机械工程英语

第2版

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普通高等教育机电类规划教材

机械工程英语

第 2 版

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本教材是按照全国机械制造专业教学指导委员会 1991 年会议制定的出版计划组织有关高等院校集体编写的。此书为第 2 版，在选材方面既注意结合机械制造专业的基础理论，又强调现代制造技术方面的发展与动向，内容安排由浅入深，循序渐进，既有工程材料及其处理、机械加工方法、公差与夹具、非传统加工方法等；又有制造领域的先进科学技术，如计算机技术、数控技术、柔性制造、计算机集成制造、虚拟制造与网络化制造、机械测量与反求工程等方面的内容。本书所载文章均选自欧美原著，对其中一些难句作了注释或给出参考译文。本书还提出较多的工程技术应用文体范例及一些常用文体的写作指南，以满足读者对提高写作能力的需要。全书收入单词和词组约 1700 条，书末还附有机械工程领域的世界著名学术机构名称、常见缩略语和参考文献。

　　本书配有多媒体电子教案，需要者请根据书末"信息反馈表"索取。

前　　言

本教材最初是按照全国机械制造专业教学指导委员会 1991 年会议提出的教材出版计划，作为高等教育机电类规划教材，为学生的专业英语课程而编写的。由华南理工大学、北京理工大学、西安理工大学及西安交通大学联合编写。全书从编写到出版历经 2 年多的时间。本书自 1996 年 10 月出版后，在全国多所高等院校使用，受到广大师生的欢迎。到 2004 年 2 月为止，已重印 12 次。由于制造领域的科技发展日新月异，我们此次修订教材，对其内容作了较大的修改和调整。

修订后的教材仍然分为两部分。第一部分为机械制造基础，内容包括工程材料及其处理、机械加工方法、公差与夹具、非传统加工方法等；第二部分的内容为先进制造技术，内容涉及制造领域的先进科学技术，如计算机技术、数控技术、工业机器人、计算机辅助设计与制造、柔性制造、计算机集成制造、虚拟制造与网络化制造、快速成形、纳米与微机械制造、半导体制造、机械测量与反求工程，以及计算机质量控制等方面的内容。为增加教材的实用性，在附录部分列出了一些常用的机械工程技术应用文体范例，内容包括产品说明书、广告、报价单及售货合同及科技论文写作指南等。此外，还附有机械工程领域著名的学术机构、协会组织的名称，以及机械和自动化方面的常见缩略语等。本教材共有 32 个单元，按 32 学时讲授，以每周一个单元的进度可供两学期使用。

本教材可供机械类及相关专业高年级学生作为专业英语阅读学习使用。本书在内容编排和选材上尽量与机械制造工程的教学内容相对应，尽量做到系统性和循序渐进，以便学生能掌握和熟悉机械领域的英语常用词汇和表达方式。考虑到现代制造技术的飞速发展，课程设置相对落后，第二部分主要选取了有助于帮助学生了解机械工程高新科技发展概况的内容，以弥补现行专业课程教学内容滞后于科技发展的不足。

本书所载文章，基本取自欧美文献原著。为保持原著的语言风格，编者根据需要，只对原文作些删节。为方便阅读，对各部分内容中的一些疑难句子，在每单元末给出语法和翻译方面的注释。书末则附有全书的词汇表。

参与这次修订工作的有华南理工大学、北京理工大学、西安交通大学及广东工业大学等院校。由华南理工大学叶邦彦担任主编，西安交通大学唐一平为副主编。北方工业大学罗学科主审。本书的修订工作，得到原华南理工大学陈统坚教授和北京理工大学孙厚芳教授的大力支持，在此对他们表示衷心的感谢。

