UNIT IV MATERIALS SELECTION CHARTS AND TESTING

Ashby material selection charts-Testing of Metallic Materials - Plastics Testing – Characterization and Identification of Plastics - Professional and Testing Organizations - Ceramics Testing - Nondestructive Inspection.

Professional and Testing Organizations

- AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)
- AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)
- FOOD AND DRUG ADMINISTRATION (FDA)
- NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)
- NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)
- NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)
- NATIONAL SANITATION FOUNDATION (NSF)
- SOCIETY OF PLASTICS ENGINEERS (SPE)
- SOCIETY OF PLASTICS INDUSTRY (SPI)
- UNDERWRITERS LABORATORIES (UL)
- TYPICAL COSTS FOR TESTING SERVICES
- INDEPENDENT TESTING LABORATORIES

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

- In 1918, when ANSI was founded, standardization activities were just beginning in the United States.ANSI is a federation of standards competent from commerce and industry, professional, trade, consumer, and labor organizations and government.
- It approves a standard only when it has verified evidence presented by a standards developer that those affected by the standard have reached substantial agreement on its provisions
- The American Society for Testing and Materials was founded in 1898. It is a scientific and technical organization formed for ‘‘the development of standards on characteristics and performance of materials, products, systems and services and

the promotion of related knowledge.'' ASTM is the world's largest source of voluntary consensus standards. The society operates through more than 135 main technical committees with 1550 subcommittees.

FOOD AND DRUG ADMINISTRATION (FDA)

- The Food and Drug Administration, first established in 1931, is an U.S. government agency of the Department of Health and Human Services. The FDA's activities are directed toward protecting the health of the nation against impure and unsafe foods, drugs, and cosmetics and other potential hazards.
- **NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY (NIST)**
- The National Bureau of Standards (NBS) was established by act of Congress in March 1901. NBS was renamed the National Institute of Standard and Technology in 1988. The bureau's overall goal is to strengthen and advance the nation's science and technology and to facilitate their effective application for public benefit.
- **NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)**
- The National Electrical Manufacturers Association was founded in 1926. This 600-member association consists of manufacturers of equipment and apparatus for the generation, transmission, distribution, and utilization of electric power. The membership is limited to corporations, firms, and individuals actively engaged in the manufacture of products included within the product scope of NEMA product subdivisions.
- **NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)**
- The National Fire Protection Association was founded in 1896 with the objective of developing, publishing, and disseminating standards intended to minimize the possibility and effect of fire and explosion. NFPA's membership consists of individuals from business and industry, fire service, health care, insurance, educational, and government institutions

NATIONAL SANITATION FOUNDATION (NSF)

- The National Sanitation Foundation, more commonly known as NSF, is an independent, nonprofit environmental organization of scientists, engineers, technicians, educators, and analysts. NSF frequently serves as a trusted neutral agency for government, industry, and consumers, helping them to resolve differences and unite in achieving solutions to problems of the environment.

SOCIETY OF PLASTICS ENGINEERS (SPE)

- The Society of Plastics Engineers was founded in 1942 with the objective of promoting scientific and engineering knowledge relating to plastics. SPE is a professional society of plastics scientists, engineers, educators, students, and others interested in the design, development, production, and utilization of plastics materials, products, and equipment.

SOCIETY OF PLASTICS INDUSTRY (SPI)

The Society of Plastics Industry is a major society, whose membership consists of manufacturers and processors of plastics materials and equipment. The society has four major operating units consisting of the Eastern Section, the Midwest Section, the New England Section, and the Western Section. SPI's Public Affairs Committee concentrates on coordinating and managing the response of the plastics industry to issues such as toxicology, combustibility, solid waste, and energy.

UNDERWRITERS LABORATORIES (UL)

Underwriters Laboratories, founded in 1894, is chartered as a not-for-profit organization to establish, maintain, and operate laboratories for the investigation of materials, devices, products, equipment, constructions, methods, and systems with respect to hazards affecting life and property

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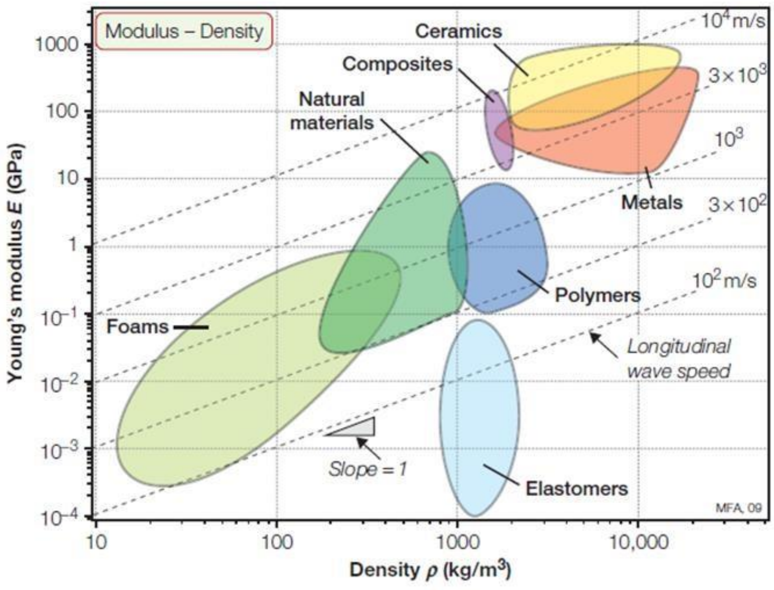
Ashby material selection charts

A useful method of doing this is by plotting them as Material Property **Charts**, sometimes called 'bubble' or '**Ashby**' **charts**, with one property on one axis and another property on the other. Each material has a range of values for each property, depending on the exact composition, grade, heat treatment, supplier etc.

There are a lot of materials, and each has a lot of properties. We need a good way to display and compare them. A useful method of doing this is by plotting them as Material Property Charts, sometimes called 'bubble' or 'Ashby' charts, with one property on one axis and another property on the other. Each material has a range of values for each property, depending on the exact composition, grade, heat treatment, supplier etc. The materials are represented on the chart as ellipses or 'bubbles', whose width and height are determined by the range of the value of the properties.

- An Ashby plot, named for Michael Ashby of Cambridge University, is a scatter plot which displays two or more properties of many materials or classes of materials. These plots are useful to compare the ratio between different properties
- These **charts** compact huge information into accessible forms. They show correlations between **material properties** to help in solving real design issues.



The idea of a material property chart: Young's modulus E is plotted against the density ρ on log scales. Each material class occupies a characteristic field. The contours show the longitudinal elastic wave speed $v = (E/\rho)^{1/2}$.

- 'Stiffness' measures how much something stretches when a load is applied. Young's modulus measures stiffness and is a material constant, i.e. it is the same whatever the size of the test-piece.
- Many applications require **stiff** materials, e.g. roof beams, bicycle frames - these materials lie at the **top** of the chart
- Many applications require **low density** materials, e.g. packaging foams - these materials lie to the **left** of the chart.
- Stiff lightweight materials are hard to find - composites appear to offer a good compromise, but they are usually quite expensive.

