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V notch test

The Charpy impact test, also commonly referred to as the Charpy V-notch test by material scientists, serves as a standardized high-strain rate examination to quantify the energy absorbed by a material upon fracture. The absorbed energy functions as an indicator of the material's notch toughness. Widely employed in various industries, this test is favored for its simplicity in preparation and execution, enabling a quick and cost-effective acquisition of results. However, a drawback is that certain outcomes are solely comparative. The Charpy impact test, introduced by Georges Augustin Albert Charpy (1865–1945) in 1901, is widely utilized for efficiently evaluating the toughness of materials. This method assesses the energy absorbed by a standard notched specimen when it fractures under an impact load. Its ongoing application as a cost-effective quality control measure remains instrumental in assessing notch sensitivity and impact toughness across various engineering materials such as metals, composites, ceramics, and polymers. The standard Charpy impact test specimen, as depicted in the procedure section, has dimensions of 55 mm × 10 mm × 10 mm, with a machined notch along one of the larger dimensions. Georges Augustin Albert Charpy father of the Charpy Impact Test The impact test is conducted by striking the specimen with a hammer on a pendulum arm, the test quantifies the absorbed energy during fracture under the impact load. Factors affecting material toughness include low temperatures, high strain rates (via impact or pressurization), and stress concentrators like notches, cracks, and voids. The Charpy impact test was designed to investigate the premature failures of machinery like steam boilers, steam engines, and military armaments. Building upon S.B. Russell's pendulum-based method, Charpy enhanced the test's precision and sensitivity by incorporating a notched sample. Recognizing the value of notch additions, Charpy's contributions led to significant improvements, earning the test its namesake. Charpy's involvement extended beyond the test's invention, encompassing various standardization initiatives and technical enhancements, solidifying his pivotal role in the development and widespread adoption of this impactful testing method. The Charpy Impact Test, also known as a V-notch test, evaluates a material's impact strength by measuring the energy required to fracture a standardized sample with a machined V-notch. Using a released pendulum, the test calculates energy absorption based on the pendulum's height before and after passing through the specimen. This inexpensive and simple test is applicable to determine a material's brittleness—higher energy indicates ductility, while lower energy suggests brittleness. The test can be conducted at varying temperatures to identify the Ductile-to-Brittle Transition Temperature for ductile materials. Despite its simplicity, the Charpy test only provides total energy data during fracture, lacking details on specific fracture phases. This test is widely used in construction and manufacturing, assessing materials' toughness and impact resistance for applications like bridges, pipelines, and machinery, aiding in the design and quality control of engineering components. Impact testing serves to assess a material's impact toughness, representing its resistance to impact forces. The ability to quantify the impact property is a great advantage in product liability and safety. This involves three main tests: the tensile impact test, the Charpy V-notch test, and the Izod impact test. Engineers use the Charpy impact test for comparative assessments, providing insights into material impact strengths. Conducted across temperature ranges, it enables plotting the Ductile-to-Brittle Transition Temperature (DBTT) on a graph, indicating when a typically ductile material turns brittle. According to ASTM E23, the primary distinction between Charpy and Izod lies in the sample's orientation—horizontal for Charpy and vertical for Izod. The Izod impact test was named after English engineer Edwin Gilbert Izod. The Izod impact test is like the Charpy impact test and is used to test materials at low temperatures. Example of IZOD and Charpy impact test The purpose of the impact test is to assess the response of a known material, such as polymers, ceramics, and composites when subjected to sudden stress. It specifically evaluates the toughness, brittleness, notch sensitivity, and impact strength of engineering materials under high-rate loading. Quantifying the impact property is advantageous for product liability and safety considerations. Various specimen types with different notch configurations, such as V-notch, U-notch, and keyhole notch, are used in impact testing. The Charpy and Izod configurations are the most common, with the key difference being the notch's