普通高等教育“十二五”规划教材

水利水电专业英语

主 编 张建伟
副主编 于国辉 赵基花 张翌娜

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内 容 提 要

本书是一本实用性和专业性都很强的水利水电英语读物。全书共分28章，每章包括两篇课文（课内、课外阅读各一篇）。文章由课文、生词、词组、专有名词组成。全书阅读材料大都选自英美原著或国外设计规范，取材广泛，文章相对独立而又相互关联，尽量将地道准确的英语语言奉献给读者。另外，本书还介绍了如何写英文摘要及科技论文。

本书可作为高等院校水利、岩土、土木等专业的师生用书，也可作为从事水利水电工程、岩土工程和土木工程等领域设计、施工和科研工作的科技人员参考。

图书在版编目（CIP）数据

水利水电专业英语 / 张建伟主编. -- 北京 : 中国水利水电出版社, 2013.1
普通高等教育“十二五”规划教材
ISBN 978-7-5170-0373-1

Ⅰ. ①水… Ⅱ. ①张… Ⅲ. ①水利水电工程－英语－高等学校－教材 Ⅳ. ①H31

中国版本图书馆CIP数据核字(2013)第011854号

书　　名	普通高等教育“十二五”规划教材 **水利水电专业英语**
作　　者	主编　张建伟　副主编　于国辉　赵基花　张翌娜
出版发行	中国水利水电出版社 （北京市海淀区玉渊潭南路1号D座　100038） 网址：www.waterpub.com.cn E-mail：sales@waterpub.com.cn 电话：(010) 68367658（发行部）
经　　售	北京科水图书销售中心（零售） 电话：(010) 88383994、63202643、68545874 全国各地新华书店和相关出版物销售网点
排　　版	中国水利水电出版社微机排版中心
印　　刷	北京嘉恒彩色印刷有限责任公司
规　　格	184mm×260mm　16开本　17印张　524千字
版　　次	2013年1月第1版　2013年1月第1次印刷
印　　数	0001—3000册
定　　价	**35.00元**

前言

随着水利水电工程建设与管理的日益国际化，熟练的专业英语知识已成为本科毕业生不可或缺的基本技能之一。根据水利水电专业教学大纲的要求，专业英语属于大学英语应用提高阶段，安排在第五至第七学期，教学时数应不少于100学时，课内外学习时数的比例应不低于1∶2。通过专业英语课学习，使学生掌握以英语为工具获取专业知识的能力，在专业英语的听、说、读、写、译等方面具有较高水平。根据编者多年的专业英语教学经验与体会，编写了《水利水电专业英语》教材，以满足高等院校水利水电工程、农业水利工程、水文与水资源及相关专业的本科专业英语教学需要和相关专业的科技人员、工程技术人员和管理人员学习专业英语的要求。

全书由27篇课文、27篇阅读材料和1个科技英语阅读与写作专题组成。课文由正文、生词（词性、中文释义）和词组或短语（中文释义）组成，其内容涉及材料力学、土力学、岩石力学、混凝土材料、水工建筑物、水力发电、水轮机、水利工程施工、地下工程、基础处理工程、科技英语阅读与写作等方面。本书语言规范，取材广泛，专业词汇丰富，适应性和针对性强，便于自学，符合素质教育的基本要求。

《水利水电专业英语》由华北水利水电学院张建伟任主编，华北水利水电学院于国辉、赵基花和黄河水利职业技术学院张翌娜任副主编。全书由张建伟统稿。教材编写大纲由编写人员集体讨论确定，各章节编写分工如下：张建伟编写第9、17、21、23、24、25、26、28单元，于国辉编写第7、11、12、14、18、20、22、27单元，赵基花编写第8、10、13、15、16、19单元，张翌娜编写第1、2、3、4、5、6单元。

本书在编写过程中得到了中国水利水电出版社的大力支持，硕士研究生程晟钊、院淑芳、张硕、左罗，本科生刘杰、伊紫函、钟晓倩等参与了书稿编辑与校对工作。本书在编写过程中参阅了书后所列文献的有关内容，编写者在此一并表示衷心感谢。

