Charpy & Izod Metals Impact Testing

Tinius Olsen 542J Impact Tester
Shown without optional safety enclosure (CE marked)

The purpose of impact testing is to determine the toughness of a material by measuring the amount of energy absorbed by a specimen as it fractures while being struck by a striker pendulum moving at high speed. The impact strength is defined as the maximum amount of energy that can be absorbed by the specimen without fracture.

In the Charpy impact test, a notch is placed in the specimen. The notch may be shaped like a V, keyhole, or U. The test piece is supported horizontally at both ends by anvils (see figure 1), and is struck behind the notch by a striker mounted at the lower end of a bar that swings like a pendulum, The energy that is absorbed during fracture is calculated by comparing the pendulum release height to that which the hammer rises after striking the specimen.

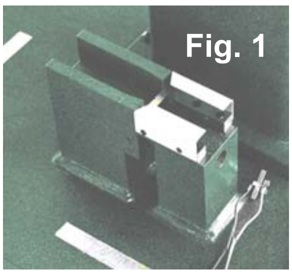

Fig. 1

In the Izod impact test, the specimen has a V shaped notch and is mounted vertically, see figure 2. The specimen is clamped at one end, with the top of the clamp corresponding to the location of the notch. It is struck on the notched side by the moving striker pendulum, and the energy needed to break off the free end is the measure of the impact strength.

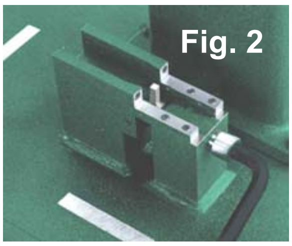

Fig. 2

This article discusses the equipment, calibration, and procedures for Charpy testing.

Impact testing equipment

Instruments for impact testing of metals have been manufactured commercially since the 1900's, and several manufacturers of testing equipment meet the requirements of ASTM E23, "Standard Test Methods for Notched Bar Impact Testing of Metallic Materials." The standard provides dimension and tolerance requirements for test specimens, the anvil supports and the striker, the pendulum action of the test machine, the testing procedure, machine verification, and the determination of fracture appearance and lateral expansion.

Over the years, the basic physical characteristics of the test machine have stayed the same, but the means of data acquisition have changed significantly. As a result, many types of equipment, ranging from analogue dial and pointers, to digital readouts, to computer interfaces, are found in various labs throughout the world. Old equipment is not necessarily obsolete. On the other hand, it may not be acceptable; results are influenced by the metrology of the parts that are subject to the most wear and tear, and some machines were manufactured before strict adherence to the specifications in ASTM E23 was deemed to be critical.

Accurate results are not possible if the equipment is not operating according to the specification; therefore, it is strongly recommended that the impact tester be calibrated and/or verified by an accredited calibration service at regular intervals.

Instrument calibration

A calibration swing is performed to ensure that energy losses due to windage and friction in the bearings and axle are within acceptable tolerances. This calibration procedure involves 11 half-free swings of the striker pendulum, during which the frictional forces incurred are measured. This short procedure is often repeated daily to make sure that energy losses within the system are consistent, current and corrected for.

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Direct Verification: Additionally, the pendulum itself must be verified, since the amount of available energy is calculated from both theoretical and practical calculations. In simple terms, a full dimensional check is performed to determine the correct amount of stored potential energy in the latched pendulum, and also to ensure that the maximum amount of available energy is imparted to the sample. This method of calibration is called direct verification.

Indirect Verification: The testing of specimens with certified values to verify the accuracy of Charpy impact machines is called an indirect verification, and this is also required. These specimens can be NIST Standard Reference Materials, or can be samples that have been verified on NIST-certified Charpy impact machines.

