专业英语系列教材

English for Mechanical and Electrical Engineering

机电工程英语

English for Mechanical and Electrical Engineering

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华中科技大学出版社
http://www.hustp.com

图书在版编目(CIP)数据

机电工程英语/李浙昆　主　编. —武汉:华中科技大学出版社,2008年2月
ISBN 978-7-5609-4371-8

Ⅰ.英…　Ⅱ.李…　Ⅲ.机电工程-英语-高等学校-教材　Ⅳ.H31

中国版本图书馆CIP数据核字(2008)第202096号

机电工程英语　　李浙昆　主　编

责任编辑:汪　漾　　封面设计:潘　群
责任校对:张　梁　　责任监印:周治超

出版发行:华中科技大学出版社(中国·武汉)
武昌喻家山　邮编:430074　电话:(027)87557437

录　排:华中科技大学惠友文印中心
印　刷:华中科技大学印刷厂

开本:787 mm×1092 mm　1/16　　印张:12　　字数:292 000
版次:2008年2月第1版　　印次:2008年2月第1次印刷　　定价:20.80元
ISBN 978-7-5609-4371-8/H·614

前　言

为了适应现代科技的迅速发展，以往的教材需要增加新的内容。学生在完成大学和研究生阶段的通用英语学习后，对专业科技英语仍较为生疏。为提高机电类本科生、研究生及工程技术人员的专业英语水平，巩固专业基础知识，同时了解机电专业中的新知识和新技术，特编写了本书。

本教材的编写，既兼顾面，又注意点，力求做到点面结合。全书共分八个部分：第一、二、三部分分别介绍机械学、电学、材料学的基础内容；第三、四、五、六、七部分分别介绍机电控制、测试、机械设计与制造、材料加工的基础与发展，内容涵盖了机电专业的主要知识点，同时包括专业发展的趋势和专业前沿的新技术；第八部分着重介绍了现代新兴技术。教材各个部分既相对独立，又相互支撑，形成较为完整的体系。教材编写体现了基础知识与专业前沿相结合，机械、电工电子与材料加工学科相结合，以及控制、测试、机构、设计与加工等专业的结合，尤其注重课程教学与自学相结合，力求形成本书的特点。

该教材由 32 篇课文、17 篇阅读材料组成，根据不同教学学时的安排，教学中可以选择部分内容进行课堂教学，部分内容作为课外阅读和自学材料。对于本科生的教学，可以选择基础性的课文为主，专业前沿的新技术、新知识的课文为辅；对于研究生的教学，应以反映专业前沿的新技术、新知识的课文为主。

教材的 8 个部分分别由昆明理工大学的 8 位教师编写。李浙昆任主编，彭澎任副主编。刘忠编写第一部分，任伟编写第二部分，彭澎编写第三部分，袁锐波编写第四部分，郭瑜编写第五部分，王立华编写第六部分，周荣锋编写第七部分，李浙昆编写第八部分。编写完成后进行了互审修改工作。任伟审阅修改第一部分，刘忠审阅修改第二部分，周荣锋审阅修改第三部分，李浙昆审阅修改第四部分，王立华审阅修改第五部分，郭瑜审阅修改第六部分，彭澎审阅修改第七部分，袁锐波审阅修改第八部分。教材编写过程中引用参考了中外学者的著作、教材、文献等，在此表示衷心感谢!

由于水平所限，编写过程中难免有纰漏和欠妥之处，请各位读者不吝赐教，以便改正。

编　者

2007 年 10 月

内 容 提 要

本书是机电工程专业英语教材，内容涵盖了机械、电子、材料等学科领域的基础理论，以及相关现代新兴技术的发展动向。具体内容包括机械零件、公差及技术测量、电工电子、工程材料等专业基础知识，以及机电控制、机械设计与制造、液压传动、材料加工、数控技术、机器人技术、计算机辅助设计与制造、微机电系统、纳米技术等现代新技术。本教材既可作为机电类本科和研究生专业英语的学习教材，也可供相关专业技术人员学习与参考。

Contents

Part 1 Mechanisms

1.1 Machine Elements

Complex machines are made up of moving parts such as inclined planes, levers, gears, cams, cranks, springs, belts, and wheels. Machines deliver a certain type of movement to a desired location from an input force applied somewhere. Some machines simply convert one type of motion to another type, such as rotary to linear. While there are a seemingly endless variety of machines, they are all based upon simple machine elements. The common machine elements discussed here include inclined planes, levers, wheels and axles, pulleys, and screws.

Inclined Plane and the Lever

An inclined plane decreases the force required to raise an object a given height by increasing the distance over which a force must be applied (see Figure 1.1.1). You can imagine lifting something twice your weight to a 4 feet high shelf, or rolling the same mass up a gently sloping surface. The latter would be much easier. For example, if lifting a 300-kilogram machine two and one-half meters into a truck, then 750 meter-kilograms of work is required. If you use an inclined plane as a loading ramp, which is 10 meters long, and neglect the small friction force, then 75 kilograms of force will be required to roll the machine up to the ramp. The total work is still 750 meter-kilograms, but the effort has been modified so that the maximum force required is only 75 kilograms and not 300 kilograms.

