DSM Somos® Leads the Way in Impact Testing

An Interview with DSM Materials Scientist Dr. Satyendra Sarmah

Q: What does impact testing actually tell us about a plastic?

Impact testing provides engineers with information about a plastic's toughness.
The tests measure the relative susceptibility of plastics to fracture under stresses applied at high speeds.

Fracturing of the test specimen involves two steps: impacting energy creates a crack in the specimen and then more energy is expended to propagate the crack to specimen failure. High speeds are chosen because a high velocity collision—such as a rock hitting a car's headlight during driving—does not provide sufficient time for the plastic to deform and absorb the energy of the impact, thus the struck material exhibits a more brittle behavior than normally observed, and the majority of the impacting energy goes into fracturing the material.

Impact tests allow designers to compare the relative impact resistance under controlled laboratory conditions and, consequently, are often used for material selection or quality control. Traditional impact tests measure energy required to cause failure. However they do not provide good information about mechanism or nature of failure, such as brittle or ductile failure, because these tests are generally not instrumented to measure stress and strain in the specimen during the test.

Q: Why do we need multiple test methods for measuring impact strength?

While all impact test measure stresses applied at various high speeds, there are significant differences in equipment, specimen geometry and results interpretation. The common impact test methods can be divided into two categories: impact by a swinging pendulum, or by a falling weight.

Charpy, Izod and tensile impact tests belong to the pendulum family while Gardner and falling dart methods belong to the second category. These tests are generally not instrumented to measure stress and strain in the specimen during the test. Instrumented impact testers include load and velocity sensors along with a high speed data acquisition system and provide information on variation of force, energy, velocity and deformation during the time of the test. This data can be utilized to obtain information regarding energy needed for crack initiation and propagation to failure, failure sensitivity to strain rate, and distinction between brittle, ductile or transition failure modes.

Impact test results are influenced by temperature, humidity, impact velocity, impactor geometry and energy, specimen geometry and preparation, etc.

Three of the most commonly used are described below:

1. Izod, notched (ASTM D 256)

A destructive test, notched Izod Impact is a single point test that measures the energy per unit thickness required to fracture a specimen under flexural impact of a swinging pendulum. The test specimen is held as a vertical cantilever beam with the bottom half clamped. The swinging pendulum strikes the free top half of the notched side of the specimen. Energy lost by the pendulum during impact is estimated as the energy absorbed by the specimen leading to failure. A typical Izod specimen is 2.5 x 0.5 inch with a 45° angle notch machined in. Notch dimensions are critical in producing acceptable results; commercial notchers designed to prevent inconsistency are available. The notch in the specimen is designed to concentrate the stress and induce a brittle failure; it minimizes plastic deformation and reduces the possibility of ductile fracture. This test can be used as a quick and easy quality control check to determine if a material meets specific impact properties or to compare materials for general toughness. It is really not applicable to composite materials because of the induced, complex and variable failure modes.

ASTM D 256 also describes the notched Charpy impact test; however the key difference lies in placement of the specimen during the test. The notched Charpy specimen is simply supported horizontally on an anvil without a clamp and is impacted on the side opposite the notch.

2. Izod, unnotched (ASTM D 4812)

Sample is tested exactly the same way as described above, except the sample specimen does not have a notch. Tests on notched specimens are believed to primarily measure crack propagation energy and not crack initiation energy, thus they do not estimate the true impact resistance of the materials. Unnotched specimens, on the other hand, are believed to provide a better estimate of total energy needed to initiate and propagate the crack to failure. Absence of a notch reduces stress concentration and promotes more ductile behavior thus providing some information to the extent a plastic will deform before breaking. The unnotched Izod test is not widely used.

3. Gardner Test (ASTM D 5420)

The Gardner test belongs to falling or drop weight class of impact testing. Impact resistance is measured by dropping known weights on the specimen from varying heights, or a test weight is raised to a selected height and then released. In turn, the weight strikes another impactor or striker which is placed on the flat test specimen. The geometry of the strikes varies depending on the type of materials being tested. The flat specimen is placed on a support plate, which may have different opening diameter as well. This method does not require notching and is believed to be better for materials which exhibit ductile behavior. The impact energy is calculated based on weight dropped, height from which weight is dropped and geometry of the striker. The test is usually performed by incrementally raising a given weight higher, then dropping till failure is observed. The test requires larger number of specimens and average impact energy is usually based on failure of half of the specimens for a given weight-height combination. Results for different materials can only be compared when specimen thickness is the same and the tests are conducted with similar striker, support plate, drop weight , etc.

Acceptable failures are complete shattering of the specimen plaque, any brittle splitting of the bottom surface, dislodging or loosening of any brittle chips, formation of radiating cracks towards the edges on either surface, formation of radial cracks within or just outside the impact zone and formation of any hole due to puncture.

It should be noted that plastics are sensitive to strain rate; the result of a 2 kg weight dropping on a specimen from 2 m height can be different from a 1 kg weight being dropped from 4 m height even though both conditions apply the same impact energy to the specimen.

Q: How do the impact strength values translate to real life plastic applications?

Toughness tends to decrease at lower temperatures (the plastic becomes stiffer and more brittle below glass transition temperature), therefore impact testing at lower temperatures becomes more critical. For automotive applications, a low temperature impact at -30 or -40°C is critical. For many E&E applications, toughness at room temperature or elevated temperatures is important in processes such as pin insertion, winding operation and soldering. Even though impact testing of a material may not always predict the behavior of a part in real life impact situations, impact testing at different temperatures can provide information on brittle to ductile failure transition.

Q: How does DSM Somos® use this information to develop better plastics?

DSM Somos measures all of its stereolithography resins via Izod notched and unnotched impact tests. As we develop SL resins that behave more like thermoplastics—such as DMX-SL™—we have begun adding impact testing normally reported for engineered plastics but not SL resins, such as the Gardner impact test. DSM Somos utilizes impact testing as an important tool for developing tougher and improved SL resins. By understanding more about failure modes, DSM Somos is well equipped to continue developing tougher SL resins.