21世纪全国高职高专机电系列实用规划教材

21st CENTURY
实用规划教材

机械专业英语图解教程

主 编 朱派龙

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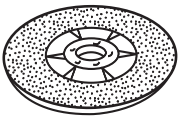
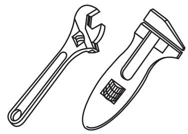
Part 1 Commonly Used Tools and Parts

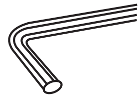
常用工具、机械零部件和机构



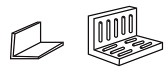
abrasive disc
磨盘、砂轮



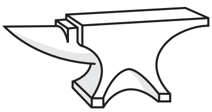
adjustable spanner
可调扳手



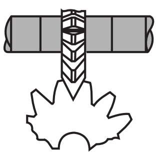
Allen key
内六角扳手



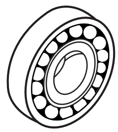
angle iron (plate)
角铁



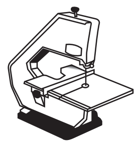
anivil
铁砧



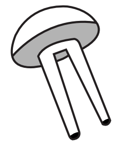
arbor
刀杆、刀柄



ball bearing
滚珠轴承

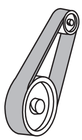


bandsaw
带锯

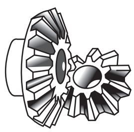


bifurcated rivet
开口铆钉

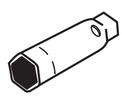
beam compass
长臂划规



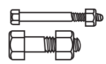
belt
皮带



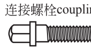
bevel gear
伞齿轮



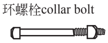
box spanner
套筒扳手



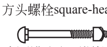
连接螺栓coupling bolt



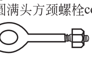
环螺栓collar bolt



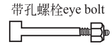
方头螺栓square-head bolt



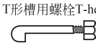
半圆满头方颈螺栓coach bolt



带孔螺栓eye bolt

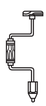


T形槽用螺栓T-head bolt



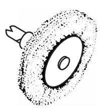
钩头螺栓hook bolt

bolt
螺栓



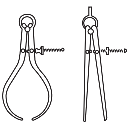
brace
弓摇钻

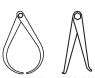
breast drill
胸压手摇钻



buffing wheel
抛光轮

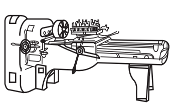
bush
衬套





外卡钳 内卡钳
external callipers internal callipers

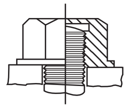
callipers
卡钳



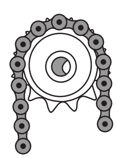
capstan/turret lathe
六角、转塔车床

cam
凸轮

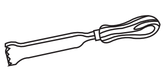
camshaft
凸轮轴



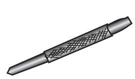
cap nut
外套螺母



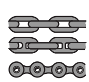
chain wheel
链轮



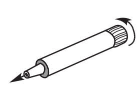
chaser
螺纹梳刀



centre punch
中心冲

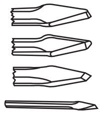
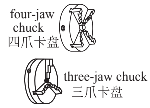
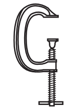
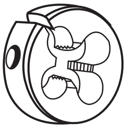
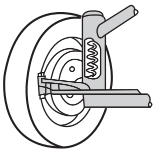
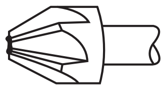
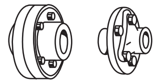
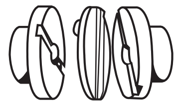
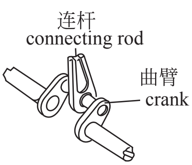
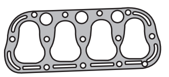
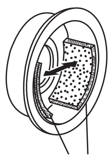
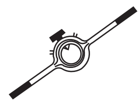
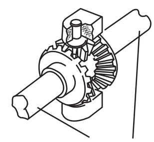
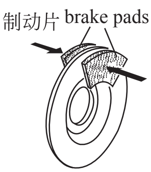
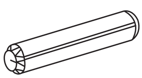
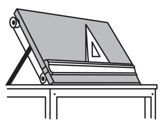
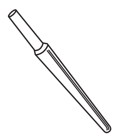
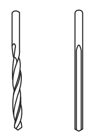
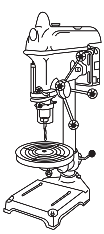
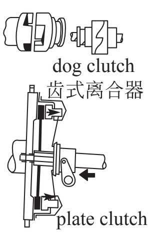
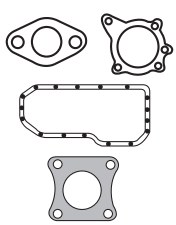
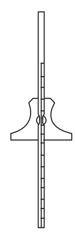
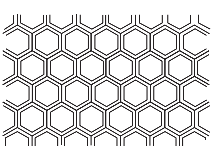
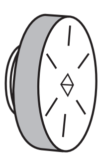
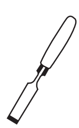
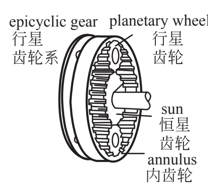


chain
链条



caulking gun
填缝枪

（续）

 cheese-head screw 圆柱头螺钉	 chisel 凿子	 cotter pin 销钉	 chuck 卡盘	 G-clamp 弓形钩、夹钳
 die 板牙、拉丝模、冲模	 coil spring 螺旋弹簧	 countersink bit 锪钻、沉头钻	 法兰式联轴节 flange coupling coupling 联轴器	 Oldham coupling 十字联轴器
 crank shaft 曲轴	 cylinder-head gasket 气缸密封垫	 drum brake 鼓形制动器	 diestock 板牙、扳手	 differential gear 差动齿轮
 disc brake 盘式制动器	 dowel 固定销，榫钉	 drawing board 绘图板	 drift 锥形铰刀	 drill 钻头
 drilling machine 钻床	 clutch 离合器	 gasket 垫片	 gauge 量仪、量具	 depth gauge 深(高)度尺
 expanded metal 网眼钢板	 faceplate 花盘	 firmer chisel 榫孔凿	 epicyclic gear 行星齿轮系	 end mill 端面铣削

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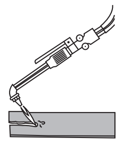
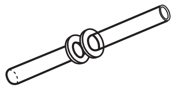
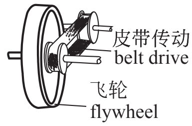
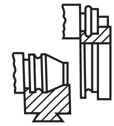
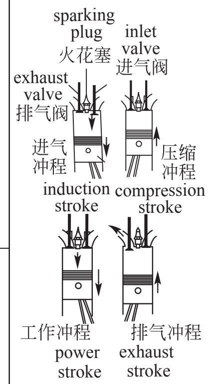

flame cutting
火焰切割

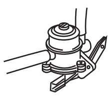

flange
法兰

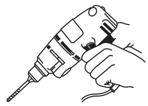


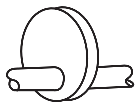

forming tool
成形刀具

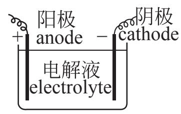


four-stroke engine
四冲程发动机

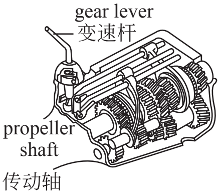

fuel pump
机油泵


electric drill
（手）电钻


eccentric wheel
偏心轮（盘）



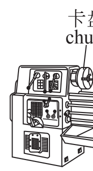
electrolysis
电解



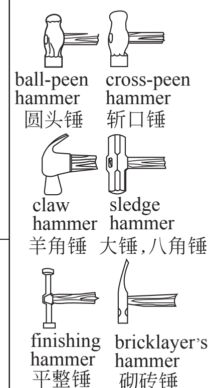
gear box
齿轮箱


hairspring
游丝


half-round file
半圆锉

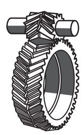


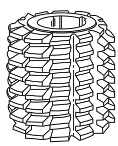
headstock
主轴箱

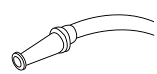


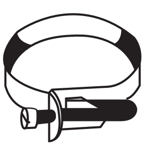
hammer
锤子

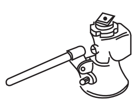
hook spanner
钩形扳手

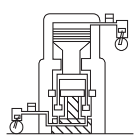

Herring-bone gear
人字齿

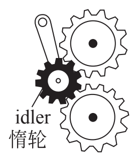

hob
齿轮滚刀、滚齿刀


hose
软管、胶管

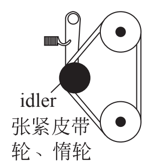

hose clip
软管夹子


hydraulic jack
液压千斤顶

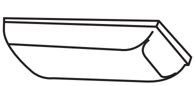

水压机
hydraulic press
hydraulic ram
液压夯锤

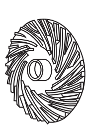


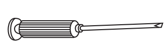
idler gear
惰轮

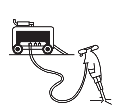


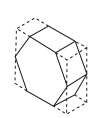
idler pulley
张紧带轮、惰轮


ingot
金属锭


impeller
叶轮

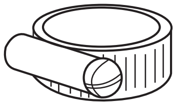

instrument screwdriver
手捻、仪表起子

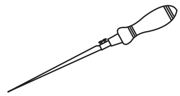

pneumatic drill
风钻

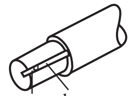

isometric projection
等角投影

（续）

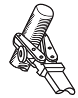
jack
千斤顶

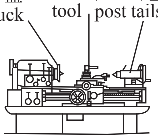

Jubilee clip
箍圈


keyhole saw
鸡尾锯、狭手锯

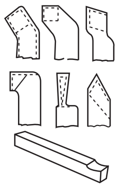


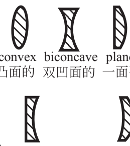
keyway
键槽


knurling
滚花



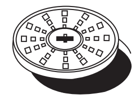
lathe
车床

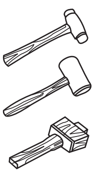

lathe tool
车刀

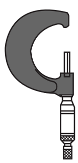


lens
透镜

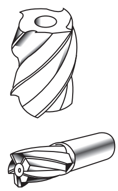

magnifying glass
放大镜

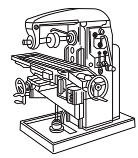

manhole
人孔

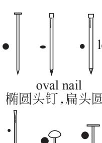

mallet
木槌


micrometer screw gauge
千分尺

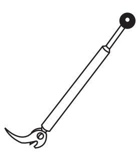

microscope
显微镜

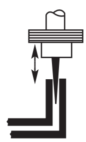

milling tools
铣刀


milling machine
铣床



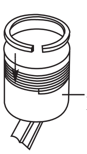
nail
钉子


nail puller
起钉器

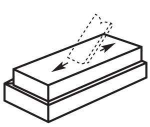

needle valve
针阀

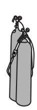
nut
螺母

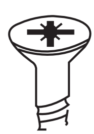

oil can
油壶

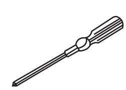


oil ring
油环

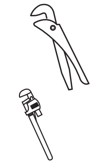

oilstone
油石


oxyacetylene welding
氧乙炔焊接

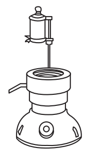

Phillips screw
十字槽螺钉


Phillips screwdriver
十字形改锥

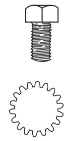
（续）



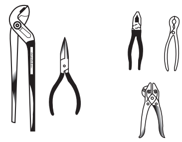
pipe wrench
管扳手、管子钳



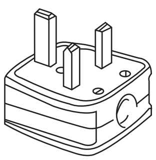
polishing machine
抛光机



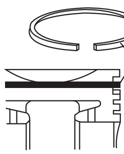
pitch
螺距、节距



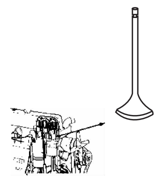
pliers
钳子、夹钳



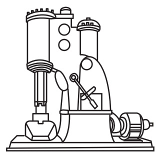
plug
插头



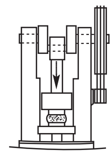
piston ring
活塞环



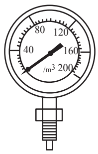
poppet valve
气门、提升阀



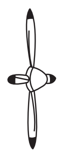
power hammer
气锤



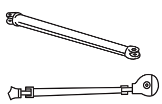
press
冲床 、压力机



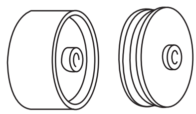
pressure gauge
压力表



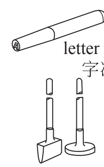
propeller
螺旋桨



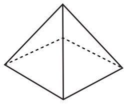
propeller shaft
传动轴



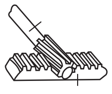
pulley
皮带轮



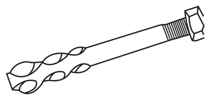
punch
冲头、戳子



pyramid
棱锥体

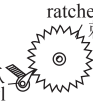


rack and pinion
齿轮齿条副

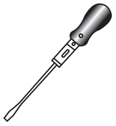


rag bolt
地脚螺栓 、棘螺栓

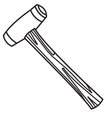
rasp
粗锉



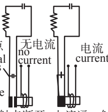
ratchet
棘轮机构



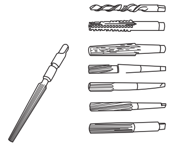
ratchet screwdriver
棘轮式改锥(旋具)