Physical Insights

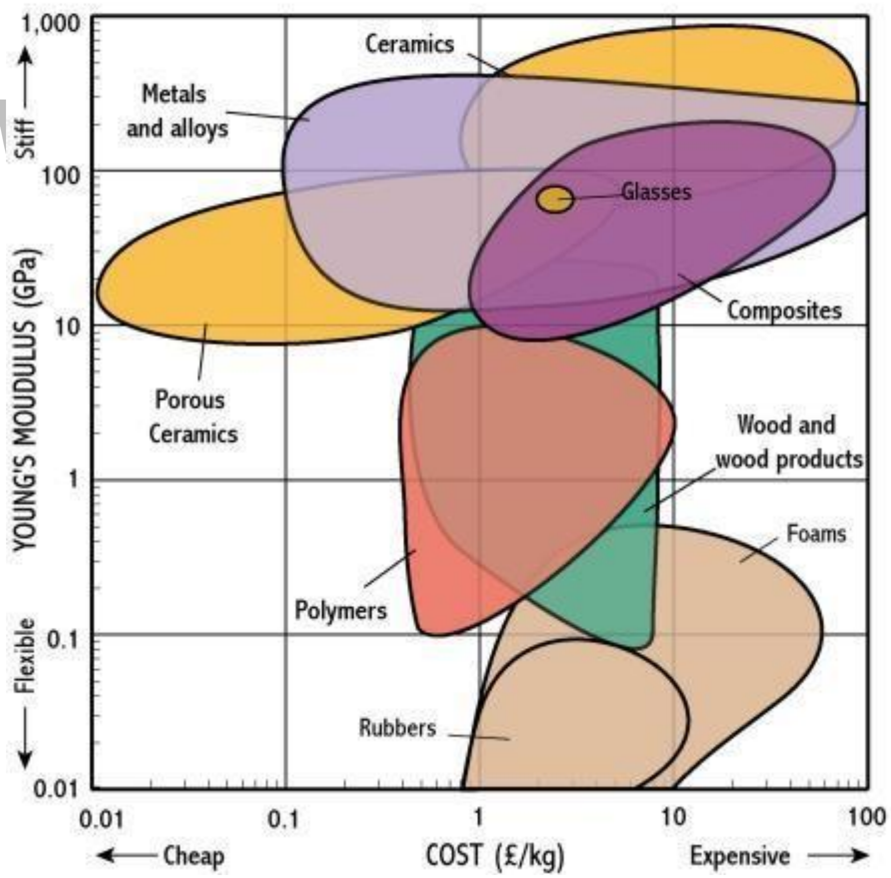
- Both paper and MDF are made from wood pulp and so have similar densities and little directional variation in Young's modulus. Although we may think of paper as more floppy than MDF, this is because we find it in much thinner sections!

- The metal bubbles are quite small - this is because alloying does not have a significant effect on density or Young's modulus.
- Woods have very different stiffnesses depending on whether they are loaded 'with' or 'across' the grain. This is because of the stiff cellulose micro-fibres.
- Note how the materials all lie roughly on a diagonal - Young's modulus is strongly *correlated* to density.
- Foams have the lowest densities because they have pores full of air.

Young's Modulus - Cost

Rollover class name to view individual materals, click chart to return to class view.

Hover mouse over property for brief definition.



General Information

- Young's modulus measures stiffness and is a material constant, i.e. it is the same whatever the size of the test-piece.
- Many applications require **stiff** materials, e.g. roof beams, bicycle frames - these materials lie at the **top** of the chart
- Many applications require **low cost** materials, e.g. packaging foams - these materials lie to the **left** of the chart.
- Cheap stiff materials lie towards the **top left** of the chart – mostly metals and ceramics.

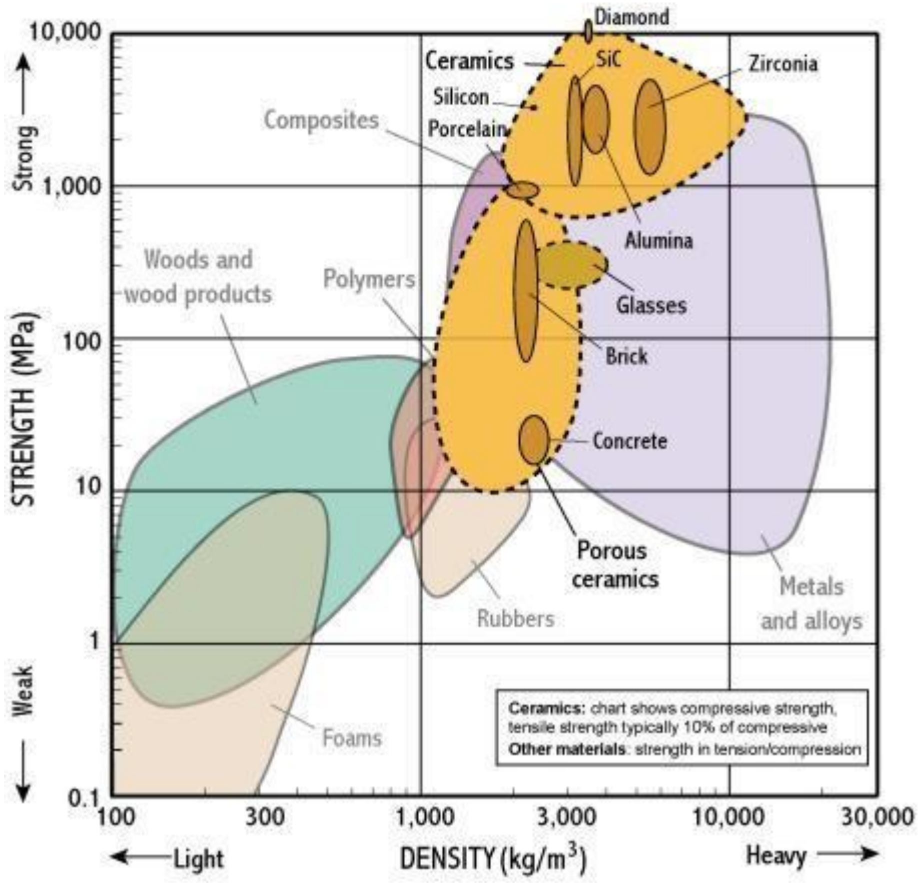
Physical Insights

- Polymers don't seem like a good choice for stiff, cheap products - but they can be reinforced by incorporating stiffeners into the design (for instance look inside a plug).
- Diamond is the stiffest material because of its full covalent bonding - but its price means it is not used for engineering applications.
- Polyethylene has a wide range for Young's modulus because the 'bubble' include both LDPE and HDPE.

Strength - Density

Rollover class name to view individual materals, click chart to return to class view.

Hover mouse over property for brief definition.