由于编者水平所限，书中难免存在不足和错误，恳请广大读者批评指正。

编 者

2012年9月

目录

Unit 1 Concept of Stress at a Point

If a body is subjected to external forces, a system of internal forces is developed. These internal forces tend to separate or bring closer together the material particles that make up the body. Consider, for example, the body shown in Fig. 1.1 (a), which is subjected to the external forces $\boldsymbol{F}_1$, $\boldsymbol{F}_2$, ⋯, $\boldsymbol{F}_i$. Consider an imaginary plane that cuts the body into two parts, as shown. Internal forces are transmitted from one part of the body to the other through this imaginary plane. Let the free-body diagram of the lower part of the body be constructed as shown in Fig. 1.1 (b). The forces $\boldsymbol{F}_1$, $\boldsymbol{F}_2$, and $\boldsymbol{F}_3$ are held in equilibrium by the action of an internal system of forces distributed in some manner through the surface area of the imaginary plane. This system of internal forces may be represented by a single resultant force $\boldsymbol{R}$ and/or by a couple. For the sake of simplicity in introducing the concept of stress, only the force $\boldsymbol{R}$ is assumed to exist. In general, the force $\boldsymbol{R}$ may be decomposed into a component F_n, perpendicular to plane are known as the normal force, and a component $\boldsymbol{F}_t$, parallel to the plane and known as the shear force.

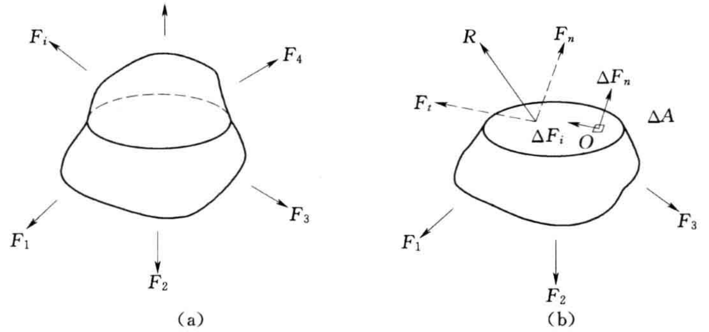

Fig. 1.1 Material particles

If the area of the imaginary plane is to be A, then F_n/A and F_t/A represent, respectively, average values of normal and shear forces per unit area called stresses. These stresses, however, are not, in general, uniformly distributed throughout the area under consideration, and it is therefore desirable to be able to determine the magnitude of both the normal and shear stresses at any point within the area. If the normal and shear forces acting over a differential element of area ΔA in the neighborhood of point O are $\Delta \boldsymbol{F}_n$ and $\Delta \boldsymbol{F}_t$, respectively, as shown in Fig. 1.1 (b), then the normal stress $\boldsymbol{\sigma}$ and the shearing stress $\boldsymbol{\tau}$ are given by the following expressions:

$$\begin{cases} \sigma = \lim\limits_{\Delta A \to 0} \dfrac{\Delta F_n}{\Delta A} \\ \tau = \lim\limits_{\Delta A \to 0} \dfrac{\Delta F_t}{\Delta A} \end{cases} \tag{1.1}$$

In the special case where the components F_n and F_t are uniformly distributed over the entire area A, then $\sigma = F_n/A$ and $\tau = F_t/A$.

Note that a normal stress acts in a direction perpendicular to the plane on which it acts and it can be either tensile or compressive. A tensile normal stress is one that tends to pull the material particles away from each other.

A shear stress, on the other hand, acts parallel to the plane on which it acts and tends to slide (shear) adjacent planes with respect to each other. Also note that the units of stress (σ or τ) consist of units of force divided by units of area. Thus, in the British gravitational system of measure, such units as pounds per square inch (psi) and kilopounds per square inch (ksi) are common. In the metric (SI) system of measure, the unit that has been proposed for stress is the Newton per square meter (N/m^2), which is called pascal and denoted by the symbol Pa. Because the pascal is a very small quantity, another SI unit that is widely used is the megapascal (10^6 pascals) and is denoted by the symbol MPa. This unit may also be written as MN/m^2.