position relative to the striker. The keyhole impact test, resembling a machined keyhole, is employed by steel casting industries and follows similar testing procedures as V and U notches. Keyhole impact testing is particularly useful for materials with restricted thickness, extending to cryogenic temperatures. Different types of notches, the V notch is used for a Charpy impact test The object of a Charpy impact test is to understand the impact energy and determine the impact strength of the desired material. The reason for doing this experiment in the industry is to make sure that you are selecting adequate materials to withstand a very high strain rate. The test method consists of a specimen being subject to an impact or instant load, to find the impact energy absorbed by the material. Results from the Charpy impact test are quantified in joules, the standard unit for energy in the International System of Units (SI). This unit represents the work executed by a 1-newton force displacing a sample by 1 meter in the direction of the force. The obtained joule value can be employed to determine the impact energy in J/m^2. This calculation involves dividing the joule value by the cross-sectional area of the sample at the notch. An example of a practical impact test would be in the automotive industry where one of the primary goals for an automaker is to ensure the vehicle they are designing can meet all FMVSS crash safety tests. To ensure the crashworthiness of a vehicle automakers ensure the vehicle's body-in-white (BIW) design can absorb the impact energy during a crash to the maximum extent while maintaining deceleration and intrusion into occupant space within desirable levels. This test also played a pivotal role in understanding the fracture challenges encountered by ships during World War II. Front Impact Crash Safty Test The impact test's qualitative outcomes offer insights into a material's ductility. A flat plane fracture indicates brittleness, while jagged edges or shear lips suggest ductility. Typically, materials exhibit a combination of both fracture types. Therefore, comparing the extent of jagged and flat surface areas in the fracture provides an estimate of the percentage of ductile and brittle characteristics. The materials required: The specimens Tinius Olsen Impact Testing Machine vernier calipers Safety glasses. wooden block (safety) Safety shield Before beginning the experiment put on safety glasses. Verify that the specimen profile measurements meet tolerance which is required to perform an accurate Charpy Impact test. See Figure 1: Impact Test Specimen below. Charpy impact test specimen 3. Raise the hammer (pendulum) all the way up until it is locked by the safeties. 4. Remove the safety block. 5. Run the Tinius Olsen Impact Testing Machine without a specimen to calibrate the machine and help account for friction error in measurement. (After every run makes sure to lock the hammer with the safeties in between runs). Perform this test 3 times and find the average of the frictional force. 6. Place the specimen so it is resting on the anvil, on the Tinius Olsen Impact Testing Machine. 7. Make sure that the notched specimen is centered and facing outward so the notch dictates how the specimen will fail. (Notch should be on facing away from the hammer, opposite to the impact side) See Figure 2: Impact Test setup Charpy impact test – Set up 8. Make sure to reset the gauge on the Tinius Olsen Impact Testing Machine (move the indicator on the scale to the end of the scale). 9. Place the safety shield to cover the Tinius Olsen Impact Testing Machine to cover and protect it from any pieces of loose metal. 10. Remove safeties so the pendulum impacts and break the specimen (do not get in the way of the hammer) Charpy impact test – Test physics 11. Use an electric brake to slow down the hammer until it comes to a stop. 12. Record measurement readings from Tinius Olsen Impact Test and subtract the force due to the friction of the bearings (step 5) 13. Repeat steps 6-11 for all specimens which will be tested Theory: The theory behind this experiment is to find out which material would be best for different applications. To make sure that materials that are picked will not fail during function due to impact loading. Equations: % error: Published data charts: Table1: Impact Test (Charpy) Data for some alloys Table 2: Tensile Test Data for some Alloys Example calculations (1018 steel): % error: Data sets/ composite scores: Table 3: Charpy impact test Result Table 4: Standard Deviations After conducting this experiment the initial suspicions were confirmed. The greater the carbon content in steel the less ductile and therefore the lower the fracture energy. A good example of this would be cast-iron. Cast iron is a very hard and brittle material since it has a carbon content greater than 2% (see iron-carbon diagram). Cast iron also only absorbed 