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Сборник текстов для самостоятельной аудиторной работы студентов машиностроительных специальностей «Технический перевод (английский язык)»

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Сборник текстов предназначен для обучения студентов машиностроительного факультета чтению и переводу профессиональной литературы на английском языке.

Сборник составлен в соответствии с требованиями учебной программы «Технический перевод (английский язык)» для студентов машиностроительных специальностей дневной, заочной полной, заочной сокращенной и вечерней форм получения образования.

Целью сборника является совершенствование навыков и умений чтения и перевода англоязычной литературы по указанным специальностям. Текстовый материал заимствован из зарубежных источников, его тематика определена программой подготовки специалистов технического профиля.

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Text 1. MECHANICAL ENGINEERING

Mechanical engineering is the branch of engineering concerned with the design, manufacture, installation, and operation of engines and machines and with manufacturing processes. It is particularly concerned with forces and motion.

The invention of the steam engine in the latter part of the 18th century, providing a key source of power for the Industrial Revolution, gave an enormous impetus to the development of machinery of all types. As a result, a new major classification of engineering dealing with tools and machines developed, receiving formal recognition in 1847 in the founding of the Institution of Mechanical Engineers in Birmingham, England.

Mechanical engineering has evolved from the practice based largely on trial and error to the application of the scientific method in research, design and production by the professional engineer. The demand for increased efficiency is continually raising the quality of work expected from a mechanical engineer and requiring a higher degree of education and training.

Four functions of the mechanical engineer, common to all branches of mechanical engineering, can be cited. The first is the understanding of and dealing with the bases of mechanical science. These include dynamics, concerning the relation between forces and motion, such as in vibration; automatic control; thermodynamics, dealing with the relations among the various forms of heat, energy, and power; fluid flow; heat transfer; lubrication; and properties of materials.

The second is the sequence of research, design, and development. This function attempts to bring about the changes necessary to meet present and future needs. Such work requires a clear understanding of mechanical science, an ability to analyze a complex system into its basic factors, and the originality to synthesize and invent.

The third is the production of products and power, which embraces planning, operation, and maintenance. The goal is to produce the maximum value with the minimum investment and cost while maintaining or enhancing longer term viability and reputation of the enterprise or the institution.

The fourth is the coordinating function of the mechanical engineer, including management, consulting, and, in some cases, marketing.

In these functions there is a long continuing trend toward the use of scientific instead of traditional or intuitive methods. Operations research, value engineering, and PABLA (problem analysis by logical approach) are typical titles of such rationalized approaches. Creativity, however, cannot be rationalized. The ability to take the important and unexpected step that opens up new solutions remains in mechanical engineering, as elsewhere, largely a personal and spontaneous characteristic.

Text 2. MATERIALS IN MECHANICAL ENGINEERING

Materials in mechanical engineering may be divided into four main classes:

1. Metals
2. Ceramics and glasses
3. Polymers and elastomers
4. Composites

Materials belonging to one of these classes exhibit comparable properties, processing routes, and most often applications as well. The criteria for the material selection are rather complex and depend on the intended application purpose. The main design criteria include strength, stiffness, fracture toughness, formability, joinability, corrosion resistance, coefficient of thermal expansion, cost, and recyclability.

Metallic materials are still the most widely used group of materials for structural applications in mechanical engineering; their order of importance is Fe, Al, Cu, Ni, and Ti.

Iron-based materials are the most widely used metallic materials, mainly because of their relatively inexpensive manufacturing and their enormous flexibility. Accordingly, the properties of Fe-based materials can be varied to a great extent, allowing precise adaptation to specific application requirements ranging from high-strength, high-temperature, and wear-resistant alloys for tools to soft or hard ferromagnetic alloys for applications in the electrical industries. Pure iron, however, is only of minor importance in structural applications since its mechanical properties are simply inadequate.

Alloying with carbon leads to the most important groups of constructional alloys, namely:

1. Steels with a carbon content of up to about 2.06% carbon
2. Cast iron, which practically contains 2.5 – 5% carbon. These Fe-C alloys exhibit outstanding properties, including widely variable mechanical properties: yield strengths, hot and cold rolling ability, weldability, chip-removing workability, high toughness, high wear resistance, high corrosion resistance, heat resistance, high-temperature resistance, high Young’s modulus, nearly 100% recyclability, and many more.

Text 3. BETTER METALS ARE VITAL TO TECHNOLOGICAL PROGRESS

Since the earliest days the preparation of metals for mechanical use was vital to the advance of civilization.

Gold, silver and copper were the first to be used by a primitive man, as they were found free in nature. Today we know more than sixty-five metals available in large enough quantities to be used in industry.

Metals are mostly solids at ordinary temperatures and possess comparatively high melting points with the exception of mercury. They are for the most part good conductors of heat and electricity, and silver is the best in this respect. They can be drawn into fine wires and hammered into thin sheets.

As to their chemical properties, metals vary widely in degree of their chemical activity: some are enormously active and others are inert. The Earth contains a large number of metals useful to man. Of all metals to be utilized in industry iron remains by far the most important. Modem industry needs considerable quantities of this metal either in the form of iron or steel.

To get the desirable characteristics in metals or to improve them the art to mix metals and other substances began to develop. The first alloys that were formed in this way were sometimes stronger, tougher, harder and more elastic than the metals of which they were composed. It is difficult to estimate nowadays how many alloys there exist in the modem world because their number increases daily.

To serve special uses modem metals and alloys must be lighter yet stronger, more corrosion-resistant, more suitable for automated fabrication yet less expensive than those available before.

Scientists are developing new processes and improving old ones in order to produce metals and alloys that will meet the present-day requirements. One of the most interesting purposes is, for instance, to make metals stronger, in other words, to strengthen them by reinforcing them with fibres.

Today transportation, communication, farming, construction and manufacturing depend on the availability of suitable metals and alloys.

Text 4. MATERIALS PROCESSING

Materials processing is the series of operations that transforms industrial materials from a raw-material state into finished parts or products. Industrial materials are defined as those used in the manufacture of “hard” goods, such as more or less durable machines and equipment produced for industry and consumers, as contrasted with disposable “soft” goods, such as chemicals, foodstuffs, pharmaceuticals, and apparel.

Materials processing by hand is as old as civilization; mechanization began with the Industrial Revolution of the 18th century, and in the early 19th century the basic machines for forming, shaping, and cutting were developed, principally in England. Since then, materials-processing methods, techniques, and machinery have grown in variety and number.

The cycle of manufacturing processes converting materials into parts and products starts immediately after the raw materials are either extracted from minerals or produced from basic chemicals or natural substances. Metallic raw materials are usually produced in two steps. First, the crude ore is processed to increase the concentration of the desired metal; this is called beneficiation. Typical beneficiation processes include crushing, roasting, magnetic separation, flotation, and leaching. Second, additional processes such as smelting and alloying are used to produce the metal that is to be fabricated into parts that are eventually assembled into a product.

In the case of ceramic materials, natural clay is mixed and blended with various silicates to produce the raw material. Plastic resins are produced by chemical methods in powder, pellet, putty, or liquid form. Synthetic rubber is also made by chemical techniques, being produced, as is natural rubber, in such forms as slabs, sheeting, crepe, and foam for fabricating into finished parts.

The processes used to convert raw materials into finished products perform one or both of two major functions: first, they form the material into the desired shape; second, they alter or improve the properties of the material.

Forming and shaping processes may be classified into two broad types – those performed on the material in a liquid state and those performed on the material in a solid or plastic condition. The processing of materials in liquid form is commonly known as casting when it involves metals, glass, and ceramics; it is called molding when applied to plastics and some other nonmetallic materials. Most casting and molding processes involve four major steps: (1) making an accurate pattern of the part, (2) making a mold from the pattern, (3) introducing the liquid into the mold, and (4) removing the hardened part from the mold. A finishing operation is sometimes needed.