Components of Stress

In the most general case, normal and shear stresses at a point in a body may be considered to act on three mutually perpendicular planes. This most general state of stress is usually referred to astriaxia. It is convenient to select planes that are normal to the three coordinates axes x, y and z and designate them as the X, Y, and Z planes, respectively. Consider these planes as enclosing a differential volume of material in the neighborhood of a given point in a stressed body. Such a volume of material is depicted in Fig. 1. 2 and is referred to as a three-dimensional stress element. On each of the three mutually perpendicular planes of the stress element, there acts a normal stress, and a shear stress which is represented by its two perpendicular components.

The notation for stresses used in this text consists of affixing one subscript to a normal stress, indicating the plane on which it is acting, and two subscripts to a shear stress, the first of which designates the plane on which it is acting and the second its direction. For example, σ_x is a normal stress acting on the X plane, τ_{xy} is a shear stress acting on the X plane and pointed in the positive y direction, and τ_{xz} is a shear stress acting in the X plane and pointed in the positive z direction.

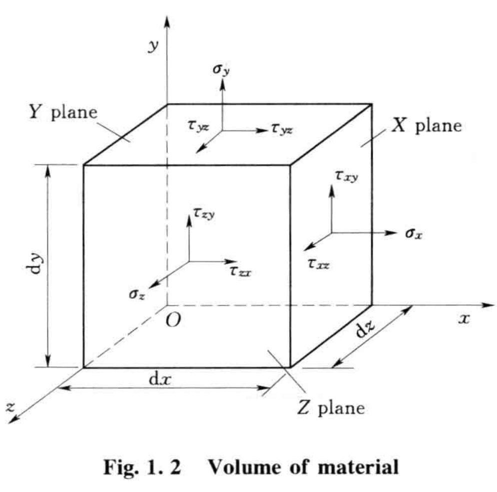

Fig. 1. 2　Volume of material

It is observed from Fig. 1. 2 that three stress components exist on each of the three mutually perpendicular planes that define the stress element. Thus there exists a total of nine stress components that must be specified in order to define completely the states of stress at any point in the body. By considerations of the equilibrium of the stress element, it can be shown that $\tau_{xy}=\tau_{yx}$, $\tau_{xz}=\tau_{zx}$, $\tau_{yz}=\tau_{zy}$, so that the number of stress components required to completely define the state of stress at a point is reduced to six.

By convention, a normal stress is positive if it points in the direction of the outward normal to the plane. Thus a positive normal stress produces tension and a negative normal stress produces compression. A component of shear stress is positive if it is pointed along the positive direction of the corresponding axis. If, however, the outward normal is in the negative direction of the coordinate axis, a positive shear stress will also be in the negative direction of corresponding axis. The stress components shown in Fig. 1. 2 are all positive. It should be noted, however, that such a sign convention for shear stress is rather cumbersome. It is only used in the analysis of triaxial stress problems that are usually dealt with in advanced courses such as the theory of elasticity.

A complete study of the triaxial or three-dimensional state of stress is beyond the scope of this chapter, and the analysis that follows is limited to the special case in which the stress components in one direction are all zero. For example, if all the condition reduces to the z direction are zero (i. e., $\tau_{xz}=\tau_{yz}=\sigma_z=0$), the stress condition reduces to a biaxial or two-dimensional state of stress in the xy plane. This state of stress is referred to as plane stress. Fortunately many of the problems encountered in practice are such that can be considered plane stress problems.

New Words and Expressions

be subject to 承受，受……的支配
external force 外力
internal force 内力
be transmitted from ... to 从……传递到
imaginary *adj*. 假想的，想像的，虚的
free-body *n*. 自由体，隔离体
equilibrium *n*. 平衡，保持平衡的能力
be decomposed into 分解
perpendicular *adj*. 垂直的，正交的
resultant force 合力
be parallel to 与……平行
normal force 法向力，正交力
shear force 剪力
uniformly *adv*. 一律地，均匀地
magnitude *n*. 大小
normal stress 法向应力，正应力
tensile *adj*. 张力的，拉力的
compressive *adj*. 有压缩力的，压缩的
slide *v*. & *n*. 滑动
adjacent *adj*. 邻近的，接近的
psi pounds per square inch 的缩写
MPa megapascal 的缩写 兆帕
gravitational *adj*. 重力的
designate *vt*. 指明，指出；*v*. 指定，指派
depict *v*. 描绘，描述
affixing *adj*. 附加的
subscript *n*. 脚标
positive *adj*. 正的
positive normal 正法向
negative direction 逆向，反方向
cumbersome *adj*. 讨厌的，麻烦的