rawhide hammer
皮锤

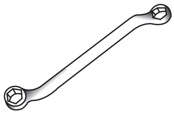
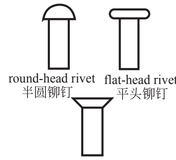
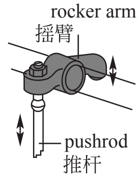
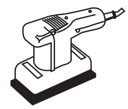
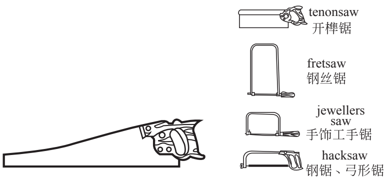
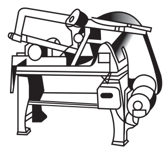
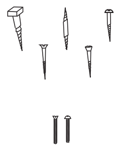
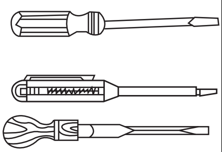
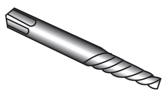
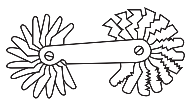
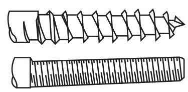
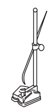
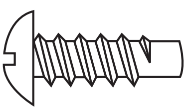
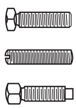
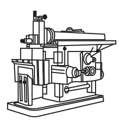
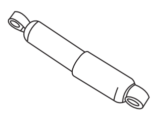
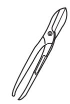
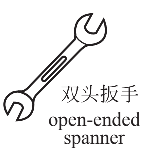
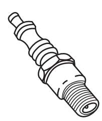
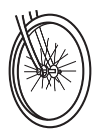
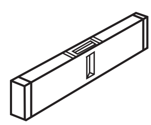
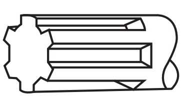
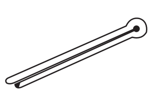
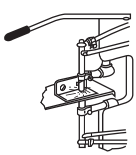
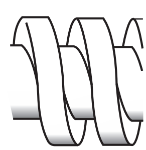
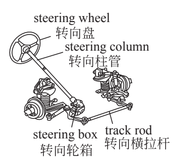


relay
继电器



reamer
铰刀

（续）

 right-angled screwdriver 直角改锥(旋具)	 ring spanner 梅花板手、闭口扳手、 眼睛扳手	 rivet 铆钉	 rocker arm 摇臂	 sander 打磨机、磨光机
 panel saw 扳锯、手扳居		 sawing machine 锯床	 screw 螺钉	 scraper 刮刀、铲运机
 screwdriver 改锥、螺丝刀	 screw extractor 起螺丝器	 screw pitch gauge 螺纹(距)规、螺纹 样板规	 screw thread 螺纹	 scribing block 划线盘
 self-tapping screw 自攻螺钉	 set screw 紧固螺钉	 shaping machine 牛头刨床	 shock absorber 减震器、缓冲器	 snips 白铁剪
 socket spanner 套筒扳手	 spanner 扳手	 sparking plug 火花塞	 spindle 心轴、主轴	 spirit level 水平仪(尺)
 splined shaft 花键轴	 split pin 开口销	 spot welding 点焊	 square thread 方螺纹	 steering gear 转向齿轮

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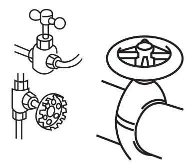
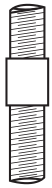
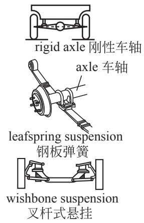
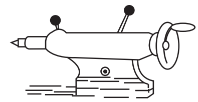
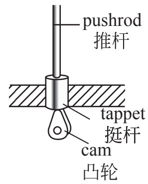

stopcock
旋塞阀


stud
双头螺柱

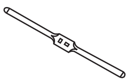


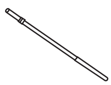
suspension system
悬挂(架)系统

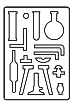

tailstock
尾座、顶针座

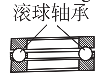


tappet
挺杆

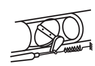

tap wrench
丝锥扳手


telescopic shaft
套筒管、伸缩轴


template
样板

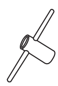


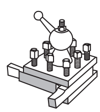
thrust bearing
止推轴承

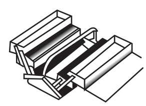

throttle valve
油门、节流阀


timing chain
正时链

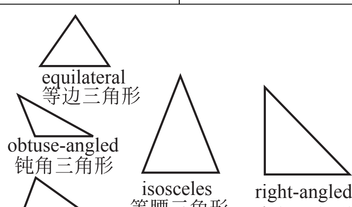

toggle joint
肘节


tommy bar
套筒扳手旋转手把

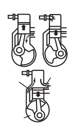

tool post
刀架

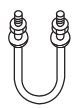

tool box
工具箱

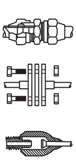

torque wrench
(spanner)扭力扳手

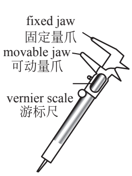


triangle 三角形

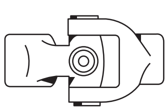

two-stoke engine
二冲程发动机


U-bolt
U形螺栓

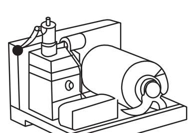

union
活(联)接头

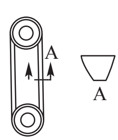


vernier calliper
gauge 游标卡尺


Hooke's joint
十字架式万向节

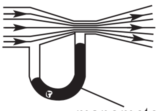
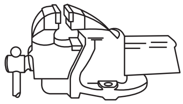
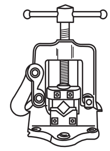
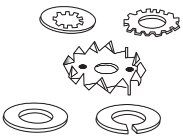
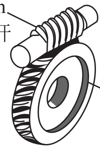
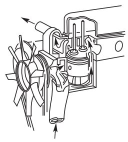
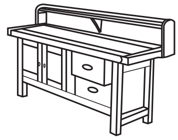
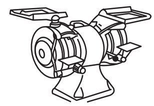
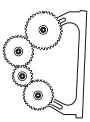
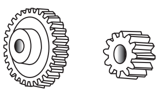
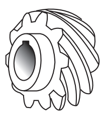
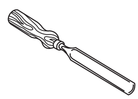
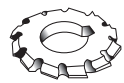
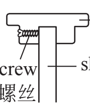
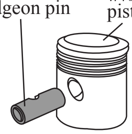
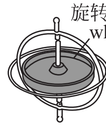
universal joint
万向节


vacuum pump
真空泵

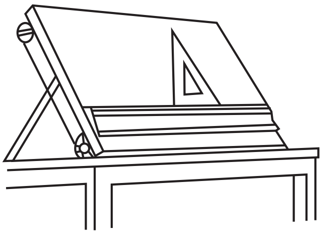


vee belt(V-belt)
三角皮带

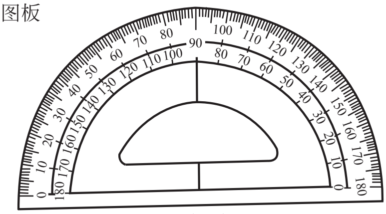
（续）

 Venturi tube 文丘里管、缩喉管	 vice 钳工台虎钳	 try square 直角尺、矩尺、方角规	 pipe vice 管子台虎钳	 V-thread 三角螺纹、 V形螺纹
 washer 垫片（圈）	 worm gear 蜗轮（蜗杆）副	 water-cooled engine 水冷发动机	 workbench 工作台	 grinding machine 砂轮机、磨床
 gear train 齿轮系	 spur gear 直齿轮、正齿轮	 spiral(helical) gear 螺旋齿轮	 gouge 弧口凿、半圆凿	 gear cutter 齿轮铣刀
 grinding wheel 磨轮、砂轮	 grub screw 平头螺钉	 gudgeon pin 活塞销	 gyroscope 陀螺仪	 tap 丝锥、龙头

