, into which a notch is machined , Figure 3a. The apparatus for making V-notch impact tests is illustrated schematically in Figure 3b.The load is applied as an impact blow from a weighted pendulum hammer that is released from a fixed height h. The specimen is positioned at the base as shown. Upon release, a knife edge mounted on the pendulum strikes and fractures the specimen at the notch, which acts as a point of stress concentration for this high-velocity impact blow. The pendulum continues its swing, rising to a maximum height h′, which is lower than h. The energy absorption, computed from the difference between h and h′, is a measure of the impact energy.

The primary differences between the Charpy and Izod techniques lies in the manner of specimen support, as illustrated in Figure 3b. Variables including specimen size and shape as well as notch configuration and depth influence the test results,Table 1.

Table 1: Differences between the Charpy and Izod techniques



	Izod Impact Test	Charpy Impact Test
Position of Specimen	Vertical	Horizontal
Direction of Notch-Face	In front of striker	Away from striker
Type of Notch	V-Notch	V-Notch & U-Notch
Striking Point	Upper Tip of specimen	Centre of specimen

The energy absorbed at fracture E can be obtained by simply calculating the difference in potential energy of the pendulum before and after the test such as,

$$E = m.\ g.\ (h-h')$$

Where m is the mass of pendulum and g is the gravitational acceleration.