triaxial *adj*. 三轴的，三维的，空间的
plane stress 平面应力
elasticity *n*. 弹力，弹性（力学）

Reading Material Theory of Stress

This chapter presents the three-dimensional theory of stress of a continuous medium. As in the theory of deformation, by a continuous medium we mean a material in which each volume of substance is sufficiently dense so that concepts such as mass density, temperature, stress, and so forth have meaning at every point in the region occupied by the material. The theory of stress rests upon Newton's laws, which are independent of the nature of materials that fall within the continuous-medium model. Consequently, the theory of stress developed here is applicable to all continuous media, regardless of their mechanical behavior of response to forces — that is, whether they behave elastically, plastically, viscoelastically, or in any other manner. The main part of the chapter is devoted to classical stress theory in which stress couples and body couples are neglected. A brief discussion of the concept of stress couples and body couples is presented in Appendix.

1 Definition of Stress

It is noted in elementary mechanics that point forces never really occur in nature; forces are always distributed throughout regions. Nevertheless, the point force is an indispensable concept in mechanics. For example, distributed forces that act on a rigid body are dynamically equivalent to a single point force and a couple.

To gain insight into the nature of distributed forces, we consider the forces that act inside a solid or a fluid. The theories of deformable bodies (fluid mechanics, elasticity, and plasticity) are based on the concept of action by direct contact. If we imagine a body to be partitioned intocells by fictitious surfaces, one cell does not exert a direct effect on another cell unless it is in contact with it. If two cells are in contact with each other along one of the fictitious surfaces of separation, a force may be transmitted from the first cell to the second cell and vice versa.

To elaborate on this idea, let us pass a fictitious plane $\boldsymbol{Q}$ through a body and mark an area A on the plane. One side of the plane $\boldsymbol{Q}$ will be designated as positive, the other side as negative (Fig. 1. 3). The material on the positive side of the plane $\boldsymbol{Q}$ exerts a force upon the material on the negative side. This force is transmitted through the plane $\boldsymbol{Q}$ by direct contact of material on the two sides of the plane. The force that is transmitted through the area A is denoted by $\boldsymbol{F}$. Note that we do not use the notations ΔA, $\Delta \boldsymbol{F}$ as in some works, as use of these notations in the limiting process that defines stress may lead to confusion with the concept of derivative of a vector. In general, $\boldsymbol{F}$ is not perpendicular to the plane $\boldsymbol{Q}$. In accordance with Newton's law of reaction, the material on the negative side of plane $\boldsymbol{Q}$ transmits, through the area A, a force equal to $-\boldsymbol{F}$. The force $\boldsymbol{F}$ is an internal force, as its reaction is exerted within the body.

The force $\boldsymbol{F}$ may be resolved into components $\boldsymbol{F}_n$ and $\boldsymbol{F}_s$, such that the component $\boldsymbol{F}_n$ is perpendicular to plane Q, and the component $\boldsymbol{F}_s$ is tangent to plane Q (Fig. 1.3). The component $\boldsymbol{F}_n$ is called the normal force on the area A, and the component $\boldsymbol{F}_s$ is called the shearing force on the area A. The word "normal" has the same meaning as the word "perpendicular".