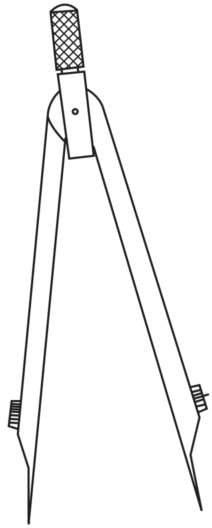
Drawing Instruments 绘图仪器



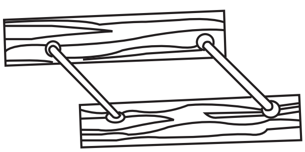
drawing board
绘图板



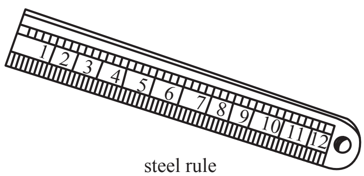
protractor
量角器,半圆规



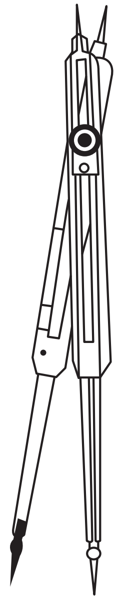
dividers
分规



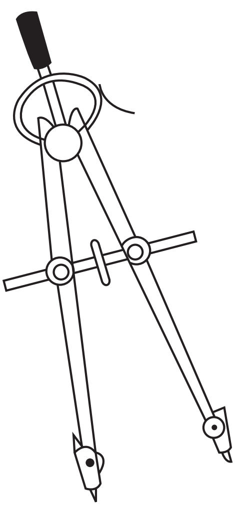
parallels
平行仪



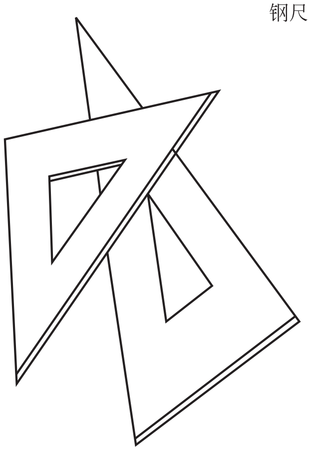
steel rule
钢尺



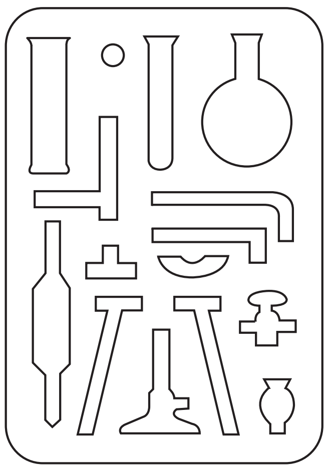
proportional dividers
比例规



compass
圆规

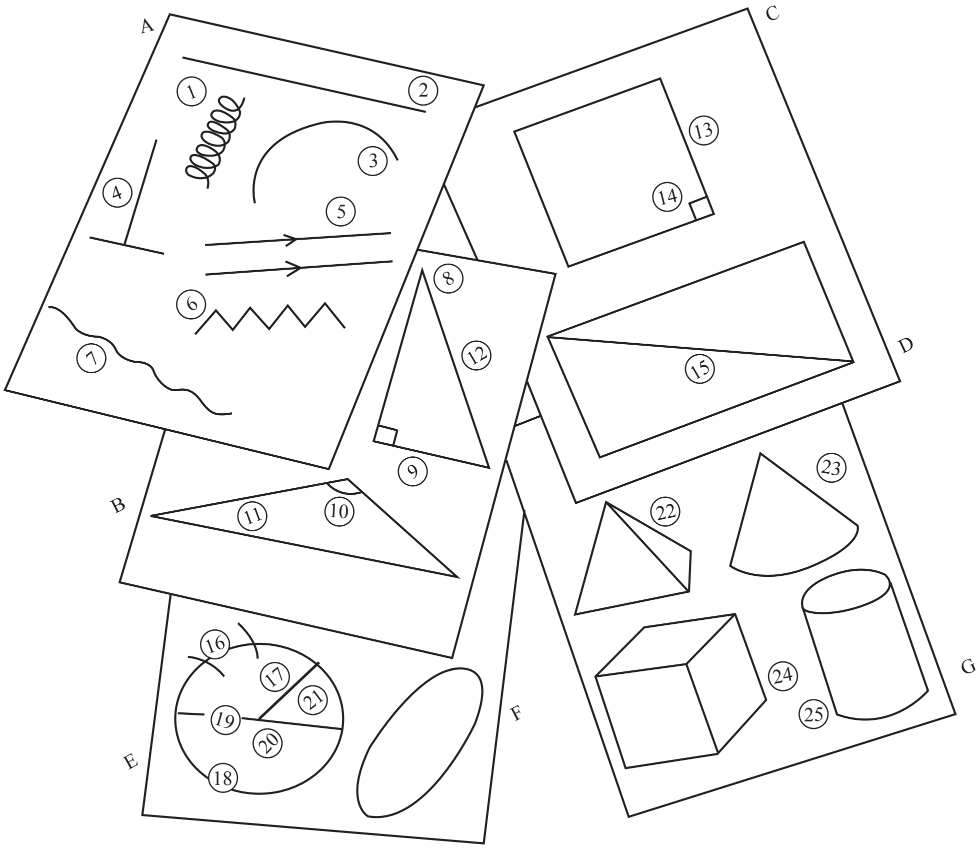


set squares
三角板



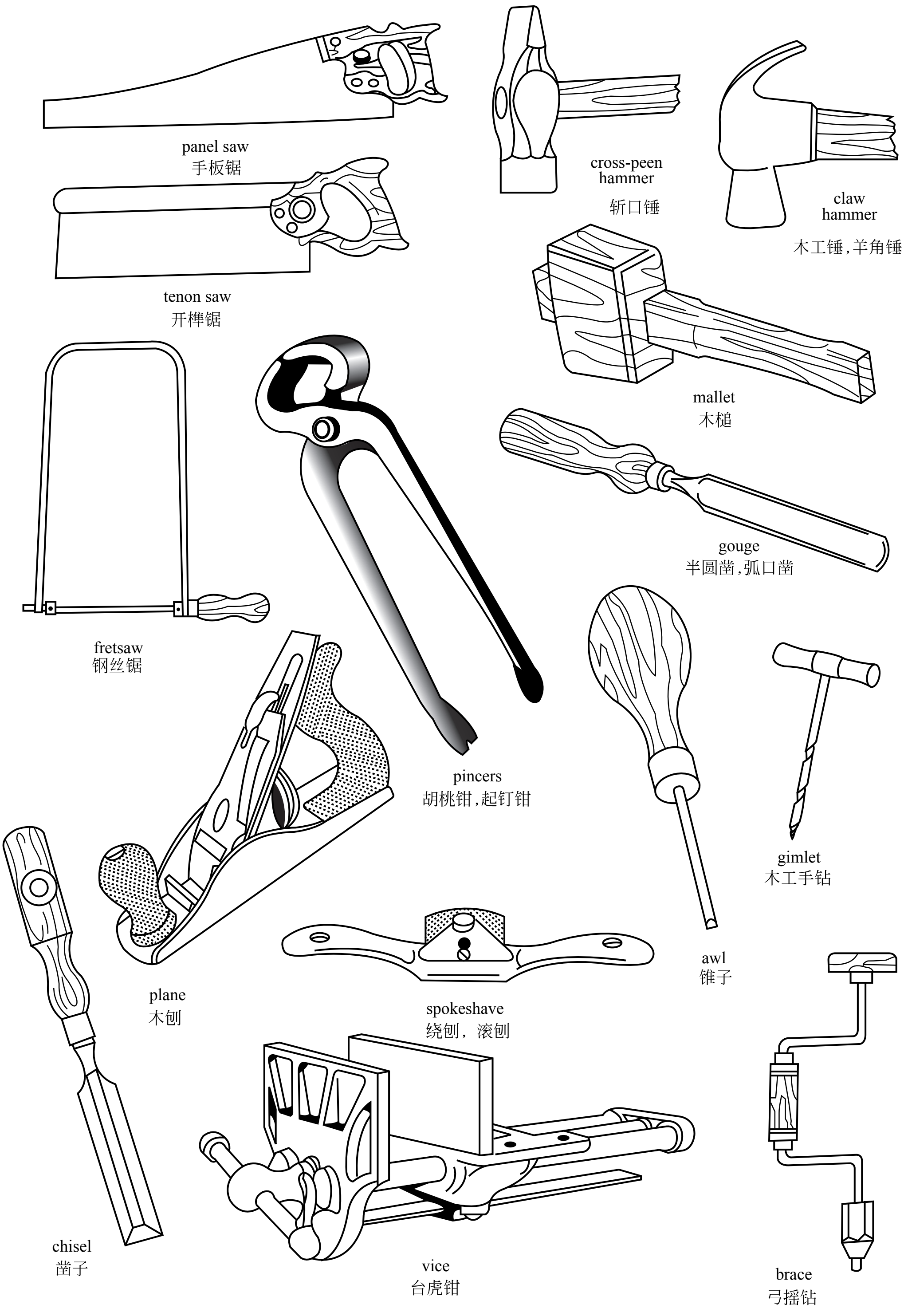
template
样板

Lines and Shapes 线条和图形

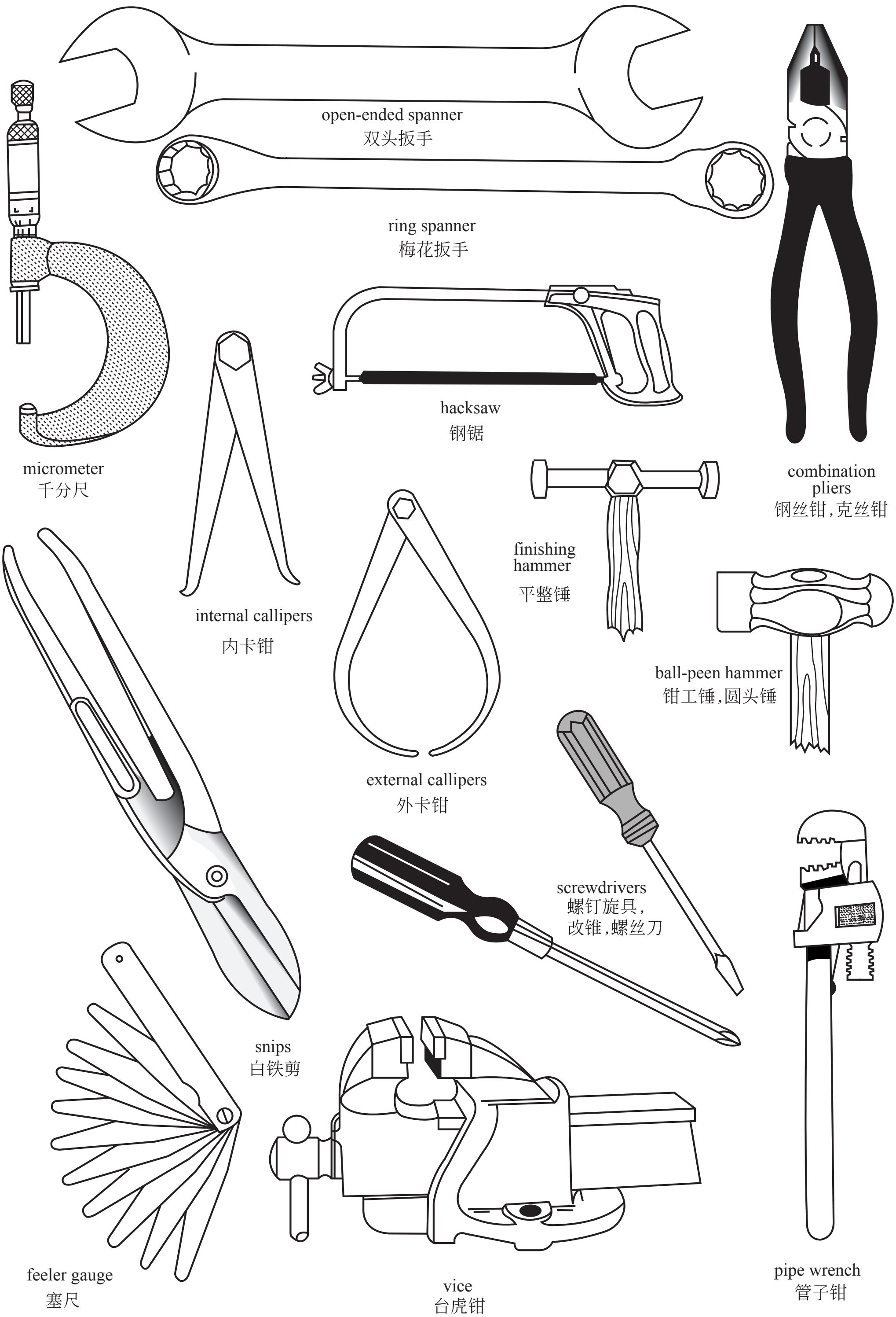


A. lines 线条
1 – spiral 螺线，蜷线
2 – straight line 直线
3 – curve 曲线
4 – perpendicular line 垂(直)线
5 – parallel lines 平行线
6 – zigzag 折线
7 – wavy line 波线
B. triangles 三角形
8 – apex 顶点
9 – base 底边
10 – obtuse angle 钝角
11 – acute angle 锐角
12 – hypotenuse 弦，斜边
C. square 正方形
13 – side 边
14 – right angle 直角
D. rectangle/oblong 矩形，长方形
15 – diagonal 对角线
E. circle 圆
16 – arc 弧形
17 – radius 半径
18 – circumference 圆周
19 – diameter 直径
20 – center 圆心
21 – section 扇形
F. oval/ellipse 椭圆
G. solid figures 立体图形
22 – pyramid 棱锥(体)，角锥(体)
23 – cone 圆锥，锥体，锥形
24 – cube 立方体
25 – cylinder 圆柱体

