**М. Г. Прадівлянний, Н. В. Рибко, Ю. В. Бойко**

# АНГЛІЙСЬКА МОВА ДЛЯ СТУДЕНТІВ МАШИНОБУДІВНИХ СПЕЦІАЛЬНОСТЕЙ

## Частина 1

Міністерство освіти і науки України
Вінницький національний технічний університет

**М. Г. Прадівлянний, Н. В. Рибко, Ю. В. Бойко**

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## Частина 1

**Навчальний посібник**

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Рецензенти:
**Н. Б. Іваницька**, доктор філологічних наук, професор
**А. М. Коломієць**, доктор педагогічних наук, професор
**В. І. Клочко**, доктор педагогічних наук, професор

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Навчальний посібник призначено для студентів, які вивчають механічну інженерію, а саме: прикладну механіку, матеріалознавство та галузеве машинобудування.

Підбір завдань у навчальному посібнику дає можливість його використання як на заняттях, так і для самостійної роботи студентів.

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## Передмова

Володіння іноземною мовою на сучасному етапі стало не лише ознакою гарної освіти, але й невід'ємною характеристикою сучасного фахівця, який має набути не тільки фахові знання за спеціальністю, а й навички практичного володіння іноземною мовою в обсязі тематики, зумовленої професійними потребами фахівця, який міг би одержувати новітню фахову інформацію через іноземні джерела.

Цей навчальний посібник призначений для підготовки студентів першого курсу навчальних закладів вищої технічної освіти всіх машинобудівних спеціальностей. Метою посібника є вивчення фахових тем, знання яких необхідно для студентів усіх машинобудівних спеціальностей – матеріалознавство (метали, сплави, пластмаси, їхні властивості, процеси обробки та виробництва), машинні частини та їхні з'єднання, принципи дії механізмів та машин).

Посібник призначено для аудиторного та позааудиторного вивчення навчального матеріалу студентами, практики всіх видів читання й мовленнєвої діяльності, а також перекладу текстів з англійської мови на українську та навпаки. Зміни в навчальному навантаженні студентів передбачають можливу зміну акцентів у роботі студентів на самостійну та індивідуальну роботу.

Посібник побудовано за тематичним принципом. Кожен розділ присвячено окремій темі. Розділи ідентичні в структурному відношенні та містять основні й додаткові тексти, тексти для самостійного вивчення, систему вправ та завдань. Побудова системи завдань до текстів визначається методичним призначенням цих текстів. Завдання пов'язані з роботою над лексичним тематичним матеріалом (введення лексичних одиниць та актуалізація їхнього вживання), інформаційним матеріалом (відповіді на запитання, вибір правильної відповіді тощо), розвитком навичок пошукового читання.

Вправи і тексти передбачають також роботу над граматичним матеріалом. Особлива увага приділяється вживанню прийменників, структурі речень, що викликають труднощі у студентів при вивченні англійської мови, а також постановці запитань, що основою подальшого розвитку усного спілкування на фахові теми. Посібник містить багато завдань з використанням та заповненням таблиць з метою не лише оволодіння лексичним матеріалом, а й повторення, систематизації та порівняння матеріалу, який вивчався рідною мовою, що сприяє подальшому розвитку дискусії та самостійного пошуку необхідної або цікавої інформації з інших джерел.

# CONTENTS

# CHAPTER 1

# FERROUS METALS

All metals can be classified as non-ferrous metals and ferrous metals. Ferrous metals are those metals which contain iron. They may have small amounts of other metals or other elements added, to give the required properties. All ferrous metals are magnetic and give little resistance to corrosion. Most commonly used ferrous metals are mild steel, high speed steel, stainless steel, high tensile steel and cast iron.

Here are some ferrous metals with are used for tool making, manufacturing of pressed components and other industrial supplies.

## Mild Steel

It is the most commonly used ferrous metal. Its major properties are toughness, high tensile strength and ductility. It contains 0.15 to 0.30% carbon. Because of low carbon content it cannot be hardened and tempered. It must be case hardened. It is normally used in manufacturing of girders, plates, nuts and bolts and other general purposes.

## Cast Iron

Cast iron is another example of commonly used ferrous metal. It is hard, brittle, strong, cheap, and self-lubricating ferrous metal. It is remelted pig iron with small amounts of scrap steel. It can be classified as white cast iron, grey cast iron, and malleable cast iron. It is normally used in the manufacturing of heavy crushing machinery, car cylinder blocks, vices, machine tool parts, brake drums, machine handle and gear wheels, plumbing fitments etc. It’s an important ferrous metal in automotive pressing.

## High Tensile Steel

It is very strong and very tough ferrous metal and is exclusively used for manufacturing of gears, shafts, engine parts etc. This is one of the most frequently used ferrous metals in industries because of its strength, hardness and toughness.

## Stainless Steel

It’s another very important ferrous metal. It comprises of 18% chromium, and 8% nickel. Its special characteristic is its strong resistance to corrosion. Its common uses are kitchen draining boards, pipes, cutlery and aircraft.

## High Speed Steel

High speed steel is also a ferrous metal. It contains medium carbon, tungsten, chromium and vanadium. It can be hardened, tempered and can be brittle. Its special characteristic is that it retains hardness at high temperatures.

## High Carbon Steel

High carbon steel is a ferrous metal which contains of 0.70% to 1.40% carbon. The major characteristic is its hardness. It is the hardest of the carbon steels, but is less ductile, tough and malleable. It is used in making of chisels, hammers, drills, files, lathe tools, taps and dies.

**Medium Carbon Steels**

As the name says, this ferrous metal contains less carbon contents, 0.30% to 0.70%. It is stronger and harder than mild steels, less ductile, tough and malleable. It is used in making metal ropes, wire, garden tools, springs etc.

**Metal Casting**

One of the basic processes of the metal-working industry is the production of metal castings. A casting may be defined as “a metal object obtained by allowing molten metal to solidify in a mold”, the shape of the object being determined by the shape of the mold cavity. A foundry is a commercial establishment for producing castings. Numerous methods have been developed through the ages for producing metal castings but the oldest method is that of making sand castings in the foundry. Primarily, work consists of metal in a furnace and pouring it into suitable sand molds where it solidifies and assumes the shape of the mold. Most castings serve as details or component parts of complex machines and products. In most cases they are used only when they are machined and finished to specified manufacturing tolerances providing easy and proper assembly of the product.

At present the foundry industry is going through a process of rapid transformation, owing to modern development of new technological methods, new machines and new material. Because of the fact that casting methods have advanced rapidly owing to the general mechanical progress of recent years there is today no comparison between the quality of castings, the complexity of the patterns produced and the speed of manufacture with the work of a few years ago [1].

EXERCISE 1

Fill in the blanks with appropriate words.

One method of classifying metals is by their content, and one common division is into (1) ____ and (2) ____. The term ferrous is derived from the Latin "Ferrum" which means (3) ____, thus ferrous metals contain iron and non-ferrous metals do not. Ferrous metals may be pure iron, like (4) ____ or they may be alloys of iron and other elements. Steel, being (5) ____, would therefore be a ferrous metal. Ferrous metals are often (6) ____, but this property is not in and of itself sufficient to classify a metal as ferrous or non-ferrous. Austenitic stainless steel, a ferrous metal, is (7) ____, while cobalt is magnetic but non-ferrous. However, since ferrous metals are the most common magnetic materials, (8) ____ are commonly used to separate them from non-ferrous metals and other materials. Common ferrous metals include the various irons and (9) ____.

---

Wrought iron, "containing iron", non-ferrous metals, magnetic, steels, an alloy of iron and carbon, non-magnetic, magnets, ferrous metals.

EXERCISE 2

Complete the sentences.

| | |
|---|---|
| 1. A casting is a metal object obtained by… | a) strong resistance to corrosion. |
| 2. A foundry is a commercial establishment for… | b) allowing molten metal to solidify in a mold. |
| 3. The special characteristic of stainless steel is its… | c) one of the oldest methods for producing metal castings. |
| 4. The shape of the casting is determined by… | d) the shape of the sand mold. |
| 5. Sand casting production is… | e) the shape of the mold cavity. |
| 6. But at first they are machined and finished to… | f) commonly used ferrous metal. |
| 7. This method consists of … | g) complex machines and products. |
| 8. Cast iron is another example of… | h) producing castings. |
| 9. Then the metal solidifies and assumes… | i) specified tolerances. |
| 10. Most castings serve as details or components parts of … | j) melting metal in a furnace and pouring it into sand molds. |

EXERCISE 3

Fill in the blanks with prepositions *because of, in, of, by, for*.

1. There are several branches … the metal working industry; foundry is one … the most important ones. 2. Metals are … great importance … our life … their useful properties. 3. They are widely used … industrial purposes. 4. Almost all the metals are found … the earth's crust … the form … ores. 5. The first metals used … men were gold, silver and copper, theses metals are found … nature … the native or metallic state. 6. This is one … the most frequently used ferrous metals … industries … its strength, hardness and toughness. 7. The cupola furnace is usually used … melting grey iron.

EXERCISE 4

Make up questions to which the italicized words are the answers.

1. *The process of making an iron casting* can simply be described as the pouring of hot liquid or molten iron into a mold of a desired shape. 2. Molten iron *is poured* from the ladles into the sand molds. 3. The iron travels along *a series passageways* in the molds to the cavities. 4. It then falls from *the bottom to top*. 5. The iron in the molds is allowed *to cool for some time* and the casting *solidifies and hardens*. 6. At this time the castings is separated from *the mold* and *the raw casting* is born. 7. Then the casting undergoes cleaning and checking *before final processing*.

EXERCISE 5

Translate the words into Ukrainian.

Non-ferrous metals, ferrous metals, resistance, mild steel, high speed steel, stainless steel, high tensile steel and cast iron, toughness, hardness, high tensile strength, ductility, white cast iron, grey cast iron, malleable cast iron, metal castings, molten metal, foundry, mold cavity, sand castings, furnace, sand mold, alloys, pig iron, blast furnace.

EXERCISE 6

Translate the sentences into Ukrainian paying attention to the italicized words.

1. *Ferrous metals* consist of *iron* combined with *carbon*, *silicon*, *phosphorus* and other elements. 2. Carbon is the most important of all the elements present in *ferrous alloys*. 3. Ferrous metals are used in industry in two general forms: *steel* and *cast iron*, which differ in the quantity of *carbon content*. 4. These two ferrous alloys are derived from *pig iron* which is produced in a *blast furnace* in the form of *pigs*. 5. Metals are usually melted and poured into a form which is called a *"mould"*. 6. This process is known as *castings*. 7. The cast metal is shaped and in the *mould* where it cools and solidifies. 8. The *shop* where metals are cast is called a *"foundry"*. 9. *Grey iron foundries* are the most numerous because *grey iron* can be cast in almost any conceivable shape and size. 10. The alloy of *grey castings* is composed of iron, carbon, silicon, phosphorus, *manganese*, and *sulphur*.

EXERCISE 7

Complete the table using information from the text.

| Name | Composition | Properties | Uses |
|---|---|---|---|
| Mild Steel | 0.15 to 0.30% carbon | | |
| High Speed Steel | | Can be hardened and tempered. Can be brittle. Retains hardness at high temperatures | |
| Stainless Steel | | | Kitchen draining boards. Pipes, cutlery, aircraft |
| High Tensile | Low carbon steel, nickel, | | |

| | | | |
|---|---|---|---|
| Steel | and chromium | | |
| High Carbon Steel | | | Chisels, hammers, drills, files, lathe tools, taps and dies |
| Medium Carbon Steels | 0.30% to 0.70% carbon | | |
| Cast Iron | | Hard, brittle, strong, cheap, self-lubricating. White cast iron, grey cast iron, malleable cast iron | |

EXERCISE 8

Answer the following questions.

1. What are the main two groups of metals? 2. What are those metals which contain iron? 3. What are the most commonly used ferrous metals? 4. Where is mild steel normally used? 5. What types of cast iron are there? 5. What ferrous metal comprises of 18% chromium, and 8% nickel? 6. Is high tensile steel exclusively used for manufacturing of gears, shafts, engine parts or for kitchen draining boards, pipes, cutlery and aircraft? 7. What ferrous metal can be brittle? 8. What is the major characteristic of high carbon steel? 9. Where is medium carbon steel used? 10. What is foundry? 11. What is casting? 12. What basic processes does sand casting consists of? 13. Can most castings be used as parts of machines immediately following their solidification&? 14. Is the foundry industry going through a process of rapid transformation? 15. What is one of the basic processes of the metal-working industry?

EXERCISE 9

Say true or false and explain.

1. All metals can be classified as non-ferrous metals and ferrous metals.
2. All ferrous metals are magnetic and they don’t give resistance to corrosion.
3. Mild steel contains 15 to 30% carbon.
4. Cast iron is remelted pig iron with small amounts of scrap steel.
5. High speed steel is contains medium carbon, tungsten, chromium and vanadium.
6. Cast iron is the hardest of the carbon steels, but is less ductile, tough and malleable.

7. Most castings serve as details or component parts of complex machines and products.
8. Because of low carbon content high carbon steel can not be hardened and tempered.
9. One of the basic processes of the metal-working industry is the production of metal castings.
10. The major characteristic of medium carbon steel is its hardness.

EXERCISE10
Translate the texts without a dictionary.

**A.** Cast Iron. The term cast iron is applied to ferrous alloys. Among the ferrous metals, cast iron occupies first place and is recognized as one of the cheapest materials used in the manufacture of everyday life products. Cast iron is not considered a very strong or tough structural material, but it is the most economical. Its low melting point, low shrinkage, good fluidity, and machine ability are properties that recommend its use [2].

**B.** Pig Iron. The chief raw material for cast iron is pig iron, which is produced in a blast furnace by smelting iron ore with coke and a flux (substances promoting fusion) such as limestone. The final analysis of the pig iron is substantially determined by the kind of iron ore used in the smelting process. Pig iron got its name from the shape of the molds in which metal from the blast furnace was cast. Originally, the pigs were cast in sand molds [3].

**C.** Modern large-volume production of pig iron is carried out by casting blast-furnace metal by means of a large machine, which is in principle an endless conveyer chain of pig molds. Some pig irons are used in gray-iron foundries, and are called foundry pig irons. Pig iron used for making steel by the acid Bessemer process or the acid open-hearth process is known as Bessemer pig iron. Basic pig iron is used for the basic open-hearth process [2].

EXERCISE11
Translate the following texts in a written form using a dictionary.