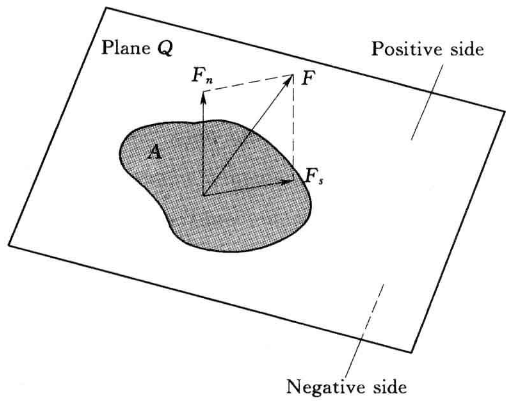

Fig. 1.3 Body and plane

The foregoing concepts are equally applicable to stationary bodies and to deforming bodies (e. g., to flowing fluids). During a deformation process, $\boldsymbol{F}_n$ and $\boldsymbol{F}_s$ ordinarily vary with time. The forces $\boldsymbol{F}_n$ and $\boldsymbol{F}_s$ naturally depend on the area A. The magnitudes of the average forces per unit area are F_n/A and F_s/A. These ratios are called the average normal stress and the average shearing stress on the area A. The concept of stress at a point is obtained by letting area A be infinitesimal. Then the forces $\boldsymbol{F}_n$ and $\boldsymbol{F}_s$ approach zero, but the ratios F_n/A and F_s/A usually approach limits different from zero. The limiting values of the ratios F_n/A and F_s/A are called the normal stress and the shearing stress on plane Q at the point where the infinitesimal area A is located. In general, these stresses depend not only on the coordinates of the infinitesimal area A but also on the plane in which the area A lies. The normal stress and the shearing stress may be regarded as normal and tangential projections of a stress vector that is associated with the infinitesimal area A. Accordingly, we may speak of the direction of the stress vector that acts at a given point on a given plane; it is the direction of the infinitesimal force that acts on the elemental area. Mathematically, the foregoing remarks may be summarized as follows:

$$\lim_{A\to 0}\frac{F_n}{A}=\sigma,\quad \lim_{A\to 0}\frac{F_s}{A}=\tau \tag{1.2}$$

Where: σ is the normal stress at a point in area A in plane Q and τ is the shearing stress at the same point in area A in plane Q.

There are significant differences between the internal forces in fluids and in solids. Solids frequently sustain large internal tensile forces. In contrast, normal forces in fluids are usually compressive. In other words, the normal force transmitted from the fluid on one side of a fictitious plane to the fluid on the other side is usually a push rather than a pull. In fluids, the reactions (pushes) measured per unit area are referred to as pressures (negative stresses). In the case of solids, we retain the terminology "stress" and consider pressures or compressions as negative stresses.

The materials that are known as fluids have another property that distinguishes them from solids. Fluid materials flow (i. e., they deform continuously) whenever shearing stresses exist. It is customary to designate this property as the definition of a fluid. Accordingly, shearing stresses cannot exist in a fluid that is at rest. This definition may be applied to ascertain whether a given material is a fluid. For example, clay does not flow unless the absolute value of the shearing stress exceeds a certain positive value. Consequently, clay is classified as a plastic solid rather than a fluid.

Intuitively, we should expect that the shearing stress in free-flowing fluids, such as air and water, must be small, even though the fluids are in motion. This observation has led to the concept of a frictionless fluid, that is, an ideal fluid. A frictionless fluid is defined to be a material in which shearing stresses cannot be developed. Much of classical hydrodynamics is concerned with frictionless fluids. However, the theory of frictionless fluids has not been so useful as it was originally expected to be, as significant shearing stresses always exist in a flowing fluid in the regions near solid boundaries.

A fluid in which shearing stresses are developed when flow occurs is said to be viscous. To some extent, all real fluids are viscous.

2 Stress Notation

In the theory of stress of continuous bodies, a distinction is made between the following two types of forces: ①body forces, acting on the elements of volume (or mass) of the body, and ② stresses, acting on surface elements inside or on the boundary of the body. Examples of body forces are gravitational forces, magnetic forces, and inertia forces. Examples of stresses (of surface forces) are contact forces between solid bodies, or hydrostatic pressure between a solid body and a fluid.

To establish a stress notation, we imagine a plane surface cutting through a body in a deformed state (stressed state) and consider the interaction between the two parts of the body across the surface of separation. For simplicity, we take the body to be a regular prism with sides parallel to axes (X, Y, Z) (Fig. 1. 4), with the plane of separation perpendicular to the X axis. The two parts of the body are shown separated for clarity. A positive X plane in the part on the left is shaded. We define a positive X plane as one whose outward normal points in the positive X direction. The shaded positive X plane is considered to be a rectangle with sides ΔY, ΔZ. The X surface, which bounds the right part of the body and coincides with the positive X surface of the left part, is also shaded in Fig. 1. 4. Because its outward normal points in the negative X direction, it is a negative X plane. As noted in Section 1, the force exerted by the negative X surface on the positive X surface is $\boldsymbol{\sigma}\ \Delta Y\ \Delta Z$, where σ is the stress vector. In general, $\boldsymbol{\sigma}$ is not perpendicular to the positive X plane. Hence, we may resolve the force $\boldsymbol{\sigma}\Delta Y\ \Delta Z$ and the associated stress into components along the positive (X, Y, Z) directions. The (X, Y, Z) components of stress are denoted by σ_{xx}, σ_{xy}, σ_{xz}, respectively. Hence, the notation σ_{xx} denotes the stress component normal to the positive X plane. Similarly, the notation σ_{xy}, σ_{xz} denotes the *shearing components* (or *tangential components*) of the stress vector that lies in the positive X plane, the components being directed in the positive Y, Z directions, respectively. We note that in the above notation the first subscript denotes the surface upon with $\boldsymbol{\sigma}$ acts, and the second subscript denotes the direction of the stress component.