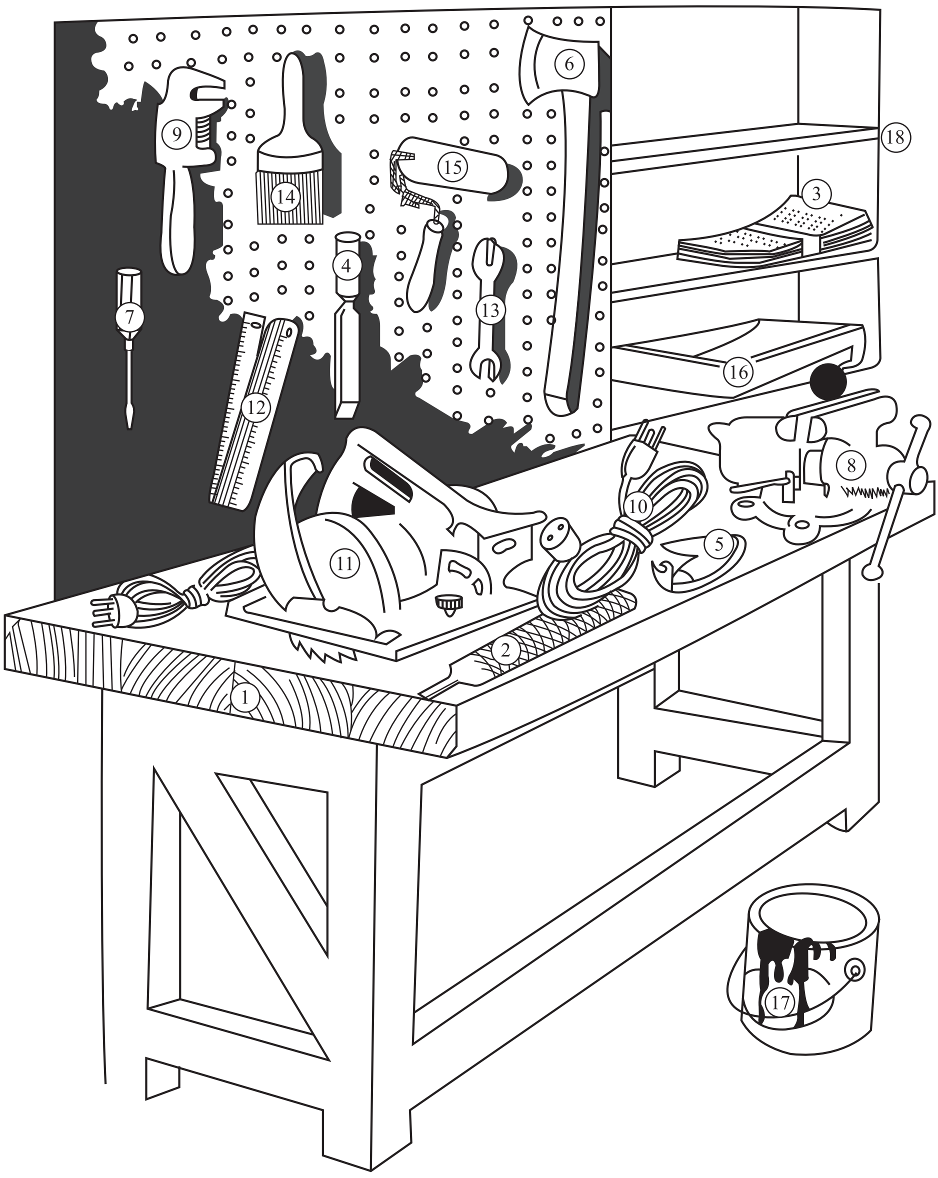
Tools for Woodwork 木工工具



Tools for Metalwork 钳工工具

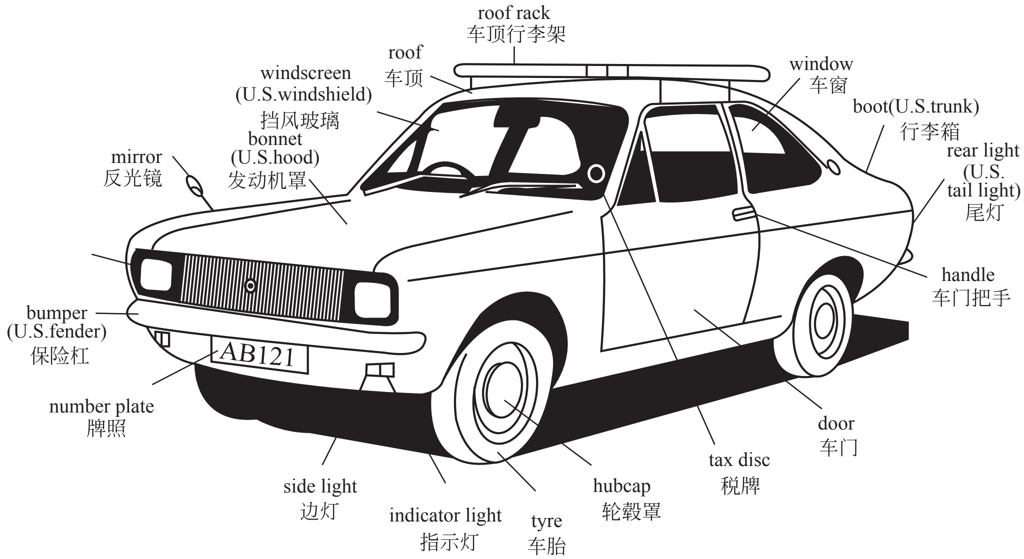


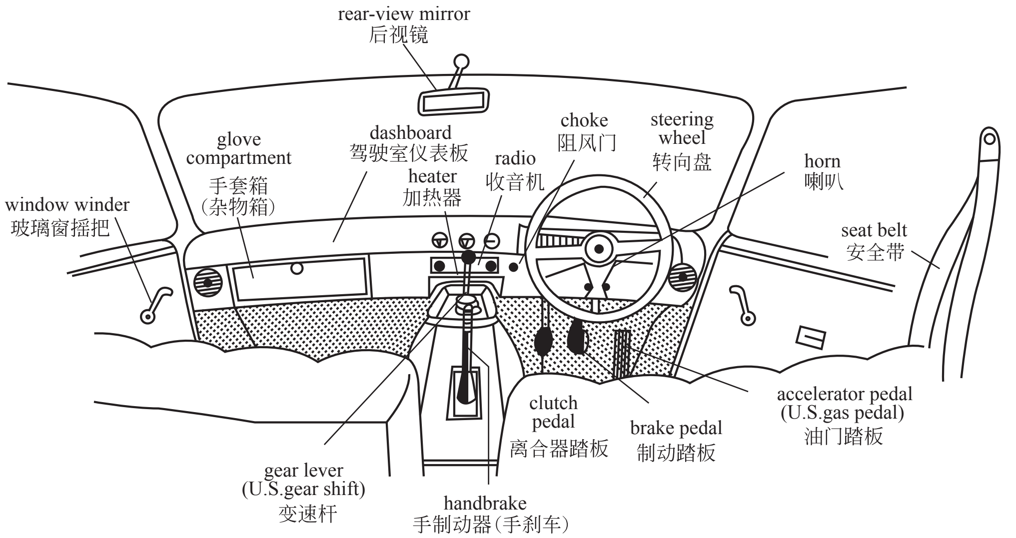
Tools in a Workshop 车间工具

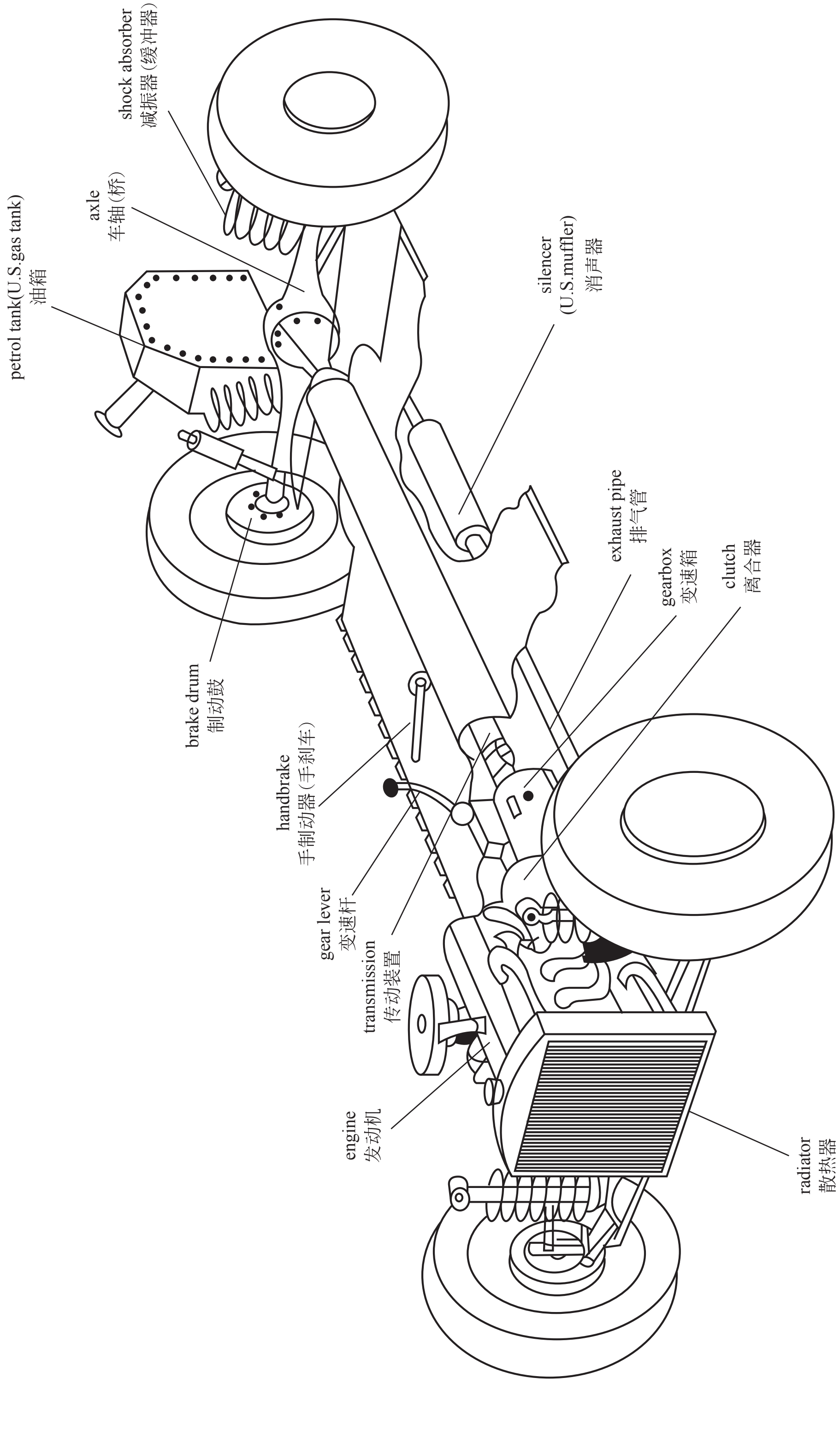


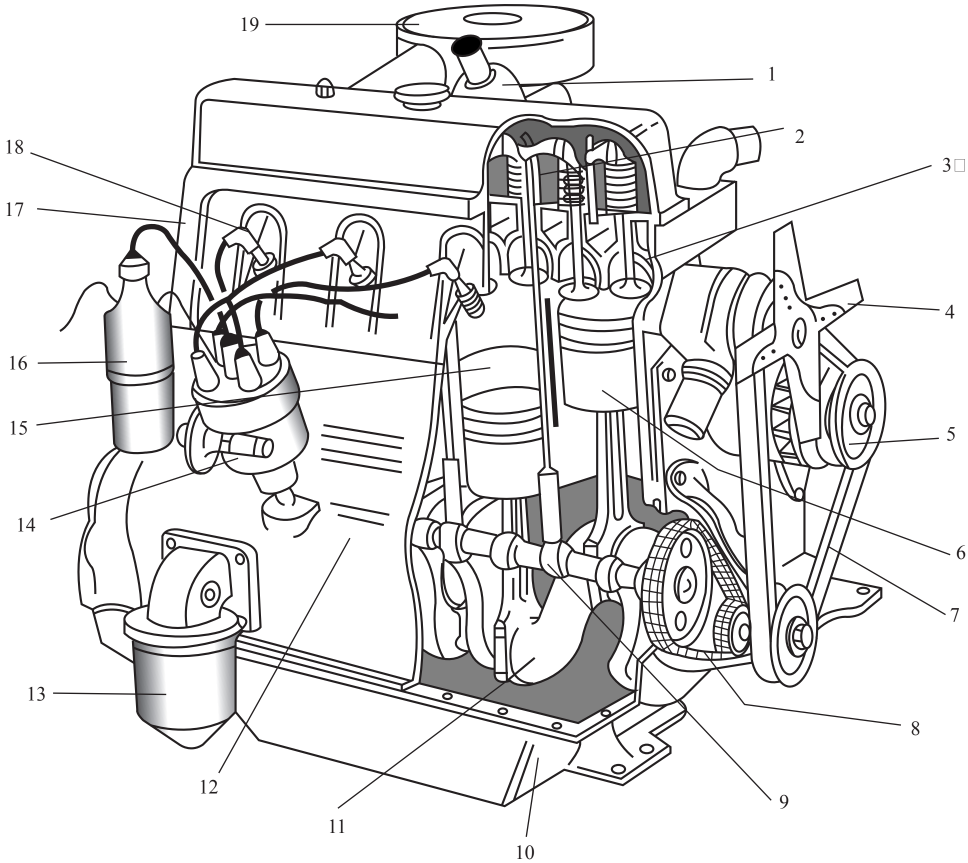
1 – workbench 工作台
2 – file 板锉
3 – sandpaper 沙纸
4 – chisel 凿刀，錾子
5 – pocket knife 电工刀，多用刀，小刀
6 – axe 斧子
7 – screwdriver 解锥，螺丝刀
8 – vise(or vice)台钳，老虎钳
9 – monkey wrench 活动扳手，活扳子
10 – extension cord(电用)延长绳路
11 – power saw 电锯
12 – folding rule 折叠尺
13 – wrench(死)呆扳手，两用扳手
14 – paintbrush 油漆刷
15 –(paint)roller(油漆)滚子
16 –(paint)pan(油漆)盘子
17 – paint can 油漆筒(罐)
18 – shelf 架子