Materials in their solid state are formed into desired shapes by the application of a force or pressure. The material to be processed can be in a relatively hard and stable condition and in such forms as bar, sheet, pellet, or powder, or it can be in a soft, plastic, or puttylike form. Solid materials can be shaped either hot or cold. Processing of metals in the solid state can be divided into two major stages: first, the raw material in the form of large ingots or billets is hot-worked, usually by rolling, forging, or extrusion, into smaller shapes and sizes; second, these shapes are processed into final parts and products by one or more smaller scale hot or cold forming processes.

After the material is formed, it is usually further altered. In materials processing, a “removal” process is one that eliminates portions of a piece or body of material to achieve a desired shape. Although removal processes are applied to most types of materials, they are most widely used on metallic materials. Material can be removed from a workpiece by either mechanical or nonmechanical means.

There are a number of metal-cutting processes. In almost all of them, machining involves the forcing of a cutting tool against the material to be shaped. The tool, which is harder than the material to be cut, removes the unwanted material in the form of chips. Thus, the elements of machining are a cutting device, a means for holding and positioning the workpiece, and usually a lubricant (or cutting oil). There are four basic noncutting removal processes: (1) in chemical milling the metal is removed by the etching reaction of chemical solutions on the metal; although usually applied to metals, it can also be used on plastics and glass, (2) electrochemical machining uses the principle of metal plating in reverse, as the workpiece, instead of being built up by the plating process, is processed in a controlled manner by the action of the electrical current, (3) electrodischarge machining and grinding erode or cut the metal by high-energy sparks or electrical discharges, (4) laser machining cuts metallic or refractory materials with an intense laser beam.

Another further alteration may be “joining,” the process of permanently, sometimes only temporarily, bonding or attaching materials to each other. The term includes welding, brazing, soldering, and adhesive and chemical bonding. In most joining processes, a bond between two pieces of material is produced by application of one or a combination of three kinds of energy: thermal, chemical, or mechanical. A bonding or filler material, the same as or different from the materials being joined, may or may not be used.

The properties of materials can be further altered by hot or cold treatments, by mechanical operations, and by exposure to some forms of radiation. The property modification is usually brought about by a change in the microscopic structure of the material. Both heat-treating, involving temperatures above room temperature, and cold-treating, involving temperatures below room temperature, are included in this category. Thermal treatment is a process in which the temperature of the material is raised or lowered to alter the properties of the original material. Most thermal-treating processes are based on time-temperature cycles that include three steps: heating, holding at temperature, and cooling. Although some thermal treatments are applicable to most families of materials, they are most widely used on metals.

Finally, “finishing” processes may be employed to modify the surfaces of materials in order to protect the material against deterioration by corrosion, oxidation, mechanical wear, or deformation; to provide special surface characteristics such as reflectivity, electrical conductivity or insulation, or bearing properties; or to give the material special decorative effects. There are two broad groups of finishing processes, those in which a coating, usually of a different material, is applied to the surface and those in which the surface of the material is changed by chemical action, heat, or mechanical force. The first group includes metallic coating, such as electroplating; organic finishing, such as painting; and porcelain enameling.

Text 5. MATERIALS TESTING (I)

Materials testing is the measurement of the characteristics and behaviour of such substances as metals, ceramics, or plastics under various conditions. The data thus obtained can be used in specifying the suitability of materials for various applications–e.g., building or aircraft construction, machinery, or packaging. A full- or small-scale model of a proposed machine or structure may be tested. Alternatively, investigators may construct mathematical models that utilize known material characteristics and behaviour to predict capabilities of the structure.

Materials testing breaks down into five major categories: mechanical testing; testing for thermal properties; testing for electrical properties; testing for resistance to corrosion, radiation, and biological deterioration; and nondestructive testing. Standard test methods have been established by such national and international bodies as the International Organization for Standardization (ISO), with headquarters in Geneva, and the American Society for Testing and Materials (ASTM), Philadelphia.

Mechanical testing

Structures and machines, or their components, fail because of fracture or excessive deformation. In attempting to prevent such failure, the designer estimates how much stress (load per unit area) can be anticipated, and specifies materials that can withstand expected stresses. A stress analysis, accomplished either experimentally or by means of a mathematical model, indicates expected areas of high stress in a machine or structure. Mechanical property tests, carried out experimentally, indicate which materials may safely be employed.

Static tension and compression tests

When subjected to tension (pulling apart), a material elongates and eventually breaks. A simple static tension test determines the breaking point of the material and its elongation, designated as strain (change in length per unit length). If a 100-millimetre steel bar elongates 1 millimetre under a given load, for example, strain is (101–100)/100 = 1/100 = 1 percent.

A static tension test requires (1) a test piece, usually cylindrical, or with a middle section of smaller diameter than the ends; (2) a test machine that applies, measures, and records various loads; and (3) an appropriate set of grips to grasp the test piece. In the static tension test, the test machine uniformly stretches a small part (the test section) of the test piece. The length of the test section (called the gauge length) is measured at different loads with a device called an extensometer; these measurements are used to compute strain.

Conventional testing machines are of the constant load, constant load-rate, and constant displacement-rate types. Constant load types employ weights directly both to apply load and to measure it. Constant load-rate test machines employ separate load and measurement units; loads are generally applied by means of a hydraulic ram into which oil is pumped at a constant rate. Constant displacement-rate testing machines are generally driven by gear-screws.

Test machine grips are designed to transfer load smoothly into the test piece without producing local stress concentrations. The ends of the test piece are often slightly enlarged so that if slight concentrations of stress are present these will be directed to the gauge section, and failures will occur only where measurements are being taken. Clamps, pins, threading, or bonding are employed to hold the test piece. Eccentric (nonuniform) loading causes bending of the sample in addition to tension, which means that stress in the sample will not be uniform. To avoid this, most gripping devices incorporate one or two swivel joints in the linkage that carries the load to the test piece. Air bearings help to correct horizontal misalignment, which can be troublesome with such brittle materials as ceramics.

Static compression tests determine a material's response to crushing, or support-type loading (such as in the beams of a house). Testing machines and extensometers for compression tests resemble those used for tension tests. Specimens are generally simpler, however, because gripping is not usually a problem. Furthermore, specimens may have a constant cross-sectional area throughout their full length. The gauge length of a sample in a compression test is its full length. A serious problem in compression testing is the possibility that the sample or load chain may buckle (form bulges or bend) prior to material failure. To prevent this, specimens are kept short and stubby.

Text 6. TENSION TESTS

Concepts such as elastic properties, fracture toughness, fatigue, plastic flow, creep, etc. belong to mechanical properties. Engineers are primarily concerned with the strength of the material, a measure of the external force required to overcome internal forces of attraction between the fundamental building blocks of the material. In most engineering applications, only very small deformation in a component under a given loading condition is tolerable, and strength governs the choice of an acceptable material. For a production engineer, the ease of inducing permanent deformation (malleability and ductility) is the critical mechanical property for the material under consideration.

In its simplest form, the basic description of a material is obtained by a tension test. The test specimen may be plate, sheet, round, wires or pipes and must conform to certain guidelines in terms of sample dimensions. Different gripping mechanisms, such as wedge grips, threads, pins or shoulders, may be considered during specimen design. It is important to ensure that the reduced section of the sample is free of defects, both microstructural and machining, and that the specimen is representative of the bulk material.

A typical tensile testing machine comprises a stiff frame, a specimen gripping device, a force measuring device (or load cells), an elongation measuring device (extensometer), and a data-recording device (X–Y plotter or computer). During a tension test certain key material properties can be evaluated as described below:

- *Young's modulus*: the ratio of axial stress to corresponding strain in the elastic region. In some materials (polymers) the elastic region of the curve is not perfectly linear and a chord method is applied to estimate elastic modulus
- *Yield strength*: the stress at which it is considered that plastic elongation of the material has commenced.