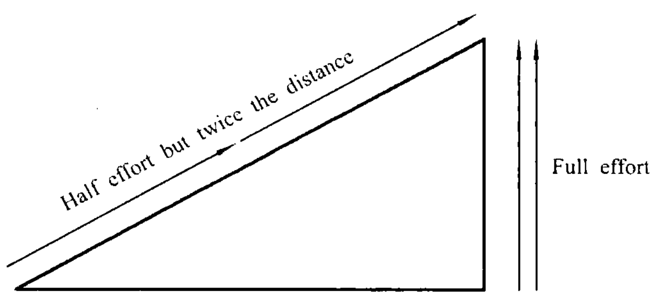


Figure 1.1.1 Inclined plane

Inclined planes are commonly put to use in cutting devices (e.g. an axe) and often two inclined planes are put back-to-back to form a wedge. In a wedge, forward movement is converted into a parting movement acting perpendicularly to the face of the blade. A zipper is simply a combination of two lower wedges for closing and an upper wedge for opening, as shown in Figure 1.1.2.

There are three factors in manipulating a lever: the fulcrum, the load, and the effort applied to the lever. The fulcrum is the point around which the lever pivots rotationally. The load is what we wish to manipulate with the lever, and usually is described by its position relative to the fulcrum, and the force (magnitude and direction) it exerts at that point. The effort is also a force that has a magnitude and a direction, and a position with respect to the fulcrum. A lever is used to change the direction of movement, and to change the magnitude of the effort.

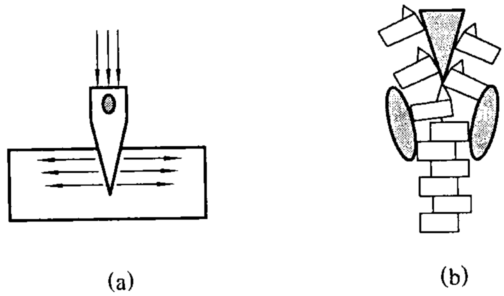


Figure 1.1.2　The inclined plane at work

(a) Axe; (b) Zipper

As shown in Figure 1.1.3, there are three different classes of levers defined by the relative positions of the fulcrum, effort, and load. The first class lever has the fulcrum positioned between the effort and the load. Examples of first class levers include: a balance, a crow bar, and scissors, etc. In the second class lever the load is placed between the fulcrum and the effort. Examples of second class levers include: a wheelbarrow, a bottle opener, and a nutcracker, etc. The third class levers place the effort between the fulcrum and the load. Examples of third class levers are a hammer, a fishing rod, and tweezers, etc. Most machines that employ levers use a combination of several levers or often of different classes.

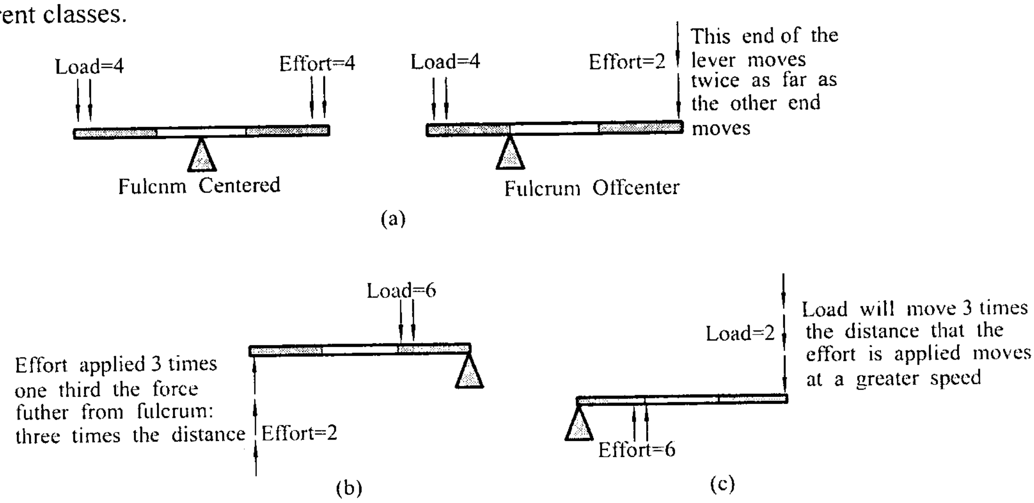


Figure 1.1.3　Classes of levers

(a) First class levers; (b) Second class levers; (c) Third class levers

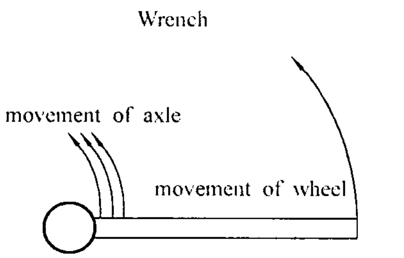
Wheel and Axle

Both the inclined plane and levers could lower the force required for a task at the price of having to apply that force over a longer distance. With wheels and axles the same is true: a force and movement of the axle is converted to a greater movement, but less force, at the circumference of the wheel. In a circular geometry, torque is a more useful concept than force and distance. The wheel and axle can be thought of as simply a circular lever, as shown in Figure 1.1.4. Many common items rely on the wheel and axle such as the screwdriver, the steering wheel, the wrench, and the faucet, etc.