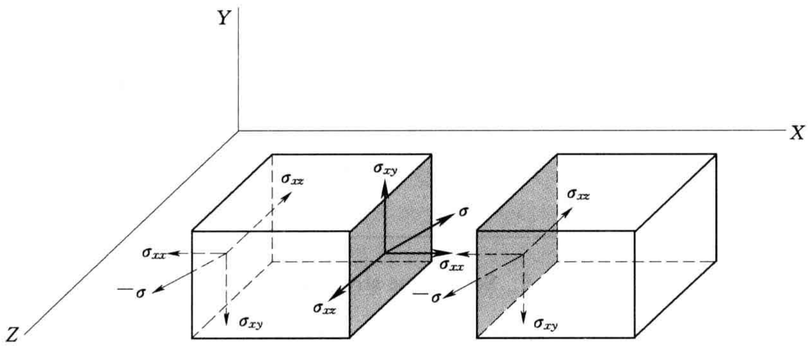

Fig. 1. 4 Stress notation

By Newton's third law (action and reaction), the stress components that act on the negative X surface (right part) must act in the opposite direction (Fig. 1. 4). Thus, a positive component σ_{xj} relative to the negative X surface means a stress component in the negative j direction. Likewise, this holds for the negative X plane of the left part (the surface obtained by a translation of the negative X surface of the right part through a distance ΔX). In the theory of deformable solids, we will consider the above convention to define positive stress components. Negative components are shown schematically by reversing the direction of the arrow denoting positive components. For example, consider an infinitesimal cubic element at a point O in a body, with sides parallel to axes (X, Y, Z) (Fig. 1. 4). The stress components acting on positive and negative planes are shown in the positive senses. Thus, on positive planes the arrowheads point in the positive senses of the corresponding axes, whereas on negative planes they point in the negative senses of the axes.

The axes (X, Y, Z) are attached to frame F. Because the body (Fig. 1. 4) is in a deformed state, the quantities (σ_{xx}, σ_{xy}, $\cdots$, σ_{zz}) are defined relative to the deformed state (stressed state) of the body. Thus, it follows that the equation of motion of the body is most simply written in terms of spatial coordinates.

The stress notation illustrated in Fig. 1. 5 is a conventional notation. However, other stress notations are common. The more frequent notations for components of the stress tensor are listed in Table 1. 1.

Index Notation. The set of nine stress components associated with the cube of Fig. 1. 5 (stress at point O) may be written in the index form σ_{ij}, i, $j=1, 2, 3$.