- *Ultimate tensile strength*: the maximum stress recorded during the tensile testing. After this stress level is reached, the specimen starts to show localized deformation called necking. The true stress continues to rise until fracture.
- *Ductility/elongation*: the ability of a material to deform before fracture under tensile load.
- *Resilience and toughness*: the ability of a material to absorb energy when deformed elastically/plastically. It is defined as the area under the stress-strain curve in the elastic and plastic region, respectively.

Text 7. MATERIALS TESTING (II)

Static shear and bending tests

Inplane shear tests indicate the deformation response of a material to forces applied tangentially. These tests are applied primarily to thin sheet materials, either metals or composites, such as fibreglass reinforced plastics.

A homogeneous material such as untreated steel casting reacts in a different way under stress than does a grained material such as wood or an adhesively bonded joint. These anisotropic materials are said to have preferential planes of weakness; they resist stress better in some planes than in others, and consequently must undergo a different type of shear test.

Shear strength of rivets and other fasteners also can be measured. Though the state of stress of such items is generally quite complicated, a simple shear test, providing only limited information, is adequate for most purposes.

Tensile testing is difficult to perform directly upon certain brittle materials such as glass and ceramics. In such cases, a measure of the tensile strength of the material may be obtained by performing a bend test, in which tensile (stretching) stresses develop on one side of the bent member and corresponding compressive stresses develop on the opposite side. If the material is substantially stronger in compression than tension, failure initiates on the tensile side of the member and, hence, provides the required information on the material tensile strength. Because it is necessary to know the exact magnitude of the tensile stress at failure in order to establish the strength of the material, however, the bending test method is applicable to only a very restricted class of materials and conditions.

Measures of ductility

Ductility is the capacity of a material to deform permanently in response to stress. Most common steels, for example, are quite ductile and hence can accommodate local stress concentrations. Brittle materials, such as glass, cannot accommodate concentrations of stress because they lack ductility; they, therefore, fracture rather easily.

When a material specimen is stressed, it deforms elastically at first; thereafter, deformation becomes permanent. A cylinder of steel, for example, may “neck” (assume an hourglass shape) in response to stress. If the material is ductile, this local deformation is permanent, and the test piece does not assume its former shape if the stress is removed. With sufficiently high stress, fracture occurs.

Ductility can be expressed as strain, reduction in area, or toughness. Strain, or change in length per unit length, was explained earlier. Reduction in area (change in area per unit area) may be measured, for example, in the test section of a steel bar that necks when stressed. Toughness measures the amount of energy required to deform a piece of material permanently. Toughness is a desirable material property in that it permits a component to deform plastically, rather than crack and perhaps fracture.

Hardness testing

Based on the idea that a material’s response to a load placed at one small point is related to its ability to deform permanently (yield), the hardness test is performed by pressing a hardened steel ball (Brinell test) or a steel or diamond cone (Rockwell test) into the surface of the test piece. Most hardness tests are performed on commercial machines that register arbitrary values in inverse relation to the depth of penetration of the ball or cone. Similar indentation tests are performed on wood. Hardness tests of materials such as rubber or plastic do not have the same connotation as those performed on metals. Penetration is measured, of course, but deformation caused by testing such materials may be entirely temporary.

Some hardness tests, particularly those designed to provide a measure of wear or abrasion, are performed dynamically with a weight of given magnitude that falls from a prescribed height. Sometimes a hammer is used, falling vertically on the test piece or in a pendulum motion.

Impact test

Many materials, sensitive to the presence of flaws, cracks, and notches, fail suddenly under impact. The most common impact tests (Charpy and Izod) employ a swinging pendulum to strike a notched bar; heights before and after impact are used to compute the energy required to fracture the bar and, consequently, the bar’s impact strength. In the Charpy test, the test piece is held horizontally between two vertical bars, much like the lintel over a door. In the Izod test, the specimen stands vertically. The shape and size of the specimen, the mode of support, notch shape and geometry, and velocities at impact are all varied to produce specific test conditions. Nonmetals such as wood may be tested as supported beams, similar to the Charpy test. In nonmetal tests, however, the striking hammer falls vertically in a guide column, and the test is repeated from increasing heights until failure occurs.

Some materials vary in impact strength at different temperatures, becoming very brittle when cold. Tests have shown that the decrease in material strength and elasticity is often quite abrupt at a certain temperature, which is called the transition temperature for that material. Designers always specify a material that possesses a transition temperature well below the range of heat and cold to which the structure or machine is exposed. Thus, even a building in the tropics, which will doubtless never be exposed to freezing weather, employs materials with transition temperatures slightly below freezing.

Text 8. HARDENESS TESTS

In general, the hardness of a material refers to its resistance to plastic deformation. However, it is an easily measurable quantity and frequently employed in quality inspection. A standard hardness test procedure involves slowly applying an indentation to the surface of the material and measuring the relevant dimensions of the depression. Depending on the shape of the indenter and method of calculation, the following hardness tests are commonly employed.

Brinell hardness: An indenter of hardened steel or tungsten carbide ball with diameter D (1 – 10 mm) is forced into the surface of a test piece and the diameter of the indentation, d, left in the surface after removal of the test force F (100 – 3000 kgf) is measured. Brinell hardness is then obtained by dividing the test force by the curved surface area of the indentation.

The Vickers hardness test uses a square-based diamond pyramid as the indenter with the included angle between the opposite faces being 136°. Due to the shape of the indenter, the Vickers hardness number is also frequently referred to as the diamond pyramid hardness number and is defined as the load divided by the surface areas of indentation.

Rockwell hardness is the most widely used hardness test in the industry due to its speed, freedom from personal error, and ability to distinguish small hardness differences in hardened steels. This test utilizes the depth of indentation, under constant load, as a measure of hardness. Major loads of 60, 100, and 150 kg are used.

Hardness testing is a very useful and reproducible method to measure and compare the mechanical strength of a material provided that sufficient precautions are taken during testing. Hardness tests are carried out on the surface of the specimen and therefore it is very important that the surface is flat, free of defects, and representative of the bulk material.

Additionally there are empirical correlations available to estimate tensile strength from hardness value and to convert a result of one type of hardness test into those of a different type. However, it is important to verify these correlations for the specific class of material under consideration, though some standard conversion tables for commercial carbon and alloy steels and aluminum alloys are available. Micro- and nanohardness testing procedures are available for measuring hardness over smaller areas, while hot hardness testers are used to measure hardness at elevated temperatures.

Text 9. MATERIALS TESTING (III)

Fracture toughness tests

The stringent materials-reliability requirements of the space programs undertaken since the early 1960s brought about substantial changes in design philosophy. Designers asked materials engineers to devise quantitative tests capable of measuring the propensity of a material to propagate a crack. Conventional methods of stress analysis and materials-property tests were retained, but interpretation of results changed. The criterion for failure became sudden propagation of a crack rather than fracture. Tests have shown that cracks occur by opening, when two pieces of material part in vertical plane, one piece going up, the other down; by edge sliding, where the material splits in horizontal plane, one piece moving left, the other right; and by tearing, where the material splits with one piece moving diagonally upward to the left, the other moving diagonally downward to the right.

Creep test

Creep is the slow change in the dimensions of a material due to prolonged stress; most common metals exhibit creep behaviour. In the creep test, loads below those necessary to cause instantaneous fracture are applied to the material, and the deformation over a period of time (creep strain) under constant load is measured, usually with an extensometer or strain gauge. In the same test, time to failure is also measured against level of stress; the resulting curve is called stress rupture or creep rupture. Once creep strain versus time is plotted, a variety of mathematical techniques is available for extrapolating creep behaviour of materials beyond the test times so that designers can utilize thousand-hour test data, for example, to predict ten-thousand-hour behaviour.

A material that yields continually under stress and then returns to its original shape when the stress is released is said to be viscoelastic; this type of response is measured by the stress-relaxation test. A prescribed displacement or strain is induced in the specimen and the load drop-off as a function of time is measured. Various viscoelastic theories are available that permit the translation of stress-relaxation test data into predictions about the creep behaviour of the material.