Components of automobile 汽车构(部)件



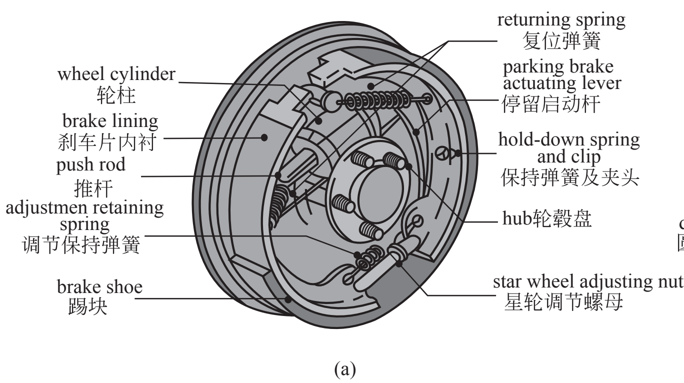



shock absorber
减振器(缓冲器)
axle
车轴(桥)
petrol tank(U.S.gas tank)
油箱
silencer
(U.S.muffler)
消声器
exhaust pipe
排气管
gearbox
变速箱
clutch
离合器
brake drum
制动鼓
handbrake
手制动器(手刹车)
gear lever
变速杆
transmission
传动装置
engine
发动机
radiator
散热器

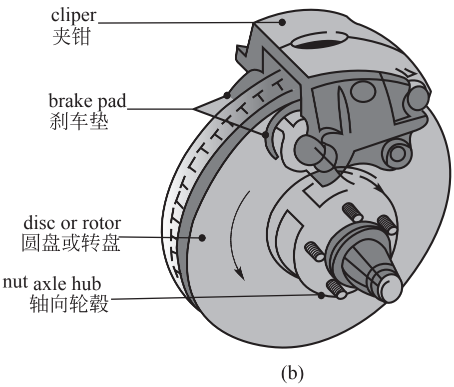


Internal combustion engine 内燃机(Petrol engine 汽油机)

1－carburetor 化油器　2－pushrod 推杆　3－valve 气门　4－fan 风扇　5－alternator 交流发动机
6－piston 活塞　7－fan belt 风扇皮带　8－timing chain 正时链　9－camshaft 曲轴
10－oil sump 曲轴箱底壳　11－crankshaft 曲轴　12－cylinder block 气缸体
13－oil filter 机油滤清器　14－distributor 分电器　15－cylinder 气缸
16－coil 点火线圈　17－cylinder head 气缸盖　18－sparking plug 火花塞
19－air filter 空气滤清器



(a)



(b)

Construct of commonly used brakes 常用制动器的结构

(a) drum brake 鼓刹　(b) disc brake 碟刹

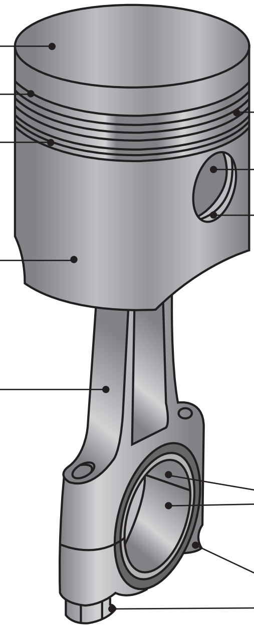
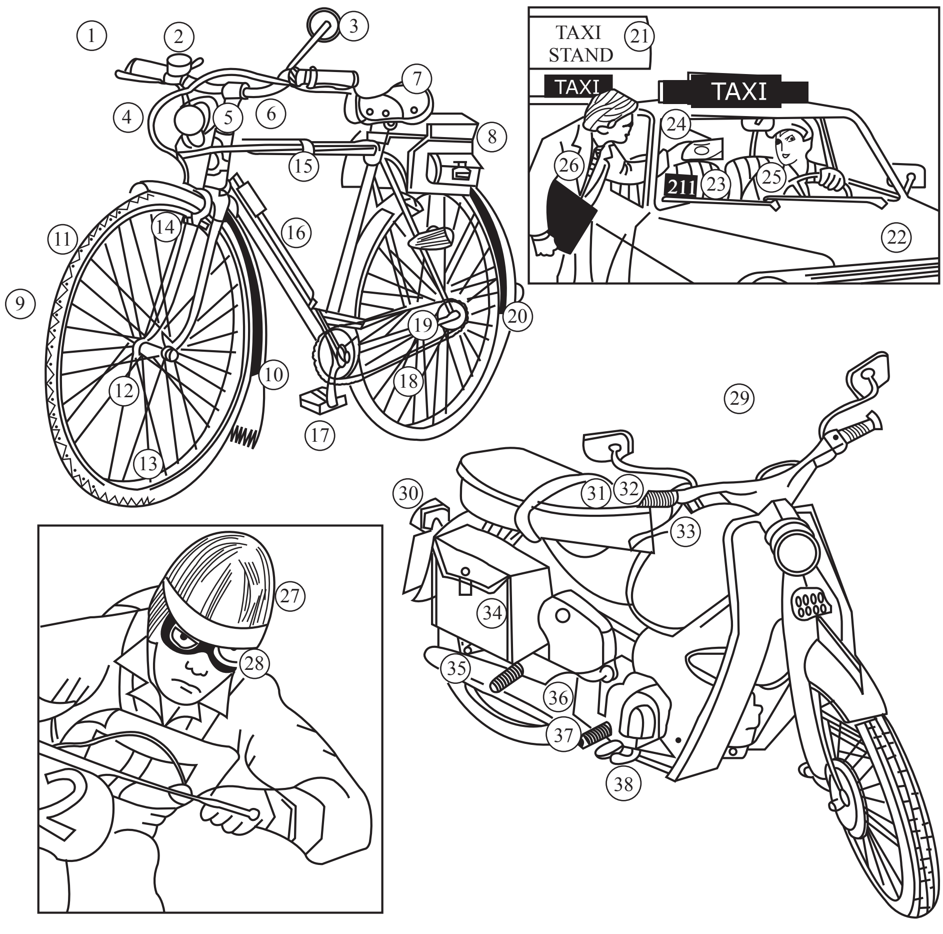


Illustration of the mechanism of piston and connecting rod 活塞连杆机构图解

Components of Bike and Motorcycle 自行车、摩托车构(部)件

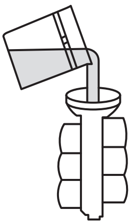
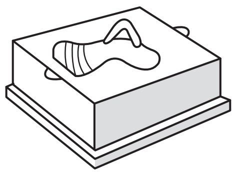
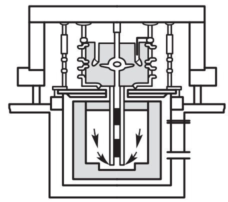
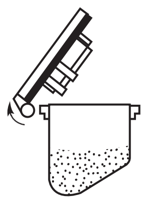
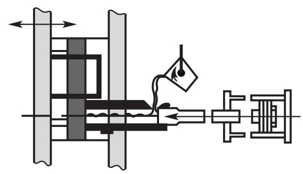
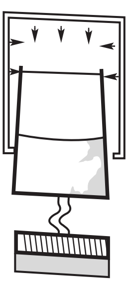
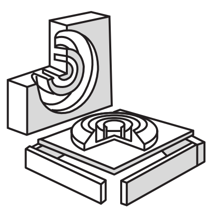
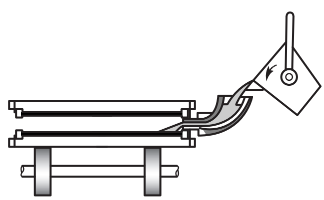
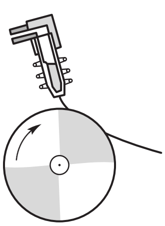
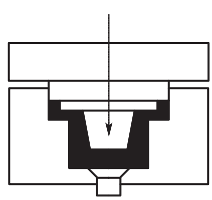


1 – bicycle/bike 自行车，脚踏车　2 – bell 铃　3 – mirror 镜　4 – cable 闸线　5 – headlight 前灯　6 – handlebars 车把　7 – seat 车座　8 – saddlebag 挂包　9 – wheel 车轮　10 – mudguard 挡泥板　11 – tire/tyre 轮胎　12 – spokes 辐条　13 – valve 汽门　14 – brake 车闸　15 – crossbar 大梁，横梁　16 – pump 打气筒　17 – pedal 脚蹬　18 – chain 链条　19 – sprocket 飞轮　20 – reflector 反射镜，回光灯　21 – taxi stand 出租汽车站　22 – taxi/cab 出租汽车　23 – meter 里程表　24 – fare 车费　25 –(taxi)driver(出租汽车)司机　26 – passenger 乘客　27 – crash helmet 头盔　28 – goggles 风镜　29 – motor scooter 摩托(跑)车　30 – rear light 尾灯　31 – seat 座位　32 – accelerator 油门　33 – brake 闸(柄)　34 – saddlebag 挂包　35 – exhaust 排气管　36 – starter 发动阀，打火脚蹬　37 – footrest 脚蹬，放脚处　38 – gearshift 脚挡

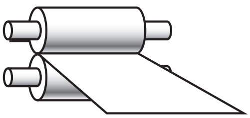
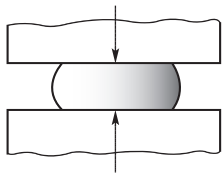
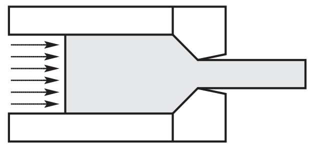
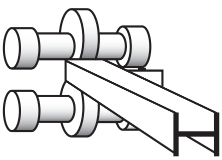
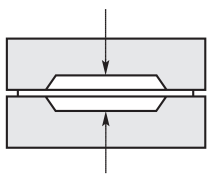
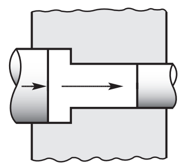
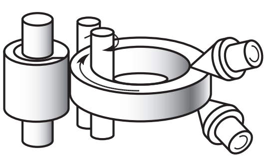
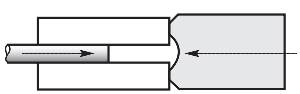
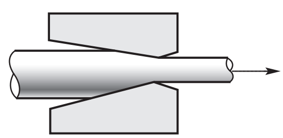
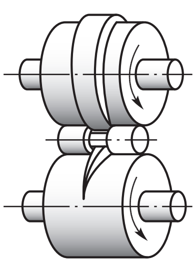
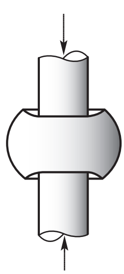
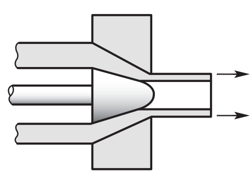
Part 2　Outline of Manufacturing Processes

