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# Some Methods for Evaluating the Mechanical Properties of Plastic

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**ABSTRACT**: Plastics play a major role in the automotive industry. As a results, the development of automotives without plastics is impossible. There are many advantages of using plastics for automobile such as: Comfort, safety, low cost, weight reduction, corrosion and impact resistance, integration potential and design freedom. Because of these benefits, plastics have gained a permanent place for themselves in vehicle body design and will continue to play a prominent role in automotive applications in future.

**Keywords;** Plastic design, plastic composition and inserts, heavy duty, steel bumper and glass headlight lens replacement parts with plastic

## Introduction

Herbs and spices have been used to fortify foods throughout history as preservatives, flavour and therapeutic agents. Use of plastic in automotive trim has offered stylists more flexibility in car design, which is evident in the wide variety of car styles and designs seen today. Over the last 50 years the use of plastics has increased primarily because of their inherent advantages such as lightweight, flexibility, in case of manufacturing intricately designed components, excellent surface finish. In addition to these advantages in most cases use of plastic as an alternative reduces manufacturing cost and improves overall performance.

One of the major fields of application for plastics is in vehicle exteriors. The use of plastics for exterior parts started in the 1960s and today plastics can be used for a wide variety of exterior applications. The percentage of plastics used for exterior parts has risen considerably in recent years. At the moment 30% of car exteriors are made up of plastics. The heavy, steel bumper and glass headlamp lenses are examples of parts to be replaced by plastics. The exterior parts replaced by plastics are fully integrated into the body and exploit the advantages of plastics for design purposes.

With knowledge of the nature of dislocations and the role they play in the plastic deformation process, we are able to understand the underlying mechanisms of the techniques that are used to strengthen and harden metals and their alloys. Thus, it becomes possible to design and tailor the mechanical properties of materials— for example, the strength or toughness of a metal– matrix composite. Basically, materials may experience two kinds of deformation: elastic and plastic. Plastic deformation is permanent, and strength and hardness are measures of a material's resistance to this deformation. On a microscopic scale, plastic deformation corresponds to the net movement of large numbers of atoms in response to an applied stress. During this process, interatomic bonds must be ruptured and then re-formed. In crystalline solids, plastic deformation most often involves the motion of dislocations, linear crystalline defects. This thesis discusses the characteristics of dislocations and their involvement in plastic deformation. Twinning, another process by which some metals deform plastically, is also treated. In addition, and probably most important, several techniques are presented for strengthening single-phase metals, the mechanisms of which are described in terms of dislocations. Finally, the latter sections of this chapter are concerned with recovery and recrystallization—processes that occur in plastically deformed metals, normally at elevated temperatures—and, in addition, grain growth. Plastic deformation corresponds to the motion of large numbers of dislocations. An edge dislocation moves in response to a shear stress applied in a direction perpendicular to its line; the mechanics of dislocation motion are represented in **Figure 1.1.** Let the initial extra half-plane of atoms be plane *A*. When the shear stress is applied as indicated (Figure 1.1*a*), plane *A* is forced to the right; this in turn pushes the top halves of planes *B*, *C*, *D*, and so on, in the same direction. If the applied shear stress is of sufficient magnitude, the interatomic bonds of plane *B* are severed along the shear plane, and the upper half of plane *B* becomes the extra half-plane as plane *A* links up with the bottom half of plane *B* (Figure 1.1*b*). This process is subsequently repeated for the other planes, such that the extra half-plane, by discrete steps, moves from left to right by successive and repeated breaking of bonds and shifting by interatomic distances of upper half-planes. Before and after the movement of a dislocation through some particular region of the crystal, the atomic arrangement is ordered and perfect; it is only during the passage of the extra half-plane that the lattice structure is disrupted. Ultimately, this extra half-plane may emerge from the right surface of the crystal, forming an edge that is one atomic distance wide; this is shown in **Figure 1.1*c*.** The process by which plastic deformation is produced by dislocation motion is termed **slip;** the crystallographic plane along which the dislocation line traverses is the *slip plane,* as indicated in **Figure 1.1.**