Text 1

Wrought iron is commercially pure iron, having a very small carbon content (not more than 0.15 percent), but usually containing some slag. It is tough, malleable, and ductile and is easily welded. However, it is too soft for blades and swords, at least for their cutting edges, which are usually made of steel with higher carbon content. Wrought iron is so named because it is "wrought" or worked from a "bloom" of porous iron mixed with slag and other impurities. The word "wrought" is an archaic past tense of the verb *to work*. As irregular past-tense forms in English have historically been phased out over long periods of time, *wrought* became *worked*. *Wrought iron* literally means *worked iron*.[3]

Text 2

Wrought iron has been used for thousands of years, and represents the "iron" that is referred to throughout western history. It is a fibrous material with many strands of slag mixed into the metal. These slag inclusions give it a "grain" resembling wood, with distinct appearance when etched. Also due to the slag, it has a fibrous look when broken or bent past its failure point. Wrought iron has been replaced to a very great extent by mild steel. It is, therefore, hardly produced at all today. It was used where a tough material is required. Wrought iron, at present, is used for rivets, chains, ornamental iron work, railway couplings, water and steam pipes, raw material for manufacturing of steel, bolts and nuts, horse shoe bars, handrails, straps for timber roof trusses, boiler tubes, roofing sheets, etc. [1].

EXERCISE12
Translate the text into English.

Виробництво чавуну

Чавун – залізовуглецевий сплав, що містить понад 2% вуглецю. Крім вуглецю, у ньому є кремній, марганець, фосфор і сірка. Найбільша кількість виплавленого чавуну (до 80...85%) надходить на виробництво сталі, а решта використовується для виробництва чавунних виливок. Основний спосіб добування чавуну – плавлення в доменних печах. Сучасні доменні печі – вертикальні печі шахтного типу з об'ємом печі 3000...5000 м$^3$ і продуктивністю 5000...5500 т чавуну за добу. Висота таких печей досягає 30...40 м. Вони працюють безперервно протягом 5–10 років. Вихідними матеріалами доменного процесу є залізна руда, паливо, повітря, а іноді й марганцеві руди. Серед залізних руд, що мають промислове застосування, розрізняють: магнітний залізняк, який містить 45...70% заліза, червоний залізняк – 55...60% заліза і бурий залізняк – 35...60% заліза.

Кремній – найважливіший після вуглецю елемент у чавуні, він збільшує рідкотекучість його при заливанні, поліпшує його ливарні властивості і робить м'якшим.

Марганець підвищує міцність чавуну. Сірка в чавуні – шкідлива домішка, що викликає червоноламкість – утворення тріщин у гарячих виливках. Крім того, сірка погіршує рідкотекучість чавуну, бо робить його густим, унаслідок чого він погано заповнює форми.

Фосфор погіршує механічні властивості чавуну і спричиняє холодноламкість – здатність виливок утворювати тріщини в холодному стані. Для машинобудівного лиття фосфор є шкідливого домішкою. Його вміст у відповідальних виливках допускається до 0,1%, у менш відповідальних – до 1,2% [5].

EXERCISE13

Prepare reports using Internet or other sources (catalogues, magazines, books, etc.) about the latest news, achievements in the field concerning the topic of the chapter.

EXERCISE 14

It’s interesting to know…

## METALS AND ALLOYS

In the last thirty years or so, due to the fast development of industry, the need for new metallic materials has enormously increased. Metals practically unheard of before, such as germanium, plutonium, and thorium, have come to light, taking their place in the electronic and atomic industries. There have also been developed high-temperature alloys for power plants capable of withstanding oxidation and erosion, new ferromagnetic materials, constructional steels, etc., intended for operating under severe stresses, or/and at extremely high or low temperatures.

Practically speaking, each metal possesses certain distinct combinations of properties, which may be varied for specific engineering applications by alloying it with relatively small amounts of other metals.

The term "alloy" is commonly used to describe a material containing more than one chemical element, the properties of the alloy being determined by the properties of the elements it consists of. The term "pure metal", on the other hand, is used for materials in which almost all chemical elements but one are eliminated.

The distinction between metals and alloys is immaterial' for describing the effects of their chemical composition on forming, such as rolling, forging, pressing, etc. But even small amounts of chemical elements, or impurities, in pure metals used in electronics may affect their performance in the same way as the comparatively large quantities of alloying elements in pure metals used in other fields of engineering. The designation "metal" is sometimes applied in metallurgy to any metallic materials without making distinction between pure metal and alloy, the first definition of the word "metal" having been formulated by M. V. Lomonosov in the following way: "A metal is a bright solid that can be forged." The most important feature of metals, however, is their high electrical conductivity which decreases as the temperature is raised.

As to the term "element", it is frequently used not only for commercially pure metals but also for some alloys containing a considerable amount of other metals, the most common but rather misleading term of this nature being "iron", when used in English-speaking countries for designation of cast iron containing a large quantity of carbon.

Otherwise, an alloy possessing properties materially different from those of the pure metal which forms its basis is designated as an alloy of this metal, such as a copper alloy, an aluminium alloy, etc., the basis of an alloy in this respect being the element which is present in a quantity over 50 per cent by weight. However, in exceptional cases, the basis of an alloy may comprise less than 50%, as in the case of an iron alloy containing 40% iron, 30% cobalt, and 30%) chromium, with the addition of two, three or more other elements.

When added to a pure metal, a certain amount of second metal may cause the change of its grain structure in two distinctly different manners: either the structure of such a binary alloy has the same homogeneous structure as that of pure metal, the alloy possessing such a structure being called a solid solution, or the second element forms crystallites different from those of the pure metal, the structure thus formed being known as heterogeneous mixture of two phases. With one phase containing less, and the other more, of the second element, the two phases are of different chemical composition.

A third element added to a binary alloy having a homogeneous structure may result again in either a homogeneous or a heterogeneous structure. If added to a binary alloy having a heterogeneous structure, the third element may either appear without any effectors add a third phase to the structure. The term "phase", when used in metallurgy, designates any homogeneous and physically distinct part of a system which is separated from other parts of the system by definite bounding surfaces.

The forming properties of binary alloys being dependent upon the properties of their elements, their quantities and their structure, the rules which govern these relations have been comparatively well established both for cold and hot working. As to the performance of alloys on hot working, it is quite different from that on cold working. Metals being generally hot-worked at temperatures where they possess the highest ductility, the knowledge of the effect of temperature on such materials is of paramount importance; therefore the selection of the proper hot-working temperature becomes the major problem a processing engineer has to deal with. Cold working causes fragmentation, distortion and possible reorientation of the grains, resulting in the increased strength and hardness and, consequently, in the loss of ductility. As compared to hot working, the stresses involved in cold working are greater. For evaluating the performance of metals and alloys on hot and cold working the processing engineer has at his disposal a large amount of information, which is not referred to in this text [4].

## Alloys

An alloy is a homogenous mixture of two or more elements, at least one of which is a metal, and where the resulting material has metallic properties. The resulting metallic substance usually has different properties (sometimes significantly different) from those of its components.

Alloys are usually prepared to improve on the properties of their components. For instance, Steel is stronger than iron, its primary component.

The physical properties of an alloy, such as density, reactivity and electrical and thermal conductivity may not differ greatly from the alloy's elements, but engineering properties, such as tensile strength, shear strength and Young’s modulus, can be substantially different from those of the constituent materials. This is sometimes due to the differing sizes of the atoms in the alloy—larger atoms exert a compressive force on neighboring atoms, and smaller atoms exert a tensile force on their neighbors. This helps the alloy resist deformation, unlike a pure metal where the atoms move more freely.

Unlike pure metals, most alloys do not have a single melting point. Instead, they have a melting range in which the material is a mixture of solid and liquid phases. The temperature at which melting begins is called the solidus, and that at which melting is complete is called the “liquidus”. However, for most pairs of elements, there is a particular ratio which has a single melting point; this is called the eutectic mixture.

Alloys can be classified by the number of their constituents. An alloy with two components is called a binary alloy; one with three is a ternary alloy, and so forth. Alloys can be further classified as either substitution alloys or interstitial alloys, depending on their method of formation. In substitution alloys, the atoms of the components are approximately the same size and the various atoms are simply substituted for one another in the crystal structure. An example of a (binary) substitution alloy is brass, made up of copper and zinc. Interstitial alloys occur when the atoms of one component are substantially smaller than the other and the smaller atoms fit into the spaces (interstices) between the larger atoms.

In practice, some alloys are used so predominantly with respect to their base metals that the name of the primary constituent is also used as the name of the alloy. For example, 14 karat gold is an alloy of gold with other elements. Similarly, the silver used in jewelry and the aluminum used as a structural building material are also alloys.

The term “alloy” is sometime used in everyday speech as a synonym for a particular alloy. For example, automobile wheels made of “aluminum alloy” are commonly referred to as simply “alloy wheels”. The usage is obviously indefinite, since steels and most other metals in practical use are also alloys.[4]

# CHAPTER 2

# STEEL

Steel in general is an alloy of iron and carbon, often with an admixture of other elements. Some alloys that are commercially called irons contain more carbon than commercial steels. Open-hearth iron and wrought iron contain only a few hundredths of 1 percent of carbon. Steels of various types contain from 0.04 percent to 2.25 percent of carbon. Cast iron, malleable cast iron, and pig iron contain amounts of carbon varying from 2 to 4 percent. A special form of malleable iron, containing virtually no carbon, is known as white-heart malleable iron. A special group of iron alloys, known as ferroalloys, is used in the manufacture of iron and steel alloys; they contain from 20 to 80 percent of an alloying element, such as manganese, silicon, or chromium.

Steels are grouped into five main classifications.

## Carbon steels

More than 90 percent of all steels are carbon steels. They contain varying amounts of carbon and not more than 1.65 percent manganese, 0.60 percent silicon, and 0.60 percent copper. Machines, automobile bodies, most structural steel for buildings, ship hulls, bedsprings, and bobby pins are among the products made of carbon steels.

## Alloy steels

These steels have a specified composition, containing certain percentages of vanadium, molybdenum, or other elements, as well as larger amounts of manganese, silicon, and copper than do the regular carbon steels. Automobile gears and axles, roller skates, and carving knives are some of the many things that are made of alloy steels.

## High-Strength Low-Alloy Steels

Called HSLA steels, they are the newest of the five chief families of steels. They cost less than the regular alloy steels because they contain only small amounts of the expensive alloying elements. They have been specially processed, however, to have much more strength than carbon steels of the same weight. For example, freight cars made of HSLA steels can carry larger loads because their walls are thinner than would be necessary with carbon steel of equal strength; also, because an HSLA freight car is lighter in weight than the ordinary car, it is less of a load for the locomotive to pull. Numerous buildings are now being constructed with frameworks of HSLA steels. Girders can be made thinner without sacrificing their strength, and additional space is left for offices and apartments [1].

## Stainless Steels

Stainless steels contain chromium, nickel, and other alloying elements that keep them bright and rust resistant in spite of moisture or the action of corrosive acids and gases. Some stainless steels are very hard; some have unusual strength and will retain that strength for long periods at extremely high and low temperatures. Because of their shining surfaces architects often use them for decorative purposes. Stainless steels are used for the pipes and tanks of petroleum refineries and chemical plants, for jet planes, and for space capsules. Surgical instruments and equipment are made from these steels, and they are also used to patch or replace broken bones because the steels can withstand the action of body fluids. In kitchens and in plants where food is prepared, handling equipment is often made of stainless steel because it does not taint the food and can be easily cleaned.

**Tool Steels**

These steels are fabricated into many types of tools or into the cutting and shaping parts of power-driven machinery for various manufacturing operations. They contain tungsten, molybdenum, and other alloying elements that give them extra strength, hardness, and resistance to wear.

**Structure of Steel**

The physical properties of various types of steel and of any given steel alloy at varying temperatures depend primarily on the amount of carbon present and on how it is distributed in the iron. Before heat treatment most steels are a mixture of three substances: ferrite, pearlite, and cementite. Ferrite is iron containing small amounts of carbon and other elements in solution and is soft and ductile. Cementite, a compound of iron containing about 7 percent carbon, is extremely brittle and hard. Pearlite is an intimate mixture of ferrite and cementite having a specific composition and characteristic structure, and physical characteristics intermediate between its two constituents. The toughness and hardness of steel that is not heat treated depend on the proportions of these three ingredients. As the carbon content of a steel increases, the amount of ferrite present decreases and the amount of pearlite increases until, when the steel has 0.8 percent of carbon, it is entirely composed of pearlite. Steel with still more carbon is a mixture of pearlite and cementite. Raising the temperature of steel changes ferrite and pearlite to an allotropic form of iron-carbon alloy known as austenite, which has the property of dissolving all the free carbon present in the metal. If the steel is cooled slowly the austenite reverts to ferrite and pearlite, but if cooling is sudden, the austenite is “frozen” or changes to martensite, which is an extremely hard allotropic modification that resembles ferrite but contains carbon in solid solution.[1]

EXERCISE 1

Fill in the blanks with appropriate words.

The most important metal in (1) ____ is iron and its alloy - steel. Steel is an alloy of iron and (2) ____. It is strong but corrodes easily through rusting, although stainless and other special steels resist (3) ____. The amount of carbon in steel influences its (4) ____ considerably. Steels of low carbon content (mild steels) are quite ductile and are used in the manufacture of sheet iron, (5) ____. (6) ____ containing from 0.2 to 0.4 per cent carbon are tougher and stronger and are used as structural steels. Both mild and medium-carbon steels are suitable for (7) ____. High-carbon steels contain from 0.4 to 1.5 per cent carbon, are hard and (8) ____ and are used in cutting tools, surgical instruments, razor blades and springs. (9) ____, also called silver steel, contains about 1 per cent carbon and is strengthened and toughened by quenching and tempering.

---

Tool steel, medium-carbon steels, corrosion, properties, forging and welding, industry, carbon, wire and pipes, brittle.

EXERCISE 2

Complete the sentences.

| | |
|---|---|
| 1. The inclusion of other elements affects … | a) extra strength and corrosion resistance, so we can get rust-proof steels. |
| 2. Manganese gives … | b) the proportions of three ingredients. |
| 3. Steel containing 4 per cent silicon is used for … | c) small amounts of carbon and other elements in solution. |
| 4. The addition of chromium gives… | d) the properties of the steel. |
| 5. Heating in the presence of carbon or nitrogen-rich materials is used … | e) chromium and tungsten plus smaller amounts of vanadium, molybdenum and other metals. |
| 6. High-speed steels, which are extremely important in machine-tools, contain … | f) to form a hard surface on steel (case-hardening). |
| 7. The toughness and hardness of a steel that is not heat treated depend on … | g) transformer cores or electromagnets because it has large grains acting like small magnets. |
| 8. Ferrite is iron containing … | h) extra strength and toughness. |

EXERCISE 3

Fill in the blanks with prepositions *with, at, by, in, of, on.*

1. Quenching is a heat treatment when metal …a high temperature is rapidly cooled … immersion …water or oil. 2. Quenching makes steel harder and more brittle … small grains structure.3. The colour … the oxide film produced … the surface … the heated metal often serves as the indicator … its temperature. 4. Tempering temperatures depend … the composition … the steel but are frequently between 100 and 650 °C. 5. Annealing is a heat treatment … which a material … high temperature is cooled slowly. 6. All these methods … steel heat treatment are used to obtain steels … certain mechanical properties for certain needs. 7. These steels have a specified composition, containing certain percentages … vanadium, molybdenum, or other elements.