各种制造工艺技术简图要览

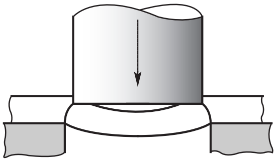
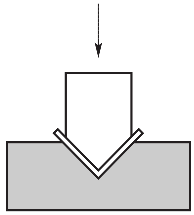
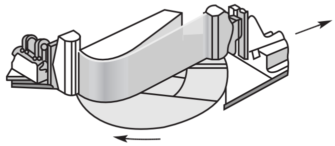
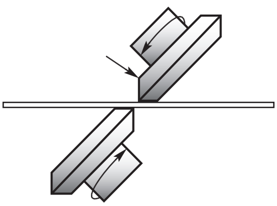
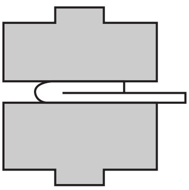
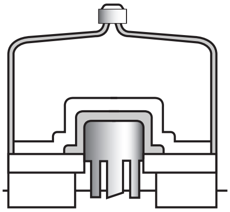
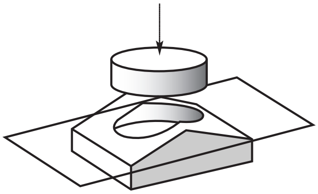
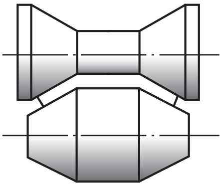
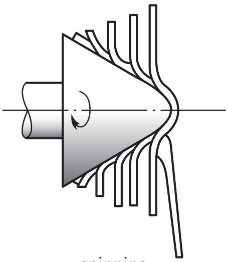
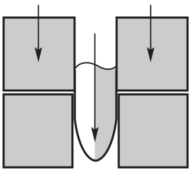
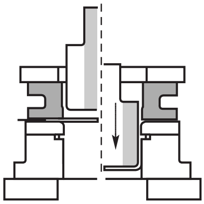
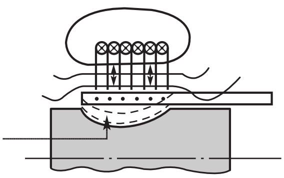
casting processes 铸造工艺

expendable pattern and mold and other 一次性模具及其他	expendable mold, permanent pattern 一次性模具、长久成形	permanent mold 长久模具
 investment casting 熔模(失蜡)铸造	 sand casting 砂型铸造	 permanent-mold casting 永久铸型
 lost foam casting 失沫铸造	 shell-mold casting 壳型造型	 die casting 压铸
 single-crystal casting 单晶铸造	 ceramic-mold casting 陶瓷模具铸造	 centrifugal casting 离心铸造
 melt-spinning process 熔旋快速固化		 squeeze casting 压实铸造

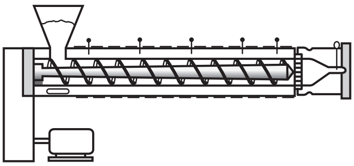
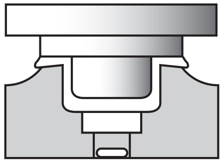
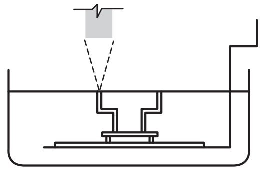
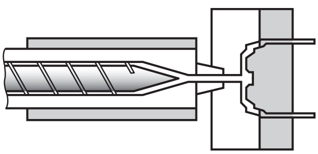
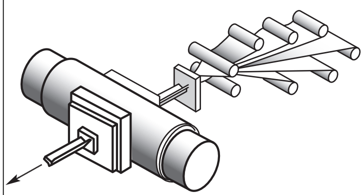
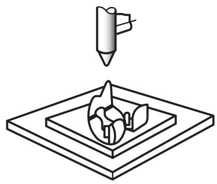
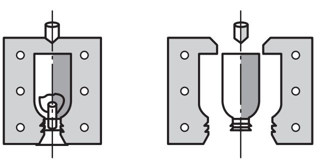
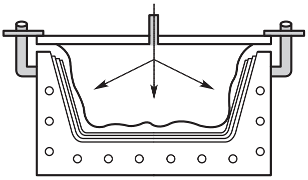
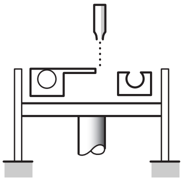
（续）

bulk deformation process 材料体积变形加工		
rolling 滚压、轧制	forging 锻压	extrusion and drawing 挤出与拉制
 flat rolling 平面轧制	 open die forging 自由锻	 direct extrusion 定向挤出
 shape rolling 型材轧制	 closed die forging 模锻	 cold extrusion 冷挤出
 ring rolling 环件轧制	 heading 锻头	 drawing 棒料拉制
 roll forging 辊锻	 piercing 锻孔	 tube drawing 管材拉制

（续）

sheet metal processes 金属板材加工		
shearing 剪切	bending and drawing 弯曲、拉深	forming 滚压
 blanking 落料	 bending 变曲	 stretch forming 延展
 slitting 剪裁	 hemming 卷边	 hydroforming 液力挤压
 punching 冲裁	 roll forming 滚压	 spinning 旋压
 pierce 冲孔	 deep drawing 拉深	 magnetic-pulse forming 磁脉冲击压

（续）

<table>
<tr><th colspan="3">polymer processing 聚合物成形加工</th></tr>
<tr><th>thermoplastics
热塑性成形</th><th>thermosets
热固性成形</th><th>rapid prototyping
快速成形</th></tr>
<tr><td>
extrusion
挤出成形</td><td>
compression molding
压缩模</td><td>
stereolithography
立体光固化成型</td></tr>
<tr><td>
injection molding
注射成形</td><td>
pultrusion□
拉出成形</td><td>
fused deposition molding
熔融沉积成型</td></tr>
<tr><td>
blow molding
吹塑成形</td><td>
vacuum-bag forming
真空包成形</td><td>
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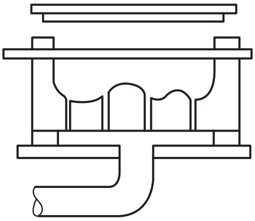
<tr><td>
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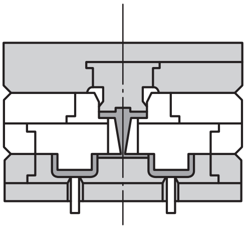
热成形</td><td>
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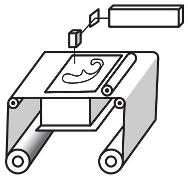
压铸模(传递模)</td><td>
laminated-object manufacturing
叠(分)层实体制造</td></tr>
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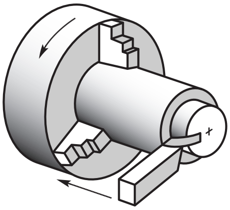
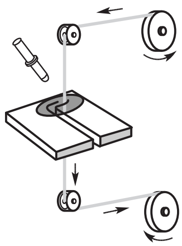
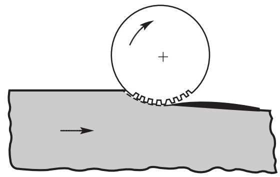
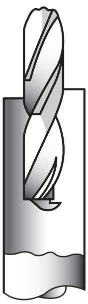
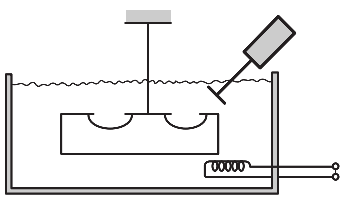
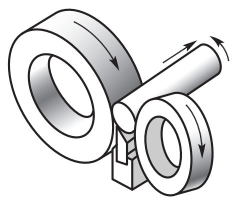
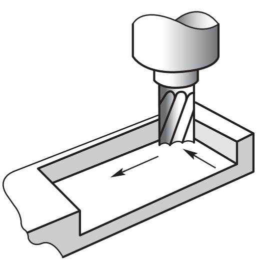
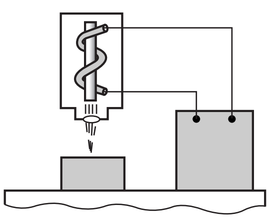
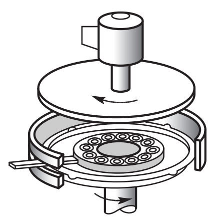
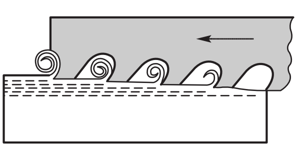
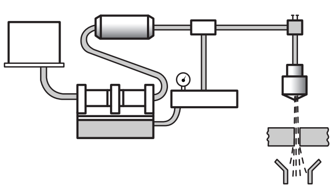
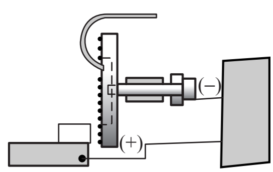
machining and finishing processes 去除加工和光整加工工艺

machining 常规加工	advanced machining 先进加工	finishing 光整加工
 turning 车削	 wire EDM 电火花线切割	 surface grinding 平面磨削
 drilling 钻削	 chemical machining 化学加工	 centerless grinding 无心磨削
 milling 铣削	 laser machining 激光加工	 lapping 研磨
 broaching 拉削	 water-jet machining 水射流加工	 electrochemical polishing 电化学磨抛

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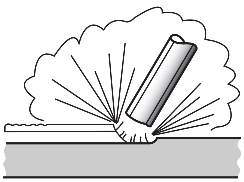
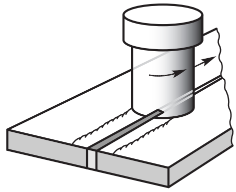
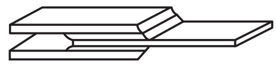
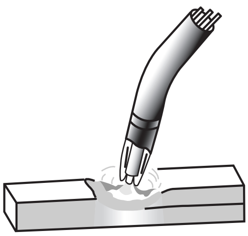
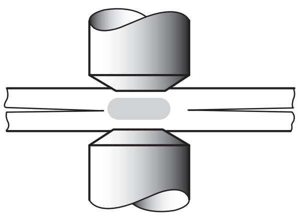
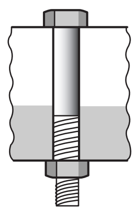
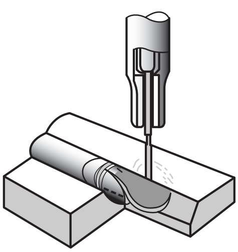
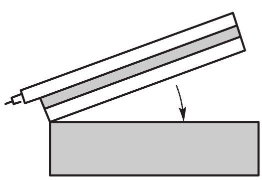
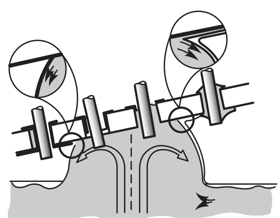
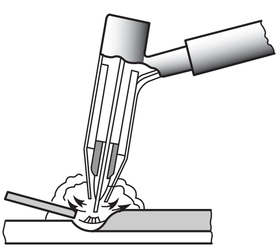
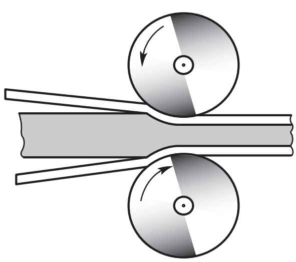
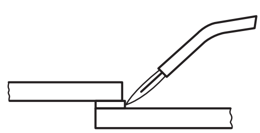
joining processes 连接工艺方法		
fusion welding 熔焊	other welding 其他焊接	fastening and bonding 紧固、粘接
 shielded metal arc welding 埋弧焊	 friction stir welding 摩擦焊接	 adhesive bonding 粘接
 gas-metal arc welding 气弧焊	 resistance welding 电阻焊接	 bolted connection 螺栓联结
 flux-cored arc welding 浇焊	 explosion welding 爆炸焊接	 wave soldering 波焊
 gas-tungsten arc welding 钨极保护焊	 cold welding 冷焊	 brazing 铜焊

Reading Materials

Passage 1: Selecting Manufacturing Processes

An extensive and continuously expanding variety of manufacturing processes are used to produce parts and there is usually more than one method of manufacturing a part from a given material. The broad categories of the processing methods for materials are as follows, referenced to the relevant part in this text and illustrated with examples for each:

(1) **Casting**: Expendable mold and permanent mold.