Fatigue

Materials that survive a single application of stress frequently fail when stressed repeatedly. This phenomenon, known as fatigue, is measured by mechanical tests that involve repeated application of different stresses varying in a regular cycle from maximum to minimum value. Most fatigue-testing machines employ a rotating eccentric weight to produce this cyclically varying load. A material is generally considered to suffer from low-cycle fatigue if it fails in 10,000 cycles or less.

The stresses acting upon a material in the real world are usually random in nature rather than cyclic. Consequently, several cumulative fatigue-damage theories have been developed to enable investigators to extrapolate from cyclic test data a prediction of material behaviour under random stresses. Because these theories are not applicable to most materials, a relatively new technique, which involves mechanical application of random fatigue stresses, statistically matched to real-life conditions, is now employed in most materials test laboratories.

Material fatigue involves a number of phenomena, among which are atomic slip (in which the upper plane of a metal crystal moves or slips in relation to the lower plane, in response to a shearing stress), crack initiation, and crack propagation. Thus, a fatigue test may measure the number of cycles required to initiate a crack, as well as the number of cycles to failure.

A cautious designer always bears the statistical nature of fatigue in mind, for the lives of material specimens tested at a common stress level always range above and below some average value. Statistical theory tells the designer how many samples of a material must be tested in order to provide adequate data; it is not uncommon to test several hundred specimens before drawing firm conclusions.

Text 10. COMPRESSIVE TESTS

Resilience and toughness are the ability of a material to absorb energy when deformed elastically or plastically.

To differentiate between elastic and plastic regions of the stress–strain curve, it is appropriate to look at the origin of strain. During elastic deformation, it is the stretching of interatomic bonds that leads to observed macroscopic strain. On the other hand, the fundamental mechanism of plastic deformation is distortion and reformation of atomic bonds. During this process the total volume of the material, however, is conserved.

During plastic deformation, dislocations within the material become operative and slip due to shear stresses acting on them. For an ideal plastic deformation, the stress required for dislocations to continue slipping is a material constant and does not depend on prior strain. However, in real materials, as deformation proceeds, more dislocations are generated within the material and additional driving force is required for slip to proceed. This phenomenon is called strain hardening and is exploited during cold working to raise yield strength of the resultant material. Strain hardening may be overcome by hot working since dislocations start to become annihilated at higher temperatures. Furthermore, mechanical properties such as elastic modulus and tensile strength are strongly temperature dependent and decrease with increasing temperature. Ductility though is found to increase with increasing temperature.

Mechanical properties such as yield strength, yield point, elastic modulus, and stress–strain curve may also be determined from compressive tests. This test procedure offers the possibility to test brittle and nonductile metals that fracture at low strains and avoids the complications arising out of necking. Solid round/rectangular cylindrical samples may be used. Surface flatness and parallelism are important considerations during sample machining. After marking the gauge length and measuring the specimen dimensions, the specimen is placed in the test fixture and aligned to ensure concentric loading. The specimen is then subjected to an increasing axial compressive load; both load and strain may be monitored either continuously or in finite increments. Compression testing is usually easier to conduct than tension test and is used more commonly at elevated temperature in plasticity or formability studies since it simulates compressive stress as is expected under rolling, forging or extrusion operation.

Text 11. MEASUREMENT OF THERMAL PROPERTIES

Thermal conductivity

Heat, which passes through a solid body by physical transfer of free electrons and by vibration of atoms and molecules, stops flowing when the temperature is equal at all points in the solid body and equals the temperature in the surrounding environment. In the process of attaining equilibrium, there is a gross heat flow through the body, which depends upon the temperature difference between different points in the body and upon the magnitudes of the temperatures involved. Thermal conductivity is experimentally measured by determining temperatures as a function of time along the length of a bar or across the surface of flat plates while simultaneously controlling the external input and output of heat from the surfaces of the bar or the edges of the plate.

Specific heat

Specific heat of solid materials (defined as heat absorbed per unit mass per degree change in temperature) is generally measured by the drop method, which involves adding a known mass of the material at a known elevated temperature to a known mass of water at a known low temperature and determining the equilibrium temperature of the mixture that results. Specific heat is then computed by measuring the heat absorbed by the water and container, which is equivalent to the heat given up by the hot material.

Thermal expansion

Expansion due to heat is usually measured in linear fashion as the change in a unit length of a material caused by a one-degree change in temperature. Because many materials expand less than a micrometre with a one-degree increase in temperature, measurements are made by means of microscopes.

Text 12. MEASUREMENT OF ELECTRICAL PROPERTIES

An understanding of electrical properties and testing methods requires a brief explanation of the free electron gas theory of electrical conduction. This simple theory is convenient for purposes of exposition, even though solid-state physics has advanced beyond it.

Electrical conductivity involves a flow or current of free electrons through a solid body. Some materials, such as metals, are good conductors of electricity; these possess free or valence electrons that do not remain permanently associated with the atoms of a solid but instead form an electron “cloud” or gas around the peripheries of the atoms and are free to move through the solid at a rapid rate. In other materials, such as plastics, the valence electrons are far more restricted in their movements and do not form a free-electron cloud. Such materials act as insulators against the flow of electricity.

The effect of heat upon the electrical conductivity of a material varies for good and poor conductors. In good conductors, thermal agitation interferes with the flow of electrons, decreasing conductivity, while, as insulators increase in temperature, the number of free electrons grows, and conductivity increases. Normally, good and poor conductors are enormously far apart in basic conductivity, and relatively small changes in temperature do not change these properties significantly.

In certain materials, however, such as silicon, germanium, and carbon, heat produces a large increase in the number of free electrons; such materials are called semiconductors. Acting as insulators at absolute zero, semiconductors possess significant conductivity at room and elevated temperatures. Impurities also can change the conductivity of a semiconductor dramatically by providing more free electrons. Heat-caused conductivity is called intrinsic, while that attributable to extra electrons from impurity atoms is called extrinsic.

Conductivity of a material is generally measured by passing a known current at constant voltage through a known volume of the material and determining resistance in ohms. The total conductivity is then calculated by simply taking the reciprocal of the total resistivity.

Text 13. TESTING FOR CORROSION, RADIATION, AND BIOLOGICAL DETERIORATION

Testing for breakdown or deterioration of materials under exposure to a particular type of environment has greatly increased in recent years. Mechanical, thermal, or electrical property tests often are performed on a material before, during, and after its exposure to some controlled environment. Property changes are then recorded as a function of exposure time. Environments may include heat, moisture, chemicals, radiation, electricity, biological substances, or some combination thereof. Thus, the tensile strength of a material may fall after exposure to heat, moisture, or salt spray or may be increased by radiation or electrical current. Strength of organic materials may be lessened by certain classes of fungus and mold.

Corrosion

Corrosion testing is generally performed to evaluate materials for a specific environment or to evaluate means for protecting a material from environmental attack. A chemical reaction, corrosion involves removal of metallic electrons from metals and formation of more stable compounds such as iron oxide (rust), in which the free electrons are usually less numerous. In nature, only rather chemically inactive metals such as gold and platinum are found in pure or nearly pure form; most others are mined as ores that must be refined to obtain the metal. Corrosion simply reverses the refining process, returning the metal to its natural state. Corrosion compounds form on the surface of a solid material. If the compounds are hard and impenetrable, and if they adhere well to the parent material, the progress of corrosion is arrested. If the compound is loose and porous, corrosion may proceed swiftly and continuously.

If two different metals are placed together in a solution (electrolyte), one metal will give up ions to the solution more readily than the other; this difference in behaviour will bring about a difference in electrical voltage between the two metals. If the metals are in electrical contact with each other, electricity will flow between them and they will corrode; this is the principle of the galvanic cell or battery. Though useful in a battery, this reaction causes problems in a structure; for example, steel bolts in an aluminum framework may, in the presence of rain or fog, form multiple galvanic cells at the point of contact between the two metals, corroding the aluminum.