EXERCISE 4

Make up questions to which the italicized words are the answers.

1. *Tempering* is a heat treatment applied to steel and certain alloys. 2. Tempering, that is re-heating to an intermediate temperature and cooling slowly, reduces *this hardness and brittleness*. 3. Higher temperatures usually give *a softer, tougher product*. 4. *After cooling* the metal again becomes malleable and ductile (capable of being bent many times without cracking). 5. *Hardened steel after quenching from a high temperature* is too hard and brittle for many applications and is also brittle. 6. Metallurgists have discovered that the change from austenite to martensite occurs *during the latter part of the cooling period.* 7. Three comparatively new processes have been developed *to avoid cracking.*

EXERCISE 5

Translate the words into Ukrainian:

Alloy, admixture, open-hearth iron, wrought iron, cast iron, carbon steel, silicon, stainless steel, handling equipment, power-driven machinery, resistance, ferrite, pearlite, cementite, toughness, austenite, solid solution, tempering, annealing, physical properties, hardening, martensite, cooling, high-speed steel, rust-resistant steel.

EXERCISE 6

Translate the sentences into Ukrainian paying attention to the italicized words:

1. *Strength, ductility, cheapness and machineability* are the four most important industrial and commercial properties of steel. 2. *Carbon steel* has been known to be the principal product of the steel industry. 3. Besides iron and carbon, it contains small quantities of *manganese, phosphorus, sulphur, and silicon*. 4. Each of these elements affects the *physical properties of steel*. 5. The most important influence of carbon is *in connection with* the hardness, strength, and ductility of the metal. 6. Manganese *comes* directly after carbon *in importance*. 7. It improves *rolling and forging qualities* of metal and at the same time minimizes the *harmful effect* of sulphur. 8. Phosphorus acts somewhat like carbon in that, that it increases *tensile strength and hardness* while decreasing ductility. 9. Silicon is an *excellent deoxidizer* or *cleaner of steel*. 10. The primary purpose of the *heat-treating process* is to control the amount, size, shape, and distribution of the cementite particles in the *ferrite*.

EXERCISE 7

Answer the following questions:

1. What is steel? 2. What are the main properties of steel? 3. What are the drawbacks of steel? 4. What kinds of steel do you know? Where are they used? 5. What gives the addition of manganese, silicon and chromium to steel? 6. What can be made of mild steels (medium-carbon steels, high-carbon steels)? 7. What kind of steels can be forged and welded? 8. How can we get rust-proof (stainless) steel? 9. What is used to form a hard surface on steel? 10. What are high-speed steels alloyed with? 11. What process improves the mechanical properties of metals? 12. What new properties have hot-worked products? 13. How does the forging of a bar affect the grains of the metal? What is the result of this? 14. How are the flow lines in the forged metal oriented and how does it affect the strength of the forged part? 15. What are the best strain-hardening alloys? Where can we use them? 16. What are the inner flaws in the metal? 17. Can a metal fracture because of the inner flaw? 18. What limits the change of the shape during forming operations?

EXERCISE 8

Say true or false and explain:

1. Alloy steels are never used in industry.
2. Steel is a very strong metal.
3. The metal is poured at an extremely low temperature.
4. High carbon steel should be hardened by heating it to a certain temperature then quickly cooling in water.
5. Chromium and tungsten are to increase the hardness and strength of steel.
6. Special alloy steels can be used for parts requiring great wear resistance.
7. Steel is a ferrous metal with no carbon content.
8. Metals such as copper and aluminum are less ductile in such operations than other metals.
9. Before heat treatment most steels are a mixture of three substances: ferrite, pearlite, and cementite.
10. Cast iron, malleable cast iron, and pig iron contain amounts of carbon varying from 20 to 40 percent.

EXERCISE9

Translate the texts without a dictionary:

**A.** An important feature of hot working is that it provides the improvement of mechanical properties of metals. Hot-working (hot-rolling or hot-forging) eliminates porosity, directionality, and segregation that are usually present in metals. Hot-worked products have better ductility and toughness than the unworked casting. During the forging of a bar, the grains of the metal become greatly elongated in the direction of flow. As a result, the toughness of the metal is greatly improved in this direction and weakened in directions transverse to the flow. Good forging makes the flow lines in the finished part oriented so as to lie in the direction of maximum stress when the part is placed in service [2].

**B.** The ability of a metal to resist thinning and fracture during cold-working operations plays an important role in alloy selection. In operations that involve stretching, the best alloys are those which grow stronger with strain (are strain hardening) — for example, the copper-zinc alloy, brass, used for cartridges and the aluminum-magnesium alloys in beverage cans, which exhibit greater strain hardening [3].

**C.** Fracture of the workpiece during forming can result from inner flaws in the metal. These flaws often consist of nonmetallic inclusions such as oxides or sulfides that are trapped in the metal during refining. Such inclusions can be avoided by proper manufacturing procedures. The ability of different metals to undergo strain varies. The change of the shape after one forming operation is often limited by the tensile ductility of the metal. Metals such as copper and aluminum are more ductile in such operations than other metals [2].

EXERCISE10
Translate the following texts in a written form using a dictionary:

Text 1

Essentially the production of steel from pig iron by any process consists of burning out the excess carbon and other impurities present in the iron. One difficulty in the manufacture of steel is its high melting point, about 1,370° C (about 2,500° F), which prevents the use of ordinary fuels and furnaces. To overcome this difficulty the open-hearth furnace was developed; this furnace can be operated at a high temperature by regenerative preheating of the fuel gas and air used for combustion in the furnace. In regenerative preheating, the exhaust gases from the furnace are drawn through one of a series of chambers containing a mass of brickwork and give up most of their heat to the bricks. Then the flow through the furnace is reversed and the fuel and air pass through the heated chambers and are warmed by the bricks. Through this method open-hearth furnaces can reach temperatures as high as 1,650° C (approximately 3,000° F) [3].

Text 2

Chemically the action of the open-hearth furnace consists of lowering the carbon content of the charge by oxidization and of removing such impurities as silicon, phosphorus, manganese, and sulfur, which combine with the limestone to form slag. These reactions take place while the metal in the furnace is at melting heat, and the furnace is held between 1,540° and 1,650° C (2,800° and 3,000° F) for many hours until the molten metal has the desired carbon content. Experienced open-hearth operators can often judge the carbon content of the metal by its appearance, but the melt is usually tested by withdrawing a small amount of metal from the furnace, cooling it, and subjecting it to physical examination or chemical analysis. When the carbon content of the melt reaches the desired level, the furnace is tapped through a hole at the rear. The molten steel then flows through a short trough to a large ladle set below the furnace at ground level. From the ladle the steel is poured into cast-iron molds that form ingots usually about 1.5 m (about 5 ft) long and 48 cm (19 in) square. These ingots, the raw material for all forms of fabricated steel, weigh approximately 2.25 metric tons in this size. Recently, methods have been put into practice for the continuous processing of steel without first having to go through the process of casting ingots [2].

EXERCISE11

Translate the text into English:

Виробництво сталі

Сталь – деформований (ковкий) сплав заліза з вуглецем (до 2%) та іншими елементами. За хімічним складом сталь поділяють на вуглецеву й леговану. Вуглецева сталь поряд із залізом і вуглецем містить марганець (до 1%) і кремній (до 0,4%), а також шкідливі домішки – сірку і фосфор. До складу легованої сталі, крім зазначених компонентів, входять так звані леговані елементи (хром, нікель, молібден, вольфрам, ванадій, титан та інші), що підвищують якість сталі, надають їй особливих властивостей.

Головною складовою, що визначає властивості сталі, є вуглець. Зі збільшенням його процентного вмісту міцність сталі підвищується, а здатність до пластичної деформації знижується.

За призначенням сталь поділяється на конструкційну та інструментальну; конструкційна сталь призначена для виготовлення деталей машин і конструкцій, а інструментальна – для виготовлення інструментів.

За способом виробництва сталь поділяють на конверторну, мартенівську та електросталь.

Найпрогресивнішим і економічним способом одержання сталі є виплавляння в кисневих конверторах, яке полягає в продуванні рідкого чавуну киснем. Час добування сталі в конверторах місткістю 300 т становить 45 хв.

Сучасна мартенівська піч являє собою велику ванну, викладену вогнетривкою цеглою. Місткість її до 900 т. Розрізняють два варіанти плавлення: скрап-процес і скрап-рудний процес. Скрап-процес проводять на машинобудівних заводах, де в піч завантажують чушковий чавун, металолом і трохи залізної руди. При скрап-рудному процесі на металургійних комбінатах в мартенівську піч додають рідкий чавун, металолом, залізну руду і флюси. Кисневе дуття збільшує продуктивність печей удвічі.

Для виплавляння сталі використовують дугові та індукційні (високочастотні) печі. Перші більш поширені, ніж другі [5].

EXERCISE12

Prepare reports using Internet or other sources (catalogues, magazines, books, etc.) about the latest news, achievements in the field concerning the topic of the chapter.

EXERCISE 13 It's interesting to know…

## History of Steel and Iron

The exact date at which people discovered the technique of smelting iron ore to produce usable metal is not known. The earliest iron implements discovered by archaeologists in Egypt date from about 3000 BC, and iron ornaments were used even earlier; the comparatively advanced technique of hardening iron weapons by heat treatment was known to the Greeks about 1000 BC.

The alloys produced by early iron workers, and, indeed, all the iron alloys made until about the 14th century AD, would be classified today as wrought iron. They were made by heating a mass of iron ore and charcoal in a forge or furnace having a forced draft. Under this treatment the ore was reduced to the sponge of metallic iron filled with a slag composed of metallic impurities and charcoal ash. This sponge of iron was removed from the furnace while still incandescent and beaten with heavy sledges to drive out the slag and to weld and consolidate the iron. The iron produced under these conditions usually contained about 3 percent of slag particles and 0.1 percent of other impurities. Occasionally this technique of iron making produced, by accident, a true steel rather than wrought iron. Ironworkers learned to make steel by heating wrought iron and charcoal in clay boxes for a period of several days. By this process the iron absorbed enough carbon to become true steel.

After the 14th century the furnaces used in smelting were increased in size, and increased draft was used to force the combustion gases through the "charge," the mixture of raw materials. In these larger furnaces, the iron ore in the upper part of the furnace was first reduced to metallic iron and then took on more carbon as a result of the gases forced through it by the blast. The product of these furnaces was pig iron, an alloy that melts at a lower temperature than steel or wrought iron. Pig iron (so called because it was usually cast in stubby, round ingots known as pigs) was then further refined to make steel.

Modern steelmaking employs blast furnaces that are merely refinements of the furnaces used by the old ironworkers. The process of refining molten iron with blasts of air was accomplished by the British inventor Sir Henry Bessemer who developed the Bessemer furnace, or converter, in 1855. Since the 1960s, several so-called minimills have been producing steel from scrap metal in electric furnaces. Such mills are an important component of total U.S. steel production. The giant steel mills remain essential for the production of steel from iron ore [4].

**Heat Treatment of Steel**

The basic process of hardening steel by heat treatment consists of heating the metal to a temperature at which austenite is formed, usually about 760° to 870° C (about 1,400° to 1,600° F) and then cooling, or quenching, it rapidly in water or oil. Such hardening treatments, which form martensite, set up large internal strains in the metal, and these are relieved by tempering, or annealing, which consists of reheating the steel to a lower temperature. Tempering results in a decrease in hardness and strength and an increase in ductility and toughness.

The primary purpose of the heat-treating process is to control the amount, size, shape, and distribution of the cementite particles in the ferrite, which in turn determines the physical properties of the steel.

Many variations of the basic process are practiced. Metallurgists have discovered that the change from austenite to martensite occurs during the latter part of the cooling period and that this change is accompanied by a change in volume that may crack the metal if the cooling is too swift. Three comparatively new processes have been developed to avoid cracking. In time-quenching the steel is withdrawn from the quenching bath when it has reached the temperature at which the martensite begins to form, and is then cooled slowly in air. In martempering the steel is withdrawn from the quench at the same point, and is then placed in a constant-temperature bath until it attains a uniform temperature throughout its cross section. The steel is then allowed to cool in air through the temperature range of martensite formation, which for most steels is the range from about 288° C (about 550° F) to room temperature. In austempering the steel is quenched in a bath of metal or salt maintained at the constant temperature at which the desired structural change occurs and is held in this bath until the change is complete before being subjected to the final cooling.

Other methods of heat treating steel to harden it are used. In case hardening, a finished piece of steel is given an extremely hard surface by heating it with carbon or nitrogen compounds. These compounds react with the steel, either raising the carbon content or forming nitrides in its surface layer. In carburizing, the piece is heated in charcoal or coke, or in carbonaceous gases such as methane or carbon monoxide. Cyaniding consists of hardening in a bath of molten cyanide salt to form both carbides and nitrides. In nitriding, steels of special composition are hardened by heating them in ammonia gas to form alloy nitrides [4].

# CHAPTER 3

# NON-FERROUS METALS

Non-ferrous metals are those metals which does not contain iron. They are not magnetic and are usually more resistant to corrosion than ferrous metals. Most commonly used non-ferrous metals are Aluminum, Copper, Brass, Lead, Tin, Gilding Metal and Zinc.

## Aluminium

Aluminium is a widely used non-ferrous metal. It is grayish-white in colour, soft and malleable. This non-ferrous metal is conductive to heat and electricity. It is corrosion resistant. Aluminium can be welded but this is difficult. Special processes need to be adopted in order to weld it properly. Due to its light weight, it is used in the manufacturing of aircrafts and boats. Its other uses are window frames, saucepans, packaging and insulation, pistons and cranks.

## Aluminium alloys (duraluminium)

Aluminium alloys (duraluminium) is composed of aluminium, copper and canganese. It’s also ductile, malleable, work hardens. It is used in the manufacturing of aircrafts and vehicle parts.

## Copper

Copper is another very important pure non-ferrous metal. It’s red in color, tough and ductile. It is very good electrical conductor and offers great resistance to corrosion. Copper can work hard or cold but it needs frequent annealing. Copper is mostly used in the manufacturing of electric wires, cables and conductors. Its other uses are water and central heating pipes and cylinders, Printed circuit boards and manufacturing of special roofs.

## Brass

Another important non-ferrous metal is Brass which is not a pure metal but combination of Copper and Zinc. It contains 65% copper and 35% Zinc. This non-ferrous metal is very corrosive, yellow in color, tarnishes very easily. It is harder than copper and its good electrical conductor.

## Lead

Lead is a pure and an important non-ferrous metal. It is the heaviest common metal. The other characteristics are its softness, malleability and brightness. It is shiny metal when new but quickly oxidizes to a dull grey. It has resistant to corrosion. Its uses are different than other non-ferrous metals. It is used in protection against X-Ray machine, paints, roof coverings, flashings etc.