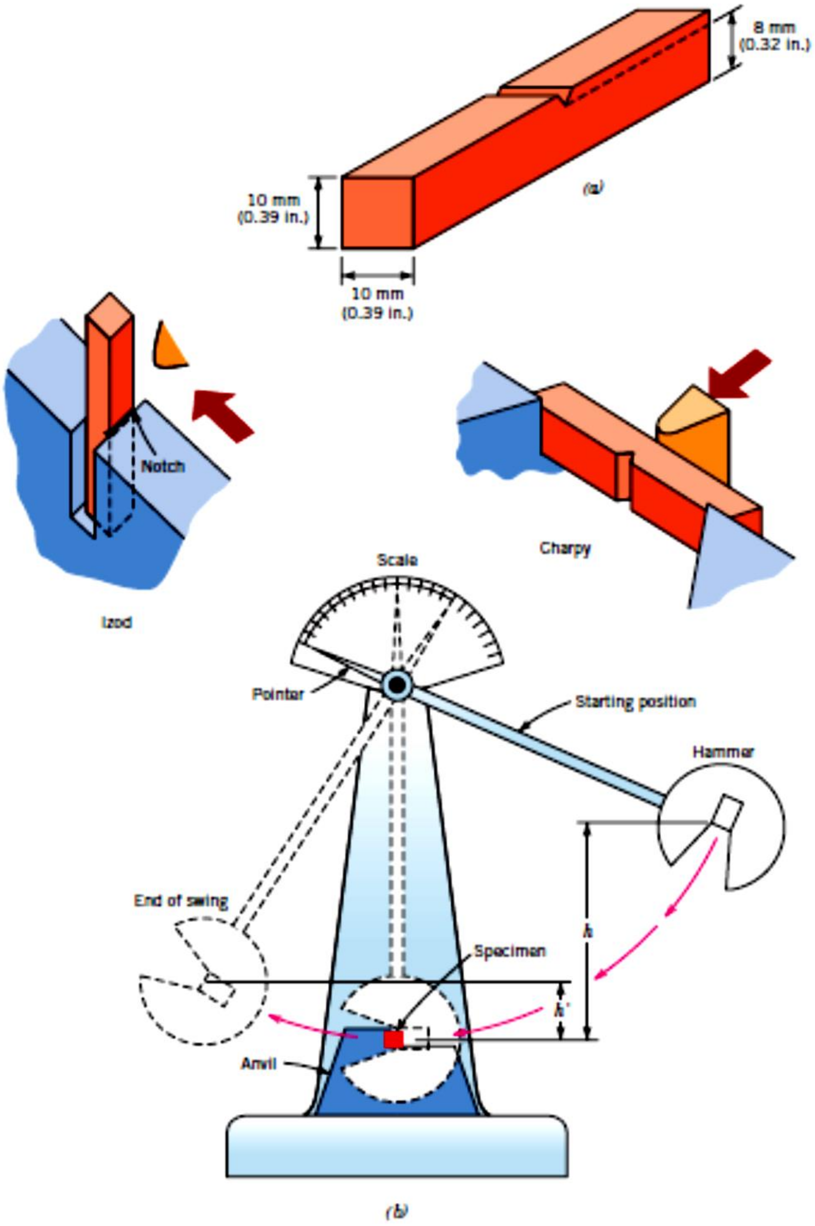


Figure 3:(*a*) Specimen used for Charpy and Izod impact tests.
(*b*) A schematic drawing of an impact testing apparatus.

The hammer is released from fixed height h and strikes the specimen; the energy expended in fracture is reflected in the difference between h and the swing height h'. Specimen placements for both Charpy and Izod tests are also shown.

The details of standard test-pieces used in both the Izod and Charpy tests are shown in Figure 4.

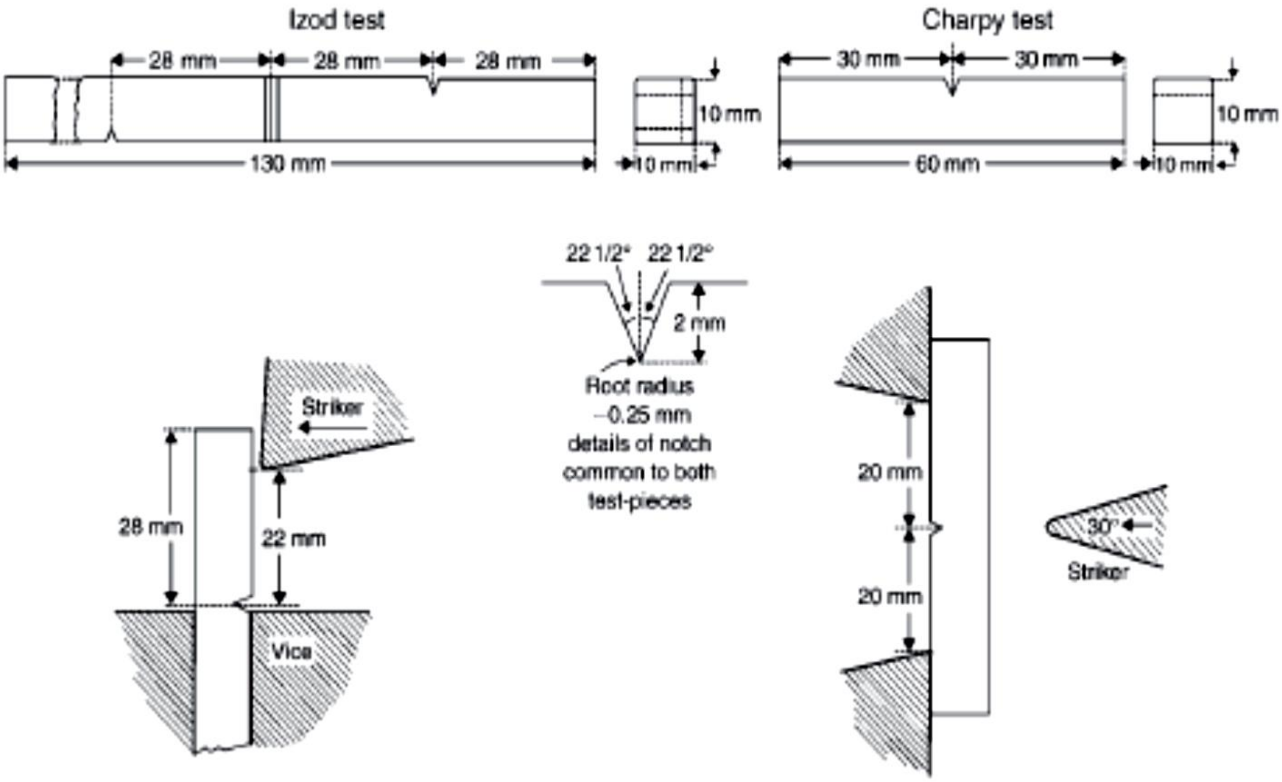


Figure 4: Details of standard test-pieces used in both the Izod and Charpy tests.