Pulley

Pulleys can be used to simply change the direction of an applied force or to provide a force/distance tradeoff in addition to a directional change, as shown in Figure 1.1.5. Pulleys are very flexible because they use ropes or chain to transfer force rather than a rigid object such as a rod.

Ropes can be routed through virtually any path. They are able to abruptly change directions in three-dimensions without consequence, except, of course, additional friction. [1] Ropes can be wrapped around a motor's shaft and either wound up or let out as the motor turns. [2]



The wheel and axle is like a circular lever

Figure 1.1.4 The wheel and axle

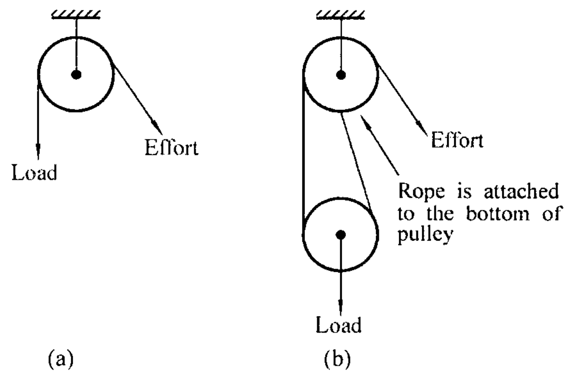


Figure 1.1.5 Pulleys

(a) Single Pulley:No force/distance tradeoff, only directional change; (b) Double Pulley Load moves half of the distance rope is pulled, but the effort is halved

Figure 1.1.6 illustrates how a compound pulley "trades" force for distance through an action/reaction force pair. In a double pulley, as the rope passes over the pulley the force is transmitted entirely but the direction has changed. The effort is now pulling up on the left side of the bottom pulley. The end of the rope is tied to the bottom of the top pulley which is fixed to the ceiling. The mechanics are the same as the rope is fixed to the ceiling. The important thing is that the end of the rope is immobile. The effort is once again transmitted entirely as the rope passes over the bottom pulley and there is a direction change. The end of the rope is attached to the ceiling so the rope is pulling down on the ceiling with the force of the effort (and half of the force of the load). We assume that the ceiling holds up, so this must mean that there is a force balancing out this downward force. The ceiling pulls up on the rope as a reaction force. This upward force is equal to the effort and now there is an upward force on the right side of the bottom pulley. From the perspective of a free-body diagram the compound pulley system could be replaced by tying two ropes to the load and pulling up on each with a force equal to the effort.

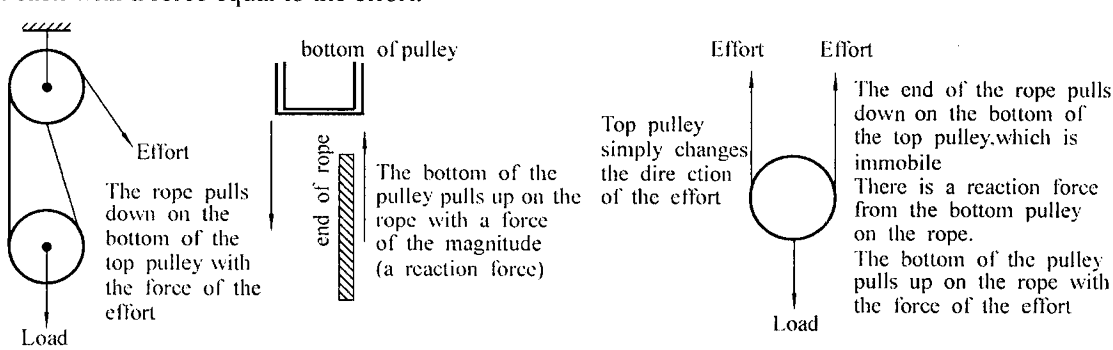


Figure 1.1.6 How compound pulleys work

The disadvantages of pulleys, in contrast to machines that use rigid objects to transfer force, are slipping and stretching. A rope will permanently stretch under tension, which may affect the future performance of a device. If a line becomes slack, then the operation of a machine may change entirely.

Also, ropes will slip and stick along pulley wheels just like belts. One solution to the problems associated with rope is to use chain. Chain is pliable like rope, and is able to transfer force along many directions, but the chain links are inflexible in tension, so that the chain will not stretch. Chains may also be made to fit on gears so that slipping is avoided.