(2) **Forming and shaping**: Rolling, forging, extrusion, drawing, sheet forming, powder metallurgy, and molding.

(3) **Machining**: Turning, boring, drilling, milling, planing, shaping, broaching, and grinding, ultrasonic machining, chemical, electrical, and electrochemical machining, and high-energy-beam machining; this category also includes micromachining for producing ultraprecision parts.

(4) **Joining**: Welding, brazing, soldering, diffusion bonding, adhesive bonding, and mechanical joining.

(5) **Finishing**: Honing, lapping, polishing, finishing, deburring, surface treating, coating, and plating.

(6) **Nanofabrication**: It is the most advanced technology and is capable of producing parts with dimensions at the nano level (one billionth), it typically involves processes such as etching techniques, electron-beams, and laser-beams. Present applications are in the fabrication of microelectromechanical systems (MEMS) and extending to nanoelectromechanical systems (NEMS), which operate on the same scale as biological molecules.

Selection of a particular manufacturing process, or a sequence of processes, depends not only on the shape to be produced but also on other factors pertaining to material properties. As examples, brittle and hard materials cannot be shaped or formed easily, whereas they can be cast, machined, or ground. Metals that are previously formed at room temperature become stronger and less ductile than they were before processing them, and thus will require higher forces and be less formable during subsequent (secondary) processing.

As described throughout this text, each manufacturing process has its own advantages and limitations, as well as production rates and product cost. Manufacturing engineers constantly are being challenged to find new solutions to manufacturing problems and cost reduction. For example, sheet metal parts traditionally have been cut and fabricated using common mechanical tools, punches, and dies. Although still widely used, some of these operations are being replaced by laser-cutting techniques in which the path of the laser can be controlled, thus increasing the capability for producing a wide variety of shapes accurately, repeatedly, and economically, as well as eliminating the need for punches and dies. However, as expected, the surface produced by punching has different characteristics than that produced by laser cutting.

Passage 2: General Trends in Manufacturing

With advances in all aspects of materials, processes, and production control, there have been certain important trends in manufacturing, as briefly outlined below.

Materials and processes: The trend is for better control of material compositions, purity, and defects (impurities, inclusions, flaws) in order to enhance their overall properties, manufacturing characteristics, reliability, service life, and recycling, while keeping material costs low. Developments are continuing on superconductors, semiconductors, nanomaterials, nanopowders, amorphous alloys, shape-memory alloys (smart materials), and coatings. Testing methods and equipment are being improved, including use of advanced computers and software, particularly for materials such as ceramics, carbides, and composites.

Concerns over material and energy savings have lead to better recyclability, as well as weight savings by improving design and engineering considerations, such as higher strength-to-weight and stiffness-to-weight ratios. Thermal treatment of materials are being conducted under better control of relevant variables for more predictable and reliable results, and surface treatment methods are being advanced rapidly. Included in these developments are advances in tool, die, and mold materials to improve their performance. Challenging recent developments in processing involve ultraprecision, micro, and nanomanufacturing, approaching atomic levels.

Computer simulation and modeling continue to be used widely in design and manufacturing, resulting in the optimization of processes and production systems, and better prediction of the effects of relevant variables on product integrity. As a result of such efforts, the speed and efficiency of product design and manufacturing is improving greatly, also affecting the overall economics of production and reducing product cost in an increasingly competitive and global marketplace.

Manufacturing systems: Continuing developments in control systems, industrial robots, automated inspection, handling and assembly, and sensor technology are having a major impact on the efficiency and reliability of all manufacturing processes and equipment. Advances in computer hardware and software, communications systems, adaptive control, expert systems, and artificial intelligence and neural net works have all helped enable the effective implementation of concepts such as group technology, cellular manufacturing, and flexible manufacturing systems, as well as modern practices in the efficient management of manufacturing enterprises.

Organizational trends: There have been important trends in the operational philosophy of manufacturing enterprises. Traditionally, the emphasis was on topdown communication in the organization and on strong control by management, with priorities for quick financial return (profits first) and growth and size (economy of scale). The major trend is now toward broad-based communication across the organization.

With global competition and the requirements for world-class manufacturing, corporate strategies are continually undergoing major changes. Manufacturing has become an integral part of long-range business planning for companies that must maintain their competitive positions and increase their market share. These are complex issues because they involve a broad range of considerations such as product type, company size, changing markets, laws and business practices in different countries, tariffs and import restrictions, geopolitics, and especially the major trends in rapidly increasing manufacturing activities in countries where labor costs are about a tenth of those in traditionally more industrialized countries. The rapidly growing field of information technology (IT) can provide the tools to help meet these major global challenges.

It has been increasingly recognized that for a manufacturing enterprise to be successful, it must respond to the following:

(1) View the people in the organization as important assets, and emphasize the importance and need for teamwork and involvement in problem solving and in decision-making processes in all aspects of operations.

(2) Encourage product innovation and improvements in productivity.

(3) Relate product innovation and manufacturing to the customer and the market, seeing the product as meeting a need.

(4) Increase flexibility of operation for rapid response to product demands, in both the domestic and the global marketplace.

(5) Encourage efforts for continuous improvement in quality.

(6) Ultimately and, most importantly, focus on customer satisfaction on a global scale.

Part 3　Various Manufacturing Processes with Diagram Illustrations 各类加工方法和设备图解

3.0　Metal Cutting Operation System 工艺系统

The work of the machine shop in building machines is to make each part to the required shape and size. The unique feature of all machine shop operations is that the parts are precisely formed to the desired shape and size by removing metal from the workpiece in the forms of chips. These metal chips may be very large or very small as in the case of grinding operations. Assembling of the finished parts is, of course, the final job. The materials to be machined is generally in the forms of hot-rolled bars, cold-drawn bars, machined bars, castings, or forgings. Tools, dies, machine parts, and engine parts frequently must have very precise dimensions and smooth surface finishes. These characteristics can sometimes be obtained by other manufacturing methods, but they must usually be achieved more economically, and to a higher degree, by machining. Value is added to the raw materials that are processed to become machine parts in the machine shop, by virtue of the work done to change their shape, provide precise dimensions, and create their final smooth surface finishes.

A typical processing system consists of four parts : machine tools, metal cutting tool, jig and fixture, and workpiece.

Machine tools Machine tools can be considered to serve four main purpose:

(1) They hold the work or the part.

(2) They hold the cutting tool or tools.

(3) They impart to the cutting tool or work or both whatever motion is required for cutting or forming the part.

(4) They are arranged, ordinarily, for regulating the cutting speed and also the feeding movement between the tool and the work.

In the production of machine parts of various shapes and sizes, the type of machine and cutting tool used will depend upon the nature of the metal-cutting operation, the character of the work, and possibly, other factors such as the number of parts required and the degree of accuracy to which the part must be made.

Machine tools are built to produce certain shapes such as cylindrical surface, holes, plane surface, irregular contour, gear teeth, etc. Many machine, however, can produce a variety of surface. Thus, machine tools are built as general purpose machine, high production machines, and as special purpose machine.

As the name implies, general purpose machine tools are designed to be quickly and easily adapted to a large variety of operations on many different kinds of parts. They are used extensively in jobbing shops, repair shops, and in tool and die shops.

High production machine are designed to perform an operation, or a sequence of operations, in a repetitive manner in order to achieve a rapid output of machined parts at minimum cost. They can be set up to machine a variety of different parts, however, thus operation is economical only when the quantity of parts to be machined is relatively large.

Special purpose machine tools are designed to perform one operation, or a sequence of operations repetitively on a specific part. These machines are usually automatic and are unarranged except when it is necessary to change and to adjust the cutting tools. They are used in mass-production shops such as are found in automotive industry.

NC machine tools have their functions programmed before operations. They are particularly useful where repeat orders for the same part are encountered. The program containing the information required to produce the part can be stored conveniently and reused when required.

Metal cutting tool The metal cutting tool separates chips from the workpiece in order to cut the part to the desired shape and size. They must meet the following conditions:

(1) The tool is harder than the metal to be cut,

(2) The tool is so shaped that its cutting edge can penetrate the work,

(3) The tool is strong and rigid enough to resist the cutting forces,

(4) There must be movement (provided by machine tools) of the tool relative to the material in order to make the cutting action possible.

There are three basic types of metal cutting tools: single-point tools, multiple-point tools, and abrasives. Single-point tool has only one cutting edge and is used for turning, boring, shaping and planning. Multiple-point tools have two or more cutting edges such as drills, reamers, and milling cutters. Grinding wheels are an example of abrasive cutting tools. Each grinding wheel has thousands of embedded abrasive particles which are capable of penetrate the workpiece and remove a tiny chip. The combined total of the tiny chips can result in a substantial amount of metal being removed from the workpiece.

Jig and fixture A fixture is device used on machine tools to hold and locate a workpiece during a manufacturing operation. A jig is a device that holds and locate a work piece but also guide the cutting tools.

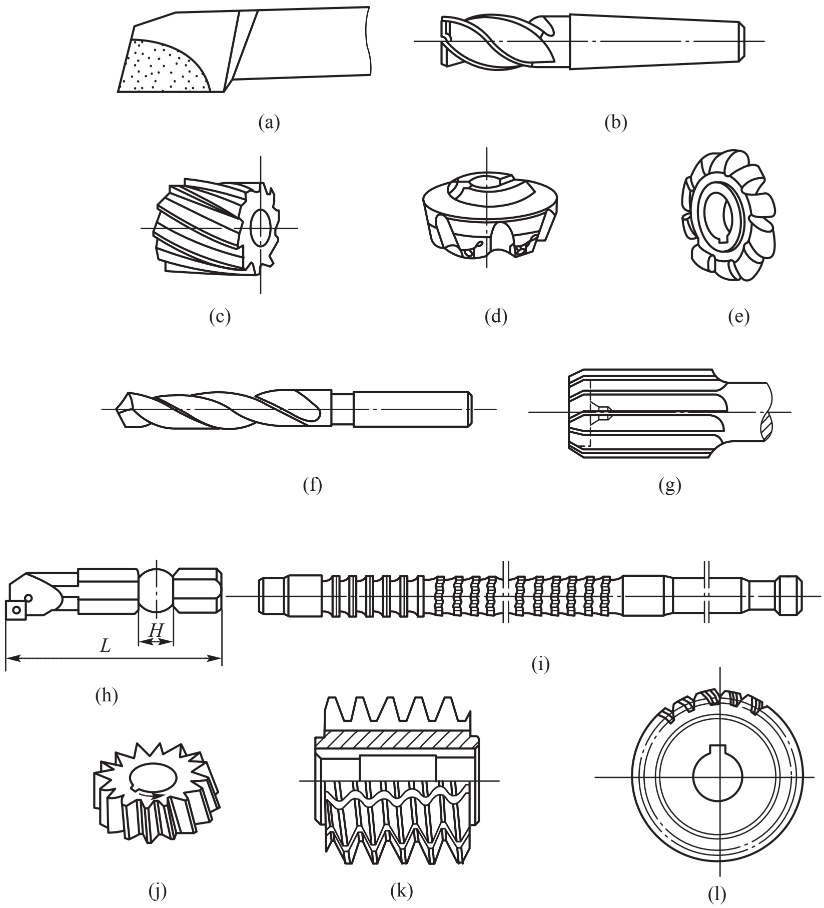
Device designed for locating and holding cutting tools are usually called tool holder.

Jig and fixture are classified as follows:

(1) Standard fixture or accessories for machine tools such as jaw chucks, machine vises, drill chucks, and so on.

(2) Stock (adaptable) jig and fixtures.