General Information

- Strength measures the resistance of a material to failure, given by the applied stress (or load per unit area)
- The chart shows yield strength in tension for all materials, except for ceramics for which compressive strength is shown (their tensile strength being much lower)
- This chart is useful for identifying materials for components which require high strength combined with low weight (top left)
- Most polymers have densities slightly greater than 1 (just sink), most woods slightly less than 1 (just float)
- High strength at low weight is so often important that a property called specific strength is defined as strength/density

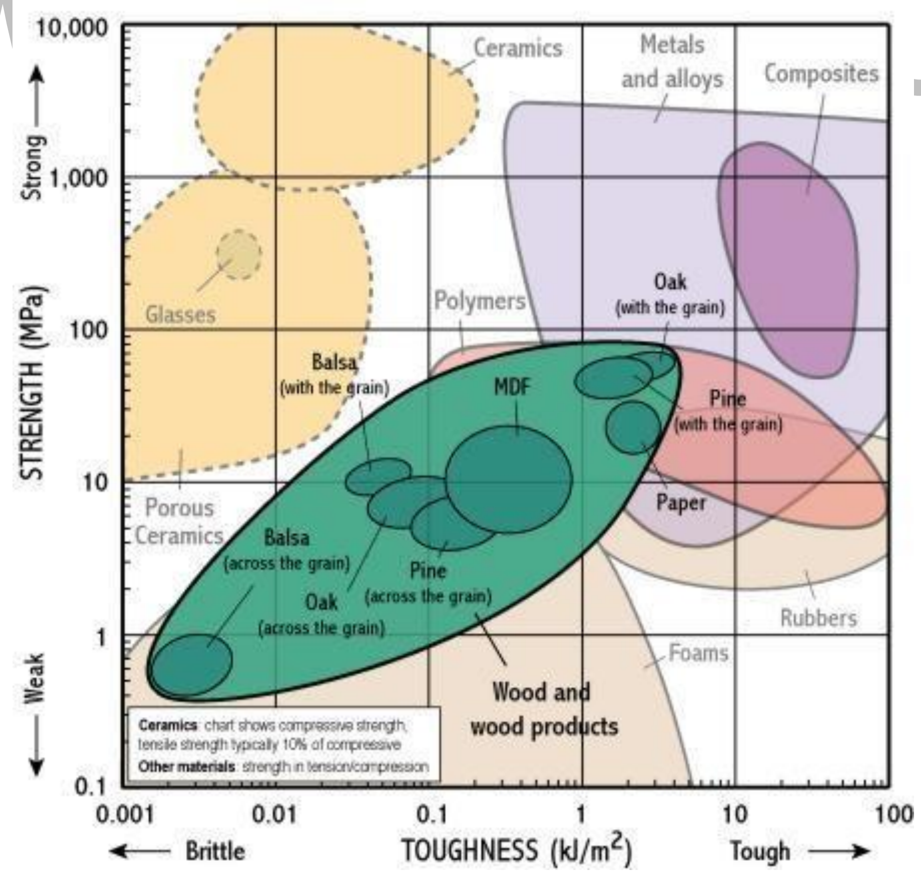
Physical Insights

- The bubbles are elongated along the strength axis, but not density. This is because alloying and heat treatments have a strong effect on strength but little on density
- Strength is correlated to density so that most materials lie on the bottom left-top right diagonal
- Composites provide a means of achieving high strength at low weight because they exploit very strong fibres in light matrices
- Woods are somewhat like polymer foams having pores full of air and so float in water.
- Wood achieves high strength at low density by its efficient cellular microstructure

Strength - Toughness

Rollover class name to view individual materals, click chart to return to class view.

Hover mouse over property for brief definition.



General Information

- Strength measures the resistance of a material to failure, given by the applied stress (or load per unit area)
- The chart shows yield strength in tension for all materials, except for ceramics for which compressive strength is shown (their tensile strength being much lower)
- Toughness measures the energy required to crack a material; it is important for things which suffer impact
- There are many cases where strength is no good without toughness, e.g. a car engine, a hammer
- Increasing strength usually leads to decreased toughness
- Tempered steel is tougher but less strong than after quenching.

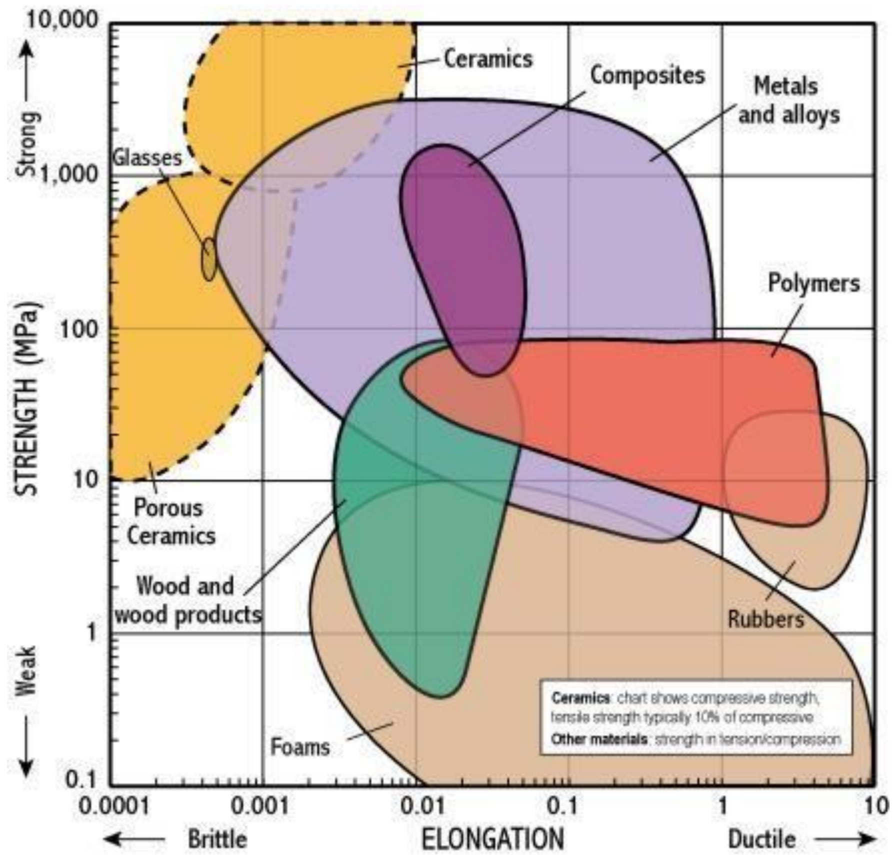
Physical Insights

- Put a pin-prick in a balloon and begin to blow it up - it will burst when the elastic energy cannot be absorbed by the growing crack
- The tensile strengths of brittle materials are very sensitive to the presence of flaws
- Quenching carbon steel makes it very hard but brittle.
- Tough materials absorb a lot of energy as a crack grows through them
- Metals are tough because they deform plastically while they crack, absorbing energy
- Cast iron is often brittle because it contains graphite flakes which behave like little cracks within the metal

Strength - Elongation

Rollover class name to view individual materals, click chart to return to class view.