<div align="right">编　者</div>

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PART I

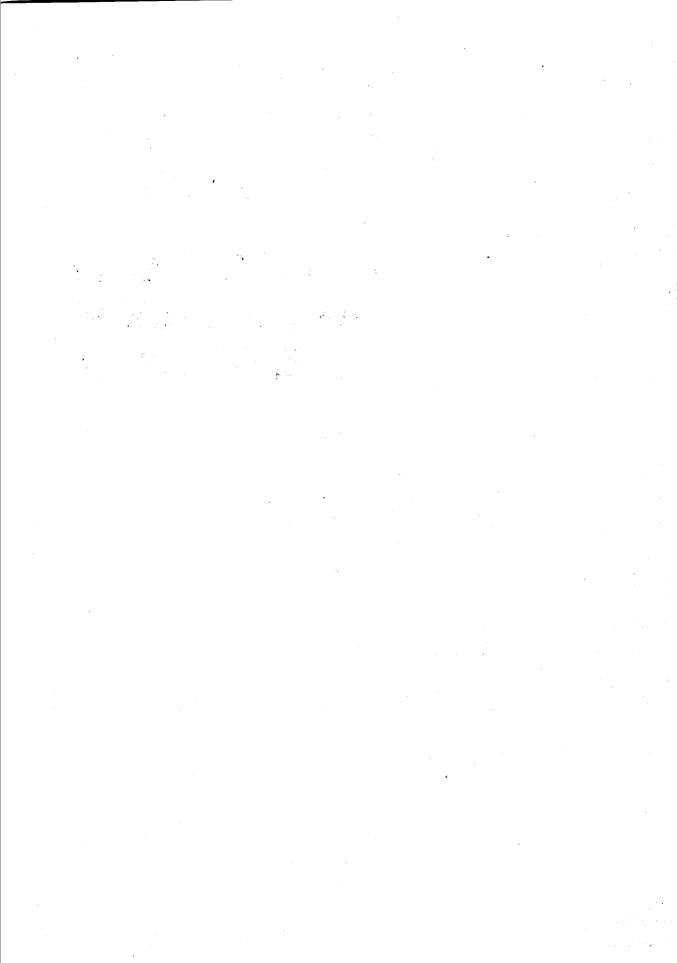# FUNDAMENTAL OF MANUFACTURING ENGINEERING

Unit 1

Advanced Engineering Materials

Types of Materials

Materials may be grouped in several ways. Scientists often classify materials by their state: solid, liquid, or gas. They also separate them into organic (once living) and inorganic (never living) materials.

For industrial purposes, materials are divided into engineering materials or nonengineering materials. Engineering materials are those used in manufacture and become parts of products. Nonengineering materials are the chemicals, fuels, lubricants, and other materials used in the manufacturing process, which do not become part of the product.

Engineering materials may be further subdivided into: ① Metals ② Ceramics ③ Composite ④ Polymers, etc.

Metals and Metal Alloys

Metals are elements that generally have good electrical and thermal conductivity. Many metals have high strength, high stiffness, and have good ductility. Some metals, such as iron, cobalt and nickel, are magnetic. At extremely low temperatures, some metals and intermetallic compounds become superconductors.

What is the difference between an alloy and a pure metal? **Pure metals** are elements which come from a particular area of the periodic table. Examples of pure metals include copper in electrical wires and aluminum in cooking foil and beverage cans. **Alloys** contain more than one metallic element. Their properties can be changed by changing the elements present in the alloy. Examples of metal alloys include stainless steel which is an alloy of iron, nickel, and chromium; and gold jewelry which usually contains an alloy of gold and nickel.

Why are metals and alloys used? Many metals and alloys have high densities and are used in applications which require a high mass-to-volume ratio. Some metal alloys, such as those based on aluminum, have low densities and are used in aerospace applications for fuel economy. [1] Many alloys also have high fracture toughness, which means they can withstand impact and are

durable.

What are some important properties of metals?

Density is defined as a material's mass divided by its volume. Most metals have relatively high densities, especially compared to polymers. Materials with high densities often contain atoms with high atomic numbers, such as gold or lead. However, some metals such as aluminum or magnesium have low densities, and are used in applications that require other metallic properties but also require low weight.

Fracture toughness can be described as a material's ability to avoid fracture, especially when a flaw is introduced. Metals can generally contain nicks and dents without weakening very much, and are impact resistant. A football player counts on this when he trusts that his facemask won't shatter.

Plastic deformation is the ability of a material to bend or deform before breaking. As engineers, we usually design materials so that they don't deform under normal conditions. You don't want your car to lean to the east after a strong west wind. However, sometimes we can take advantage of plastic deformation. The crumple zones in a car absorb energy by undergoing plastic deformation before they break.

The atomic bonding of metals also affects their properties. In metals, the outer valence electrons are shared among all atoms, and are free to travel everywhere. Since electrons conduct heat and electricity, metals make good cooking pans and electrical wires. It is impossible to see through metals, since these valence electrons absorb any photons of light which reach the metal. [2] No photons pass through.

Alloys are compounds consisting of more than one metal. Adding other metals can affect the density, strength, fracture toughness, plastic deformation, electrical conductivity and environmental degradation. For example, adding a small amount of iron to aluminum will make it stronger. Also, adding some chromium to steel will slow the rusting process, but will make it more brittle.

Ceramics and Glasses

A ceramic is often broadly defined as any inorganic nonmetallic material. By this definition, ceramic materials would also include glasses; however, many materials scientists add the stipulation that "ceramics" must also be crystalline.