Corrosion testing is performed to ascertain the performance of metals and other materials in the presence of various electrolytes. Testing may involve total immersion, as would be encountered in seawater, or exposure to salt fog, as is encountered in chemical-industry processing operations or near the oceans where seawater may occur in fogs. Materials are generally immersed in a 5 percent or 20 percent solution of sodium chloride or calcium chloride in water, or the solution may be sprayed into a chamber where the specimens are freely suspended. In suspension testing, care is taken to prevent condensate from dripping from one specimen onto another. The specimens are exposed to the hostile environment for some time, then removed and examined for visible evidence of corrosion. In many cases, mechanical tests after corrosion exposure are performed quantitatively to ascertain mechanical degradation of the material. In other tests, materials are stressed while in the corrosive environment. Still other test procedures have been developed to measure corrosion of metals by flue or stack gases.

Radiation

Materials may be tested for their reactions to such electromagnetic radiation as X rays, gamma rays, and radio-frequency waves, or atomic radiation, which might include the neutrons emitted by uranium or some other radioactive substance. Most affected by these forms of radiation are polymers, such organic compounds as plastic or synthetic rubber, with long, repeated chains of similar chemical units.

Radiation tests are performed by exposing the materials to a known source of radiation for a specific period of time. Test materials may be exposed by robot control to nuclear fuels in a remote chamber, then tested by conventional methods to ascertain changes in their properties as a function of exposure time. In the field, paint samples may be exposed to electromagnetic radiation (such as sunlight) for prolonged periods and then checked for fading or cracking.

Exposure to radiation is usually, but not always, detrimental to strength; for example, exposure of polyethylene plastic for short periods of time increases its tensile strength. Longer exposures, however, decrease tensile strength. Tensile and yield strength of a type of carbon-silicon steel increase with exposure to neutron radiation, although elongation, reduction in area, and probably fracture toughness apparently decrease with exposure. Certain wood/polymeric composite materials are even prepared by a process that employs radiation. The wood is first impregnated with liquid organic resin by high pressure. Next, the wood and resin combination is exposed to radiation, causing a chemical change in the form of the resin that produces a strengthened material.

Biological deterioration

In recent years there has been considerable activity in the new field of formulating tests to ascertain the resistance of organic materials to fungi, bacteria, and algae. Paints, wrappers, and coatings of buried pipelines, structures, and storage tanks are typical materials exposed to biological deterioration.

When biological composition of the soil in a given area is unknown, colonies or cultures of its various fungi, bacteria, or algae are isolated and incubated by standard laboratory techniques. These are then used to test materials for biological degradation or to test the effectiveness of a fungicide or bactericide. In testing for algae resistance, for example, treated and untreated strips of vinyl film are immersed in growing tanks along with seed cultures of algae plants. Within three days, luxuriant algae growths appear on untreated samples.

Text 14. NONDESTRUCTIVE TESTING

The tensile-strength test is inherently destructive; in the process of gathering data, the sample is destroyed. Though this is acceptable when a plentiful supply of the material exists, nondestructive tests are desirable for materials that are costly or difficult to fabricate or that have been formed into finished or semifinished products.

Liquids

One common nondestructive technique, used to locate surface cracks and flaws in metals, employs a penetrating liquid, either brightly dyed or fluorescent. After being smeared on the surface of the material and allowed to soak into any tiny cracks, the liquid is wiped off, leaving readily visible cracks and flaws. An analogous technique, applicable to nonmetals, employs an electrically charged liquid smeared on the material surface. After excess liquid is removed, a dry powder of opposite charge is sprayed on the material and attracted to the cracks. Neither of these methods, however, can detect internal flaws.

Radiation

Internal as well as external flaws can be detected by X-ray or gamma-ray techniques in which the radiation passes through the material and impinges on a suitable photographic film. Under some circumstances, it is possible to focus the X rays to a particular plane within the material, permitting a three-dimensional description of the flaw geometry as well as its location.

Sound

Ultrasonic inspection of parts involves transmission of sound waves above human hearing range through the material. In the reflection technique, a sound wave is transmitted from one side of the sample, reflected off the far side, and returned to a receiver located at the starting point. Upon impinging on a flaw or crack in the material, the signal is reflected and its traveling time altered. The actual delay becomes a measure of the flaw’s location; a map of the material can be generated to illustrate the location and geometry of the flaws. In the through-transmission method, the transmitter and receiver are located on opposite sides of the material; interruptions in the passage of sound waves are used to locate and measure flaws. Usually a water medium is employed in which transmitter, sample, and receiver are immersed.

Magnetism

As the magnetic characteristics of a material are strongly influenced by its overall structure, magnetic techniques can be used to characterize the location and relative size of voids and cracks. For magnetic testing, an apparatus is used that contains a large coil of wire through which flows a steady alternating current (primary coil). Nested inside this primary coil is a shorter coil (the secondary coil), to which is attached an electrical measuring device. The steady current in the primary coil causes current to flow in the secondary coil through the process of induction. If an iron bar is inserted into the secondary coil, sharp changes in the secondary current can indicate defects in the bar. This method only detects differences between zones along the length of a bar and cannot detect long or continuous defects very readily. An analogous technique, employing eddy currents induced by a primary coil, also can be used to detect flaws and cracks. A steady current is induced in the test material. Flaws that lie across the path of the current alter resistance of the test material; this change may be measured by suitable equipment.

Text 15. DEVELOPMENT OF MACHINES

The high standard of living in the developed countries owes much to mechanical engineering. The mechanical engineer invents machines to produce goods and develops machine tools of increasing accuracy and complexity to build the machines.

The principal lines of development of machinery have been an increase in the speed of operation to obtain high rates of production, improvement in accuracy to obtain quality and economy in the product, and minimization of operating costs. These three requirements have led to the evolution of complex control systems.

The most successful production machinery is the machine integrating the mechanical design iwith the control system. A modern transfer (conveyor) line for the manufacture of automobile engines is a good example of the mechanization of a complex series of manufacturing processes. Developments are in hand to automate production machinery further, using computers to store and process the vast amount of data required for manufacturing a variety of components with a small number of versatile machine tools.

The steam engine provided the first practical means of generating power from heat to augment the old sources of power from muscle, wind, and water. One of the first challenges to the new profession of mechanical engineering was to increase thermal efficiencies and power; this was done principally by the development of the steam turbine and associated large steam boilers. The 20th century witnessed a continued rapid growth in the power output of turbines for driving electric generators, together with a steady increase in thermal efficiency and reduction in capital cost per kilowatt of large power stations. Finally, mechanical engineers acquired the resource of nuclear energy, whose application demanded an exceptional standard of reliability and safety involving the solution of entirely new problems.

The mechanical engineer is also responsible for the much smaller internal combustion engines, both reciprocating (gasoline and diesel) and rotary (gas-turbine and Wankel) engines, with their widespread transport applications. In the transportation field generally, in air and space as well as on land and sea, the mechanical engineer has created the equipment and the power plant, collaborating increasingly with the electrical engineer, especially in the development of suitable control systems.

The skills applied to war by the mechanical engineer are similar to those required in civilian applications, though the purpose is to enhance destructive power rather than to raise creative efficiency. The demands of war have channeled huge resources into technical fields, however, and led to developments that have profound benefits in peace. Jet aircraft and nuclear reactors are notable examples.

The earliest efforts of mechanical engineers were aimed at controlling the human environment by draining and irrigating land and by ventilating mines.

Refrigeration and air conditioning are examples of the use of modern mechanical devices to control the environment.

Many of the products of mechanical engineering, together with technological developments in other fields, give rise to noise, the pollution of water and air, and the dereliction of land and scenery. The rate of production, both of goods and power, is rising so rapidly that regeneration by natural forces can no longer keep pace. A rapidly growing field for mechanical engineers and others is environmental control, comprising the development of 1) machines and processes that will produce fewer pollutants and 2) new equipment and techniques that can reduce or remove the pollution already generated.