Hover mouse over property for brief definition.



General Information

- Strength measures the resistance of a material to failure, given by the applied stress (or load per unit area)
- The chart shows yield strength in tension for all materials, except for ceramics for which compressive strength is shown (their tensile strength being much lower)
- Elongation measures the percentage change in length before fracture
- Elongation to failure is a measure of ductility

Physical Insights

- Ceramics have very low elongations (<1%) because they can not plastically deform

- Metals have moderate elongation to failure (1-50%) with deformation occurring by plastic flow
- Thermoplastics have large elongations (>100%) because the molecules can stretch out and slide over one another
- Rubbers have long elastic elongations because the chains can coil/uncoil elastically
- Thermosets have low elongations (<5%) because the molecules are bonded together into a network so that they cannot slide over one another
- One way to strengthen a metal is to make plastic flow difficult – this reduces the ductility and elongation

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Ceramics Testing

- Ceramics are being used in an ever-increasing capacity in numerous industrial and scientific applications. Advanced ceramics, in particular, have great future possibilities for use in a wide variety of applications where their unique combination of properties can achieve better results than other materials such as metals and polymers.
- Testing ceramics helps determine if they are suited for specific applications. Typically this involves a series of tests to measure the material's mechanical properties. These properties include the yield strength, ultimate strength, tensile strength, compressive strength, flexural strength, fracture strength, hardness, fracture resistance and creep rate. With the knowledge of these values the behavior that is expected from the ceramic during the application can be predicted and it can be shown if it will succeed or fail.

MECHANICAL TESTING

With the increasing role of ceramics in technology, further understanding of mechanical properties has become increasingly more important. This has resulted in the use and standardization of various test methods to better understand and quantify mechanical properties. Test methods reveal such properties as strength, fatigue, fracture resistance, creep, and slow crack growth, which contribute to design, scientific understanding, and estimations of service life among others.

Creep

Similar to the fracture testing methods previously discussed, the three test methods used to determine creep characteristics in ceramics are the tensile, compressive, and flexural tests. The primary differences in the test fixtures are that the gauge section must be heated to the desired elevated temperature and an alternate method of measuring deflection such as extensometers must be employed because of the increased temperature

Hardness

Hardness is an important property to quantify in ceramics. Measured hardness indicates the ability of the ceramic to resist deformation by a hard object. Usually, Knoop or Vickers diamond indenters are used in conjunction with a microindentation hardness machine

Fracture Toughness

The brittle nature of ceramics results in low resistance to fracture, quantificial as fracture toughness, which is an important factor in many applications of ceramics. Fracture toughness is a measure of a specimen's ability to resist further growth of a crack. Low fracture toughness values increase the risk of catastrophic failure of a ceramic component. Ceramic matrix composites (CMCs) have better fracture toughness compared to monolithic ceramics as the additional reinforcing elements help to deter crack growth. The concepts of the linearelastic fracture mechanics (LEFM) method commonly used for other materials can be applied to monolithic ceramics for the purpose of analysis.

Fatigue

Fatigue testing is an important design tool for the designer of ceramic components where reliability and lifetime estimates need to be made. Fatigue tests for ceramics generally cover the three situations of cyclic fatigue, static fatigue, and dynamic fatigue.

Thermal Expansion

Thermal expansion is an important property that quantifies the volume change a material undergoes when it is subjected to temperature changes This characteristic is valuable to the engineer or scientist involved in ceramic design or research. The coefficient of thermal expansion (COTE), _, is strongly related to the strength of the atomic bonds. Energy must be put into the material for the atoms to move from their equilibrium positions.

Other Techniques

X-ray diffraction can give insight into the structure of ceramics. The tensor components of thermal expansion can be determined with X-ray diffraction through the measuring of changes of the interplanar spacing with relation to the temperature.

Thermal Conductivity

Thermal conductivity is a measure of the rate of heat transfer in a given material by conduction. The heat flowrate through a material is proportional to the heated area of the material and the temperature gradient across the specimen

Laser Flash Method

Another method for determining thermal conductivity is the laser flash method, which involves quickly heating a thin ceramic specimen on one side via a quick ‘‘thermal pulse’’ from a laser and then using the measured temperature values over time of the back face of the specimen to calculate thermal diffusivity and conductivity. Thermal diffusivity, _, is a different means of expressing a material’s heat conduction properties. Thermal diffusivity takes into account that heat can diffuse through a material subject to different boundary conditions, causing both spatial and temporal variations of temperature.

Heat Capacity

Heat capacity is a property that refers to the amount of energy that must be added or subtracted from a material to raise or lower its temperature. The amount of energy required to raise the temperature of a material by a degree varies from material to material based on its properties. Specific heat at a constant pressure, *cp*, is the most common expression of a material's heat capacity and is defined as the amount of heat needed to raise the temperature of one gram of a substance by one kelvin at a constant pressure.

Calorimetry

Calorimetry can be used to determine the heat capacity of a ceramic material. A specific amount of a material test specimen is heated to an initial temperature with an external furnace and then deposited into a calorimeter of a lower temperature. The calorimeter measures the heat energy that the test specimen gives off while cooling to the equilibrium temperature that is between the specimen and calorimeter temperature.

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Characterization and Identification of Plastics

- Today there are countless numbers of processors consuming in excess of 100 million pounds of material every year. An increasing number of processors are looking into various techniques for characterizing the incoming plastic resin to guard against batch-to-batch variations. Such variation in the properties and the process ability of the polymer have been very costly.

There are numerous ways of characterizing a polymer. Some are very basic and simple, others are more sophisticated and complex. The five most common and widely accepted tests are:

1. Melt index (melt flowrate) test,
2. Rheological tests
3. Viscosity tests
4. Gel permeation chromatography
5. Thermal analysis [thermogravimetric analysis (TGA),
6. Thermomechanical analysis(TMA)
7. Differential scanning calorimetry (DSC)
8. Spectroscopy

- The melt index, also known as melt flow rate (MFR), test measures the rate of extrusion of a thermoplastic material through an orifice of specific length and diameter under prescribed conditions of temperature and pressure.
- This test is primarily used as a means of measuring the uniformity of the flowrate of the material. The reported melt index values help to distinguish between the different grades of a polymer

- **Rheological tests**
- Rheology is defined as study of flow. Viscosity is the measure of resistance to flow due to internal friction when one layer of fluid is caused to move in relationship to another layer.
- The greater the friction, the greater the amount of force required to cause this
- movement, which is called *shear*.
  - Shearing occurs whenever the fluid is physically moved or disturbed as in pouring, mixing, and spraying. Highly viscous fluids, therefore, require more force to move then less viscous materials. The velocity gradient is a measure of the speed at which the intermediate layers move with respect to each other. It describes the shearing the liquid experiences and is thus called *shear rate*.
  - Instruments developed for measuring the flow properties of polymers are known as rheometers. Many different types of rheometers have been developed. Data analysis and interpretation has been simplified with newly developed Windows-based software

Viscosity Tests

Viscosity is defined as the property of resistance to flow exhibited within the body of a material expressed in terms of a relationship between the applied shearing stress and the resulting rate of strain in shear.