## Zinc

Zink is also a pure and an important non-ferrous metal. A layer of oxide protects it from corrosion. It is bluish-white in color and easily worked. It is used to makes brass by mixing and processing with Copper. It is used as coating layer for steel galvanized corrugated iron roofing, tanks, buckets, rust-proof paints etc [1].

**Tin**

Tin is a pure non-ferrous metal. It is white in color, soft and corrosion resistant. It is used in Tinplate and making bronze.

**Gilding metal:**

This non-ferrous metal comprises of 85% copper and 15% zinc. It is corrosion resistant, golden in color and enamels well. Its uses are beaten metalwork and artificial jewelry manufacturing.

Non-ferrous metals offer a wide variety of mechanical properties and material characteristics. Non-ferrous metals are specified for structural applications requiring reduced weight, higher strength, nonmagnetic properties, higher melting points, or resistance to chemical and atmospheric corrosion. They are also specified for electrical and electronic applications.

Material selection for a mechanical or structural application requires some important considerations, including how easily the material can be shaped into a finished part and how its properties can be either intentionally or inadvertently altered in the process. Depending on the end use, metals can be simply cast into the finished part, or cast into an intermediate form, such as an ingot, then worked, or wrought, by rolling, forging, extruding, or other deformation process. Although the same operations are used with ferrous as well as non-ferrous metals and alloys, the reaction of non-ferrous metals to these forming processes is often more severe. Consequently, properties may differ considerably between the cast and wrought forms of the same metal or alloy.

To shape both non-ferrous and ferrous metals, designers use processes that range from casting and sintered powder metallurgy (P/M) to hot and cold working. Each forming method imparts unique physical and mechanical characteristics to the final component [1].

EXERCISE 1

Fill in the blanks with appropriate words:

(1) ____ such as brass, some stainless steel, lead and (2) ____ cause quality control concerns in recycled glass processing. Depending on the (3) ____, undetected metal contaminants can cause costly problems with equipment and products. Non-ferrous metals can cause damage to (4) ____ in container and fiberglass manufacturing. Non-ferrous metals also may cause (5) ____ where processed recycled glass is used in composition materials.

Finally, the presence of non-ferrous metals can cause a (6) ____. Magnetic removal of ferrous metals is straightforward because ferrous metals physically react to (7) ____, facilitating their removal. Non-ferrous metals and ceramic contaminants pose greater challenges because the (8) ____ for their effective removal is more complicated. These contaminants also become (9) ____ to remove in proportion to the fineness of the processed material being cleaned.

---

Non-ferrous metals, compatibility problems, technology, increasingly difficult, end-use application, furnaces and glass forming equipment, disclosure problem, magnetic fields, aluminum.

EXERCISE 2

Complete the sentences.

| | |
|---|---|
| 1. Zinc is … | a) the manufacturing of aircrafts and vehicle parts. |
| 2. Lead is … | b) the manufacturing of electric wires, cables and conductors. |
| 3. Zinc alloys offer … | c) a relatively cheap element. |
| 4. The low price and good casting properties justify … | d) very corrosive, yellow in colour, tarnishes very easily. |
| 5. Tin is used in … | e) relatively small, which makes it expensive. |
| 6. The occurrence of copper in earth's crust is … | f) 85% copper and 15% zinc. |
| 7. Brass metal is … | g) tinplate and making bronze. |
| 8. Gilding metal comprises of … | h) a good corrosion resistance, especially against rain. |
| 9. Copper is mostly used in … | i) shiny metal when new but quickly oxidizes to a dull grey. |
| 10. Aluminium alloys are used in … | j) the application in mass-production by injection moulding. |

EXERCISE 3

Fill in the blanks with prepositions *with, of, in, at, for*

1. The non-ferrous industries deal … a similar cross-section … material types … the production … metals such as copper, nickel, lead and zinc. 2. But … these industries much more time and effort is spent … analyzing exploratory core body samples since these metals are generally present … much lower concentrations … the earths crust than is iron and more widely dispersed. 3. Aluminum and copper are widely used … high electrical conductibility applications where the presence … some elements … even a trace level can give rise to unacceptable high power losses … electrical transmission lines. 4. … aluminum an added concern is the fact that the anodizing characteristics … the metal are strongly influenced by the presence … certain elements. 5. Thus … both, copper and aluminum, the most relevant analytical data concern is the detection limits achievable … a spectrometer.

EXERCISE 4

Make up questions to which the italicized words are the answers:

1. *Non-ferrous metals* offer a wide variety of mechanical properties and material characteristics. 2. Metals can be simply cast into *the finished part.*

3. *With the rapid development of the production base* in China, India and the Far East, the flow of non-ferrous scrap metals has switched increasingly from West to East. 4. The two steps for non-ferrous contaminant screening are detection and removal. 5. *The magnetic field size and length of time the material is exposed to detection* are set to the physical characteristics of recycled glass. 6. Wrought aluminum alloys are also strengthened by *cold working*.

EXERCISE 5

Translate the words into Ukrainian:

Corrosion, structural applications, higher strength, electrical application, ingot, finished part, forging, rolling, alloys, manufacturing, light weight, electrical conductor, annealing, coating layer, rust-proof paints, thermal conductivity, melting temperature, castability, toughness, mass-production, recycling, weldability, machinability, formability.

EXERCISE 6

Translate the sentences into Ukrainian paying attention to the italicized words:

1. The occurrence of copper in *earth's crust* is relatively small, which makes it expensive and *recycling necessary*. 2. Excellent *corrosion resistance* and *high electric and thermal conductivity* govern many of the applications in e.g. electrics or decoration. 3. In many cases, copper is alloyed to increase mechanical and manufacturing properties and *resistance against wear and corrosion*. 4. *Biphasic alloys* are often used for bearings. 5. Alloying often has a negative effect on *conductivity*. 6. Cast copper is often alloyed with large amounts of brass or bronze, decreasing the *melting temperature*, increasing *casting properties*. 7. Commercial casting alloys include *heat-treatable and non heat-treatable* compositions. 8. Zinc alloys have an excellent *castability*, related with their low *melting temperatures*, and are therefore perfectly fit for casting from *sand casting* to *injection moulding*. 9. Very low *wall thicknesses* are achievable and the surface hardly requires any *after-treatment*. 10. The strength of Zinc alloys is relatively low, and their tendency *to creep* makes them *unsuitable* for use at temperatures above 100C.

EXERCISE 7

Complete the table using information from the text:

| **Name** | **Composition** | **Properties** | **Uses** |
|---|---|---|---|
| Aluminium | | | Aircraft, boats, window frames, saucepans, packaging and insulation, pistons and crank |
| Aluminium alloys-Duraluminium) | | Ductile, Malleable, Work Hardens | |
| | Pure metal | | Electrical wire, cables and conductors, water and central heating pipes and cylinders. Printed circuit boards, roofs |
| Brass | 65% copper +35% zinc | | |
| Lead | | The heaviest common metal. Soft, malleable, bright and shiny when new but quickly oxidizes to a dull grey. Resistant to corrosion | |
| | | A layer of oxide protects it from corrosion, bluish-white, easily worked | Makes brass. Coating for steel galvanized corrugated iron roofing, tanks, buckets, rust-proof paints |
| Tin | Pure metal | | |
| | 85% copper+15% zinc | Corrosion resistant, golden colour, enamels well | |

EXERCISE 8

Answer the following questions:

1. What metals are called non-ferrous? 2. What color is aluminum? 3. What are the properties of aluminum? 4. Why is aluminum used in the manufacturing of aircrafts and boats? 5. What are the properties of Copper? 6. Where is Copper used? 7. Is Brass a pure metal? 8. What are the characteristics of Lead? 9. Where is Zink used? 10. What are non-ferrous metals specified for?

EXERCISE 9

Say true or false and explain:

1. Non-ferrous metals are those metals which contain iron.
2. Metals can be simply cast into the finished part or cast into an intermediate form.
3. Properties may differ considerably between the cast and wrought forms of the same metal or alloy.
4. Copper is a widely used non-ferrous metal. It is Grayish-White in colour, soft and malleable. This non-ferrous metal is conductive to heat and electricity.
5. Aluminium is mostly used in the manufacturing of electric wires, cables and conductors. Its other uses are water and central heating pipes and cylinders, Printed circuit boards and manufacturing of special roofs.
6. Lead is very corrosive, yellow in colour, tarnishes very easily.
7. Zink is used as coating layer for steel galvanized corrugated iron roofing, tanks, buckets, rust-proof paints etc.
8. Brass comprises of 85% copper and 15% zinc.
9. The occurrence of copper in earth's crust is relatively small, which makes it expensive and recycling necessary.
10. Each forming method imparts unique physical and mechanical characteristics to the final component.

EXERCISE10

Translate the texts without a dictionary:

**A.** Magnesium is very abundantly available, for example in sea water. The extracting process however takes a large amount of energy: 72 MJ/kg Mg, which makes it relatively expensive. Magnesium has a density even lower than aluminium. Magnesium is not covered by a protective oxide layer, but oxidation rates are normally low. In wet environments protection is necessary (anodizing, coating). Strength can only be enhanced by alloying. Castability of magnesium is good, and its machinability is excellent: it is fast and offers a high quality. For that reason castings of magnesium and alloys represent about 85% of the magnesium applications [2].

**B.** Nickel is an element of very rare occurrence, and is therefore quite expensive. Nickel has a high strength, also at very high temperatures, while the toughness is still good, even at very low temperatures. Nickel provides an excellent resistance against corrosion, also up to elevated temperatures. Alloying is done to increase the mechanical properties, to shift the working temperature to even higher levels (over 1000°C), and to increase the corrosion resistance, at high temperatures and in aggressive environments. The good high temperature properties of Nickel alloys explain their widespread use as turbine blades for example [3].

**C.** Aluminium is very well available in the form of bauxite. The reason for its high price is the large amount of electric energy, necessary for the extraction process: 148 MJ/kg Al. Recycling of used material (secondary aluminium) takes considerably less energy. Therefore recycling is favourable, although some alloying elements cause problems. Corrosion resistance is good, especially for pure aluminium. Castability and weldability of aluminium are good, due to the low melting temperatures caused by the alloying elements. Manufacturing of aluminium by machining is difficult because of the high plasticity [3].

EXERCISE11

Translate the following texts in a written form using a dictionary:

Text 1

The two steps for non-ferrous contaminant screening are detection and removal. Several manufacturers produce equipment for non-ferrous metal separation. The most prevalent technology is known as an "eddy-current" detection system. An eddy current is an electric current induced within a conductor (in this case the non-ferrous metal) when that conductor either moves through a non-uniform magnetic field or is subjected to a change in magnetic flux. When non-ferrous metals in a glass stream are exposed to an alternating magnetic field, an eddy-current system can detect their presence with a proximity sensor. This technology is well suited to identify non-ferrous metals within a commingled stream of material such as recycled glass [2].

Text 2

After the non-ferrous material is detected it must be removed from the stream. This is done with a diverter mechanism to reject contaminants. The diverter may be either a mechanical gate or a pneumatic blast. Diverter mechanisms must function very rapidly to remove metal particles and to prevent diverting an excess quantity of glass. High sensitivity detectors can sense particles down to less than j inch in size. The removal mechanism is timed to reject a small portion of the contaminated cullet including the non-ferrous metal. The rejected materials are discharged through a different port to ensure segregation. Some systems include cascading secondary and tertiary detection conveyor systems to compound contaminate removal efficiency [3].

EXERCISE12
Translate the text into English:

**Кольорові метали**

Кольорові метали та їхні сплави широко застосовують у машинобудуванні. Кольорові метали застосовують в основному у вигляді сплавів, оскільки в чистому вигляді вони мають низьку міцність. Найпоширеніші в промисловості сплави на основі міді, олова, магнію та інших металів.

Мідь за своїм призначенням – найміцніший технічний матеріал у машинобудуванні. Вона сплавляється з багатьма металами, добре проводить електрику і тепло, поступаючись у цьому тільки сріблу, її використовують для виготовлення електричних проводів, деталей електрообладнання тощо.

Латунь називають сплав міді з цинком. Вміст цинку в сплаві може коливатися від 4 до 45%. До складу латуні, крім міді й цинку, можуть входити алюміній, нікель, залізо, марганець, олово і кремній. Такий сплав називають спеціальною латунню. Вона має підвищену корозійну стійкість, кращі технологічні й механічні властивості.

Бронзою називають сплав міді з оловом, алюмінієм, нікелем та іншими елементами. Бронза має високі антифрикційні й механічні властивості, а також добру корозійну стійкість. Вона призначена для виготовлення арматури і деталей механізмів, що працюють у вологій атмосфері та в інших агресивних середовищах.

Алюміній має високу електро- і теплопровідність. Його найбільше застосовують в електротехнічній промисловості для виготовлення проводів, кабелів, обмоток тощо. Основна частина алюмінію призначена для одержання сплавів, оскільки вони мають кращі механічні властивості. Алюмінієві сплави поділяють на ливарні і такі, що деформуються (оброблювані тиском). Ливарні алюмінієві сплави застосовують при виготовленні деталей. Вони мають досить високу міцність, стійкі проти корозії, добре обробляються різанням, їх використовують для виготовлення корпусів і кришок двигунів, поршнів тощо [5].

EXERCISE 13

Prepare reports using Internet or other sources (catalogues, magazines, books, etc.) about the latest news, achievements in the field concerning the topic of the chapter.

EXERCISE 14

It's interesting to know…

## Copper

Copper conducts electricity at a rate 97% that of silver, and is the standard for electrical conductivity. Copper provides a diverse range of properties: good thermal and electrical conductivity, corrosion resistance, ease of forming, ease of joining, and color. In addition, however, copper and its alloys have relatively low strength-to-weight ratios and low strengths at elevated temperatures. Some copper alloys are also susceptible to stress-corrosion cracking unless they are stress relieved.

Copper and its alloys - the brasses and bronzes - are available in rod, plate, strip, sheet, tube shapes, forgings, wire, and castings. These metals are grouped according to composition into several general categories: coppers, high-copper alloys, brasses, leaded brasses, bronzes, aluminum bronzes, silicon bronzes, copper nickels, and nickel silvers.

Copper-based alloys form adherent films that are relatively impervious to corrosion and that protect the base metal from further attack. Certain alloy systems darken rapidly from brown to black in air. Under most outdoor conditions, however, copper surfaces develop a blue-green patina. Lacquer coatings can be applied to retain the original alloy color. An acrylic coating with benzotriazole as an additive lasts several years under most outdoor, abrasion-free conditions.

Although they work harden, copper and its alloys can be hot or cold worked. Ductility can be restored by annealing or heating incident to welding or brazing operations. For applications requiring maximum electrical conductivity, the most widely used copper is C11000, "tough pitch," which contains approximately 0.03% oxygen and a minimum of 99.0% copper. In addition to high electrical conductivity, oxygen-free grades C10100 and C10200 provide immunity to embrittlement at high temperature. The addition of phosphorus produces grade C12200 – the standard water-tube copper.