Alloy	Charpy Impact Energy Joules (ft-lb)
AISI 1020 Steel, rolled	17 (12.5)
AISI 4320 Steel, quenched 900°C (1650°F), 425°C (800°F) temper	7.0 (5.16)
Aluminium 2048	10.3 (7.6)
Aluminium 201.0-T6 Casting Alloy	5.0-15.0 (3.69-11.1)
UNS C95800, Copper Casting Alloy	13.0 (9.59)
Austempered Ductile Iron - ASTM 897 Grade 1 (125-80-10)	12.0 (8.85)
Beryllium (Be)	1.5-5.5 (1.11-4.06)
Magnesium AM60B-F, Die Cast	2.8 (2.07)
Niobium Nb-1Zr (Wah Chang WC-1ZR, Fansteel 80) Reactor Grade	126 (92.9)
Steel grade DH32 - ASTM A131	35.0 (25.8)
Titanium Ti-5A1-2.5Sn	24.0 (17.7)
Titanium IMI 834	15.0 (11.1)
Stainless Steel, annealed (Carpenter Custom 450®)	133 (98.1)
Tool Steel, Alloy 53 (Carpenter Pyrow ear)	130 (95.9)
Hastelloy S, Alloy (Haynes) Plate 12.7mm (1/2 in) thick	190 (140)
Inconel 725, Nickel Superalloy (UNS N07725) (Special Metals) age hardened strip	83.0 (61.2)
Stainless Steel 301, annealed (UNS S30100) (Allegheny Ludlum)	150 (111)
Nickel base alloy (UNS N10276) (Allegheny Ludlum)	325 (240)
Stainess, austenitic (Nitronic 50) annealed	315 (232)
Stainless Steel AISI 304	325 (240)

Test Procedure

As with most precise activities, the bulk of the critical work is done in the preparation, while the actual test is completed extremely quickly. In fact, a typical impact test takes approximately 10 milliseconds. The procedure is as follows:

1. Latch the pendulum in its upright position.

2. Place the specimen on the anvils with special Charpy tongs. These tongs typically have a fill-in section for the notched specimen, and are usually just slightly smaller than the width between the anvils – this way the sample is easily placed in the centre of the test area. The sample is placed such that the notched surface is facing away from the direction of impact.

3. After making sure that the swing plane of the pendulum arm is clear, release the pendulum and allow it to break the specimen.

4. Once the test is complete, allow the pendulum to swing back close to the original release point, and push the pendulum back into the latched position. Some models have a motorized return capability in which a brake is activated, stopping the swinging pendulum. The motor then returns the pendulum back into its original latched position.

Alternate temperatures

Most Charpy impact testing is performed at other-than-room-temperature conditions, typically lower temperatures, so that the transition temperature and the upper and lower shelf regions may be analyzed. In these cases, the ASTM standard states that the sample has to be at the test temperature for a minimum of five minutes prior to testing. Additionally, the locating tongs, used to put the sample in place on the support anvils, must be kept at the test temperature. When the system is ready, the sample must be removed from the cooling medium and placed on the anvils. Then the test must be performed within five seconds of removing the sample from the cooling medium.

An alternative to this is a heating and/or cooling system that can bring the sample to test temperature on the support anvils – in fact, the anvils are part of the heating and cooling system. This can be an expensive option, but it has many benefits. It allows accurate placement of the test specimen, rapid cooling or heating of the sample and, since no time constraint is imposed on completion of the test, a subsequent faster throughput of accurately tested samples.

Interpretation of results

The most common test result that the machine gives is the absorbed energy. This is taken as the difference between the amount of available energy in the striker immediately prior to impact, and the energy remaining after breaking the sample, after correction for windage and friction losses.

The amount of energy available prior to impact is the amount of potential energy in the pendulum at its starting/latched position. The amount of energy remaining after the sample break is measured by recording the height of the pendulum swing after it has broken the sample. Typically, a pointer and analog scale will allow a direct, corrected, measurement of absorbed energy although more recent machines have digital shaft encoders that can provide the same information.

Machines are also available with strain gauged strikers that can be connected to high-speed data capture equipment. This can be connected to a computer running data analysis software that can show a graphical representation of the impact in terms of force versus time.

All commercial acceptance testing must report the following information:

- *Specimen type,*
- *Test temperature,*
- *Absorbed energy, and*
- *Other contractual requirements.*

Additionally, other results can be reported for non-commercial acceptance. These may include:

- *Lateral expansion*
- *Unbroken specimens*
- *Fracture appearance*
- *Specimen orientation*
- *Specimen location*

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