The measurement and control of rheological properties are usually performed with simple devices called ‘‘viscometers’’ or ‘‘viscosimeters

Gel Permeation Chromatography

- Quite often traditionally used tests such as melt index or viscosity tests do not provide enough information about the processibility of the polymer. Such tests only measure an average value and tell us nothing about the distribution that makes up the average.
- Gel permeation chromatography (GPC) is the method of choice for determining the molecular weight distribution of a polymer. This technique has gained wide acceptance among the plastic material manufacturers and the processors because of its relatively low cost, simplicity, and its ability to provide accurate, reliable information in a very short time.

Thermal Analysis Techniques

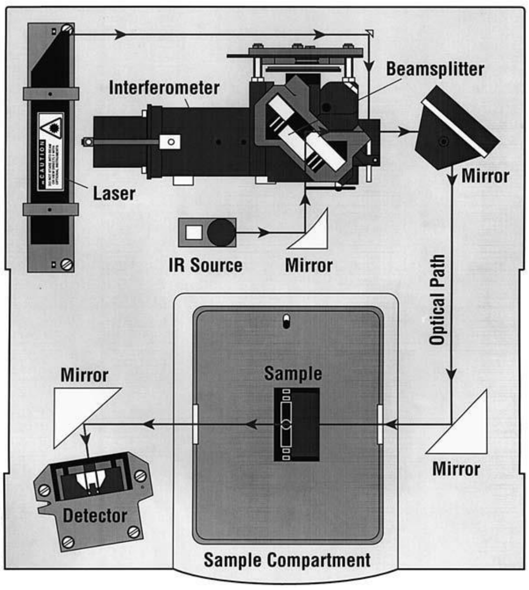
- Thermal analysis (TA) consists of a family of analytical techniques in which a property of the sample is monitored against time or temperature while the temperature of the sample is programmed. Properties include weight, dimension, energy take-up, differential temperature, dielectric constant, mechanical modulus evolved gases, and other, less common attributes.

Thermo mechanical Analysis (TMA)

- When a sample is heated, its dimensions change because of thermal expansion, stress reorientation, and deformation under an imposed stress. Thermo mechanical analysis consists of measuring these properties using a constant force on the sample. Under a no-load or fixed load, it measures dimensional change in the vertical direction as the sample temperature is controlled.

Spectroscopy

- Infrared spectroscopy is one of the most widely used material analysis techniques for over 70 years. An infrared spectrum represents a fingerprint of a sample with absorption peaks that correspond to the frequencies of vibrations between the bonds of the atoms making up the material. Because each different material is a unique combination of atoms, no two compounds produce the exact same infrared spectrum. This fact allows a positive identification of polymeric materials. By studying the size of the peaks in the spectrum, one can also determine the amount of material present.



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Nondestructive Inspection

The term nondestructive inspection (NDI) or nondestructive evaluation (NDE) is defined as that class of physical and chemical tests that permit the detection and/or measurement of the significant properties or the detection of defects in materials, components, or structures without impairing their usefulness. The NDI process is often complicated by the fact that many modern materials are by nature anisotropic. Most of the current NDI techniques were developed for isotropic materials such as metals. There are many methods available to conduct the NDE or NDI ceptance in the NDI community. These qualities are

1.Accuracy. The instrument must accurately measure some property of the material or structure that can be used to infer either properties or the presence of flaws.

2. Reliability. The instrument must be highly reliable. That is, it must consistently detect and quantify flaws or a property with a high degree of reliability. If an instrument is not reliable, then it will misdiagnosed properties or flaws can lead to failure of the component, property damage, and potential loss of life.

3. Simplicity. The instruments that are most useful are those that may be used by factory or repair-level technicians. Instrumentation that requires highly skilled operators are very rarely used by the inspection community.

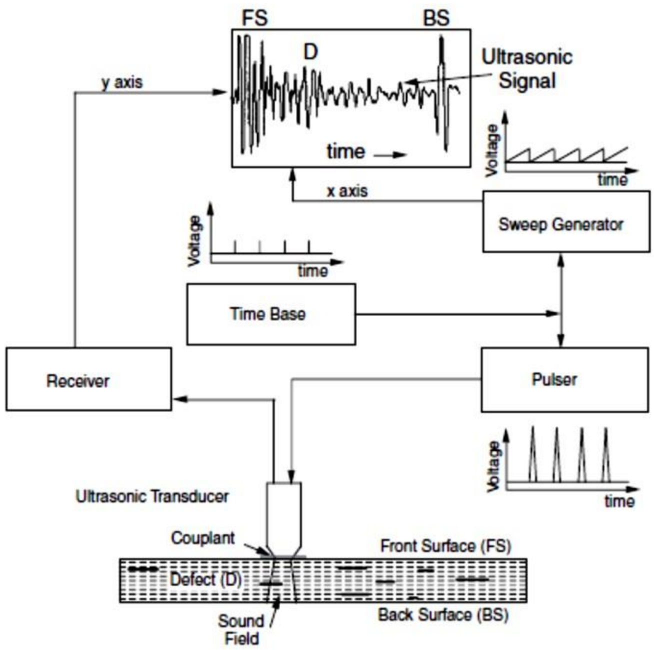
4. Low Cost. An instrument need not be low cost in an absolute sense. Instead, it must be inexpensive relative to the value of the component under test or the cost of a failure

or aborted mission. For flight-critical aircraft components, as much as 12% of the value of the component may be spent in inspection.

Ultrasonic methods utilize high-frequency sound waves to inspect the interior of parts. Sound waves are mechanical or elastic waves that propagate in fluid and solid media. Ultrasonic inspection is analogous to the use of sonar to detect schools of fish or map the ocean floor.8 Both the government and industry have developed standards for ultrasonic inspections. These include but are not limited to the ASTM specifications 214-68, 428-71, and 494-75 and military specification MIL-1-8950H. Acoustic and ultrasonic testing can take many forms. Ultrasonic testing (UT) ranges from simple coin tapping to the transmission and reception of very high frequency waves into a part in order to analyze its internal structure.

Reflection and Transmission of Sound

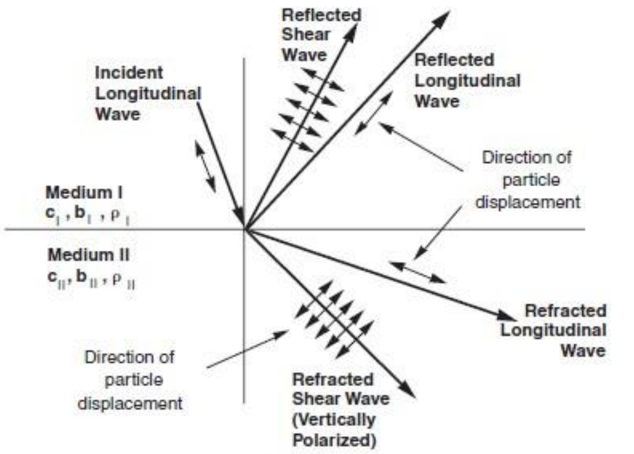
Almost all the acoustic energy incident on air /solid interfaces is reflected because of the large impedance mismatch between air and most solids. For this reason, a coupling media, with impedance close to that of the part, is used to couple the sonic energy from the transducer into the part. A liquid couplant has obvious advantages for parts with a complex geometry, and water is the couplant of choice for most inspection situations. The receiver, in addition to amplifying the returning echoes, also gates the echoes that return between the front surface and rear surfaces of the component. Thus, any unusually occurring echo can either be displayed separately or used to set off an alarm.