Text 16. MACHINE TOOLS – A MEASURE OF MAN'S PROGRESS

The variety and combinations of machine tools today are unlimited. Some of them are very small and can be mounted on a work-bench but others are so large that we have to construct special buildings to house them.

There are some basic operations at any workshop. They are turning, drilling, threading, etc. The main machine tool of such a workshop is the multipurpose lathe. What is a lathe? It is a power-driven machine with special tools which can cut or form metal parts. The metal that cuts another metal must be very hard and so tools should be made of very hard steel alloys. The tool itself is very small in comparison with the mechanism that is to direct it.

Technological progress improves accuracy of machine tools. Today's equipment can produce parts with very high accuracy. One can find a number of machine tools that can measure and inspect their production themselves that is machine tools that handle the parts mechanically and automatically. Such machines can hold the parts which are to be measured and are able to indicate precise measurements themselves. A great many of such “clever” machines can be found today in our industry.

Since machine tools become faster and more complex, automatic measurements and inspection ought to be of greater importance. Automation is one of the main factors of engineering progress.

Flexible production lines form the basis for automated workshops. The main principle of such a flexible line is the fact that it can be switched over from one product to another, which has a similar structure but a different outline, almost instantaneously. It is equally efficient in conditions of both mass and small-batch production and will serve to increase the productivity.

Text 17. DEVELOPMENT OF ROBOTICS

Robotics is based on two related technologies: numerical control and teleoperators. Numerical control (NC) is a method of controlling machine tool axes by means of numbers that have been coded on punched paper tape or other media. It was developed during the late 1940s and early 1950s. The first numerical control machine tool was demonstrated in 1952 in the United States at the Massachusetts Institute of Technology (MIT). Subsequent research at MIT led to the development of the APT (Automatically Programmed Tools) language for programming machine tools.

A teleoperator is a mechanical manipulator that is controlled by a human from a remote location. Initial work on the design of teleoperators can be traced to the handling of radioactive materials in the early 1940s. In a typical implementation, a human moves a mechanical arm and hand at one location, and these motions are duplicated by the manipulator at another location.

Industrial robotics can be considered a combination of numerical-control and teleoperator technologies. Numerical control provides the concept of a programmable industrial machine, and teleoperator technology contributes the notion of a mechanical arm to perform useful work. The first industrial robot was installed in 1961 to unload parts from a die-casting operation. Its development was due largely to the efforts of the Americans George C. Devol, an inventor, and Joseph F. Engelberger, a businessman. Devol originated the design for a programmable manipulator, the U.S. patent for which was issued in 1961. Engelberger teamed with Devol to promote the use of robots in industry and to establish the first corporation in robotics–Unimation, Inc.

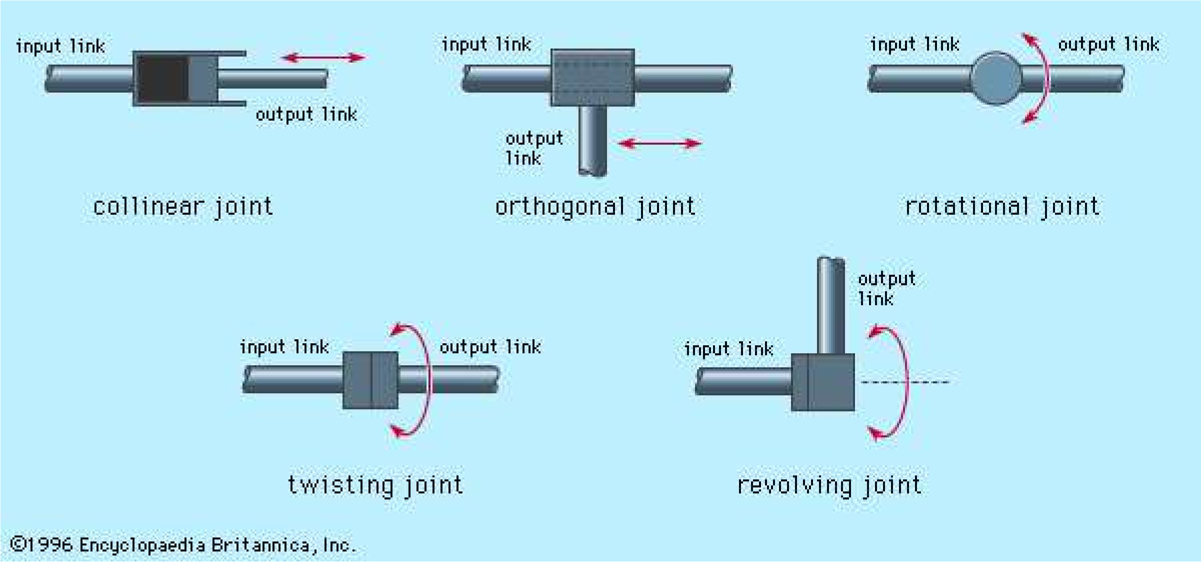
The robot manipulator

The most widely accepted definition of an industrial robot is one developed by the Robotic Industries Association:

An industrial robot is a reprogrammable, multifunctional manipulator designed to move materials, parts, tools, or specialized devices through variable programmed motions for the performance of a variety of tasks.

The technology of robotics is concerned with the design of the mechanical manipulator and the computer systems used to control it. It is also concerned with the industrial applications of robots, which are described below.

The mechanical manipulator of an industrial robot is made up of a sequence of link and joint combinations. The links are the rigid members connecting the joints. The joints (also called axes) are the movable components of the robot that cause relative motion between adjacent links. As shown in the Figure, there are five principal types of mechanical joints used to construct the manipulator. Two of the joints are linear, in which the relative motion between adjacent links is translational, and three are rotary types, in which the relative motion involves rotation between links.



Types of mechanical joints used in robot manipulators

The manipulator can be divided into two sections: (1) an arm-and-body, which usually consists of three joints connected by large links, and (2) a wrist, consisting of two or three compact joints. A gripper attached to the wrist grasps a work part or a tool (e.g., a spot-welding gun) to perform a process. The two manipulator sections have different functions: the arm-and-body is used to move and position parts or tools in the robot's work space, while the wrist is used to orient the parts or tools at the work location. The arm-and-body section of most commercial robots is based on one of four configurations. Each of the anatomies, as they are sometimes called, provides a different work envelope (i.e., the space that can be reached by the robot's arm) and is suited to different types of applications.

Robot programming

The computer system that controls the manipulator must be programmed to teach the robot the particular motion sequence and other actions that must be performed in order to accomplish its task. There are several ways that industrial robots are programmed. One method is called lead-through programming. This requires the manipulator to be driven through the various motions needed to perform a given task, recording the motions into the robot's computer memory. This can be done either by physically moving the manipulator through the motion sequence or by using a control box to drive the manipulator through the sequence.

A second method of programming involves the use of a programming language very much like a computer programming language. However, in addition to many of the capabilities of a computer programming language (i.e., data processing, computations, communicating with other computer devices, and decision making), the robot language also includes statements specifically designed for robot control. These capabilities include (1) motion control and (2) input/output. Motion-control commands are used to direct the robot to move its manipulator to some defined position in space. For example, the statement "move P1" might be used to direct the robot to a point in space called P1. Input/output commands are employed to control the receipt of signals from sensors and other devices in the work cell and to initiate control signals to other pieces of equipment in the cell. For instance, the statement "signal 3, on" might be used to turn on a motor in the cell, where the motor is connected to output line 3 in the robot's controller.

Text 18. ROBOTS IN MANUFACTURING

Today most robots are used in manufacturing operations; the applications can be divided into three categories: (1) material handling, (2) processing operations, and (3) assembly and inspection.