Ductile-to-Brittle Transition

One of the primary functions of Charpy and Izod tests is to determine whether a material experiences a ductile-to-brittle transition with decreasing temperature and, if so, the range of temperatures over which it occurs. Widely used steels can exhibit this ductile-to-brittle transition with disastrous consequences. The ductile to brittle transition is related to the temperature dependence of the measured impact energy absorption.

At higher temperatures the Charpy V notch energy is relatively large, in correlation with a ductile mode of fracture. As the temperature is lowered, the impact energy drops suddenly over a relatively narrow temperature range, below which the energy has a constant but small value; that is, the mode of fracture is brittle.

Alternatively, appearance of the failure surface is indicative of the nature of fracture and may be used in transition temperature determinations. For ductile fracture this surface appears fibrous or dull, as in the steel specimen of Figure 5 that was tested at 79 °C. Conversely, totally brittle surfaces have a granular (shiny) texture the -59°C specimen, Figure 5.

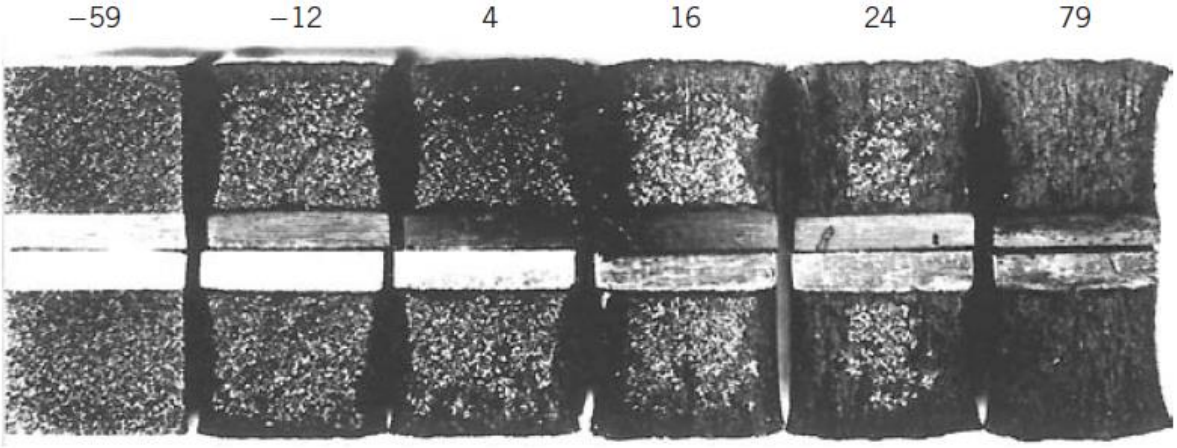


Figure 5: Photograph of fracture surfaces of A36 steel Charpy V-notch specimens tested at indicated temperatures (in °C).

For many alloys there is a range of temperatures over which the ductile-to-brittle transition occurs this presents some difficulty in specifying a single ductile-to-brittle transition temperature.

Structures constructed from alloys that exhibit this ductile-to-brittle behavior should be used only at temperatures above the transition temperature, to avoid brittle and catastrophic failure.

Classic examples of this type of failure occurred, with disastrous consequences, during World War II when a number of welded transport ships, away from battle, suddenly split in half. The ships were constructed of a steel alloy that possessed adequate toughness according to room temperature tensile tests. The brittle fractures occurred at relatively low ambient temperatures, at about 4 ^{o}C, in the vicinity of the transition temperature of the alloy. Each fracture crack originated at some point of stress concentration, probably a sharp corner or fabrication defect, and then propagated around the entire size of the ship.