Screw

The screw is basically an inclined plane (see Figure 1.1.7) wrapped around a cylinder. In an inclined plane, a linear force in the horizontal plane is converted to a vertical "lifting" force. With a screw, a rotary force in the horizontal plane is converted to a vertical "lifting" force. When a wood screw is turned, the threads of the screw push up on the wood. A reaction force from the wood pushes back down on the screw threads and in this way the screw moves down even though the force of turning the screw is in the horizontal plane. Screws are known for high friction, which is why they are used to hold things together. A worm gear is sometimes used in machines, it also has high friction that can waste considerable power.

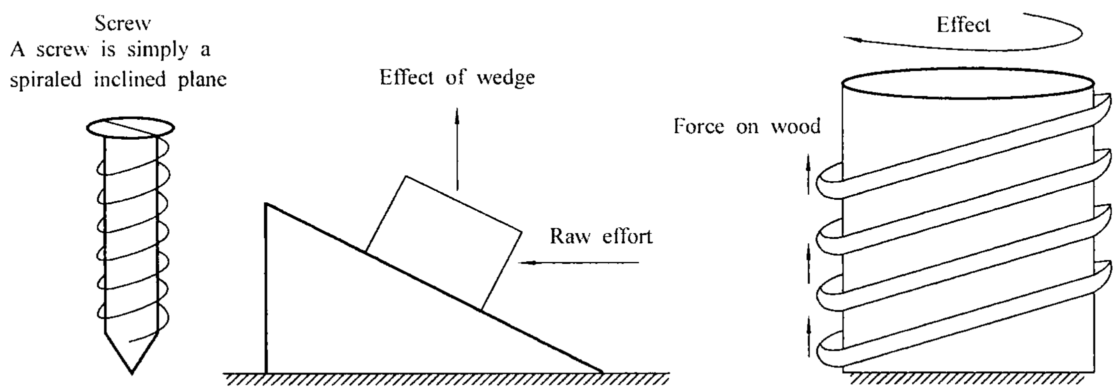


Figure 1.1.7 The screw

Key Words & Expressions

element ['elimənt] *n.* 元素，元件
lever ['li:və, 'levə] *n.* 杆，杠杆
gear [giə] *n.* 齿轮、传动装置
cam [kæm] *n.* 凸轮
crank [kræŋk] *n.* [机]曲柄
spring [spriŋ] *n.* 弹簧
axle ['æksl] *n.* 轮轴、车轴
pulley ['puli] *n.* 滑车、滑轮、皮带轮
wedge [wedʒ] *n.* 楔
perpendicularly [ˌpə:pən'dikjuləli] *ad.* 垂直地，正交地 *n.* 垂线
blade [bleid] *n.* 刀刃，刀片
zipper ['zipə] *n.* 拉链
fulcrum ['fʌlkrəm] *n.* 杠杆的支点、支点
pivot ['pivət] *n.* 枢轴、支点、(讨论的)中心点、重点
balance ['bæləns] *n.* 平衡
crow bar 撬杠
slipping ['slipiŋ] *a.* 渐渐松弛的,渐渐不行了的
slack [slæk] *n.* 松弛，静止
wheelbarrow ['wi:lbærəu] *n.* 独轮手推车、手推车
nutcracker ['nʌtkrækə(r)] *n.* 胡桃钳
tweezers ['twi:zəz] *n.* 镊子，小钳
circumference [sə'kʌmfərəns] *n.* 圆周，周围
torque [tɔ:k] *n.* 扭矩、转矩
screwdriver ['skru:draivə] *n.* 螺丝起子
wrench [rentʃ] *n.* 扳钳、扳手
faucet ['fɔ:sit] *n.* 龙头、旋塞,(连接管子的)插口
tradeoff ['treid.ɔ:f] *n.* (公平)交易、折中，权衡
rigid ['ridʒid] *a.* 刚硬的、刚性的、严格的
wound-up *a.* 松弛的
pliable ['plaiəbl] *a.* 柔软的、圆滑的、柔韧的

Notes

[1] They are able to abruptly change directions in three-dimensions without consequence, except, of course, additional friction. 拉绳的作用力方向可以在三维空间内任意改变，当然，摩擦力除外。

[2] Ropes can be wrapped around a motor' s shaft and either wound up or let out as the motor turns. 拉绳可以环绕在电机的输出轴上，当电机转动时，拉绳被卷起或者被展开。

Comprehension Exercises

Write a T in front of a statement if it is true or write an F if it is false according to the text.

(1) The function of an inclined plane is to save energy and increase efficiency.

(2) A lever consists of the load, the effort and the fulcrum.

(3) Both effort and load are means with which people can manipulate the lever.

(4) The fulcrum is always situated between the effecting points of both effort and load on a lever.

(5) The wheel and axle can convert a powerful force and movement to a greater movement, but less force.

(6) The disadvantages of pulleys are slipping and stretching of the rope.

(7) A pulley uses rigid objects to transfer force.

(8) Both a screw and an inclined plane work under the same principle.