High-copper alloys contain small amounts of alloying elements that improve strength with some loss in electrical conductivity. In amounts of 1%, for example, cadmium increases strength by 50%, with a loss in conductivity to 85%. Small amounts of cadmium raise the softening temperature in alloy C11600, which is used widely for printed circuits. Tellurium or sulfur, present in small amounts in Grades C14500 and C14700, has been shown to increase machinability [5].

Copper alloys do not have a sharply defined yield point, so yield strength is reported either as 0.5% extension under load, or as 0.2% offset. On the most common basis (0.5% extension), yield strength of annealed material is approximately one-third the tensile strength. As the material is cold worked or hardened, it becomes less ductile, and yield strength approaches tensile strength.

Copper is specified according to temper, which is established by cold working or annealing. Typical levels are: soft, half-hard, hard, spring, and extra-spring. Yield strength of a hard-temper copper is approximately two-thirds of tensile strength.

For brasses, phosphor bronzes, or other commonly cold-worked grades, the hardest available tempers are also the strongest and represent approximately 70% reduction in area. Ductility is sacrificed, of course, to gain strength. Copper-beryllium alloys can be precipitation hardened to the highest strength levels attainable in copper-base alloys.

All copper alloys resist corrosion by fresh water and steam. Copper nickels, aluminum brass, and aluminum bronzes provide superior resistance to saltwater corrosion. Copper alloys have high resistance to alkalies and organic acids, but have poor resistance to inorganic acids. One corrosive situation encountered, particularly in the high-zinc alloy, is dezincification. The brass dissolves as an alloy, but the copper constituent redeposits as a porous, spongy metal. Meanwhile, the zinc component is carried away by the atmosphere or deposited on the surface as an insoluble compound.

Coppers, high-copper alloys. Both wrought and cast compositions have a designated minimum copper content and may include other elements or additions for special properties.

Brasses. These alloys contain zinc as the principal alloying element and may have other designated elements. The wrought alloys are comprised of copper-zinc alloys, copper-zinc-lead alloys (leaded brasses), and copper-zinc-tin alloys (tin brasses). The cast alloys are comprised of copper-zinc-tin alloys (red, semired and yellow brasses), manganese bronze alloys (high-strength yellow brasses), leaded manganese bronze alloys (leaded high-strength yellow brasses), and copper-zinc-silicon alloys (silicon brasses and bronzes).

Bronzes. Wrought bronze alloys comprise four main groups: copper-tin-phosphorus alloys (phosphor bronzes), copper-tin-lead-phosphorus alloys (leaded phosphor bronzes), and copper-silicon alloys (silicon bronzes). Cast alloys also have four main families: copper-tin alloys (tin bronzes), copper-tin-lead alloys (leaded and high-leaded tin bronzes), copper-tin-nickel alloys (nickel-tin bronzes), and copper-aluminum alloys (aluminum bronzes).

Copper-nickels**.** These are either wrought or cast alloys containing nickel as the principal alloying element.

Copper-nickel-zinc alloys. These are known as nickel silvers, from their color.

Leaded coppers. These are cast alloys containing 20% lead or more [5].

## CHAPTER 4

## MATERIALS CLASSIFICATION

Most materials can be further divided into groups. The grouping of materials is based on their properties or their origin. Here is the way to classify some materials.

**Woods.** There are two types of wood, hardwood and softwood. It sounds simple, but the words *hard* and *soft* have nothing to do with the hardness of the wood. The difference is in the tree that the wood came from. Hardwoods come from trees that have broad leaves, for example, walnut and maple. Softwoods come from trees that have needles, such as pine and fir.

**Metals.** There are two types of metals also, ferrous and nonferrous. Ferrous is a Latin word for *iron*. The difference between ferrous and nonferrous is that ferrous metals contain iron and nonferrous metals do not. Ferrous metals include iron and many types of steel. Nonferrous metals include copper, tin, lead, aluminium, gold and silver.

**Plastics.** Plastics are non-metallic, synthetic, carbon-based materials. They can be moulded, shaped, or extruded into flexible sheets, films, *or* fibres. Plastics are synthetic polymers. Polymers consist of long-chain molecules made of large numbers of identical small molecules (monomers). The chemical nature of a plastic is defined by the monomer (repeating unit) that makes up the chain of the polymer. Polyethylene is a polyolefin; its manumit unit is ethene (formerly called ethylene). Other categories are acrylics (such as polymethylmethacrylate styrene (such as polystyrene), vinyl (such polyvinyl chloride (PVC)), polyurethanes, polyamides (such nylons), polyether, acetales, phenolics, cellulosics, and amino resins. The molecules can be natural cellulose**,** wax, and natural rubber - or synthetic polyethylene and nylon. In co-polymers, more than monomer is used.

The giant molecules of which polymers consist can be linear, branched, or cross-linked, depending of plastic. Linear and branched molecules are thermoplastic (soften when heated), whereas cross-linked molecules are thermosetting (harden when heated).

Most plastics are synthesized from organic chemicals or from natural gas or coal. Plastics are light-weight compared to metals and are good electrical insulators. The best insulators now are epoxy resins and teflon. Teflon or polytetrafluoroethylene (PTFE) was first made in 1938 and was produced commercially in 1950 [6].

Plastics can be classified into two broad types.

1. **Thermoplastics** soften on heating, and then harden again when cooled. Thermoplastic molecules are also coiled and because of this they are flexible and easily stretched. Typical example of thermoplastics is polystyrene. Polystyrene resins are characterized by high resistance to chemical and mechanical stresses at low temperatures and by very low absorption of water. These properties make the polystyrenes especially suitable for radio-frequency insulation and for parts used at

low temperatures in refrigerators and in airplanes. PET (polyethylene terephthalate) is a transparent thermoplastic used for soft-drinks bottles. Thermoplastics are also viscoelastic, that is, they flow (creep) under stress. Examples are polythene, polystyrene and PVC.

2. **Thermosetting plastics (thermosets)** do not soften when heated, and with strong heating they decompose. In most thermosets final cross-linking, which fixes the molecules, takes place after the plastic has already been formed. Thermosetting plastics have a higher density than thermoplastics. They are less flexible, more difficult to wretch, and are less subjected to creep. Examples of thermosetting plastics include urea-formaldehyde or polyurethane and epoxy resins, most polyesters, and phenolic polymers such as phenol-formaldehyde resin.

**Composite materials.** The combinations of two or more different materials are called composite materials. They usually have unique mechanical and physical properties because they combine the best properties of different materials. For example, a fiber-glass reinforced plastic combines the high strength of thin glass fibres with the ductility and chemical resistance of plastic. Nowadays composites are being used for structures such as bridges, boat-building etc.

Composite materials usually consist of synthetic fibres within a matrix, a material that surrounds and is tightly bound to the fibres. The most widely used type of composite material is polymer matrix composites (PMCs). PMCs consist of fibres made of a ceramic material such as carbon or glass embedded in a plastic matrix. Usually the fibres make up about 60 per cent by volume. Composites with metal matrices or ceramic matrices are called metal matrix composites (MMCs) and ceramic matrix composites (CMCs), respectively.

Continuous-fiber composites are generally required for structural applications. The specific strength (strength-to-density ratio) and specific stiffness (elastic modulus-to-density ratio) of continuous carbon fiber PMCs, for example, can be better than metal alloys have. Composites can also have other attractive properties, such as high thermal or electrical conductivity and a low coefficient of thermal expansion [6].

EXERCISE 1

Fill in the blanks with appropriate words:

Plastics are usually produced by synthesis from such natural materials as water, air, salt, coal and natural gas. The technology is simple and cheap. While (1) ____ (solid, cheap, uniform) in finished state, plastics are liquid at some stage of manufacture, and it is easy to form plastics into various shapes. Plastics are different in (2) ____ (hardness, properties, needs), characteristics and (3) ____ (pressure, application, thermosets). Plastics are (4) ____ (reliable, available, thermoplastics), (5) ____ (expensive, cheap, structural), durable. Plastics resist (6) ____ (weight, strength, corrosion). Plastics are machined like (7) ____ (metals, forgings, carbon). Their (8) ____ (lightness, high weight, colour), strength, hardness, chemical resistance, (9) ____ (color, durability, application) make it possible to use plastics in electric and electronic equipment, transportation, agriculture, etc. The application of plastics is (10) ____ (achieving, satisfying, calling for) the requirements of all industries.

EXERCISE 2

Complete the sentences.

| | |
|---|---|
| 1. Polythene is … | a) structures such as bridges, boat-building etc. |
| 2. Polystyrene is … | b) composite materials |
| 3. Fabricating composite materials is … | c) their properties or their origin. |
| 4. Nowadays, composites are being used for … | d) thermoplastic produced by the polymerization of styrene. |
| 5. Most plastics are synthesized from … | e) a complex process. |
| 6. The combinations of two or more different materials are called … | f) that ferrous metals contain iron and nonferrous metals do not. |
| 7. The difference between ferrous and nonferrous is … | g) epoxy resins and teflon. |
| 8. The best insulators now are … | h) a white waxy solid with very low density, reasonable strength and toughness but low stiffness. |
| 9. Hardwoods come from … | i) organic chemicals or from natural gas or coal. |
| 10. The grouping of materials is based on … | j) trees that have broad leaves, for example, walnut and maple. |

EXERCISE 3

Fill in the blanks with prepositions *of, for, from, by, in:*

1. Plastics are a group … new materials. 2. Continuous-fiber composites are generally required … structural applications. 3. Polythene is a plastic made … ethane. 4. The characteristics … a material are called its properties that make it useful … certain products. 5. The first human-made plastic was invented … Alexander Parkes … 1862; he called this plastic Parkesine. 6. There are two types … wood, hardwood and softwood. 7. Polymers consist … long-chain molecules made … large numbers … identical small molecules.

EXERCISE 4

Make up questions to which the italicized words are the answers:

1. *PMC* is fabricated so that all the fibers are lined up parallel to one another. 2. *To aid in predicting and preventing failures*, composites are tested before and after construction. 3. Composite materials have gained popularity (despite their generally high cost) *in high-performance*

*products* that need to be lightweight. 4. One example of a composite material is *concrete*, which uses *cement* as a binding material in combination with gravel as a reinforcement. 5. *Composite materials* take advantage of the different strengths and abilities of different materials. 6. When building an aircraft, for example, engineers need *lightweight, strong* material. 7. Wood has always been used extensively *for furniture*.

EXERCISE 5

Translate the words into Ukrainian:

Hardwood, softwood, carbon-based materials, synthetic polymers, polyethylene, thermoplastics, polystyrene, thermosetting plastics, composite materials, fiber-glass reinforced plastic, polymer matrix composites, metal matrix composites, ceramic matrix composites, continuous-fiber composites, high thermal or electrical conductivity, high resistance to chemical and mechanical stresses, low absorption of water.

EXERCISE 6

Translate the sentences into Ukrainian paying attention to the italicized words:

1. The development of plastics has come from the use of *natural plastic materials* to the use of *chemically modified natural materials* and finally to completely synthetic molecules. 2. *PVC* is a colourless solid with *outstanding resistance* to water, alcohols, and concentrated acids. 3. *Epoxy resins* have *outstanding adhesion, toughness and resistance* to attack from chemicals. 4. Typically, most common composite materials, including *fiberglass and carbon fiber*, include at least two parts, the *substrate* and the *resin*. 5. Fiber-reinforced composite materials can be divided into two main categories normally referred to as *short fiber-reinforced materials* and *continuous fiber-reinforced materials*. 6. A *thermoplastic* is a *polymer* that turns to a liquid when heated and freezes to a very *glassy state* when cooled sufficiently.7. As scientist and engineers further learn and develop new techniques *to extract various components* from wood, or alternatively *to modify wood*, for example by adding components to wood, new more advanced products will appear on the marketplace [1].

EXERCISE 7

Answer the following questions:

1. What is called «composite materials»? 2. What is the definition of plastics? 3. What are the best properties of fiberglass? 4. What are the main types of polymers? 5. What do composite materials usually consist of? 6. What do polymers consist of? 7. What is used as filler or fibers in composites? 8. What

are the most important properties of plastics? 9. How are composite materials with ceramic and metal matrices called? 10. What are the advantages of composites? 11. What plastics are the best electrical insulators? 12. What are the disadvantages of composites? 13. What is the basic chemical element in plastics formula? 14. What are the features of the epoxy resin? 15. What is PVC usually used for? 16. What are the typical applications of polystyrene?

EXERCISE 8

Say true or false and explain:

1. The grouping of materials is based on their properties or their origin.
2. The difference between ferrous and nonferrous is that ferrous metals do not contain iron and nonferrous metals contain it.
3. Plastics are metallic, synthetic, carbon-based materials and they can be moulded, shaped, or extruded into flexible sheets, films, *or* fibers.
4. Plastics are light-weight compared to metals and are good electrical insulators.
5. Teflon or polytetrafluoroethylene (PTFE) was first made in 1738 and was produced commercially in 1850.
6. Thermoplastics soften on heating, and then harden again when cooled.
7. Thermosetting plastics have a lower density than thermoplastics.
8. Nowadays composites are being used for structures such as bridges, boat-building etc
9. The most widely used type of composite material is polymer matrix composites (PMCs).
10. Plastics can be classified into four broad types.

EXERCISE9

Translate the texts without a dictionary:

**A.** There are also two types of plastics: thermoplastic and thermoset. The difference is very simple. Thermoplastic can be melted and remelted many times using heat. Thermosetting plastics change chemically when they set. They cannot be remelted. Acrylic plastic is an example of thermoplastic. It can be reheated many times to change its shape. Bakelite is a common plastic used for electrical plugs and cooking-pot handles [2].

**B.** By combining different materials, new and often better properties can be obtained. Composite materials such as fiberglass and carbon graphite or graphite-epoxy are very lightweight and strong. They are used to make high-performance aircraft wings and lightweight sporting goods such as tennis racquets. Materials are chosen by their characteristics. The characteristics of a material are called its properties that make it useful for certain products [3].

**C.** Natural rubber is an elastomer (an elastic hydrocarbon polymer) that was originally derived from a milky colloidal suspension, or latex, found in the juice of some plants. It is useful directly in this form (indeed, the first appearance of rubber in Europe is cloth waterproofed with unvulcanized latex from Brazil) but, later, in 1839, Charles Goodyear invented vulcanized rubber; this a form of natural rubber heated with, mostly, sulfur forming cross-links between polymer chains (vulcanization), improving elasticity and durability [4].