Refraction of Sound

The direction of propagation of acoustic waves is described by the acoustic equivalent of Snell's law. the directions of propagation are determined with the following equation:

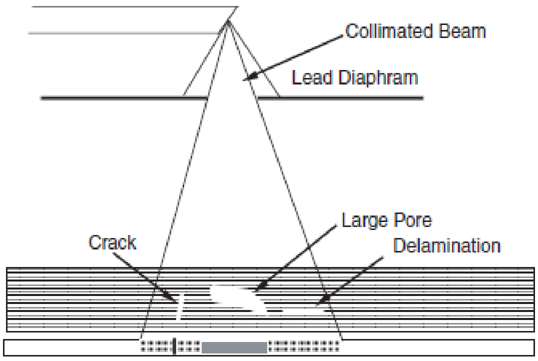
$$\frac{\sin\theta_i}{c_I} = \frac{\sin\theta_r}{c_I} = \frac{\sin\gamma_r}{b_I} = \frac{\sin\theta_t}{c_{II}} = \frac{\sin\gamma_t}{b_{II}}$$



Schematic representation of Snell's law and the mode conversion of a longitudinal wave incident on a solid/solid interface.

RADIOGRAPHY

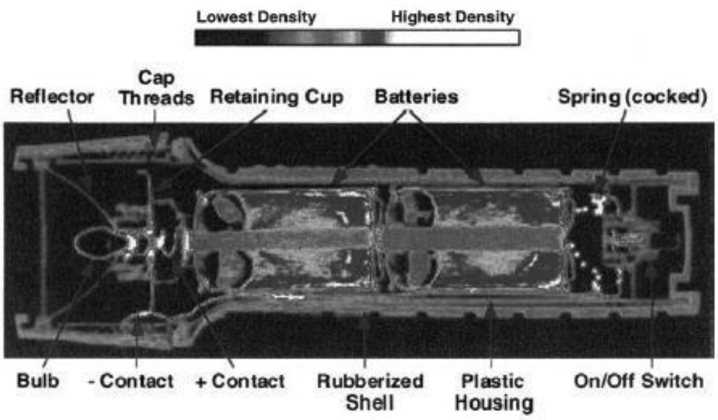
In classical NDE radiography the projected X-ray attenuation for a multitude of paths through a specimen are recorded as a two-dimensional image on some type of recording media. In computed tomography (CT), the attenuation values are used to calculate a cross-sectional image of the component being inspected.



Schematic radiograph of a typical composite with typical flaws.

Computed Tomography

Another advance in industrial radiography with and unrealized capability to link NDE with engineering design and analysis is computed tomography (CT). The principle advantage of this method is that it produces an image of a thin slice of the specimen under examination. This slice is parallel to the path of the Xray beam as it passes through the specimen as contrasted to the image produced by classical radiography, where the image is formed on a plane perpendicular to the path of the X-ray beam on passage through the specimen. The classical radiographic image can be difficult to interpret because it collapses all of the image information in the specimen between the source of X-rays and



Computed tomography of flashlight.

the recording media, whereas the CT image is computed or calculated from X-ray intensity data and does not contain information from planes outside the thin slice.

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Plastics Testing

In the last two decades, just about every manufacturer has turned to plastics to achieve cost reduction, automation, and high yield. The lack of history along with the explosive growth and diversity of polymeric materials has forced the plastics industry into placing extra emphasis on testing and developing a wide variety of testing procedures. Through the painstaking efforts of various standards organizations, material suppliers, and mainly the numerous committees of the American Society for Testing and Materials (ASTM), over 10,000 different test methods have been developed.

The following are some of the major reasons for testing:

1. To prove design concepts
2. To provide a basis for reliability
3. Safety
4. Protection against product liability suits
5. Quality control
6. To meet standards and specifications
7. To verify the manufacturing process
8. To evaluate competitors' products
9. To establish a history for new materials

Tensile Tests (ASTM D638, ISO 527-1)

Tensile elongation and tensile modulus measurements are among the most important indications of strength in a material and are the most widely specified properties of plastic materials. Tensile test, in a broad sense, is a measurement of the ability of a material to withstand forces that tend to pull it apart and to determine to what extent the material stretches before breaking. Tensile modulus, an indication of the relative stiffness of a material, can be determined from a stress–strain diagram. Different types of plastic materials are often compared on the basis of tensile strength, elongation, and tensile modulus data. Many plastics are very sensitive to the rate of straining and environmental conditions. Therefore, the data obtained by this method cannot be considered valid for applications involving load-time scales or environments widely different from this method. The tensile property data are more useful in preferential selection of a particular type of plastic from a large group of plastic materials and such data are of limited use in actual design of the product. This is because the test does not take into account the time-dependent behavior of plastic materials.

1.2 Flexural Properties (ASTM D790, ISO 178)

The stress–strain behavior of polymers in flexure is of interest to a designer as well as a polymer manufacturer. Flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis. The stresses induced due to the flexural load are a combination of compressive and tensile stresses. Flexural properties are reported and calculated in terms of the maximum stress and strain that occur at the outside surface of the test bar. Many polymers do not break under flexure even after a large deflection that makes determination of the ultimate flexural strength impractical for many polymers. In such cases, the common practice is to report flexural yield strength when the maximum strain in the outer fiber of the specimen has reached 5%. For polymeric materials that break easily under flexural load, the specimen is deflected until a rupture occurs in the outer fibers.

Drop Impact Test

This falling-weight impact test is primarily designed to determine the relative ranking of materials according to the energy required to break flat rigid plastic specimens under various conditions of impact of a striker impacted by a falling weight. A free-falling weight, or a tup, is used to determine the impact resistance of the material

Instrumented Impact Testing

One of the biggest drawbacks of the conventional impact test methods is that it provides only one value—the total impact energy—and nothing else. The conventional tests cannot provide additional information on the ductility, dynamic toughness, fracture, and yield loads or the behavior of the specimen during the entire impact event. This effectively limits the application of non instrumented impact test methods to quality control and material ranking. Instrumented impact testers are generally suited for research and development as well as advance quality control. Instrumented impact testers measure force continuously while the specimen is penetrated. The resulting data can be used to determine type of failure and maximum load, in addition to the amount of energy required to fracture the specimen. One of the most common type of failures occurring from ductile to brittle transition at low temperatures can only be observed by studying the load– energy–time curve. The fracture mode of a plastic is sensitive to the changes in temperature, and can change abruptly at or near the materials transition temperature.