1.2 Tolerances and Fits

Machine parts are manufactured so they are interchangeable. In other words, each part of a machine or mechanism is made to a certain size and shape so it will fit into any other machine or mechanism of the same type. To make the part interchangeable, each individual part must be made to a size that will fit the mating part in the correct way. It is not only impossible, but also impractical to make many parts to an exact size. This is because machines are not perfect, and the tools become worn. A slight variation from the exact size is always allowed. The amount of this variation depends on the kind of part being manufactured. For example, a part might be made 1.5 inches in diameter with a variation allowed 0.001 inch, above and below this size. Therefore, the part could be 1.499 to 1.501 inches and still be the correct size. These are known as the limits. The difference between upper and lower limits is called the tolerance.

Quality and accuracy are major considerations in making machine parts. Interchangeable parts require suitable accuracy to fit together. Both of dimensions of parts given on engineering drawings and manufactured dimensions should be exactly the same and fit properly. [1] Unfortunately, it is impossible and unnecessary to make things to an exact shape or dimension. Most dimensions have a varying degree of accuracy and means of specifying acceptable limitations in dimensional variance that an object will tolerate and still have its function. [2]

Size, Tolerance and Allowance

Size usually includes nominal, basic, design, and actual size, etc.

Nominal size generally identifies the overall size of an object without any error.

Basic size is the size from which the limits of size are derived by the application of allowances and tolerances.

Design size is the size from which you derive the limits of size by the use of tolerances.

Actual size is the manufactured size of the object that may be larger or smaller than the nominal size. See Figure 1.2.1.

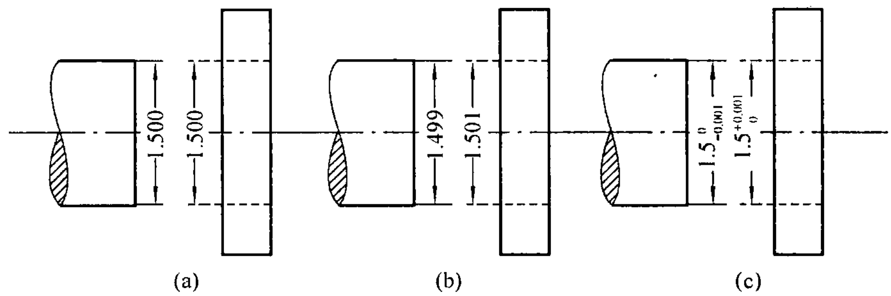


Figure 1.2.1 Indicating object size

(a) Basic size; (b) Actual size; (c) Design size

Tolerance is the total permissible variation in the size of a part or the total amount of a specific dimension that may vary from a minimum limit to a maximum limit.

Unilateral tolerances indicate variation from the basic size in one direction.

Bilateral tolerances indicate variation from the basic size in both directions. See Figure 1.2.2.

Allowance is the intentional difference between the maximum material limits of mating parts (a hole and a shaft) . This is a minimum clearance (positive allowance) or maximum interference (negative allowance) between mating parts.

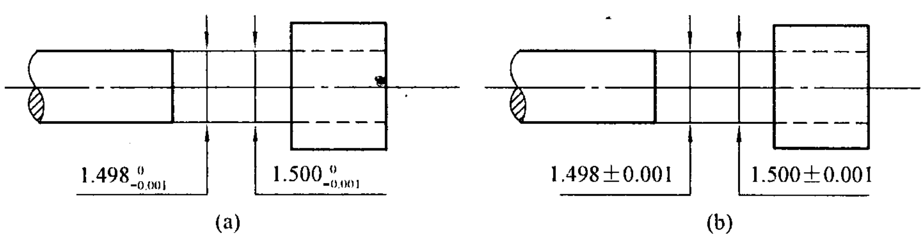


Figure 1.2.2 Indicating tolerance

(a) Unilateral tolerance; (b) Bilateral tolerance

Fit

Fit is the general range of tightness resulting from the application of a specific combination of allowance and tolerances in the design of mating parts. How mating parts or assemblies fit together with component parts could be referred to as different fits: clearance fit, interference fit, or transition fit.

Clearance fit is a fit that always enables a clearance between the hole and shaft in the coupling. The lower limit size of the hole is greater or at least equal to the upper limit size of the shaft.

Transition fit is a fit where (depending on the actual sizes of the hole and shaft) both clearance and interference may occur in the coupling. Tolerance zones of the hole and shaft partly or completely interfere.

Interference fit is a fit always ensuring some interference between the hole and shaft in the coupling. The upper limit size of the hole is smaller or at least equal to the lower limit size of the shaft.

Figure 1.2.3 illustrates the difference among three fits.

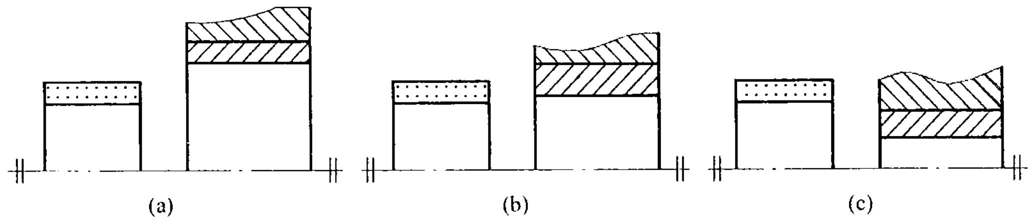


Figure 1.2.3 The difference among clearance fit, transition fit, and interference fit
(a) Clearance fit; (b) Transition fit; (c) Interference fit

Basic hole system

The basic hole system is a system of fits in which the design of the hole's lower limit is the basic size and has a unilateral tolerance. When specifying the tolerances for a hole and cylinder and determining their dimensions, you should begin calculating by assuming either the minimum (smallest) hole or the maximum (largest) shaft size if they are to fit together well. Figure 1.2.4 illustrates the basic hole system.