EXERCISE10

Translate the following texts in a written form using a dictionary:

Text 1

Wood is an organic material; in the strict sense it is produced as secondary xylem in the stems of trees (and other woody plants). In a living tree it conducts water and nutrients to the leaves and other growing tissues, and has a support function, enabling woody plants to reach large sizes or to stand up for themselves. However, wood may also refer to other plant materials with comparable properties, and to material engineered from wood, or wood chips or fiber. Wood has been an important construction material since humans began building shelters, houses and boats. Nearly all boats were made out of wood until the late 19th century, and wood remains in common use today in boat construction. New domestic housing in many parts of the world today is commonly made from timber-framed construction [2].

Engineered wood products are becoming a bigger part of the construction industry. They may be used in both residential and commercial buildings as structural and aesthetic materials. In buildings made of other materials, wood will still be found as a supporting material, especially in roof construction, in interior doors and their frames, and as exterior cladding [3].

Text 2

Although composite materials have certain advantages over conventional materials, composites also have some disadvantages. For example, PMCs and other composite materials tend to be highly anisotropic-that is, their strength, stiffness, and other engineering properties are different depending on the orientation of the composite material. For example, if a PMC is fabricated so that all the fibers are lined up parallel to one another, then the PMC will be very stiff in the direction parallel to the fibers, but not stiff in the perpendicular direction. The designer, who uses composite materials in structures subjected to multidirectional forces, must take these anisotropic properties into account. Also, forming strong connections between separate composite material components is difficult. The advanced composites have high manufacturing costs. Fabricating composite materials is a complex process. However, new manufacturing techniques are developed. It will become possible to produce composite materials at higher volumes and at a lower cost than is now possible, accelerating the wider exploitation of these materials [2].

EXERCISE11

Translate the text into English:

Пластмаси

Пластмаса – це штучно створені матеріали на основі синтетичних або природних полімерів. Пластмаси формують при підвищеній температурі, у той час коли вони мають високу пластичність. Сировиною для отримання полімерів є нафта, природний газ, кам'яне вугілля, сланці.

Поширенню пластмас сприяють їхня мала густина, що значно зменшує масу деталей, висока корозійна стійкість, широкий діапазон властивостей. Добрі антифрикційні характеристики багатьох пластмас дають можливість з успіхом застосовувати їх для виготовлення підшипників ковзання. Високий коефіцієнт тертя деяких пластмас дозволяє використовувати їх для гальмових пристроїв.

Важливою перевагою пластмас є можливість їхньої переробки у вироби найбільш продуктивними способами – литтям та видавлюванням. Водночас пластмасам притаманні і деякі недоліки: невисокі міцність, твердість і жорсткість, низька теплостійкість, низька теплопровідність, здатність старіти. При старінні зменшується еластичність і міцність пластмас, збільшується їхні жорсткість і крихкість. Під еластичністю розуміють здатність матеріалу до великих оборотних деформацій [5].

EXERCISE12

Prepare reports using Internet or other sources (catalogues, magazines, books, etc.) about the latest news, achievements in the field concerning the topic of the chapter

EXERCISE 13

It's interesting to know…

**RESINS**

Resins that cannot be softened by heating include the phenolics, furan resins, aminoplastics, alkyds, alleys, epoxy resins, polyurethanes, some polyesters, and silicones.

**Phenolics or phenol-aldehydes**

The important commercial phenolic resin Bakelite is based on phenol and formaldehyde. The two processes in general use are the one-step process producing resol resins (the first stage in the formation of a phenolic resin) that are either liquid or brittle, soluble, fusible solids, from more than one molecule of formaldehyde per phenol molecule; and the two-step process, using an excess of phenol to produce novolacs, resins that have no reactive methylol groups and must be mixed with an aldehyde to undergo further reaction.

Resol resins thermoset on heating and are used for adhesives. Novolacs require a further source of formaldehyde in the form of hexamethylenetetramine to produce molding powders. Both resins are run out from the reaction vessel, after removal of water by distillation, and ground up, then compounded on heated, rolls with fillers that vary from wood flour to mica; for strength and heat resistance fibrous asbestos is used as filler (hexamethylenetetramine is also added at this stage in the case of the two-step resin). Final grinding produces the molding powders, which on further heat treatment will yield the typical thermoset resin.

Phenolic moldings are resistant to heat, chemicals, and moisture and are preferred for wet-dry applications as in washing machines. Their stability to heat and low heat conductivity suit them for use in appliance parts, and their electrical insulation qualities qualify them for electric fittings such as switches, plugs, and distributor caps; resistance to hydraulic fluids has led to their use in automotive parts. All these applications have been made more economical by the development of injection molding and extrusion methods. Complex phenols are used in manufacture of brake linings [4].

**Furan resins**

Furfural is a five-member ring compound (i.e., the basic molecule has a ring shape and contains five atoms) of four carbon atoms and one oxygen atom, carrying the aldehyde group, – CHO; it reacts like formaldehyde with phenols in the presence of an acid catalyst to give a rigid polymer with high chemical resistance, used for coatings in industry. It can be prepared in semi liquid form with a low viscosity and remarkable penetrating power when applied to porous forms such as foundry sand cores or graphite blocks, being in this respect superior to other liquid resins.

**Polyester resin**

Polyester resin, tends to have yellowish tint, and is suitable for most backyard projects. Its weaknesses are that it is UV sensitive and can tend to degrade over time, and thus generally is also coated to help preserve it. It is often used in the making of surfboards and for marine applications. Its hardener is a MEKP, and is mixed at 14 drops per oz. MEKP is composed of methyl ethyl ketone peroxide, a catalyst. When MEKP is mixed with the resin, the resulting chemical reaction causes heat to build up and cure or harden the resin.

**Vinylester resin**

Vinylester resin tends to have a purplish to bluish to greenish tint. This resin has lower viscosity than polyester resin, and is more transparent. This resin is often billed as being fuel resistant, but will melt in contact with gasoline. This resin tends to be more resistant over time to degradation than polyester resin, and is more flexible. It uses the same hardener as polyester resin (at the same mix ratio) and the cost is approximately the same [6].

## Categories of fiber-reinforced composite materials

Fiber-reinforced composite materials can be divided into two main categories normally referred to as short fiber-reinforced materials and continuous fiber-reinforced materials. Continuous reinforced materials will often constitute a layered or laminated structure. The woven and continuous fiber styles are typically available in a variety of forms, being pre-impregnated with the given matrix (resin), dry, unidirectional tapes of various widths, plain weave, and harness satins, braided, and stitched. The short and long fibers are typically employed in compression molding and sheet molding operations. These come in the form of flakes, chips, and random mate (which can also be made from a continuous fiber laid in random fashion until the desired thickness of the ply / laminate is achieved) [4].

# CHAPTER 5

# PROPERTIES OF MATERIALS

Materials science and technology is the study of materials and how they can be fabricated to meet the needs of modern technology. Using the laboratory techniques and knowledge of physics, chemistry, and metallurgy, scientists are finding new ways of using metals, plastics and other materials.

Engineers must know how materials respond to external forces, such as tension, compression, torsion, bending, and shear. All materials respond to these forces by elastic deformation. That is, the materials return their original size and form when the external force disappears. The materials may also have permanent deformation or they may fracture. The results of external forces are creep and fatigue [4].

## A list of materials properties

### Strength

It is the property of resistance to external loads or stresses without incurring structural damage. The strength of metals and alloys depends upon two factors, namely, the strength of the crystals of which the metals are constructed and the tenacity of adherence between these crystals. A **stress** is the force within a body which resists deformation due to an externally applied load. If this load acts upon a surface of unit area, it is called a **unit force** and the stress resisting it a **unit stress**. When an external force acts upon an elastic material, the material is deformed and the deformation is in proportion to the load. This distortion or deformation is **strain**.

### Tensile Strength

It is the maximum force a material can withstand in tension (pulling) compression (squashing), torque (twisting) and shearing (sideways pressure).

### Elasticity

Any material subjected to an external load is distorted or strained. Elasticity stressed materials return to their original dimensions when the load is released if the load is not too great. The property of regaining the original dimensions upon removal of the external load is known as **elasticity**. The elasticity of a metallic substance is a resistance of its atoms to separation or compression or rotation about one another, and thus is a fundamental property of the material. So elasticity is demonstrated as a function of atomic forces.

### Hardness

It is the resistance a materials has to cutting and surface indentations.

### Stiffness (rigidity)

It is a measure of the resistance to deformation such as stretching or bending. The Young modulus is a measure of the resistance to simple stretching or compression. It is the ratio of the applied force per unit area (stress) to the fractional elastic deformation (strain). Stiffness is important when a rigid structure is to be made.

### Ductility

It is the ability of a material to deform without breaking. One of the great advantages of metals is their ability to be formed into the shape that is needed, such as car body parts. Materials that are not ductile are brittle. Ductile materials can absorb energy by deformation but brittle materials cannot.

### Toughness

It is the resistance of a material to breaking when there is a crack in it. For a material of given toughness, the stress at which it will fail is inversely proportional to the square root of the size of the largest defect present. Toughness is different from strength: the toughest steels, for example, are different from the ones with highest tensile strength.

### Creeps resistance

It is the resistance to a gradual permanent change of shape, and it becomes especially important at higher temperatures. A successful research has been made in materials for machine parts that operate at high temperatures and under high tensile forces without gradually extending, for example the parts of plane engines.

### Density (specific weight)

It is the amount of mass in a unit volume. It is measured in kilograms per cubic meter. The density of water is 1000 kg/m$^3$ but most materials have a higher density and sink in water. Aluminium alloys, with typical densities around 2800 kg/m$^3$ are considerably less dense than steels, which have typical densities around 7800 kg/m$^3$. Density is important in any application where the material must not be heavy.

### Heaviness

It is the denseness of materials. A dense material will be heavy in relation to its size.

### Malleability

It is the property of a metal which permits permanent deformation by compression without rupture.

### Brittleness

Brittleness implies sudden failure. It is the property of breaking without warning, i.e. without visible permanent deformation. Failure of metals and alloys under repeated or altering stresses, too small to produce even a permanent deformation when applied statically, is called **fatigue failure**.

### Corrosion Fatigue

Failure by corrosion fatigue is a fatigue failure in which corrosion has lowered the endurance limit by the formation of pits that act as centers for the development of fatigue cracks.

### Heat and Electrical Conductivity

It is the measure of how well a material can conduct heat or electricity [6].

EXERCISE 1

Fill in the blanks with appropriate words:

Fatigue is the (1) ____ (disappearance, growth, property) of cracks under stress. It occurs when a (2) ____ (mechanical, chemical, optional) part is subjected to a repeated or cyclic stress, such as vibration. Even when the maximum stress never (3) ____ (increases, decreases, exceeds) the elastic limit, failure of the (4) ____ (material, worker, liquid) can occur even after a short time. No (5) ____ (reformation, deformation, destination) is seen during fatigue, but small localized (6) ____ (holes, cracks, spots) develop and propagate through the material until the remaining cross-sectional area cannot support the (7) ____ (maximum, average, minimum) stress of the cyclic (8) ____ (stress, vibration, force). Knowledge of tensile stress, elastic limits, and the (9) ____ (hardness, resistance, brittleness) of materials to creep and fatigue are of (10) ____ (no, some, basic) importance in engineering.

EXERCISE 2

Complete the sentences.

| | |
|---|---|
| 1. Hardness | a) The amount of hammering, pressing and shaping a material can take without breaking. |
| 2. Toughness | b) The measure of how well a material can conduct heat or electricity. |
| 3. Tensile Strength | c) The resistance to a gradual permanent change of shape. |
| 4. Malleability | d) The resistance a materials has to cutting and surface indentations. |
| 5. Ductility | e) The denseness of materials. |
| 6. Elasticity | f) The length that a material can be stretched and return to its original length when released. |
| 7. Heat and Electrical Conductivity | g) The measure of how a material withstands a heavy load without breaking. |
| 8. Heaviness | h) This describes the amount of energy a material can absorb without breaking. |
| 9. Strength | i) The length that a material can be stretched without breaking. |
| 10. Creeps resistance | j) The maximum force a material can withstand in tension, compression, torque and shearing. |

EXERCISE 3

Fill in the blanks with prepositions without *of, in, for, at:*

1. Strength is the force per unit area (stress) that a material can support … failing. 2. The units are the same as those … stiffness, MN/m2, but … this case the deformation is irreversible. 3. The yield strength is the stress … which a material first deforms plastically. 4. … a metal the yield strength may be less than the fracture strength, which is the stress … which it breaks. 5. Many materials have a higher strength … compression than … tension. 6. The quality … hardness is a combination … a number … physical and mechanical properties

EXERCISE 4

Make up questions to which the italicized words are the answers:

1. *Brittle materials* have low toughness. 2. Glass can be broken along a chosen line *by first scratching it with a diamond*. 3. Composites can be designed *to have considerably greater toughness* than their constituent materials. 4. The example of a very tough composite is *fiberglass* that is *very flexible and strong*. 5. Materials properties may be determined *by standardized test methods*. 6. *Tensile strength* can be defined for liquids as well as solids. 7. Stiffness is important *when a rigid structure is to be made*.

EXERCISE 5

Translate the words into Ukrainian:

Tension, compression, torsion, bending, shear, creep, fatigue, strength, stress, unit force, unit stress, strain, tensile strength, elasticity, hardness, stiffness, ductility, toughness, creeps resistance, density, heaviness, malleability, brittleness, corrosion fatigue, heat conductivity, electrical conductivity.

EXERCISE 6

Translate the sentences into Ukrainian paying attention to the italicized words:

1. The temperature at which a metal melts is called the *melting point*. 2. The metals of lower melting points are generally the *soft metals* and those of high melting – the *hard metals*. 3. The term "*boiling point*" refers to the temperature at which the metal boils under normal atmospheric pressure. 4. The *boiling point* of a substance depends on the surrounding pressure. 5. The *electrical conductivity* of a substance is the *electrical conducting power* of a unit length per unit of *cross-sectional area*. 6. The *electrical resistance* of metals or alloys is increased by decreasing the size of the crystals and, therefore, increasing the

number of crystal boundaries. 7. The *resistivity of metals* is also increased in most cases by an increase in temperature. 8. *Heat-conductivity* is measured as the *heat-conducting ability* of a unit length or thickness of a substance per unit of cross-sectional area. 9. *Magnetism* is measured as the *magnetic force* exerted by a unit volume of a substance under standard magnetizing force. 10. *Porosity*, the quality of containing pores, is lack of *denseness*.

EXERCISE 7

Answer the following questions:

1. What are the main properties of materials? 2. What is the density of a material? 3. What are the units of density? 4. Where low density is needed? 5. What are the densities of water, aluminium and steel? 6. A measure of what properties is stiffness? 7. When stiffness is important? 8. What is Young modulus? 9. What is strength? 10. What is a unit force? 11. What is tensile strength? 12. What is ductility? Give the examples of ductile materials. Give the examples of brittle materials. 13. What is toughness? 14. What properties of steel are necessary for the manufacturing of: a) springs, b) car body parts, c) bolts and nuts, d) cutting tools? 15. 10. Where is aluminium mostly used because of its lightweight?