A glass is an inorganic nonmetallic material that does not have a crystalline structure. Such materials are said to be amorphous.

Properties of Ceramics and Glasses

Some of the useful properties of ceramics and glasses include high melting temperature, low density, high strength, stiffness, hardness, wear resistance, and corrosion resistance. [3] Many ceramics are good electrical and thermal insulators. Some ceramics have special properties: some ceramics are magnetic materials; some are piezoelectric materials; and a few special ceramics are su-

perconductors at very low temperatures. Ceramics and glasses have one major drawback: they are brittle.

Ceramics are not typically formed from the melt. This is because most ceramics will crack extensively (i. e. form a powder) upon cooling from the liquid state. Hence, all the simple and efficient manufacturing techniques used for glass production such as casting and blowing, which involve the molten state, cannot be used for the production of crystalline ceramics. Instead, "sintering" or "firing" is the process typically used. In sintering, ceramic powders are processed into compacted shapes and then heated to temperatures just below the melting point. At such temperatures, the powders react internally to remove porosity and fully dense articles can be obtained.

An optical fiber contains three layers: a core made of highly pure glass with a high refractive index for the light to travel, a middle layer of glass with a lower refractive index known as the cladding which protects the core glass from scratches and other surface imperfections, and an outer polymer jacket to protect the fiber from damage. [4] In order for the core glass to have a higher refractive index than the cladding, the core glass is doped with a small, controlled amount of an impurity, or dopant, which causes light to travel slower, but does not absorb the light. Because the refractive index of the core glass is greater than that of the cladding, light traveling in the core glass will remain in the core glass due to total internal reflection as long as the light strikes the core/cladding interface at an angle greater than the critical angle. The total internal reflection phenomenon, as well as the high purity of the core glass, enables light to travel long distances with little loss of intensity.

Composites

Composites are formed from two or more types of materials. Examples include polymer/ceramic and metal/ceramic composites. Composites are used because overall properties of the composites are superior to those of the individual components. For example: polymer/ceramic composites have a greater modulus than the polymer component, but aren't as brittle as ceramics.

Two types of composites are: fiber-reinforced composites and particle-reinforced composites.

Fiber-reinforced Composites

Reinforcing fibers can be made of metals, ceramics, glasses, or polymers that have been turned into graphite and known as carbon fibers. Fibers increase the modulus of the matrix material. The strong covalent bonds along the fiber's length give them a very high modulus in this direction because to break or extend the fiber the bonds must also be broken or moved.

Fibers are difficult to process into composites, making fiber-reinforced composites relatively expensive. Fiber-reinforced composites are used in some of the most advanced, and therefore most expensive sports equipment, such as a time-trial racing bicycle frame which consists of carbon fibers in a thermoset polymer matrix. Body parts of race cars and some automobiles are composites made of glass fibers (or fiberglass) in a thermoset matrix.

Fibers have a very high modulus along their axis, but have a low modulus perpendicular to their

axis. Fiber composite manufacturers often rotate layers of fibers to avoid directional variations in the modulus.

Particle-reinforced Composites

Particles used for reinforcing include ceramics and glasses such as small mineral particles, metal particles such as aluminum, and amorphous materials, including polymers and carbon black.

Particles are used to increase the modulus of the matrix, to decrease the permeability of the matrix, to decrease the ductility of the matrix. An example of particle-reinforced composites is an automobile tire which has carbon black particles in a matrix of polyisobutylene elastomeric polymer.

Polymers

A polymer has a repeating structure, usually based on a carbon backbone. The repeating structure results in large chainlike molecules. Polymers are useful because they are lightweight, corrosion resistant, easy to process at low temperatures, and generally inexpensive.

Some important characteristics of polymers include their size (or molecular weight), softening and melting points, crystallinity, and structure. The mechanical properties of polymers generally include low strength and high toughness. Their strength is often improved using reinforced composite structures.

Important Characteristics of Polymers

Size. Single polymer molecules typically have molecular weights between 10, 000 and 1 ,000 ,000 g/mol—that can be more than 2 ,000 repeating units depending on the polymer structure! The mechanical properties of a polymer are significantly affected by the molecular weight, with better engineering properties at higher molecular weights.

Thermal transitions. The softening point (glass transition temperature) and the melting point of a polymer will determine which it will be suitable for applications. These temperatures usually determine the upper limit for which a polymer can be used. For example, many industrially important polymers have glass transition temperatures near the boiling point of water (100 ℃, 212 ℉), and they are most useful for room temperature applications. Some specially engineered polymers can withstand temperatures as high as 300 ℃ (572 ℉).