In the illustration, the minimum hole size is the basic size. To calculate the maximum diameter of the shaft, assume an allowance of 0.003 inch and subtract that from the basic hole size. [3]

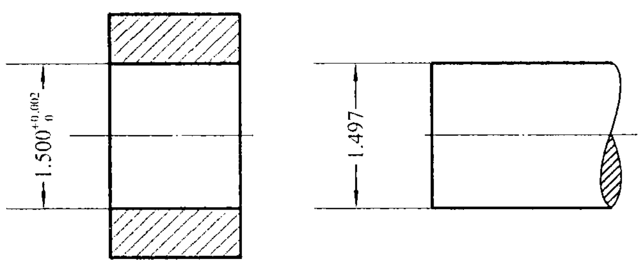


Figure 1.2.4 The basic hole system (tolerance=0.002)

If selecting a tolerance of 0.002 inch, apply the tolerance to both the hole and the shaft. This gives a maximum hole (1.502 inches) and minimum shaft (1.495 inches). The minimum clearance fit is the difference between the smallest hole (1.500 inches) and the largest shaft (1.497 inches) that is 0.003 inch. The maximum clearance fit is the difference between the largest hole (1.502 inches) and the smallest shaft (1.495 inches) that is 0.007 inch.

Determine the maximum shaft size of an interference fit by adding the allowance (0.003 inch) to the basic hole size (1.500 inches), which is 1.503 inches.

Basic shaft system

It will be the same as the basic hole system. The basic shaft system still is a system of fits in which the design size of the shaft's upper limit is the basic size and also has a unilateral tolerance. Figure 1.2.5 illustrates the basic shaft system.

From the illustration, we clearly know that the maximum shaft size is the basic size. To obtain the minimum hole diameter, assume an allowance of 0.003 inch and add that to the basic shaft size. If selecting a tolerance of 0.002 inch, add the tolerance to the hole and shaft to obtain the maximum hole (1.505 inches) and the minimum shaft (1.498 inches). The clearance fit is the difference between the smallest hole (1.503 inches) and the largest shaft (1.500 inches) that is 0.003 inch. The maximum clearance fit is the difference between the largest hole (1.505 inches) and the smallest shaft (1.498

inches) that is 0.007 inches. Determine the minimum hole size of an interference fit by subtracting the allowance (0.003 inch) from the basic shaft size (1.500 inches) that is 1.497 inches.

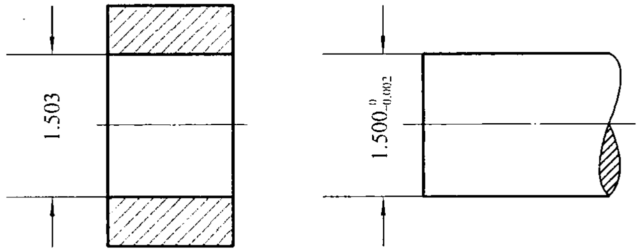


Figure 1.2.5　The basic shaft system (tolerance=0.002)

Key Words & Expressions

tolerance ['tɔlərəns]　*n.* 公差、容忍　*vt.* 给(机器部件等)规定公差

nominal ['nɔminl]　*a.* 名义上的

unilateral ['ju:nilætərəl]　*a.* 单方面、单边的、片面的

bilateral [bai'lætərəl]　*a.* 有两面的、双边的

clearance ['kliərəns]　*n.* 间隙、游隙

decimal ['desiməl]　*a.* 十进的、小数的　*n.* 小数、十进制

equivalent [i'kwivələnt]　*a.* 相等的、相当的　*n.* 等价物、相等物

arbitrarily ['ɑ:bitrərili]　*ad.* 武断地，任意地、专横地

Notes

[1] Both of dimensions of parts given on engineering drawings and manufactured dimensions should be exactly the same and fit properly.　加工出来的零件尺寸应当与设计图上所给出的零件尺寸非常接近，并且能够正确配合。

[2] Most dimensions have a varying degree of accuracy and means of specifying acceptable limitations in dimensional variance that an object will tolerate and still have its function.　为保证零件发挥其正常功能，其大多数尺寸都有不同的精度要求，并且对尺寸变化范围的标注也是各不相同的。

[3] To calculate the maximum diameter of the shaft, assume an allowance of 0.003 inch and subtract that from the basic hole size.　假设公差是 0.003 英寸，那么轴的最大直径应当是孔的基本尺寸减去 0.003 英寸。

Comprehension Exercises

Answer the following questions briefly.