High-Speed Impact Tests **(*ASTM D3763, ISO 6603-2*)**

An ever-increasing demand for engineering plastics and the need for sophisticated and meaningful impact test methods for characterizing these materials have forced the industry into developing new high-speed impact tests. These tests not only provide the basic information regarding the toughness of the polymeric materials but also provide other important data of interest, such as the load–deflection curve and the total energy absorption. The high-speed impact test overcomes the basic limitations of conventional impact testing methods as discussed previously. The rate of impact can be varied from 30 to 570,000 in. /min.

Abrasion Resistance Tests

The material's ability to resist abrasion is most often measured by its loss in weight when abraded with an abraser. The most widely accepted abraser in the industry is called the Taber abraser. A variety of wheels with varying degree of abrasiveness is available. The grade of ''calibrase'' wheel designated CS-17 with 1000-g load seems to produce satisfactory results with almost all plastics. For softer materials less abrasive wheels with smaller load on the wheels may be used. The test specimen is usually a 4-in.-diameter disk or a 4-in.2 plate having both surfaces substantially plane and parallel. A –1-in.-diameter hole is drilled in 2 the center. Specimens are conditioned employing standard conditioning practices prior to testing. To commence testing, the test specimen is placed on a revolving turntable. Suitable abrading wheels are placed on the specimen under certain set dead-weight loads. The turntable is started and an automatic counter records the number of revolutions. Most tests are carried out to at least 5000 revolutions. The specimens are weighed to the nearest milligram. The test results are reported as weight loss in mg/1000 cycles. The grade of abrasive wheel along with amount of load at which the test was carried out is always reported along with results.

Fatigue Resistance

The behavior of materials subjected to repeated cyclic loading in terms of flexing, stretching, compressing, or twisting is generally described as fatigue. Such repeated cyclic loading eventually constitutes a mechanical deterioration and progressive fracture that leads to complete failure.

Hardness Tests

Hardness is defined as the resistance of a material to deformation, particularly permanent deformation, indentation, or scratching. Hardness is purely a relative term and should not be confused with wear and abrasion resistance of plastic materials. Polystyrene, for example, has a high Rockwell hardness value but a poor abrasion resistance. Hardness test can differentiate relative hardness of different grades of a particular plastic. However, it is not valid to compare hardness of various types of plastics entirely on the basis of one type of test, since elastic recovery along with hardness is involved. The test is further complicated by a phenomenon such as creep. Many tests have been devised to measure hardness. Since plastic materials vary considerably with respect to hardness, one type of hardness test is not applicable to cover the entire range of hardness properties encountered. Two of the most commonly used hardness tests for plastics are the Rockwell hardness test and the Durometer hardness test. Rockwell hardness is used for relatively hard plastics such as acetals, nylons, acrylics, and polystyrene. For softer materials such as flexible polyvinyl chloride (PVC), thermoplastic rubbers, and polyethylene, Durometer hardness is often used.

Tests for Elevated Temperature Performance

Designers and material selectors of plastic products constantly face the challenge of selecting a suitable plastic for elevated temperature performance. The difficulty arises due to the varying natures and capabilities of various types and grades of plastics at elevated temperatures. Many factors are considered when selecting a plastic for a high-temperature application. The material must be able to support a design load under operating conditions without objectionable creep or distortion. The material must not degrade or lose necessary additives that will cause drastic reduction in the physical properties during the expected service life.

UNIT IV MATERIALS SELECTION CHARTS AND TESTING

Ashby material selection charts-Testing of Metallic Materials - Plastics Testing – Characterization and Identification of Plastics - Professional and Testing Organizations - Ceramics Testing - Nondestructive Inspection.

Testing of Metallic Materials

- **Metallic Material Testing** Standards focus on hardness, tensile, and fatigue **testing**, approaching the issues from multiple angles to provide a range of information. Together, standardized **testing** provides valuable information to determine the reliability of **metallic materials** and the products and structures using them.
- The American Society for Testing and Materials (ASTM) is one of the world's largest standards development organizations with over 34,000 members responsible for more than 10,000 standards.

- Tensile and compressive property testing
- creep and stress relaxation testing
- Hardness and impact testing
- Fracture toughness testing
- Fatigue testing
- Other mechanical testing
- Environmental considerations

Tensile and Compressive Property Testing

- These tests are typically performed using a universal mechanical testing instrument. A tensile test is a method for determining behavior of materials under axial tensile loading. A compression test is a method for determining the behavior of materials under a compressive load.

The Method of Compression Test Under High Pressure in a Cubic Press and The Strength of Granite | Standard Test Method for Tensile Properties of Polymer Matrix Composites Materials | Standard test Method for Tensile Strength of Advanced Ceramics | Standard Test Method for Compressive Properties of Rigid Plastics

Creep and stress relaxation testing

- A creep test, sometimes referred to as a stress-relaxation test, is used to determine the amount of deformation a material experiences over time while under a continuous tensile or compressive load at a constant temperature.
- Creep tests are fundamental for materials that are needed to withstand certain operation temperatures under load. For materials such as metals or alloys, their material properties change significantly at higher or lower temperatures. Creep tests are commonly performed on the following components and materials:
- Metal Working
- Springs
- Soldered Joints
- High-Temperature Materials

Hardness and impact testing

- A hardness test is typically performed by pressing a specifically dimensioned and loaded object (indenter) into the surface of the material you are testing. The hardness is determined by measuring the depth of indenter penetration or by measuring the size of the impression left by an indenter.

Fracture toughness testing

- Fracture toughness testing is a mechanical test method used to determine the energy needed to initiate and cause failure within a material. It can also be used in combination with fatigue testing, corrosion testing, and elevated temperatures to determine the useful life of the material under different conditions.

Fatigue testing

Fatigue testing is defined as the process of progressive localized permanent structural change occurring in a material subjected to conditions that produce fluctuating stresses and strains at some point or points and that may culminate in cracks or complete fracture after a sufficient number of fluctuations.

Destructive testing (DT)

- Bend test
- Impact test – Further categorized as Charpy test and Izod test
- Hardness test
- Tensile test
- Fatigue test
- Corrosion resistance test
- Wear test

The following are some of the major reasons for testing:

- 1. To prove design concepts
- 2. To provide a basis for reliability
- 3. Safety

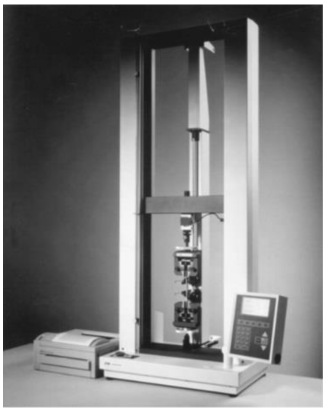
- 4. Protection against product liability suits
- 5. Quality control
- 6. To meet standards and specifications
- 7. To verify the manufacturing process
- 8. To evaluate competitors products
- 9. To establish a history for new materials

Mechanical properties

- In practical applications, plastics are subjected to a single, steady deformation without the presence of other adverse factors such as environment and temperature.
- Since the published values of the mechanical properties of plastics are generated from tests conducted in a laboratory under standard test conditions, the danger of selecting and specifying a material from these values is obvious.
- A thorough understanding of mechanical properties, tests employed to determine such properties, and the effect of adverse conditions on mechanical properties over a long period is extremely important.