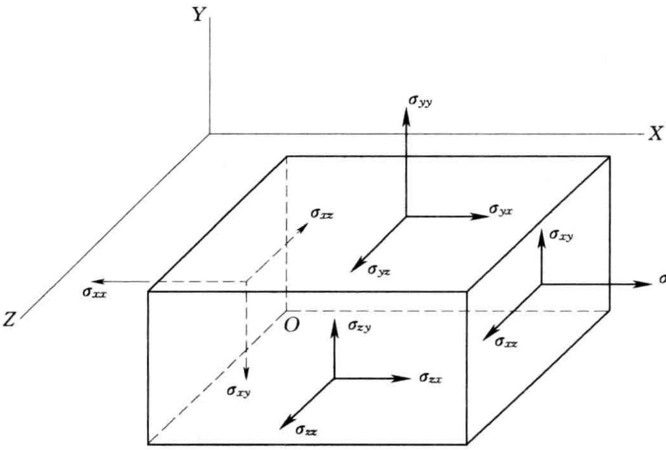

Fig. 1. 5 Set of nine stress components

Table 1. 1 **Summary of Stress Notations**

Engineering	σ_x	σ_y	σ_z	$\tau_{xy}=\tau_{yx}$	$\tau_{xz}=\tau_{zx}$	$\tau_{yz}=\tau_{zy}$
Some American writers	σ_{xx}	σ_{yy}	σ_{zz}	$\sigma_{xy}=\sigma_{yz}$	$\sigma_{xz}=\sigma_{zx}$	$\sigma_{yz}=\sigma_{zy}$
Love (also some Russian and English writers)	X_x	Y_y	Z_z	$X_y=Y_x$	$X_z=Z_x$	$Y_z=Z_y$
Planck	$-X_x$	$-Y_y$	$-Z_z$	$-X_y=-Y_x$	$-X_z=-Z_x$	$-Y_z=-Z_y$
Some English writers	P	Q	R	S	T	U

Here we have employed the notation

$$\left.\begin{array}{l}\sigma_{xx}=\sigma_{11},\sigma_{yy}=\sigma_{22},\sigma_{zz}=\sigma_{33}\\ \sigma_{xy}=\sigma_{12},\sigma_{xz}=\sigma_{13},\sigma_{yz}=\sigma_{23}\end{array}\right\} \tag{1.3}$$

and so on.

New Words and Expressions

three-dimensional 三维的；立体的
mechanical *adj*. 机械的；呆板的；手工操作的
appendix *n*. 附录；阑尾；附加物
dynamically *adv*. 充满活力地；不断变化地
partitioned *vt*. 分割（partition 的过去分词）
elaborate *adj*. 精心制作的；详尽的；煞费苦心
confusion *n*. 混淆，混乱；困惑
perpendicular *adj*. 垂直正交的；直立陡峭的
stationary *adj*. 固定的；静止的
magnitudes *n*. 大小；量级；震级
infinitesimal *adj*. 无穷小的；极小的
tangential *adj*. 切线的，正切的
vector *n*. 矢量
mathematically *adv*. 算术地，数学上地
tensile *adj*. 拉力的；可伸长的
fictitious *adj*. 虚构的；假想的；假装的
terminology *n*. 术语，用辞

customary *n.* 习惯；惯例
designate *vt.* 指定；指派；把……定名为
clay *n.* 黏土；泥土；肉体；似黏土的东西
observation *n.* 观察；监视；观察报告
frictionless *adj.* 无摩擦的；光滑的
hydrodynamics *n.* 流体力学；水动力学
notation *n.* 符号；注释
gravitational *adj.* 重力的，引力的
magnetic *adj.* 有磁性的；有吸引力的
inertia *n.* 惯性；迟钝
prism *n.* 棱镜；棱柱
parallel *n.* 平行线；*adj.* 平行的，相同的
subscript *n.* 下标；脚注
likewise *adv.* 同样地
schematically *adv.* 计划性地；按照图式

Unit 2 Mechanical Properties of Material

An engineering stress-strain diagram representing the behavior of steel alloys and aluminum alloys in tension is shown schematically in Fig. 2. 1. These diagrams will be used to introduce and discuss the significant mechanical properties of materials.

The diagram shown in Fig. 2. 1 define two ranges of material behavior known as the elastic and plastic (or inelastic) ranges. In genenal, the elastic range is that of the diagram a linear relation between the stress and the strain (approximately segment OA in Fig. 2. 1), and it is the part of the stress-strain diagram that has already been discussed and is expressed mathematically by Hooke's law (i. e. , $\varepsilon=\sigma/E$)) up to the proportional limit for the material. The plastic or inelastic range is that part of the stress-strain diagram that defines a nonlinear relation between the stress and the strain and is reprensented by segment by segment BF in Fig. 2. 1. Several empirical equations have been proposed to describe the inelastic relation between the stress and the strain, but the most widely used is the one known as the Ramberg-Osgood, which may be expressed as follows:

$$\varepsilon=\frac{\omega}{E}+\left(\frac{\sigma}{B}\right)^{n} \qquad (2.1)$$

Where: B and n are constants for a given material. The Ramberg-Osgood relation as expressed in equation (2. 1) will be utilized to develop the use of the modified tangent modulus method for the analysis of columns.