(1) What are tolerance and fit?

(2) What is the difference between basic size and nominal size?

(3) Please give an example to illustrating the concept of limits.

(4) How do you determine the minimum dimension of a hole and the maximum dimension of a shaft in a basic hole system?

(5) How do you determine the minimum dimension of a hole and the maximum dimension of a shaft in a basic shaft system?

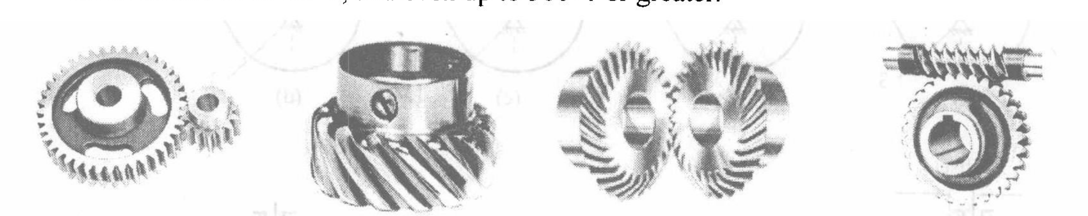
1.3 Gears and Cams

Gears

Gears are machine elements that transmit motion by means of successively engaging teeth. Gears can transmit motion from one rotating shaft to another, or to a rack that translates. Gears can change the rate of rotation of a machinery shaft and also can change the direction of the axis of rotation and can change rotary motion to linear motion when mating with racks.

There are a number of different standard gear types. Examples include spur gears, change gears, cluster gears, helical gears, herringbone gears, straight bevel or spiral bevel gears, worm gears, and so on and so forth.

- Spur gears are straight-toothed and among the most common type of gears. They have straight teeth, and are mounted on parallel shafts. Sometimes, many spur gears are used at once to create very large gear reductions.
- Change gears resemble spur gears with a keyway that mates with a hub for rapid changing.[1]
- Cluster gears are spur gears with an integral hub whose end can accept others, hubless gears.[2]
- The teeth on helical gears are cut at an angle to the face of the gear. When two teeth on a helical gear system engage, the contact starts at one end of the tooth and gradually spreads as the gears rotate, until the two teeth are in full engagement.
- In herringbone gears, each tooth comprises of two opposing helices. They transmit power and motion between parallel axes and may or may not have a center groove.
- Straight bevel gears are straight-toothed and transmit power and motion between intersecting shafts.
- Spiral bevel gears are the bevel counterpart of the helical gears and can give a much smoother tooth action than straight bevel gears, but they are difficult to manufacture.
- Worm gears are used when large gear reductions are needed. It is common for worm gears to have reductions of 20 : 1, and even up to 300 : 1 or greater.



(a) (b) (c) (d)

Figure 1.3.1 Classification of gears

(a) spur gears; (b) helical gears; (c) spiral bevel gears; (d) worm gears

Gears differ in terms of related components, tooth type, and materials of construction. Anti-backlash gears have a mechanical assist such as a spring to take up any play between meshing gear teeth, thus avoiding backlash when gears direction changes. Ground teeth provide smoother, higher-precision tooth form. Materials for gears may include aluminum, brass, bronze, cast iron, carbon or alloy steel, hardened steel, stainless steel, and a wide variety of plastic materials. A rack is a straight component with gear teeth; typically straight-toothed that mate with pinion (spur gear). Pinions usually are drive gears that drive racks or larger gears. They can be physically similar to spur gears, and occasionally helical gears. So the "pinion" designation is primarily used to indicate that the device is the driving gear in a rack and pinion configuration.

Cams

A cam is a convenient device for transforming one motion into another. The transformation of one of the simple motions, such as rotation, into any other motions is often conveniently accomplished by means of a cam mechanism. A cam mechanism usually consists of two moving elements, the cam and the follower. Cam devices are versatile and almost any arbitrarily-specified motion can be obtained. In some instances, they offer the simplest and the most compact way to transform motions.

A cam may be defined as a machine element having a curved outline or a curved groove, which, by its oscillation or rotation motion, gives a predetermined specified motion to another element called the follower. The cam has a very important function in the operation of many classes of machines, especially those of the automatic types, such as printing presses, shoe machinery, textile machinery, gear-cutting machines, and screw machines. In any class of machinery in which automatic control and accurate timing are paramount, the cam is a kind of indispensable parts of mechanism. The possible applications of cams are unlimited, and their shapes occur in a great variety.

We can classify cam mechanisms by the modes of input/output motion, the configuration and arrangement of the follower, and the shape of the cam. We can also classify cams by the different types of motion events of the follower and by means of a great variety of the motion characteristics of the cam profile. For example, cam mechanisms can be classified into four categories by the modes of input/output motions (see Figure 1.3.2).