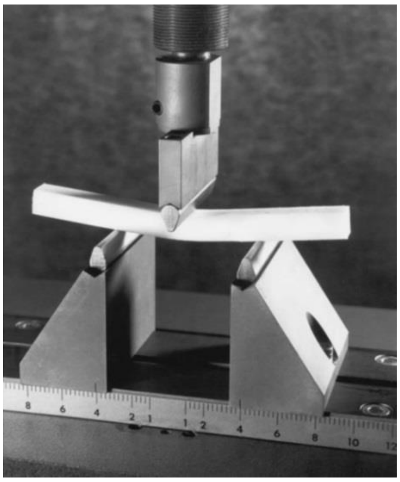
Tensile Tests (ASTM D638, ISO 527-1)

- Tensile elongation and tensile modulus measurements are among the most important indications of strength in a material and are the most widely specified properties of plastic materials.
- Tensile test, in a broad sense, is a measurement of the ability of a material to withstand forces that tend to pull it apart and to determine to what extent the material stretches before breaking



Flexural Properties (ASTM D790, ISO 178)

- The stress–strain behavior of polymers in flexure is of interest to a designer as well as a polymer manufacturer. Flexural strength is the ability of the material to withstand bending forces applied perpendicular to its longitudinal axis.
- The stresses induced due to the flexural load are a combination of compressive and tensile stresses.
- Many polymers do not break under flexure even after a large deflection that makes determination of the ultimate flexural strength impractical for many polymers.



Thermal properties

- Thermal properties of plastic materials are equally as important as mechanical properties. Unlike metals, plastics are extremely sensitive to changes in temperature.
- The molecular weight of the polymer affects the low temperature flexibility and low-temperature brittleness. Many other factors such as intermolecular bonding, cross-linking, and copolymerization all have a considerable effect on thermal properties.
- The thermal behavior of polymeric materials is rather complex. Therefore, in designing a plastic part or selecting a plastic material from the available thermal property data, one must thoroughly understand the short-term as well as the long-term effect of temperature on properties of that plastic material.

Tests for Elevated Temperature Performance

- Designers and material selectors of plastic products constantly face the challenge of selecting a suitable plastic for elevated temperature performance. The difficulty arises due to the varying natures and capabilities of various types and grades of plastics at elevated temperatures. Many factors are considered when selecting a plastic for a high-temperature application.

1. Short-term effects
  a. Heat deflection temperature
  b. Vicat softening temperature
  c. Torsion pendulum
2. Long-term effects
  a. Long-term heat resistance test
  b. Underwriters Laboratory (UL) temperature index
  c. Creep modulus/creep rupture tests

Brittleness Temperature (ASTM D746, ISO 974)

- Brittleness temperature is defined as the temperature at which plastics and elastomers exhibit brittle failure under impact conditions. Yet another way to define brittleness temperature is the temperature at which 50% of the specimens tested exhibit brittle failure under specified impact conditions

Electrical properties

- The unbeatable combination of characteristics such as ease of fabrication, low cost, light weight, and excellent insulation properties have made plastics one of the most desirable materials for electrical applications.
- Although the majority of applications involving plastics are insulation related, plastics can be made to conduct electricity by simply modifying the base material with proper additives such as carbon black.
- Plastics not only act as effective insulators but also provide mechanical support for field carrying conductors. For this very reason, the mechanical properties of plastic materials used as insulators become very important. Typical electrical applications of plastic material include plastic-coated wires, terminals, connectors, industrial and household plugs, switches, and printed circuit boards.
- The key electrical properties of interest are dielectric strength, **dielectric constant, dissipation factor, volume and surface resistivity, and arc resistance**

- **Dielectric Constant** is the ratio of the capacity of a condenser made with a particular dielectric to the capacity of the same condenser with air as the dielectric. For a plastic used to support and insulate components of an electrical network from each other and ground, generally it is desirable to have a low level of dielectric constant. For a material to function as the dielectric of a capacitor, on the other hand, it is desirable to have a high value of dielectric constant, so the capacitor may be physically as small as possible.

- **Dissipation Factor** is the ratio of the real power (in phase power) to the reactive power (power 90 deg out of phase). It is also defined as the ratio of conductance of a capacitor in which the material is the dielectric to its susceptance or the ratio of its parallel reactance to its parallel resistance. It is the tangent of the loss angle and the cotangent of the phase angle. Dissipation factor is a measure of the conversion of reactive power to real power, showing as heat.

- Electrodes are placed on or embedded in the surface of a test specimen. The following properties are calculated:

  Insulation resistance is the ratio of direct voltage applied to the electrodes to the total current between them; dependent upon both volume and surface resistance of the specimen. In materials used to insulate and support components of an electrical network, generally it is desirable to have insulation resistance as high as possible.

  Volume resistivity is the ratio of the potential gradient parallel to the current in the material to the current density. Surface resistivity is the ratio of the potential gradient parallel to the current along its surface to the current per unit width of the surface. Knowing the volume and surface resistivity of an insulating material makes it possible to design an insulator for a specific application.

Weathering properties

The increased outdoor use of plastics has created a need for a better understanding of the effect of the environment on plastic materials. The environmental factors have significant detrimental effects on appearance and properties. The severity of the damage depends largely on factors such as the nature of the environment, geographic location, type of polymeric material, and duration of exposure.

The major environmental factors that seriously affect plastics are:

- Solar radiations—ultraviolet (UV), infrared (IR), X-rays
- Microorganisms, bacteria, fungus, mold
- High humidity
- Ozone, oxygen
- Water: vapor, liquid, or solid
- Thermal energy
- Pollution: industrial chemicals

Characterization and Identification of Plastics

- Today there are countless numbers of processors consuming in excess of 100 million pounds of material every year. An increasing number of processors are looking into various techniques for characterizing the incoming plastic resin to guard against batch-to-batch variations. Such variation in the properties and the processability of the polymer have been very costly.

There are numerous ways of characterizing a polymer. Some are very basic and simple, others are more sophisticated and complex. The five most common and widely accepted tests are:

- Melt index (melt flowrate) test,
- Rheological tests
- Viscosity tests
- Gel permeation chromatography
- Thermal analysis [thermogravimetric analysis (TGA),
- Thermomechanical analysis(TMA)
- Differential scanning calorimetry (DSC)
- Spectroscopy

The melt index, also known as melt flow rate (MFR), test measures the rate of extrusion of a thermoplastic material through an orifice of specific length and diameter under prescribed conditions of temperature and pressure. This test is primarily used as a means of measuring the uniformity of the flowrate of the material. The reported melt index values help to distinguish between the different grades of a polymer