Proportional Limit. The proportional limit for a given material represents the value of stress beyond which the material no longer behaves in such a way that the stress is proportional to strain. The proportional limit, σ_p, is represented by the ordinate to point A in Fig. 2. 1.

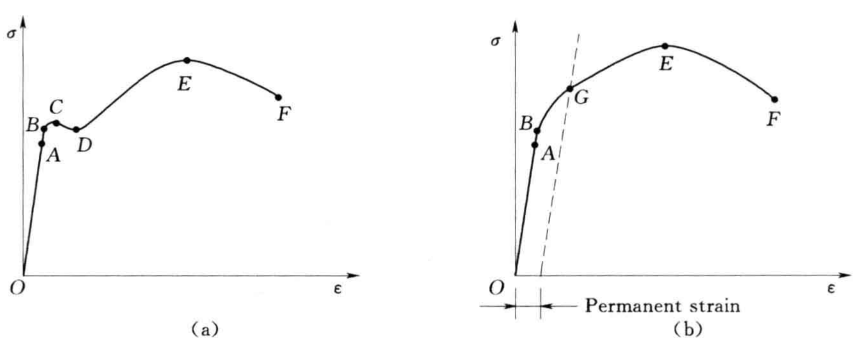

Fig. 2. 1 Elastic and plastic ranges

Elastic limit. The elastic limit, σ_e, for a given material is the value of stress beyond which the material experiences a permanent deformation even after the stress is removed. Thus, if the material is loaded to any level of stress within the elastic limit and the load is then removed, it will regain its original dimensions and is said to behave elastically. However, if the load exceeds the elastic limit before it is removed, the material does not fully regain its initial dimensions. In such a case the material is said to experience a permanent deformation.

The elastic limit is represented by the ordinate to point *B* in Fig. 2. 1. Its determination, experimentally, is extremely difficult, and therefore its exact location on the stress-strain diagram is usually not known, even though it is generally higher than the proportional limit $\boldsymbol{\sigma}_p$. For all practical purposes, however, the elastic limit $\boldsymbol{\sigma}_e$ and the proportional limit $\boldsymbol{\sigma}_p$ may be assumed tohave the same value.

Modulus of Elasticity. The modulus of elasticity, *E*, is the constant of proportionality between stress and strain in Hooke's law. Physically, it represents the slope of the stress-strain diagram within the proportional range of the material (i. e, the slope of the straight segment *OA* in Fig. 2. 1). The term stiffness is used to describe the capacity of materials to resist deformation in the elastic range and it is measured by the modulus of elasticity. For example, steels with a modulus of elasticity of about 30×10^6 psi are stiffer than aluminums, with a modulus of elasticity about 10×10^6 psi.

Yield Point. The yield point, σ_y, is the stress at which the material continues to deform without further increase in the stress. The stress may even decrease slightly as the deformation continues past the yield point. Some material, notably the plain carbon steels, exhibit a well-defined yield point, as shown by point *C* in Fig. 2. 1 (b). If the stress decreases past this point, it is referred to as the upper yield point, in contrast to the lower yield point represented by point *D* in Fig. 2. 1 (b) and beyond which the stress increases with further strain.

Yield Strength. For materials having a stress-strain diagram such as shown in Fig. 2. 1 (b) (those that do not exhibit a well-defined yield point) a value of stress, known as the yield strength for the material, is defined as one producing a certain amount of permanent strain. Although several values of permanent strain may be used in defining the yield strength for a material, the most commonly encountered values are 0. 0020 and 0. 0035.

To determine the yield strength, $\boldsymbol{\sigma}_s$, the assigned numerical value of permanent strain is measured along the strain axis of the stress-strain diagram to locate a point through which a line is drawn parallel to the straight portion (segment *OA*) of this diagram. The straight line is then extended until it intersects the stress-strain curve at the desired point. This construction is shown schematically in Fig. 2. 1 (b), in which the ordinate to point *G* represents the value of the yield strength for the material.

Ultimate strength. The ultimate strength, σ, represents the ordinate to the highest point in the stress-strain diagram and is equal to the maximal load carried by the specimen