Material-handling applications include material transfer and machine loading and unloading. Material-transfer applications require the robot to move materials or work parts from one location to another. Many of these tasks are relatively simple, requiring robots to pick up parts from one conveyor and place them on another. Other transfer operations are more complex, such as placing parts onto pallets in an arrangement that must be calculated by the robot. Machine loading and unloading operations utilize a robot to load and unload parts at a production machine. This requires the robot to be equipped with a gripper that can grasp parts. Usually the gripper must be designed specifically for the particular part geometry.

In robotic processing operations, the robot manipulates a tool to perform a process on the work part. Examples of such applications include spot welding, continuous arc welding, and spray painting. Spot welding of automobile bodies is one of the most common applications of industrial robots in the United States. The robot positions a spot welder against the automobile panels and frames to complete the assembly of the basic car body. Arc welding is a continuous process in which the robot moves the welding rod along the seam to be welded. Spray painting involves the manipulation of a spray-painting gun over the surface of the object to be coated. Other operations in this category include grinding, polishing, and routing, in which a rotating spindle serves as the robot's tool.

The third application area of industrial robots is assembly and inspection. The use of robots in assembly is expected to increase because of the high cost of manual labour common in these operations. Since robots are programmable, one strategy in assembly work is to produce multiple product styles in batches, reprogramming the robots between batches. An alternative strategy is to produce a mixture of different product styles in the same assembly cell, requiring each robot in the cell to identify the product style as it arrives and then execute the appropriate task for that unit.

The design of the product is an important aspect of robotic assembly. Assembly methods that are satisfactory for humans are not necessarily suitable for robots. Using a screw and nut as a fastening method, for example, is easily performed in manual assembly, but the same operation is extremely difficult for a one-armed robot. Designs in which the components are to be added from the same direction using snap fits and other one-step fastening procedures enable the work to be accomplished much more easily by automated and robotic assembly methods.

Inspection is another area of factory operations in which the utilization of robots is growing. In a typical inspection job, the robot positions a sensor with respect to the work part and determines whether the part is consistent with the quality specifications.

In nearly all industrial robotic applications, the robot provides a substitute for human labour. There are certain characteristics of industrial jobs performed by humans that identify the work as a potential application for robots: (1) the operation is repetitive, involving the same basic work motions every cycle; (2) the operation is hazardous or uncomfortable for the human worker (*e.g.,* spray painting, spot welding, arc welding, and certain machine loading and unloading tasks); (3) the task requires a work part or tool that is heavy and awkward to handle; and (4) the operation allows the robot to be used on two or three shifts.

Text 19. WHAT IS COMPUTER AIDED MANUFACTURING (CAM)?

Since about 1970 there has been a growing trend toward the use of computers to perform many of the functions related to design and production. The technology associated with this trend is called CAD/CAM, for computer-aided design and computer-aided manufacturing.

Computer Aided Manufacturing (CAM) is the use of software and computer-controlled machinery to automate a manufacturing process. Based on that definition, you need three components for a CAM system to function:

1) software that tells a machine how to make a product by generating toolpaths;

2) machinery that can turn raw material into a finished product;

3) post processing that converts toolpaths into a language machines can understand.

These three components are connected together with tons of human labor and skill.

CAD to CAM Process

Without CAM, there is no CAD. CAD focuses on the design of a product or part. How it looks, how it functions. CAM focuses on how to make it. The start of every engineering process begins in the world of CAD. Engineers will make either a 2D or 3D drawing, whether that’s a crankshaft for an automobile, the inner skeleton of a kitchen faucet, or the hidden electronics in a circuit board. In the world of CAD, any design is called a model and contains a set of physical properties that will be used by a CAM system. When a design is complete in CAD, it can then be loaded into CAM. This is traditionally done by exporting a CAD file and then importing it into CAM software. Once your CAD model is imported into CAM, the software starts preparing the model for machining. Machining is the controlled process of transforming raw material into a defined shape through actions like cutting, drilling, or boring. CAM software prepares a model for machining by working through several actions, including:

1) Checking if the model has any geometry errors that will impact the manufacturing process.
2) Creating a toolpath for the model, which is a set of coordinates the machine will follow during the machining process.
3) Setting any required machine parameters including cutting speed, voltage, cut/pierce height, etc.
4) Configuring nesting where the CAM system will decide the best orientation for a part to maximize machining efficiency.

Once the model is prepared for machining, all of that information gets sent to a machine to physically produce the part. However, we can’t just give a machine a bunch of instructions in English, we need to speak the machine language. To do this all of our machining information is converted into a language called G-code. This is the set of instructions that controls a machine’s actions including speed, feed rate, coolants, etc. G-code is easy to read once you understand the format, for example:

G01 X1 Y1 F20 T01 S500.

This breaks down from left to right as:

G01 indicates a linear move, based on coordinates X1 and Y1.

F20 sets a feed rate, which is the distance the machine travels in one spindle revolution.

T01 tells the machine to use Tool 1, and S500 sets the spindle speed.

Once the G-code is loaded into the machine and an operator hits start, our job is done. Now it’s time to let the machine do the job of executing G-code to transform a raw material block into a finished product.

All modern manufacturing centers will be running a variety of computer numerical control (CNC) machines to produce engineered parts. The process of programming a CNC machine to perform specific actions is called CNC machining. Before CNC machines came to be, manufacturing centers were operated manually by machinists. These days the only human intervention required for running a CNC machine is loading a program, inserting raw material, and then unloading a finished product.

CNC Routers

These machines cut parts and carve out a variety of shapes with high speed spinning components. For example, a CNC router used for woodworking can make easy work of cutting plywood into cabinet parts. It can also easily tackle complex decorative engraving on a door panel. CNC routers have 3-axis cutting capabilities, which allows them to move along the X, Y, and Z axes.

Water, Plasma & Laser Cutters

These machines use precise lasers, high pressure water, or a plasma torch to perform a controlled cut or engraved finished. Manual engraving techniques can take months to complete by hand, but one of these machines can complete the same work in hours or days. Plasma cutters are especially useful for cutting through electrically conductive materials like metals.

Milling Machines

These machines chip away at a variety of materials like metal, wood, composites, etc. Milling machines have enormous versatility with a variety of tools that can accomplish specific material and shape requirements. The overall goal of a milling machine is to remove mass from a raw block of material as efficiently as possible.

Lathes

These machines also chip away at raw materials like a milling machine, they just do it differently. A milling machine has a spinning tool and stationary material, where a lathe spins the material and cuts with a stationary tool.

Electrical Discharge Machines (EDM)

These machines cut a desired shape out of raw material through an electrical discharge. An electrical spark is created between an electrode and raw material, with the spark temperature reaching 8,000 to 12,000 degrees Celsius. This allows an EDM to melt through nearly anything in a controlled and ultra precise process.

The Human Element of CAM

Back in the 1950s when CNC machining was first introduced by John T. Parsons, skillfully operating machines required an enormous amount of training and practice. In the days of manual machining, being a machinist was a badge of honor that took years of training to perfect. A machinist had to do it all – read blueprints, know which tools to use, define feeds and speeds for specific materials, and carefully cut a part by hand. It wasn’t just about precise manual dexterity. Being a machinist was, and still is, both an art and a science. These days, the modern machinist is alive and well, as man, machine and software combine to move our industry forward. Skills that used to take 40 years to master can now be conquered in a fraction of the time. New machines and CAM software have given us more control than ever to design and make better and more innovative products.

Today the role of a traditional machinist is shifting. The environment of modern machinists played out with three typical roles:

The Operator. This individual loads raw materials into a CNC machine and run completed parts through the final packaging process.

The Setup Operator. This individual performs the initial configuration for a CNC machine, which includes loading a G-code program and setting up tools.

The Programmer. This individual takes the drawing for a CAD model and decides how to make it with their available CNC machines. Their job is to define the toolpaths, tools, speeds, and feeds in the G-code to get the job done.

In a typical workflow the programmer will hand off his program to the setup operator, who will then load the G-code into the machine. Once the machine is ready to roll, the operator will then make the part. In some shops these roles might combine and overlap into the responsibilities of one or two people.