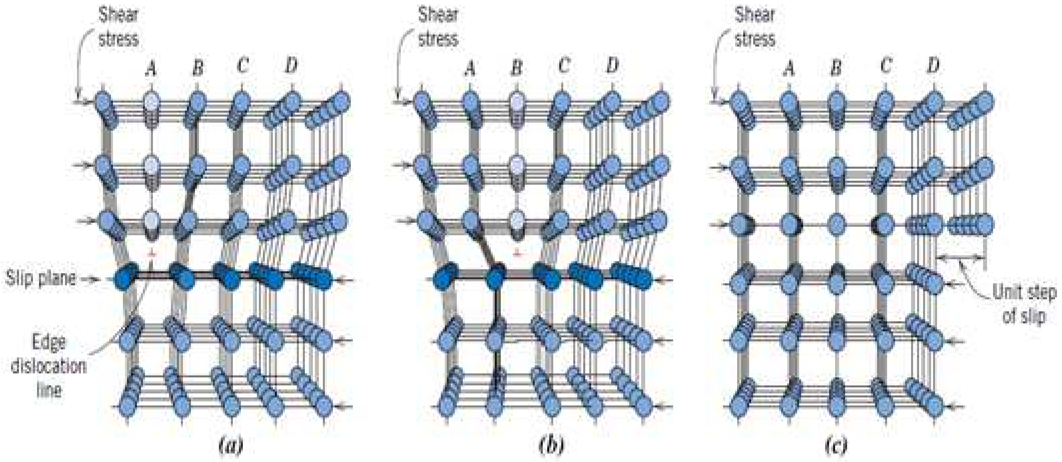


**Figure 1: The mechanics of dislocation motion**

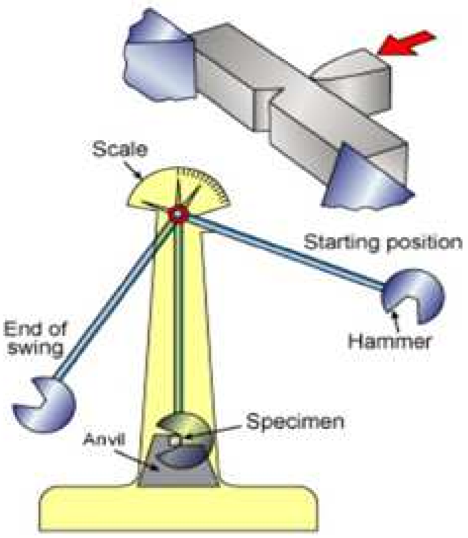
The Charpy impact test makes use of a pendulum arm attached to a pre-calibrated energy gauge. The material specimen is customized to take the shape of a bar with a small V- or U-shaped notch in the middle.

To conduct the experiment, the pendulum arm is set at a particular position correspondent to an energy setting. The arm is released and its hammer end is allowed to hit the centre of the specimen. The impact strength of the material is determined by the amount of energy needed to break or fracture the specimen. 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. The test was pivotal in understanding the fracture problems of ships during World War II.

The Standard methods for Notched Bar Impact Testing of Metallic Materials can be found in ASTM E23, ISO 148-1 or EN 10045-1 (retired and replaced with ISO 148-1), 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 qualitative results of the impact test can be used to determine the ductility of a material. 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.



**Picture 2: Charpy V-notch test**

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 low-strength materials that do exhibit change in fracture mode with temperature such as body-centered cubic (BCC) transition metals.

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.

This kind of impact test is similar to the Charpy test in the sense that it also uses a hammer attached to a pendulum arm to hit a custom-made specimen bar and measure the energy needed to fracture it.

The main difference between the Izod test and the Charpy test is the orientation of the specimen in the measuring equipment. While the specimen is set horizontally in the Charpy impact test, the Izod test examines a vertically positioned sample with a V-Notch. Here, the pendulum hammer is made to strike the upper tip of the notched specimen.