1 ft-lbs of force from the impact. So what is observed after conducting the Charpy test is a brittle fracture or "clean cut", the material does not look like it was pulled apart as in other samples. See Figure 3: Cast-iron specimen below. Figure 4: Cast-Iron Specimen Unlike the Cast-iron the 1018 steel was the most ductile material and absorbed on average 44 ft-lbs. When the steel was tested it looked like the steel was pulled apart similar to a piece of taffy. The internal structure of the steel was destroyed. Also during one of the trials the hammer did not completely break the steel, it was still held together by a small outer layer. To see a sample of the 1018 steel please see Figure 4: 1018 Steel Specimen Figure 5: 1018 Steel Specimens The final specimen that was tested was the 6061 aluminum alloy. The aluminum was in the middle of both the cast iron and steel, as the aluminum was not as ductile as the steel but it was also not as brittle as the cast iron. On average the absorbed energy of 6061 was 11 ft-lbs. after the hammer broke the specimen it looked like it had minor pulling of the internal structure but nothing too major. To see a sample of the 6061 aluminum alloy please see Figure 5: 6061 Aluminum alloy specimen at the top of the following page. Figure 5: 6061 Aluminum alloy specimen The amount of energy absorbed by each specimen should be equal to the total area under the stress-strain diagram. The 6061 Aluminum alloy has an average impact strength of 11 ft-lbs and when compared to the closest alloy in the charts provided which was 2028, plate aluminum had an impact energy of 7.6 ft-lbs. By comparing these two figures I ended up with a 44.7% error. The 1018 steel had an average impact strength of 44 ft-lbs. when compared the 1018 steel to the closest material I found on the charts which were 8630 low-alloy steel, which had an impact strength of 41 ft-lbs. This comparison resulted in a 7.31% difference. Cast Iron was difficult to compare to other alloys because there was no real material that was close to casting iron, so after comparing the different properties of cast iron to the list of alloys in Table 2: Tensile Test Data for some Alloys, it decided to compare cast iron to AZ31B Magnesium which had impact energy of 3.7 ft-lbs. this resulted in a 68.7% error. These % errors are very high but justifiable because we did not have the correct information to compare to. Morrow H. , Kokernak, R. person's statics and strength of materials 7th edition, 2010 pg 480 Hiyam Farhat, Chapter 3 – Materials and coating technologies, Editor(s): Hiyam Farhat, Operation, Maintenance, and Repair of Land-Based Gas Turbines, Elsevier, 2021, Pages 63-87, ISBN 9780128218341, //www.sciencedirect.com/science/article/pii/B9780128218341000071 Method of measuring the amount of energy absorbed by a material during fracture A modern impact test machine. Mechanical failure modes Buckling Corrosion Corrosion fatigue Creep Fatigue Fouling Fracture Hydrogen embrittlement Impact Liquid metal embrittlement Mechanical overload Metal-induced embrittlement Stress corrosion cracking Sulfide stress cracking Thermal shock Wear Yielding vte In materials science, the Charpy impact test, also known as the Charpy V-notch test, is a standardized high strain rate test which determines the amount of energy absorbed by a material during fracture. Absorbed energy is a measure of the material's notch toughness. It is widely used in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. A disadvantage is that some results are only comparative.[1] The test was pivotal in understanding the fracture problems of ships during World War II.[2][3] The test was developed around 1900 by S. B. Russell (1898, American) and Georges Charpy (1901, French).[4] The test became known as the Charpy test in the early 1900s due to the technical contributions and standardization efforts by Charpy. In 1896, S. B. Russell introduced the idea of residual fracture energy and devised a pendulum fracture test. Russell's initial tests measured un-notched samples. In 1897, Frémont introduced a test to measure the same phenomenon using a spring-loaded machine. In 1901, Georges Charpy proposed a standardized method improving Russell's by introducing a redesigned pendulum and notched sample, giving precise specifications.[5] A vintage impact test machine. Yellow cage on the left is meant to prevent accidents during pendulum swing, pendulum is seen at rest at the bottom The apparatus consists of a pendulum of known mass and length that is dropped from a known height to impact a notched specimen of material. The energy transferred to the material can be inferred by comparing the difference in the height of the hammer before and after the fracture (energy absorbed by the fracture event). The notch in the sample affects the results of the impact test,[6] thus it is necessary for the notch to be of regular dimensions and geometry. The size of the sample can also affect results, since the dimensions determine whether or not the material is in plane strain. This difference can greatly affect the conclusions made.