Crystallinity. Polymers can be crystalline or amorphous, but they usually have a combination of crystalline and amorphous structures (semi-crystalline).

Interchain interactions. The polymer chains can be free to slide past one another (thermoplastic) or they can be connected to each other with crosslinks (thermoset or elastomer). Thermoplastics can be reformed and recycled, while thermosets and elastomers are not reworkable.

Intrachain structure. The chemical structure of the chains also has a tremendous effect on the properties. Depending on the structure the polymer may be hydrophilic or hydrophobic (likes or hates water), stiff or flexible, crystalline or amorphous, reactive or unreactive.

Notes:

1. Some alloys, such as those based on aluminum, have low densities and are used in aerospace applications for fuel economy.

句意：某些金属合金，例如铝基合金，其密度低，可用于航空宇宙工业，可节约燃料。

2. It is impossible to see through metals, since these valence electrons absorb any photons of light which reach the metal.

句意：透过金属不可能看得见，因为这些价电子吸收到达金属的光子。

3. Some of the useful properties of ceramics and glasses include high melting temperature, low density, high strength, stiffness, hardness, wear resistance, and corrosion resistance.

句意：高熔点、低密度、高强度、高刚度、高硬度、高耐磨性和抗腐蚀性是陶瓷和玻璃的一些有用特性。

4. An optical fiber contains three layers: a core made of highly pure glass with a high refractive index for the light to travel, a middle layer of glass with a lower refractive index known as the cladding which protects the core glass from scratches and other surface imperfections, and an outer polymer jacket to protect the fiber from damage.

句意：光导纤维有三层：核心由高纯玻璃制成，该玻璃是高折射指数光传输材料；中间层是低折射指数玻璃，是保护核心玻璃表面不被擦伤或表面完整性不被破坏的所谓覆层；最外层是塑料（聚合体）护套，可保护光导纤维不受损。

Unit 2

Heat Treatment of Metals

The understanding of heat treatment is embraced by the broader study of metallurgy. Metallurgy is the physics, chemistry, and engineering related to metals from ore extraction to the final product. Heat treatment is the operation of heating and cooling a metal in its solid state to change its physical properties. According to the procedure used, steel can be hardened to resist cutting action and abrasion, or it can be softened to permit machining. With the proper heat treatment internal stresses may be removed, grain size reduced, toughness increased, or a hard surface produced on a ductile interior. The analysis of the steel must be known because small percentages of certain elements, notably carbon, greatly affect the physical properties.

Alloy steels owe their properties to the presence of one or more elements other than carbon, namely nickel, chromium, manganese, molybdenum, tungsten, silicon, vanadium, and copper. [1]Because of their improved physical properties they are used commercially in many ways not possible with carbon steels.

The following discussion applies principally to the heat treatment of ordinary commercial steels known as plain carbon steels. With this process the rate of cooling is the controlling factor, rapid cooling from above the critical range results in hard structure, whereas very slow cooling produces the opposite effect.

A Simplified Iron-carbon Diagram

If we focus only on the materials normally known as steels, a simplified diagram is often used. Those portions of the iron-carbon diagram near the delta region and those above 2% carbon content are of little importance to the engineer and are deleted. [2]A simplified diagram, such as the one in Fig. 2. 1, focuses on the eutectoid region and is quite useful in understanding the properties and processing of steel.

The key transition described in this diagram is the decomposition of single-phase austenite (γ) to the two-phase ferrite plus carbide structure as temperature drops. Control of this reaction, which arises due to the drastically different carbon solubility of austenite and ferrite, enables a wide range of properties to be achieved through heat treatment.

To begin to understand these processes, consider a steel of the eutectoid composition, 0.77%

carbon, being slow cooled along line x-x' in Fig. 2. 1. At the upper temperatures, only austenite is present, the 0. 77% carbon being dissolved in solid solution with the iron. When the steel cools to 727 ℃ (1341 ℉), several changes occur simultaneously. The iron wants to change from the FCC austenite structure to the BCC ferrite structure, but the ferrite can only contain 0. 02% carbon in solid solution. [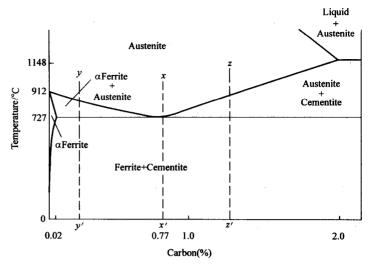 3] The rejected carbon forms the carbon-rich cementite intermetallic with composition Fe_3C. In essence, the net reaction at the eutectoid is