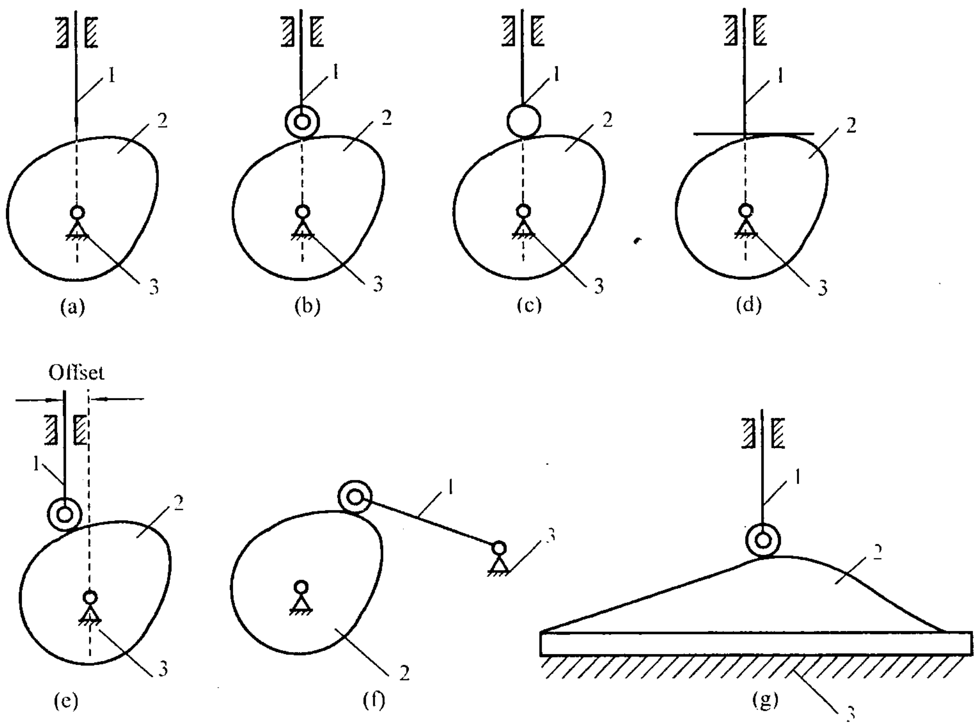


Figure 1.3.2 Classification of cam mechanisms

1. follower; 2. cam; 3. frame

- Rotating cam-translating follower (Figure 1.3.2 (a), (b), (c), (d), (e)). In this kind of cam-follower system, the follower can be classified into four types: central opposite follower (Figure 1.3.2(a)), follower with wheel (Figure 1.3.2(b)、(c)), flat bottom follower (Figure 1.3.2(d)) and offset follower (Figure 1.3.2(e)).
- Rotating follower (Figure 1.3.2 (f)). The follower arm swings or oscillates in a circular arc with respect to the follower pivot.
- Translating cam-translating follower (Figure 1.3.2 (g)).
- Stationary cam-rotating follower: the follower system revolves with respect to the center line of the vertical shaft.

In a cam mechanism, when the cam turns through one motion cycle, the follower executes a series of events consisting of rises, dwells and returns. Rise is the motion of the follower away from the cam center, dwell is the motion during which the follower is at rest, and return is the motion of the follower toward the cam center.

Key Words & Expressions

hubless ['hʌblis] *a.* 无轮毂的
keyway ['ki:ˌwei] *n.* 键沟
hub [hʌb] *n.* 毂
right-angle *n.* 直角
herringbone ['heriŋbəun] *n.* 交叉缝式，人字形
comprise [kəm'praiz] *v.* 包含，由……组成
groove [gru:v] *n.* 凹槽，坡口
mesh [meʃ] *n.* [机]啮合 *vt.* 啮合，编织 *vi.* 落网、相啮合
backlash ['bæklæʃ] *n.* 反冲
play *n.* [机]游隙、窜动
brass [brɑ:s] *n.* 黄铜、黄铜制品
bronze [brɔnz] *n.* 青铜(铜与锡合金)，铜像
rack *n.* 齿条
pinion ['pinjən] *n.* 小齿轮
follower *n.* 从动件
oscillation [ˌɔsi'leiʃən] *n.* 摆动、振动
paramount ['pærəmaunt] *a.* 极为重要的
indispensable [ˌindis'pensəbl] *n.* 不可缺少之物 *a.* 不可缺少的、绝对必要的
translate *v.* 转换；迁移，平移
revolve [ri'vɔlv] *v.* (使)旋转，考虑，循环出现

Notes

[1] Change gears resemble spur gears with a keyway that mates with a hub for rapid changing. 和直齿圆柱齿轮类似，变速齿轮通过键槽与轮毂的配合来实现快速更换（变速）。

[2] Cluster gears are spur gears with an integral hub whose end can accept others, hubless gears. 齿轮组是一些带有完整的轮毂的直齿圆柱齿轮，它们的端部能够与其他无毂齿轮形成连接。

Comprehension Exercises

Match the items in Column A with their Chinese equivalents in Column B.

(1)

A	B
spur gear	(a) 齿轮齿条
helical gear	(b) 伞齿轮
change gears	(c) 无齿(侧)隙齿轮
cluster gear	(d) 斜齿轮