EXERCISE 8

Say true or false and explain:

1. Any material subjected to an internal load is distorted or strained.
2. The Young modulus is a measure of the resistance to simple stretching or compression.
3. Materials that are ductile are brittle
4. Ductile materials can absorb energy by deformation but brittle materials cannot.
5. The density of water is 100 $kg/m^3$ but most materials have a higher density and sink in water.
6. Density is important in any application where the material must be heavy.
7. Brittleness is the property of breaking without warning, i.e. without visible permanent deformation.
8. Engineers must know how materials respond to external forces, such as tension, compression, torsion, bending, and shear.
9. The strength of metals and alloys depends upon many different factors.
10. Density is the amount of mass in a unit volume.

EXERCISE9

Translate the texts without a dictionary:

**A.** Compression is a pressure causing a decrease in volume. When a material is subjected to a bending, shearing, or torsion (twisting) force, both tensile and compressive forces are simultaneously at work. When a metal bar is bent, one side of it is stretched and subjected to a tensional force, and the other side is compressed [2].

**B.** Tension is a pulling force; for example, the force in a cable holding a weight. Under tension, a material usually stretches, returning to its original length if the force does not exceed the material's elastic limit. Under larger tensions, the material does not return completely to its original condition, and under greater forces the material ruptures [3].

**C.** Creep is a slow, permanent deformation that results from steady force acting on a material. Materials at high temperatures usually suffer from this deformation. The gradual loosening of bolts and the deformation of components of machines and engines are all the examples of creep. In many cases the slow deformation stops because deformation eliminates the force causing the creep. Creep extended over a long time finally leads to the rupture of the material [3].

EXERCISE10

Translate the following texts in a written form using a dictionary:

Text 1

Chemical Properties of Metals

Most metals are chemically reactive, reacting with oxygen in the air to form oxides over changing timescales (for example iron rusts over years and potassium burns in seconds). The alkali metals react quickest followed by the alkaline earth metals. The transition metals take much longer to oxidize (such as iron, copper, zinc, nickel). Others, like palladium, platinum and gold, do not react with the atmosphere at all. Some metals form barrier layers of oxide on their surface which cannot be penetrated by further oxygen molecules and thus retain their shiny appearance and good conductivity for many decades (like aluminium, some steels and titanium). The oxides of metals are basic (as opposed to those of nonmetals, which are acidic). Painting or anodizing metals are good ways to prevent their corrosion. However, a more reactive metal in the electro chemical series must be chosen for coating, especially when chipping of the coating is expected. Water and the two metals form an electro chemical cell, and if the coating is less reactive than the coatee, the coating actually promotes corrosion [4].

Text 2

Physical Properties of Metals

Traditionally, metals have certain characteristic physical properties. They are usually shiny (they have "luster"), have a high density, are ductile and malleable, usually have a high melting point, are usually hard, and conduct electricity and heat well. However, this is mainly because the low density, soft, low melting point metals happen to be reactive, and we rarely encounter them in their elemental, metallic form. Metals conduct sound well, that is, they are sonorous. The electrical and thermal conductivity of metals originate from the fact that in the metallic bond the outer electrons of the metal atoms form a gas of nearly free electrons, moving as an electron gas in a background of positive charge formed by the ion cores. Good mathematical predictions for electrical conductivity, as well as the electrons' contribution to the heat capacity and heat conductivity of metals can be calculated from the free electron model, which does not take the detailed structure of the ion lattice into account [4].

EXERCISE11

Translate the text into English:

**Властивості металів**

Метали – це клас хімічних елементів з певними хімічними і фізичними властивостями: метали добре проводять електрику і тепло, непрозорі, але можуть відбивати світло; ковкі, що дозволяє надавати виробам з них потрібну форму і розкатувати в плоскі пластинки; пластичні, що дає можливість витягати тонкий дріт. Сфера застосування металів визначається їхніми властивостями. Властивості металів поділяють на: механічні, технологічні, фізичні та хімічні. До основних механічних властивостей належить: ударна в'язкість, пластичність, міцність і твердість металу. До технологічних властивостей – фізична і технологічна зварюваність, ковкість, плавкість, оброблюваність різанням. До фізичних властивостей металів належить: колір, питома маса, теплова і електрична провідність, магнітні якості. Хімічні властивості металів – це стійкість проти корозії, жароміцність.

Легкою рухливістю валентних електронів пояснюється висока електропровідність і теплопровідність металів. Найкращими провідниками електричного струму є срібло, мідь, золото і алюміній. Характерна особливість металів – металічний блиск, тобто здатність добре відбивати світло. Але ця здатність проявляється лише тоді, коли метал утворює суцільну і гладку (поліровану) поверхню.

Дуже важливою властивістю більшості металів є пластичність, тобто здатність змінювати зовнішню форму при дії сторонньої сили і зберігати набуту форму після припинення впливу зовнішньої дії. За густиною метали умовно поділяють на легкі (густина яких менша 5 г/см$^3$) і важкі (густина яких більша 5 г/см$^3$). За температурами плавлення метали теж різко відрізняються один від одного. Найнижчу температуру плавлення має ртуть (-39 °C), а найвищу – вольфрам (+3410 °C). За забарвленням метали умовно поділяють на чорні – залізо, манган та їхні чисельні сплави (чавун, сталь) – і кольорові, до яких належать усі інші метали [5].

EXERCISE12

Prepare reports using Internet or other sources (catalogues, magazines, books, etc.) about the latest news, achievements in the field concerning the topic of the chapter.

EXERCISE 13

It's interesting to know…

**Tensile strength**

Tensile strength is indicated by the maxima of a stress-strain curve and, in general, indicates when necking will occur. As it is an intensive property, its value does not depend on the size of the test specimen. It is, however, dependent on the preparation of the specimen and the temperature of the test environment and material. Tensile strength, along with elastic modulus and corrosion resistance, is an important parameter of engineering materials used in structures and mechanical devices. It is specified for materials such as alloys, composite materials, ceramics, plastics and wood. There are three definitions of tensile strength: Yield strength - the stress at which material strain changes from elastic deformation to plastic deformation, causing it to deform permanently. Ultimate strength - the maximum stress a material can withstand when subjected to tension, compression or shearing. Breaking strength - the stress coordinate on the stress-strain curve at the point of rupture.

Metals including steel have a linear stress-strain relationship up to the yield point. In some steels the stress falls after the yield point. This is due to the interaction of carbon atoms and dislocation in the stressed steel. Cold worked and alloy steels do not show this effect. For most metals yield point is not sharply defined. Below the yield strength all deformation is recoverable, and the material will return to its initial shape when the load is removed. This recoverable deformation is known as elastic deformation. For stresses above the yield point the deformation is not recoverable, and the material will not return to its initial shape. This unrecoverable deformation is known as plastic deformation. For many applications plastic deformation is unacceptable, and the yield strength is used as the design limitation.

After the yield point, steel and many other ductile metals will undergo a period of strain hardening, in which the stress increases again with increasing strain up to the ultimate strength. If the material is unloaded at this point, the stress-strain curve will be parallel to that portion of the curve between the origin and the yield point. If it is reloaded it will follow the unloading curve up again to the ultimate strength, which has become the new yield strength [4].

After a metal has been loaded to its yield strength it begins to "neck" as the cross-sectional area of the specimen decreases due to plastic flow. When necking becomes substantial, it may cause a reversal of the engineering stress-strain curve, where decreasing stress correlates to increasing strain because of geometric effects. This is because the engineering stress and engineering strain are calculated assuming the original cross-sectional area before necking. If the graph is plotted in terms of *true stress* and *true strain* the curve will always slope upwards and never reverse, as true stress is corrected for the decrease in cross-sectional area. Necking is not observed for materials loaded in compression. The peak stress on the engineering stress-strain curve is known as the *ultimate strength*. After a period of necking, the material will rupture and the stored elastic energy is released as noise and heat. The stress on the material at the time of rupture is known as the breaking strength.

Ductile metals do not have a well defined yield point. The yield strength is typically defined by the "0.2% offset strain". The yield strength at 0.2% offset is determined by finding the intersection of the stress-strain curve with a line parallel to the initial slope of the curve and which intercepts the abscissa at 0.2%. Brittle materials such as concrete and carbon fiber do not have a yield point, and do not strain-harden which means that the ultimate strength and breaking strength are the same. Typical brittle materials do not show any plastic deformation but fail while the deformation is elastic. One of the characteristics of a brittle failure is that the two broken parts can be reassembled to produce the same shape as the original component. A typical stress strain curve for a brittle material will be linear. Testing of several identical specimens will result in different failure stresses. The curve shown below would be typical of a brittle polymer tested at very slow strain rates at a temperature above its glass transition temperature. Some engineering ceramics show a small amount of ductile behavior at stresses just below that causing failure but the initial part of the curve is a linear.

In brittle materials such as rock, concrete, cast iron, or soil, tensile strength is negligible compared to the compressive strength and it is assumed zero for many engineering applications. Glass fibers have a tensile strength stronger than steel, but bulk glass usually does not. This is due to the Stress Intensity Factor associated with defects in the material. As the size of the sample gets larger, the size of defects also grows. In general, the tensile strength of a rope is always less than the tensile strength of its individual fibers. Tensile strength can be defined for liquids as well as solids. For example, when a tree draws water from its roots to its upper leaves by transpiration, the column of water is pulled upwards from the top by capillary action, and this force is transmitted down the column by its tensile strength. Air pressure from below also plays a small part in a tree’s ability to draw up water, but this alone would only be sufficient to push the column of water to a height of about ten meters, and trees can grow much higher than that [6].

# CHAPTER 6

# METAL WORKING PROCESSES

Metals are important in industry because they can be easily deformed into useful shapes. A lot of metal working processes have been developed for certain applications. They can be divided into five broad groups:

1) rolling,
2) extrusion,
3) drawing,
4) forging,
5) sheet-metal forming.

During the first four processes metal is subjected to large amounts of strain (deformation). But if deformation goes at a high temperature, the metal will recrystallize, that is, new strain-free grains will grow instead of deformed grains. For this reason metals are usually rolled, extruded, drawn, or forged above their recrystallization temperature. This is called hot working. Under these conditions there is no limit to the compressive plastic strain to which the metal can be subjected.

Other processes are performed below the recrystallization temperature. These are called cold working. Cold working hardens metal and makes the part stronger. However, there is a limit to the strain before a cold part cracks [6].

## Rolling

Rolling is the most common metalworking process. More than 90 percent of the aluminum, steel and copper produced are rolled at least once in the course of production. The most common rolled product is sheet. Rolling can be done either hot or cold. If the rolling is finished cold, the surface will be smoother and the product stronger.

## Extrusion

Extrusion is pushing the billet to flow through the orifice of a die. Products may have either a simple or a complex cross section. Aluminum window frames are the examples of complex extrusions.

Tubes or other hollow parts can also be extruded. The initial piece is a thick-walled tube, and the extruded part is shaped between a die on the outside of the tube and a mandrel held on the inside.

In back-extrusion the workpiece is placed in the bottom of a hole and a loosely fitting ram is pushed against it. The ram forces the metal to flow back around it, with the gap between the ram and the die determining the wall thickness. The example of this process is the manufacturing of aluminum beer cans [4].

## Drawing

Drawing consists of pulling metal through a die. An example of drawing is wire drawing. The diameter reduction that can be achieved in one die is limited, but several dies in series can be used to get the desired reduction.

## Sheet metal forming

Sheet metal forming is widely used when parts of certain shape and size are needed. It includes forging, bending and shearing. One characteristic of sheet metal forming is that the thickness of the sheet changes little in processing. The metal is stretched just beyond its yield point (2 to 4 percent strain) in order to retain the new shape. Bending can be done by pressing between two dies. Shearing is a cutting operation similar to that used for cloth.

Each of these processes may be used alone, but often all three are used on one part. For example, to make the roof of an automobile from a flat sheet, the edges are gripped and the piece pulled in tension over a lower die. Next an upper die is pressed over the top, finishing the forming operation, and finally the edges are sheared off to give the final dimensions [6].

## Forging

Forging is the shaping of a piece of metal by pushing with open or closed dies. It is usually done hot in order to reduce the required force and increase the metal's plasticity.

Open-die forging is usually done by hammering a part between two flat faces. It is used to make parts that are too big to be formed in a closed die or in cases where only a few parts are to be made. The earliest forging machines lifted a large hammer that was then dropped on the workpiece, but now air or steam hammers are used, since they allow greater control over the force and the rate of forming. The part is shaped by moving or turning it between blows.

Closed-die forging is the shaping of hot metal within the walls of two dies that come together to enclose the workpiece on all sides. The process starts with a rod or bar cut to the length needed to fill the die. Since large, complex shapes and large strains are involved, several dies may be used to go from the initial bar to the final shape. With closed dies, parts can be made to close tolerances so that little finish machining is required.

Two closed-die forging operations are given special names. They are upsetting and coining. Coining takes its name from the final stage of forming metal coins, where the desired imprint is formed on a metal disk that is pressed in a closed die. Coining involves small strains and is done cold. Upsetting involves a flow of the metal back upon itself. An example of this process is the pushing of a short length of a rod through a hole, clamping the rod, and then hitting the exposed length with a die to form the head of a nail or bolt [4].

EXERCISE 1

Fill in the blanks with appropriate words:

The process of (1) ____ an iron casting can simply be described as the (2) ____ of hot liquid or (3) ____ iron into a mold of a desired (4) ____. Molten iron is poured from the (5) ____ into the sand molds. The iron travels along a series of passageways in the molds to the (6) ____. It then falls from the (7) ____ to top. The iron in the molds is allowed to cool for some time and the casting (8) ____ and hardens. At this time the (9) ____ is separated from the mold and the raw casting is born. Then the casting undergoes (10) ____ and checking before final processing.

Pouring, shape, solidifies, cleaning, casting, bottom, ladles, molten, making, cavities.

EXERCISE 2

Complete the sentences.

| | |
|---|---|
| 1. Metals are important in industry… | a) because they can be easily deformed into useful shapes. |
| 2. Drawing consists of … | b) when parts of certain shape and size are needed. |
| 3. Two closed-die forging operations are … | c) the most common metalworking process. |
| 4. Closed-die forging is the shaping of hot metal within the walls of two dies … | d) pulling metal through a die. |
| 5. Sheet metal forming is widely used … | e) hammering a part between two flat faces. |
| 6. The example of back-extrusion is … | f) upsetting and coining. |
| 7. Extrusion is … | g) pushing the billet to flow through the orifice of a die. |
| 8. Rolling is … | h) sheet. |
| 9. The most common rolled product is … | i) that come together to enclose the workpiece on all sides. |
| 10. Open-die forging is usually done by … | j) the manufacturing of aluminum beer cans. |

EXERCISE 3

Fill in the blanks with prepositions *of, in, with, from, by:*

1. An example …drawing is wire drawing. 2. Cooking utensils and articles … similar shape are also "drawn". 3. But this drawing is accomplished … a press, and generally starts … a circle … sheet … the proper thickness. 4. The part is shaped … moving or turning it between blows. 5. The stamping process has now been largely replaced … a special sort … grinding operation. 6. Extremely large or heavy castings are made … floor molding. 7. The oldest commercial method … making metal castings consists … forming a cavity … sand and filling the cavity … molten metal.