Outside of day-to-day machine operations, there is also the manufacturing engineer on staff. In a new shop setup, this individual typically establishes systems and determines an ideal manufacturing process. For existing setups, a manufacturing engineer will monitor equipment and product quality while handling other managerial tasks.

The Impact of CAM

We have John T. Parsons to thank for introducing a punch card method to program and automate machinery. In 1949 the United States Air Force funded Parsons to build an automated machine that could outperform manual NC machines. With some help from MIT, Parsons was able to develop the first NC prototype. From there the world of CNC machining started to take off. In the 1950s the United States Army bought NC machine and loaned them out to manufacturers. The idea was to incentive companies to adopt the new technology into their manufacturing process. During this time we also saw MIT develop the first universal programming language for CNC machines: G- code.

The 1990s brought the introduction of CAD and CAM on the PC, and has completely revolutionized how we approach manufacturing today. The earliest CAD and CAM jobs were reserved for expensive automotive and aerospace applications, but today different software is available for manufacturing shops of any shape and size.

Since its inception, CAM has delivered a lot of improvements to the manufacturing process, including:

improved machine capabilities (CAM systems can take advantage of advanced 5-axis machinery to deliver more sophisticated and higher quality parts);

improved machine efficiency (today’s CAM software provides high-speed machine toolpaths that help us manufacture parts faster than ever);

improved material usage (with additive machinery and CAM systems, we’re able to produce complex geometries with minimal waste which means lower costs).

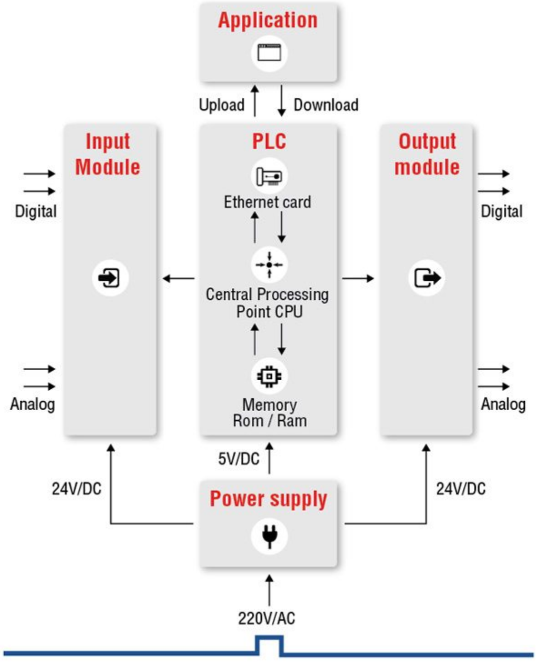
Text 20. PROGRAMMABLE LOGIC CONTROLLER

A Programmable Logic Controller, or PLC, is a computer used for industrial automation. These controllers can automate a specific process, a machine function, or even an entire production line.

How does a PLC work?

The PLC receives information from connected sensors or input devices, processes the data, and triggers outputs based on pre-programmed parameters.

Depending on the inputs and outputs, the PLC can monitor and record run-time data such as machine productivity or operating temperature, automatically start and stop processes, generate alarms if a machine malfunctions, and more. Programmable Logic Controllers are a flexible and robust control solution, adaptable to almost any application.



There are a few key features that set PLCs apart from industrial PCs, microcontrollers, and other industrial control solutions:

- I/O – The PLC's CPU stores and processes program data, but input and output modules connect the PLC to the rest of the machine; these I/O modules are what provide information to the CPU and trigger specific results. I/O can be either analog or digital; input devices might include sensors, switches, and meters, while outputs might include relays, lights, valves, and drives. Users can mix and match PLC's I/O in order to get the right configuration for their application.
- Communications – In addition to input and output devices, the PLC might also need to connect with other kinds of systems; for example, users might want to export application data recorded by the PLC to a supervisory control and data acquisition (SCADA) system, which monitors multiple connected devices. PLCs offer a range of ports and communication protocols to ensure that the PLC can communicate with these other systems.
- HMI – In order to interact with the PLC in real time, users need an HMI, or Human Machine Interface. These operator interfaces can be simple displays, with a text-readout and keypad, or large touchscreen panels more similar to consumer electronics, but either way, they enable users to review and input information to the PLC in real time.

Advanced PLC Features

In today's world of the Industrial Internet of Things (iIoT), and Industry 4.0 programmable controllers are called upon to communicate data via Web browser, connect to databases via SQL, and even to the cloud data via MQTT.

The All-In-One PLC

An All-in-One PLC integrates the controller with the HMI panel, creating a compact, easy-to-use automation solution. Users no longer need to configure PLC to panel communication and can program both the Ladder Logic and

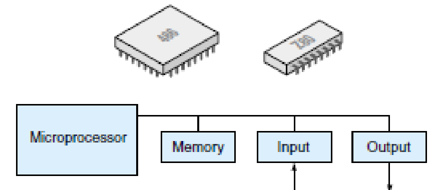
HMI design in a single software environment. An all-in-one approach saves time, reduces wiring, and cuts the cost of purchasing multiple devices.

How is a PLC Programmed

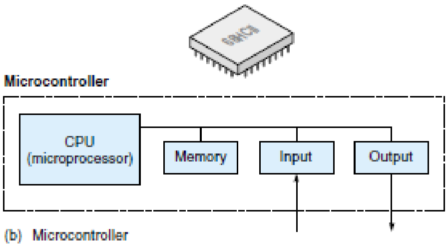
A PLC program is usually written on a computer and then is downloaded to the controller. Most PLC programming software offers programming in Ladder Logic, or “C”. Ladder Logic is a traditional programming language. It mimics circuit diagrams with “rungs” of logic read left to right. Each rung represents a specific action controlled by the PLC, starting with an input or series of inputs that result in an output. Because of its visual nature, Ladder Logic can be easier to implement than many other programming languages. “C” programming is a more recent innovation. Some PLC manufacturers supply control programming software.

Text 21. MICROPROCESSORS AND MICROCONTROLLERS

The digital integrated circuit (IC) called a microprocessor [Figure a], has ushered in a whole new era for control systems electronics. This revolution has occurred because the microprocessor brings the flexibility of program control and the computational power of a computer to bear on any problem. Automatic control applications are particularly well suited to take advantage of this technology, and microprocessor-based control systems are rapidly replacing many older control systems based on analog circuits or electromechanical relays. One of the first microprocessor-based controllers made specifically for control applications was the programmable logic controller (PLC). A microprocessor is not a computer and requires additional components such as memory and input/output circuits to make it operate. However, the microcontroller [Figure b], which is a close relative of the microprocessor, contains all the computer functions on a single IC.



(a) Microprocessor



(b) Microcontroller

Microcontrollers lack some of the power and speed of the newer microprocessors, but their compactness is ideal for many control applications; most so-called microprocessor-controlled devices, such as vending machines, use microcontrollers.

Having a microprocessor in a control system has several advantages.

- They can process data very quickly and much faster than a human can.
- Due to these fast speeds they can react very quickly to change in the control system.
- Control systems can run 24/7.
- Outputs are consistent and error free.
- Low level signals from sensors, once converted to digital, can be transmitted long distances virtually error-free.
- A microprocessor can easily handle complex calculations and control strategies.
- Long-term memory is available to keep track of parameters in slow-moving systems.
- It is easy to change the control strategy by loading a new program; no hardware changes are required.
- Microprocessor controllers can be connected to the computer network within an organization. This allows designers to enter program changes and read current system status from their desk terminals.

However there are several disadvantages.

- It may cost a lot of money to develop the software for a control system as they are specialized.
- The system will not be able to run in the case of a power shortage.
- The system will not be able to run in the case of a computer malfunction.
- A computer can't react to the events that it has not been programmed for.
- It can cause some concern if total control of a system and the decisions are handed over to a computer.

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