[7] The Standard methods for Notched Bar Impact Testing of Metallic Materials can be found in ASTM E23,[8] ISO 148-1[9] or EN 10045-1 (retired and replaced with ISO 148-1),[10] where all the aspects of the test and equipment used are described in detail. The quantitative result of the impact tests the energy needed to fracture a material and can be used to measure the toughness of the material. There is a connection to the yield strength but it cannot be expressed by a standard formula. Also, the strain rate may be studied and analyzed for its effect on fracture. The ductile-brittle transition temperature (DBTT) may be derived from the temperature where the energy needed to fracture the material drastically changes. However, in practice there is no sharp transition and it is difficult to obtain a precise transition temperature (it is really a transition region). An exact DBTT may be empirically derived in many ways: a specific absorbed energy, change in aspect of fracture (such as 50% of the area is cleavage), etc.[1] The qualitative results of the impact test can be used to determine the ductility of a material.[11] If the material breaks on a flat plane, the fracture was brittle, and if the material breaks with jagged edges or shear lips, then the fracture was ductile. Usually, a material does not break in just one way or the other and thus comparing the jagged to flat surface areas of the fracture will give an estimate of the percentage of ductile and brittle fracture.[1] According to ASTM A370,[12] the standard specimen size for Charpy impact testing is 10 mm × 10 mm × 55 mm. Subsize specimen sizes are: 10 mm × 7.5 mm × 55 mm, 10 mm × 6.7 mm × 55 mm, 10 mm × 5 mm × 55 mm, 10 mm × 3.3 mm × 55 mm, 10 mm × 2.5 mm × 55 mm. Details of specimens as per ASTM A370 (Standard Test Method and Definitions for Mechanical Testing of Steel Products). According to EN 10045-1 (retired and replaced with ISO 148),[10] standard specimen sizes are 10 mm × 10 mm × 55 mm. Subsize specimens are: 10 mm × 7.5 mm × 55 mm and 10 mm × 5 mm × 55 mm. According to ISO 148,[9] standard specimen sizes are 10 mm × 10 mm × 55 mm. Subsize specimens are: 10 mm × 7.5 mm × 55 mm, 10 mm × 5 mm × 55 mm and 10 mm × 2.5 mm × 55 mm. According to MPIF Standard 40,[13] the standard unnotched specimen size is 10 mm (±0.125 mm) x 10 mm (±0.125 mm) x 55 mm (±2.5 mm). The impact energy of low-strength metals that do not show a change of fracture mode with temperature, is usually high and insensitive to temperature. For these reasons, impact tests are not widely used for assessing the fracture-resistance of low-strength materials whose fracture modes remain unchanged with temperature. Impact tests typically show a ductile-brittle transition for high-strength materials that do exhibit change in fracture mode with temperature such as body-centered cubic (BCC) transition metals. Impact tests on natural materials (can be considered as low-strength), such as wood, are used to study the material toughness and are subjected to a number of issues that include the interaction between the pendulum and a specimen as well as higher modes of vibration and multiple contacts between pendulum tup and the specimen.[14][15][16] Generally, high-strength materials have low impact energies which attest to the fact that fractures easily initiate and propagate in high-strength materials. The impact energies of high-strength materials other than steels or BCC transition metals are usually insensitive to temperature. High-strength BCC steels display a wider variation of impact energy than high-strength metal that do not have a BCC structure because steels undergo microscopic ductile-brittle transition. Regardless, the maximum impact energy of high-strength steels is still low due to their brittleness.[17] Izod impact strength test Brittle Impact force ^ a b c Meyers Marc A; Chawla Krishan Kumar (1998). Mechanical Behaviors of Materials. Prentice Hall. ISBN 978-0-13-262817-4. ^ "The Design and Methods of Construction Of Welded Steel Merchant Vessels: Final Report of a (U.S. Navy) Board of Investigation". Welding Journal. 26 (7): 569. July 1947. ^ Williams, M. L. & Ellinger, G. A (1948). Investigation of Fractured Steel Plates Removed from Welded Ships. National Bureau of Standards Rep. ^ Siewert ^ Cedric W. Richards (1968). Engineering materials science. Wadsworth Publishing Company, Inc. ^ Kurishita H, Kayano H, Narui M, Yamazaki M, Kano Y, Shibahara I (1993). "Effects of V-notch dimensions on Charpy impact test results for differently sized miniature specimens of ferritic steel". Materials Transactions. 34 (11). 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No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material.