EXERCISE 4

Make up questions to which the italicized words are the answers:

1. Virtually all metals can be *forged*. 2. The range of physical and mechanical properties available from forged products involves *the entire spectrum of ferrous and non-ferrous metallurgy.* 3. An important feature of hot working is that *it provides the improvement of mechanical properties of metals*. 4. *Hot-worked products* have better ductility and toughness than the unworked casting. 5. The ability of a metal to resist thinning and fracture during cold-working operations plays an important role in *alloy selection*. 6. The change of the shape after one forming operation is often limited by *the tensile ductility of the metal*. 7. Metals such as *copper and aluminum* are more ductile in such operations than other metals.

EXERCISE 5

Translate the words into Ukrainian:

Rolling, extrusion, drawing, forging, sheet-metal forming, metalworking process, back-extrusion, bending, shearing, closed-die forging, open-die forging, cast structure, casting, toughness, coining, to resist, stamping process, cold-working operations.

EXERCISE 6

Translate the sentences into Ukrainian paying attention to the italicized words:

1. Whether a designer is looking for *impact strength*, *corrosion resistance*, *high tensile strength*, or *long fatigue life*, there is an alloy appropriate to the application that can be forged. 2. Surface scratches caused by defects in the *die*, *foreign particles* that get into the metal, and other faults, may be very troublesome. 3. *Hot-working (hot-rolling or hot-forging)* eliminates *porosity*, *directionality*, and *segregation* that are usually present in metals. 4. During the *forging* of a bar, the grains of the metal become greatly elongated in the direction of flow. 5. The *toughness* of the metal is greatly improved in this direction and weakened in directions transverse to the flow. 6. Good forging makes the *flow lines* in the finished part oriented so as to lie in the direction of *maximum stress* when the part is placed in service. 7. In operations that involve *stretching*, the best alloys are those which grow stronger with strain (are *strain hardening*) — for example, the copper-zinc alloy, brass, used for cartridges and the aluminum-magnesium alloys in beverage cans, which exhibit greater strain hardening. 8. *Fracture* of the workpiece during forming can result from *inner flaws* in the metal. 9. These flaws often consist of *nonmetallic inclusions* such as oxides or sulfides that are trapped in the metal during *refining*. 10. Such inclusions can be avoided by proper *manufacturing procedures*.

EXERCISE 7

Answer the following questions:

1. Why are metals so important in industry? 2. What are the main metalworking processes? 3. Why are metals worked mostly hot? 4. What properties does cold working give to metals? 5. What is rolling? 6. Where is it used? 7. What is extrusion? 8. What shapes can be obtained after extrusion? 9. What are the types of extrusion? 10. How can the reduction of diameter in wire drawing be achieved? 11. What is sheet metal forming and where it can be used? 12. What is close-die forging? 13. What is forging? 14. What are the types of forging? 15. What types of hammers are used now? 16. Where are coining and upsetting used? 17. What process is used in wire production?

EXERCISE 8

Translate the texts without a dictionary:

**A.** Rolling and forging serve the following two purposes: first, they serve the purely mechanical purpose of getting the steel into the desired shape; and second, but by no means of minor importance, they improve the mechanical properties by destroying the cast structure. This breaking up of the cast structure or "refining the grain" is important because it makes the steel stronger and more ductile and gives it greater shock resistance. Where simple shapes are to be made in large quantity, rolling is the most economical process and it is used for sheets, structural shapes, rails, etc, as well as for the production of intermediate shapes for wire drawing or forging [2].

**B.** The process of shaping steel by rolling consists essentially of passing the material between two rolls revolving in opposite directions but at the same peripheral speed. The rolls are spaced so that the distance between them is somewhat less than the height of the section entering them. The rolls grip the piece of metal and deliver it reduced in diction and increased in length in proportion to the reduction. The amount of reduction and the width of the piece will govern the amount of lateral spreading [2].

**C.** Another method of working that has special applications is extrusion. In this process, a heated ingot of the metal is squirted through a die under very great pressure. Its purpose is to produce special shapes, such as moldings, small structural shapes, hollow cylinders, and so forth, at a moderate cost. It is very often possible for production of shapes that could not be produced by rolling or any other method. And the possibility of making these odd shapes has considerably increased the usefulness of aluminum alloys in architectural work and in the construction of trucks, railroad cars, and other equipment. The extrusion of hollow cylindrical blooms, from which tubing can be drawn, is also very important [3].

EXERCISE 9

Translate the following texts in a written form using a dictionary:

Text 1

Most forging grade metal is pre-worked to remove defects. This pre-working results in directional alignment of grain flow, which when properly forged, produces directional properties in strength, ductility and resistance to impact. Continuous grain flow around the part shape is most desirable. Since bar stock and plate have unidirectional grain flow, any change in contour from machining will cut flow lines, exposing grain ends and leaving the metal sensitive to stress corrosion and fatigue failure. Most castings have no grain flow or directional strength.

The increased emphasis on optimizing the efficiency of all kinds of consumer and industrial products has increased the service requirements for mechanical parts. Forging makes metal parts stronger than other metal working methods. Thus forging has become more than just a way of making metal parts; it has become an indispensable method of making high strength metal components. To the designer, the structural integrity of forgings means realistic safety factors based on materials that will respond predictably to the environment without costly special processing [4].

Text 2

For many purposes, the simplest process of producing metal articles is that of casting the molten metal into a suitable mold. The relatively low melting point of aluminum permits the use of a variety of casting processes that are not suitable for metals like iron and copper. The cheapest type of mold is one made of moist ("green") sand, which is rammed around a wooden or metallic pattern. Where only a limited number of castings are to be made, or where the casting is very large or intricate, sand molds produce the cheapest castings.

If very large numbers of the same castings are to be produced, and if the casting is not too large, a permanent mold (usually iron) may be used, because of the moderate casting temperatures employed, and may produce castings that are both cheaper and metallurgically superior. By rapidly forcing metal under pressure into a suitable permanent mold, "die castings" are produced. They have very high surface smoothness and dimensional accuracy. A special type of plaster used for molds produces castings with surface smoothness and dimensional accuracy comparable with those of die castings, but with somewhat lower mechanical properties [6].

EXERCISE 10

Translate the text into English:

Протягування – операція механічної обробки, у якій використовується багатолезовий інструмент – протяжка, що являє собою стержень з різальними зубцями на поверхні. У повзуні горизонтально-протяжного верстата закріплюється протяжка, яка пропущена через отвір деталі, що обертається. Протяжка за допомогою повзуна переміщується поступально, при цьому метал знімається малими шарами кожним зубцем протяжки. Висота зубців протяжки поступово збільшується і діаметр отвору розточується. Протягуванням можна обробляти внутрішні та зовнішні поверхні з використанням протяжок різного профілю.

Волочіння – спосіб обробки металів тиском, що полягає у протягуванні вальцьованих або пресованих заготовок крізь отвір, поперечний переріз якого менший за поперечний переріз заготовки, а конфігурація отвору формує заданий профіль виробу. Інструмент для волочіння – волока – має робочий отвір, що складається з чотирьох зон: вхідної (мастильної), деформувальної, калібрувальної та вихідної. Волоки виготовляють з інструментальних сталей, а для волочіння дуже тонкого дроту – з технічних алмазів [5].

EXERCISE 11

Prepare reports using Internet or other sources (catalogues, magazines, books, etc.) about the latest news, achievements in the field concerning the topic of the chapter.

EXERCISE 12 It's interesting to know…

**The Fundamental of Forging**

Forging is the oldest known metalworking processes. It is believed to have begun when early man discovered he could beat pieces of ore into useful shapes. History tells us that forging was widely practiced at the time when written records first appeared.

The blacksmith was one of the first to realize the advantages of forging. Although he did not know why, he knew that hammering a piece of hot metal not only resulted in a usable shape, it improves its strength. It is this inherent improvement in strength of metal that has placed forgings in the most highly stressed applications in machines.

To understand why forging improves the mechanical properties of metal, it is important to recognize that metal is made up of grains. Each grain is an individual crystal, and when the grains are large, cracks can occur and propagate along the grain boundaries. Therefore, it is desirable to minimize the grain size in a metal.

Reducing the metal's grain size is one of the things forging does so well. Forging breaks down a coarse-grained structure producing a chemically homogeneous wrought structure with much smaller grains by controlled plastic deformation. In forging, controlled plastic deformation whether at elevated temperature or cold (at room temperature) results in greater metallurgical soundness and improved mechanical properties of the metal [6].

Metal shaping by controlled plastic deformation is the basis for all forging operations. Because of the diversity of forging end-use applications, however, a wide range of processes and equipment have been developed to produce forgings. Some processes are ideally suited to make large parts, others, small parts, and still others, rings. Modern forging is not only carried out in virtually all metals, it is done at temperatures ranging from more than 2500°F to room temperature. Part configuration generally determines the forging method chosen.

**Sand Casting**

Selection of a casting method depends primarily upon: 1) quantity of parts, 2) size of the part, 3) tolerances and finish, 4) physical characteristics, 5) part configuration, the metal to be cast.

The oldest commercial method of making metal castings consists of forming a cavity in sand and filling the cavity with molten metal. After the metal solidifies, the sand is sand is broken away, and the casting is removed, trimmed, and cleaned. Sand molds are made in two or more sections: bottom (drag), top (cope), and intermediate sections (cheeks) when required. Joints between sections are the parting lines. The sand is contained in flasks, made of metal or some wood.

Molten metal is poured into the sprue, and connecting runners conduct the metal to the casting cavity. Riser cavities in the cope sand over heavy sections of the casting serve as metal reservoirs. They fill with molten metal as the cavity is filled and, as the casting solidifies and shrinks, the risers feed molten metal to the heavy, slowly solidifying sections, thus minimizing porosity in the part. Slag floats to the top of the risers and thus is not incorporated into the casting. Sprue, runner, and risers are trimmed from the casting after it is removed from the sand.

Cores are hard shapes of sand placed in the mold to produce hollow castings. Patterns of wood or metal are used to prepare the mold. Extremely large or heavy castings are made by floor molding. Here, the mold is made in the floor of foundry using the earth as the flask. Advantages and disadvantages: sand casting offers the least expensive method for producing general-purpose castings. Pattern equipment is relatively inexpensive and long lasting. Sand castings are more subject to human control than parts made by other casting processes. More material must be left on a sand casting to permit machining for a finished surface [4].

APPENDIXES

Table 1 – Suffixes of nouns

| Suffixes | Examples |
|---|---|
| -age | postage |
| -ance | importance |
| -ence | independence |
| -er | programmer |
| -or | operator |
| -ism | capitalism |
| -dom | kingdom |
| -ness | darkness |
| -ship | friendship |
| -ation | dictation |
| -tion | execution |
| -ion | action |
| -sion | confession |
| -ian | politician |
| -ist | typist |
| -yst | analyst |
| -ness | kindness |
| -ment | measurement |
| -ity | ability |
| -ure | pleasure |
| -ing | building |
| -ary | dictionary |
| -ery | bakery |
| -cy | accuracy |
| -ee | employee |
| -hood | brotherhood |

Table 2 – Suffixes of verbs

| Suffixes | Examples |
|---|---|
| -ize | computerize |
| -ate | dictate |
| -fy | simplify |
| -en | shorten |

Table 3 – Suffixes of adjectives

| Suffixes | Examples |
|---|---|
| -able | comparable |
| -ible | divisible |
| -ant | important |
| -al | verbal |
| -ial | partial |
| -ical | electrical |
| -ar | circular |
| -ary | reactionary |
| -ic | automatic |
| -ive | active |
| -ian | Russian |
| -an | Mexican |
| -ous | famous |
| -ious | religious |
| -ful | helpful |
| -y | rainy |
| -less | careless |
| -ish | greenish |
| -ing | coding |
| -ate | affectionate |

Table 4 – Suffixes of adverbs

| Suffixes | Examples |
|---|---|
| -ly | kindly |
| -wards | downwards |

Table 5 – Prefixes of size

| Prefixes | Examples |
|---|---|
| macro- | macroeconomics |
| micro- | microeconomics |
| maxi- | maxicomputer |
| mini- | minicomputer |
| mega- | megabyte |

Table 6 – Prefixes of location

| **Prefixes** | **Examples** |
|---|---|
| ex- | external |
| inter- | internal |
| out- | outdoors |
| up- | upstairs |
| trans- | transatlantic |

Table 7 – Prefixes of number

| **Prefixes** | **Examples** |
|---|---|
| bi- | bilingual |
| tri- | triangle |
| quad- | quadruple |
| penta- | pentagon |
| hex- | hexadecimal |
| septem- | septuagenarian |
| oct- | octal |
| dec- | decimal |
| multi- | multinational |
| mono- | monochromatic |

Table 8 – Negative (opposite) prefixes

| **Prefixes** | **Examples** |
|---|---|
| un- | uncontrolled |
| in- | incomplete |
| im- | impossible |
| il- | illegal |
| ir- | irregular |
| non- | non-programmable |
| mis- | misunderstand |
| dis- | dislike |
| anti- | antisocial |
| de- | demagnetize |
| under- | underestimate |
| over- | overestimate |
| ab- | abnormal |
| contra- | contradict |

Table 9 – Prefixes of time

| Prefixes | Examples |
|---|---|
| pre- | prehistoric |
| post- | postwar |

Table 10 – Other prefixes

| Prefixes | Examples |
|---|---|
| auto- | automatic |
| re- | rewrite |
| over- | overheat |
| co- | coordinate |
| ex- | ex-wife |
| neo- | neoclassical |
| pan- | pan-Asian |
| extra- | extrasensory |
| for- | forward |
| inter- | interrelated |
| prime- | prime-minister |
| retro- | retroactive |
| ultra- | ultraliberal |
| semi- | semisphere |
| super- | superstar |
| sub- | subgroup |

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**Прадівлянний Микола Григорович,**
**Рибко Наталія Вікторівна,**
**Бойко Юлія Василівна**

# АНГЛІЙСЬКА МОВА ДЛЯ СТУДЕНТІВ МАШИНОБУДІВНИХ СПЕЦІАЛЬНОСТЕЙ
## Частина 1

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Вінницький національний технічний університет,
інформаційний редакційно-видавничий центр.
ВНТУ, ГНК, к. 114.
Хмельницьке шосе, 95,
м. Вінниця, 21021.
Тел. (0432) 65-18-06.
**press.vntu.edu.ua**;
*E-mail*: kivc.vntu@gmail.com.

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