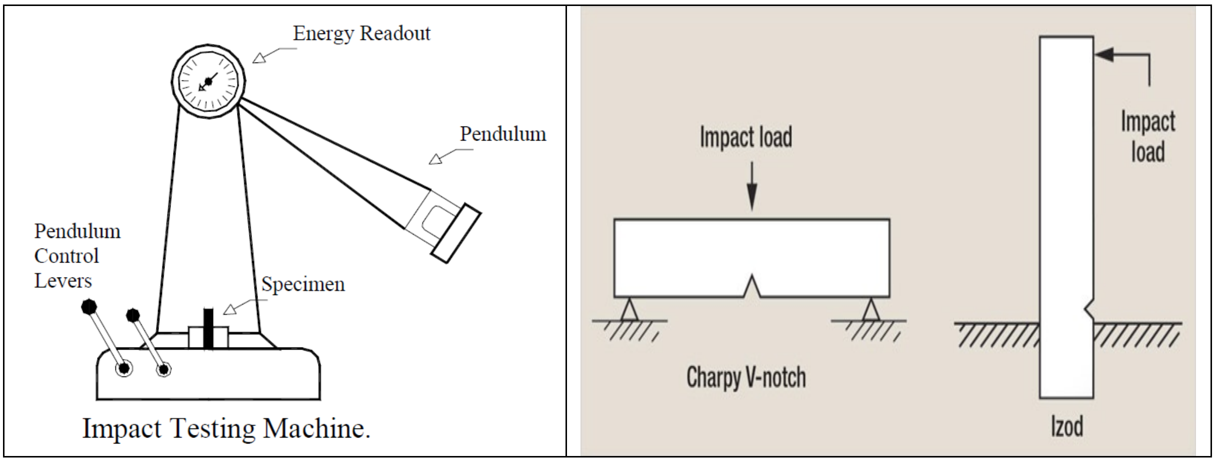
Other differences include the specimen size, notch face direction, type of hammer, and type of tested material. The Charpy test examines metal specimens with the notch facing away from a striking ball peen hammer. The Izod test, on the other hand, is used to test relatively longer metal or plastic specimens with the notch facing towards a farming hammer.

The Izod impact strength test is an ASTM standard method of determining the impact resistance of materials. A pivoting arm is raised to a specific height (constant potential energy) and then released. The arm swings down hitting a notched sample, breaking the specimen. The energy absorbed by the sample is calculated from the height the arm swings to after hitting the sample. A notched sample is generally used to determine impact energy and notch sensitivity.

The test is similar to the Charpy impact test but uses a different arrangement of the specimen under test. The Izod impact test differs from the Charpy impact test in that the sample is held in a cantilevered beam configuration as opposed to a three-point bending configuration.

Impact is a very important phenomenon in governing the life of a structure. For example, in the case of an aircraft, impact can take place by a bird hitting a plane while it is cruising, or during take-off and landing the aircraft may be struck by debris that is present on the runway, and as well as other causes. It must also be calculated for roads if speed breakers are present, in bridge construction where vehicles punch an impact load, etc.

Impact tests are used in studying the toughness of material. A material's toughness is a factor of its ability to absorb energy during plastic deformation. Brittle materials have low toughness as a result of the small amount of plastic deformation they can endure. The impact value of a material can also change with temperature. Generally, at lower temperatures, the impact energy of a material is decreased. The size of the specimen may also affect the value of the Izod impact test because it may allow a different number of imperfections in the material, which can act as stress risers and lower the impact energy.



**a)** **b)**

**Picture 3: Given pictures a) and b) defines Impact Test Machine and Charpy V-notch**

Tensile tests are usually carded out on wire, strip or machined samples with either circular or rectangular cross section. Test pieces are screwed into or gripped in jaws and stretched by moving the grips apart at a constant rate while measuring the load and the grip separation.

This data is plotted as load vs extension and then converted to engineering stress (load/original area) vs engineering strain (fractional change in length over the test section assuming the deformation is uniform).

In special circumstances, the actual stress and strain may be calculated if the true cross section is measured during the test. AS1391 sets out the requirements for sample size, test methods and equipment and includes examples of the typical shapes of stress vs strain plots which may be expected when tensile tests are performed.

The uniform section gauge length (where the deformation is presumed to be contained) can be between 25 and 100mm tong. The orientation of the sample relative to rolling or solidification directions will obviously affect the results obtained.

Normal parameters measured are the yield stress at 0.2% deformation (estimated by using a rule parallel to the initial linear portion of the load/elongation plot and offsetting the measurement by 0.2% displacement), the maximum stress, Rm, or the ultimate tensile stress (UTS), i.e. the maximum applied stress and the ductility which is measured by percent reduction in area of the fracture face or the percentage change in gauge length.

If the sample necks significantly, the (high strain) final part of the curve will dip below the UTS. Brittle materials will only deform by a small amount before fracture. The slope of the linear portion approximates the elastic modulus (or Young's modulus) while the area under the entire, non-linear portion of the curve gives the energy absorbed during deformation, and is thus an indication of toughness.

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