Fig. 2. 1　Simplified iron-carbon diagram

$$\text{austenite} \quad \rightarrow \text{ferrite} \quad + \text{cementite}$$
$$0.77\% C \qquad 0.02\% C \qquad 6.67\% C$$

Since this chemical separation of the carbon component occurs entirely in the solid state, the resulting structure is a fine mechanical mixture of ferrite and cementite. Specimens prepared by polishing and etching in a weak solution of nitric acid and alcohol reveal the lamellar structure of alternating plates that forms on slow cooling. This structure is composed of two distinct phases, but has its own set of characteristic properties and goes by the name pearlite, because of its resemblance to mother-of-pearl at low magnification. [4]

Steels having less than the eutectoid amount of carbon (less than 0. 77%) are known as hypoeutectoid steels. Consider now the transformation of such a material represented by cooling along line y-y' in Fig. 2. 1. At high temperatures, the material is entirely austenite, but upon cooling enters a region where the stable phases are ferrite and austenite. Tie-line and lever-law calculations show that low-carbon ferrite nucleates and grows, leaving the remaining austenite richer in carbon. [5] At 727 ℃ (1341 ℉), the austenite is of eutectoid composition (0. 77% carbon) and further cooling transforms the remaining austenite to pearlite. The resulting structure is a mixture of primary or proeutectoid ferrite (ferrite that formed above the eutectoid reaction) and regions of pearlite.

Hypereutectoid steels are steels that contain greater than the eutectoid amount of carbon. When such steel cools, as shown in z-z' of Fig. 2. 1 the process is similar to the hypo-eutectoid case, except that the primary or proeutectoid phase is now cementite instead of ferrite. As the carbon-rich phase forms, the remaining austenite decreases in carbon content, reaching the eutectoid composition at 727 ℃ (1, 341 ℉). As before, any remaining austenite transforms to pearlite upon slow cooling through this temperature.

It should be remembered that the transitions that have been described by the phase diagrams are

for equilibrium conditions, which can be approximated by slow cooling. With slow heating, these transitions occur in the reverse manner. However, when alloys are cooled rapidly, entirely different results may be obtained, because sufficient time is not provided for the normal phase reactions to occur, in such cases, the phase diagram is no longer a useful tool for engineering analysis.

Hardening

Hardening is the process of heating a piece of steel to a temperature within or above its critical range and then cooling it rapidly. If the carbon content of the steel is known, the proper temperature to which the steel should be heated may be obtained by reference to the iron-iron carbide phase diagram. However, if the composition of the steel is unknown, a little preliminary experimentation may be necessary to determine the range. A good procedure to follow is to heat-quench a number of small specimens of the steel at various temperatures and observe the results, either by hardness testing or by microscopic examination. When the correct temperature is obtained, there will be a marked change in hardness and other properties.

In any heat-treating operation the rate of heating is important. Heat flows from the exterior to the interior of steel at a definite rate. If the steel is heated too fast, the outside becomes hotter than the interior and uniform structure cannot be obtained. If a piece is irregular in shape, a slow rate is all the more essential to eliminate warping and cracking. The heavier the section, the longer must be the heating time to achieve uniform results. Even after the correct temperature has been reached, the piece should be held at that temperature for a sufficient period of time to permit its thickest section to attain a uniform temperature.

The hardness obtained from a given treatment depends on the quenching rate, the carbon content, and the work size. In alloy steels the kind and amount of alloying element influence only the harden ability (the ability of the work piece to be hardened to depths) of the steel and do not affect the hardness except in unhardened or partially hardened steels.

Steel with low carbon content will not respond appreciably to hardening treatments. As the carbon content in steel increases up to around 0.60% , the possible hardness obtainable also increases. Above this point the hardness can be increased only slightly, because steels above the eutectoid point are made up entirely of pearlite and cementite in the annealed state. Pearlite responds best to heat-treating operations; any steel composed mostly of pearlite can be transformed into hard steel.

As the size of parts to be hardened increases, the surface hardness decreases somewhat even though all other conditions have remained the same. There is a limit to the rate of heat flow through steel. No matter how cool the quenching medium may be, if the heat inside a large piece cannot escape faster than a certain critical rate, there is a definite limit to the inside hardness. However, brine or water quenching is capable of rapidly bringing the surface of the quenched part to its own temperature and maintaining it at or close to this temperature. Under these circumstances there would always be some finite depth of surface hardening regardless of size. This is not true in oil quenching, when the surface temperature may be high during the critical stages of quenching.