(3) Special jig and fixture are designed for a definite operation to machine a definite



Types of commonly used cutting tools 常用刀具类型

(a) turning tool 车刀　(b) vertical milling tool 立式铣刀　(c) peripheral milling cutter 周铣刀　(d) face milling cutter 端铣刀　(e) groove milling cutter 沟槽铣刀　(f) twist drill 麻花钻　(g) reamer 铰刀　(h) boring cutter 镗刀　(i) pull broach 拉刀　(j) gear shaper cutter 插齿刀　(k) gear hob 滚齿刀　(l) gear shaving tool 剃齿刀

workpiece and are manufactured individually.

Jig and fixtures are of great importance in the production of machine parts, whose roles can be summarized as:

(1) eliminate laying out workpiece before machining,

(2) increase machining accuracy,

(3) increase productivity,

(4) save operator labour,

(5) make the use of lower skilled labour possible,

(6) decrease expenditures on quality control of the machined parts,

(7) widen the technological capability of machine tools, i. e., increase the versatility of machining performance,

(8) either fully or partly automate the machine tool.

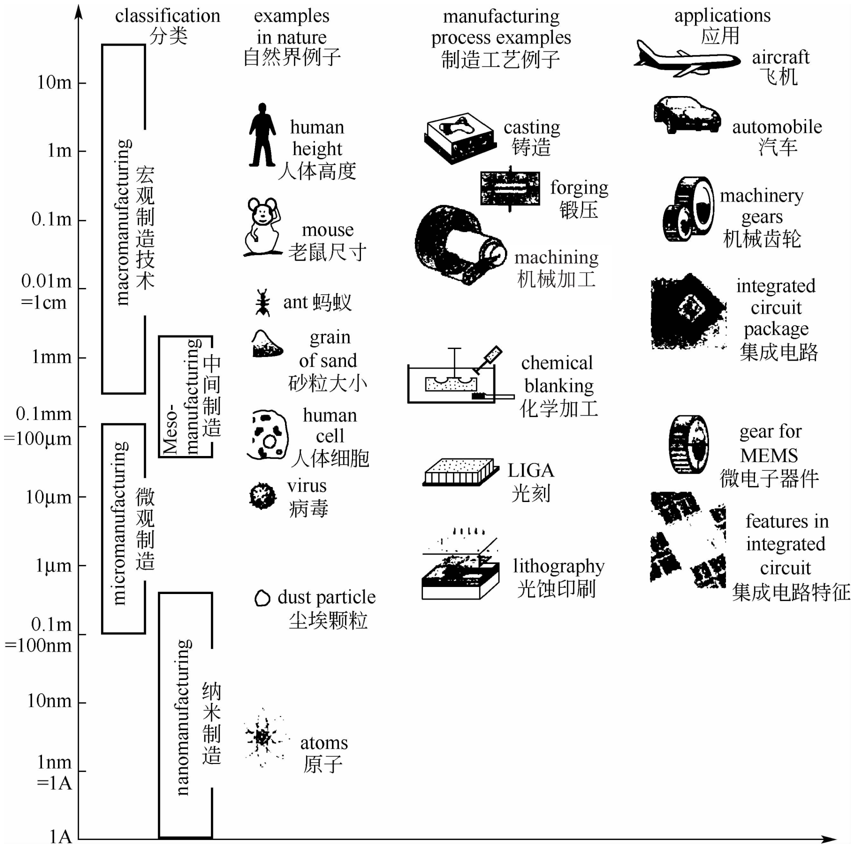


Fig. Illustration of the regime of macro-, meso-, micro-, and nano-manufacturing

图 宏观、中等尺寸、微观和纳米制造技术领域图解

Reading Materails

Passage 1: Basic Elements of Machine Tools

The various components that are present in all machine tools may be identified as follows:

Work holding device To hold the workpiece in the correct orientation to achieve the required accuracy in manufacturing, e. g. various kinds of chucks.

Tool holding device To hold the cutting tool in the correct position with respect to the workpiece and provide enough holding force to counteract the cutting forces acting on the tool, e. g. tool post.

Work motion mechanism To provide the necessary speeds to the workpiece for generating the requisite surface, e. g. head stock.

Tool motion mechanism To provide the various motions needed for the tool in conjunction with workpiece motion in order to generate the different surface profiles as desired, e. g. carriage, saddle.

Support structure To support all the mechanisms as mentioned above and maintain their relative position with respect to each other and also allow for relative movement between the various parts to obtain the requisite part profile and accuracy, e. g. bed.

The various motions that need to be provided in the machine tool are cutting speed and feed. The range of speed and feed rates to be provided in a given machine tool depends upon the capability of the machine tool and the range of work materials that are expected to be processed. Basically the actual speed and feed chosen depends upon the work material, production rate desired, surface finish required, and accuracy expected.

Passage 2: General Work Holding Methods

Work holding in machining is an important function which affects the gained accuracy. There are a large number of work holding devises to cater for different work profiles, of which, the most used are vices, chucks and clamps.

Vices These are used for general purpose work holding on milling machines, shapers and grinding machines. The vice consists of a fixed jaw and moving jaw and is generally useful for jobs which are prismatic and with plane faces. The location available is the jaw surface which is generally plane. However it is also possible to change the types of jaw to suit the external contour of the job. For example a VEE jaw(or V-jaw block) can be used for cylindrical external contours.

Chucks Chucks are basically used for axi-symmetric jobs and for irregular surfaces where the job requires to be rotated during the machining operation or in between. They are generally used in lathes, cylindrical grinding machines and milling machines fitted with dividing heads. The chucks may have two, three or four jaws depending upon the desired fixturing requirement.

Clamps The tables of machine tools generally are the flat surfaces with accurately machined T-slots which are generally used for work holding purpose. Various clamps and locating elements are available to hold complex surfaces on these surfaces.

Passage 3: Computer-Integrated Manufacturing

Beginning with computer graphics and computer-aided modeling, design, and manufacturing, the use of computers has been extended to computer-integrated manufacturing (CIM) in which software and hardware are integrated from product concept through product distribution in the marketplace. Computer-integrated manufacturing is particularly effective because of its capability for making possible:

(1) Responsiveness to rapid changes in market demand and product modifications.

(2) Better use of materials, machinery, and personnel, and reduction in inventory.

(3) Better control of production and management of the total manufacturing operation.

(4) The manufacture of high-quality products at low cost.

The following is an outline of the major applications of computers in manufacturing:

Computer numerical control (CNC) First implemented in the early 1950s, this is a method of controlling the movements of machine components by direct insertion of coded instructions in the form of numerical data.

Adaptive control (AC) The parameters in a manufacturing process are adjusted automatically to optimize production rate and product quality, and to minimize cost. Parameters such as forces, temperatures, surface finish, and dimensions of the part are monitored constantly; if they move outside the acceptable range, the system adjusts the process variables until the parameters again fall within the specified range.

Industrial robots Introduced in the early 1960s, industrial robots have been replacing humans in operations that are repetitive, dangerous, and boring, thus reducing the possibility of human error, decreasing variability in product quality, and improving productivity. Robots with sensory-perception-capabilities have been developed (intelligent robots), with movements that simulate those of humans.

Automated handling of materials Computers have made possible highly efficient handling of materials and components in various stages of completion (work in progress), such as when being moved from storage to machines, from machine to machine, and at points of inspection, inventory, and shipment.

Automated and robotic assembly systems These systems mainly have replaced costly assembly by human operators, although humans still have to perform some of these operations. Products are now designed or redesigned so that they can be assembled more easily and faster by machines.

Computer-aided process planning (CAPP) This system is capable of improving productivity by optimizing process plans, reducing planning costs, and improving the consistency of product quality and reliability. Functions such as cost estimating and monitoring of work standards (time required to perform a certain operation) are also incorporated into the system.

Group technology (GT) The concept of group technology is that parts can be grouped and produced by classifying them into families, according to similarities in design and similarities in the manufacturing processes employed to produce the part. In this way, part designs and process plans can be standardized and families of similar parts can be produced efficiently and economically.

Just-in-time production (JIT) The principal of JIT is that supplies of raw materials, parts, and components are delivered to the manufacturer just in time to be used, parts and components are produced just in time to be made into subassemblies and assemblies, and products are finished just in time to be delivered to the customer. As a result, inventory-carrying costs are low, part defects are detected right away, productivity is increased, and high-quality products are made at low cost.

Cellular manufacturing (CM) This system utilizes workstations (manufacturing cells) that usually contain several production machines controlled by a central robot, each machine performing a different operation on the part.

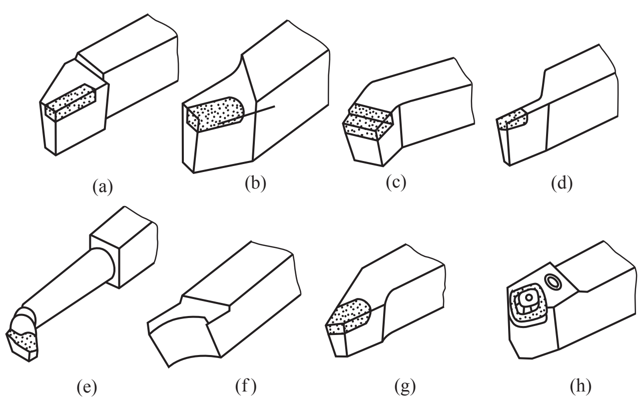
Flexible manufacturing systems（FMS） These systems integrate manufacturing cells into a large unit，all interfaced with a central computer. Although very costly，FMS is capable of efficiently producing parts in small runs and of changing manufacturing sequences on different parts quickly；this flexibility enables them to meet rapid changes in market demand for all types of products.

Expert systems（ES） These systems basically are complex computer programs，they have the capability to perform various tasks and solve difficult real-life problems much as human experts would.

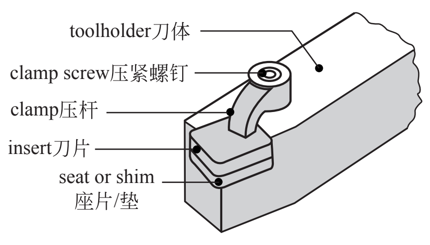
Artificial intelligence（AI） This important field involves the use of machines and computers to replace human intelligence. Computer-controlled systems are now capable of learning from experience and of making decisions that optimize operations and minimize costs. Artificial neural networks（ANN），which are designed to simulate the thought processes of the human brain，have the capability of modeling and simulating production facilities，monitoring and controlling manufacturing processes，diagnosing problems in machine performance，conducting financial planning，and managing a company's manufacturing strategy.

In view of these continuing advances and their potential，some experts have envisioned the factory of the future. Although highly controversial，and viewed as unrealistic by some，this is a system in which production will take place with little or no direct human intervention. Ultimately，the human role is expected to be confined to the supervision，maintenance，and upgrading of machines，computers，and software.

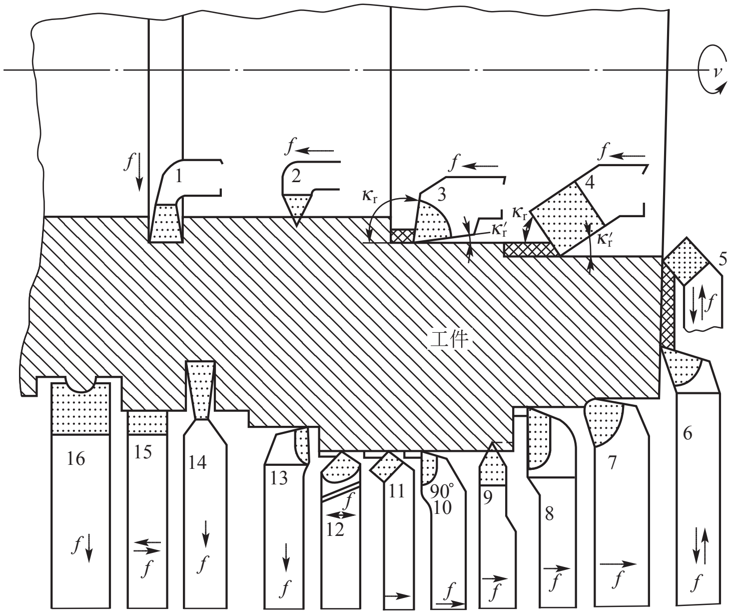
3.1 Turning and Lathe 车削加工及车床



Various types of turning tools 车刀种类

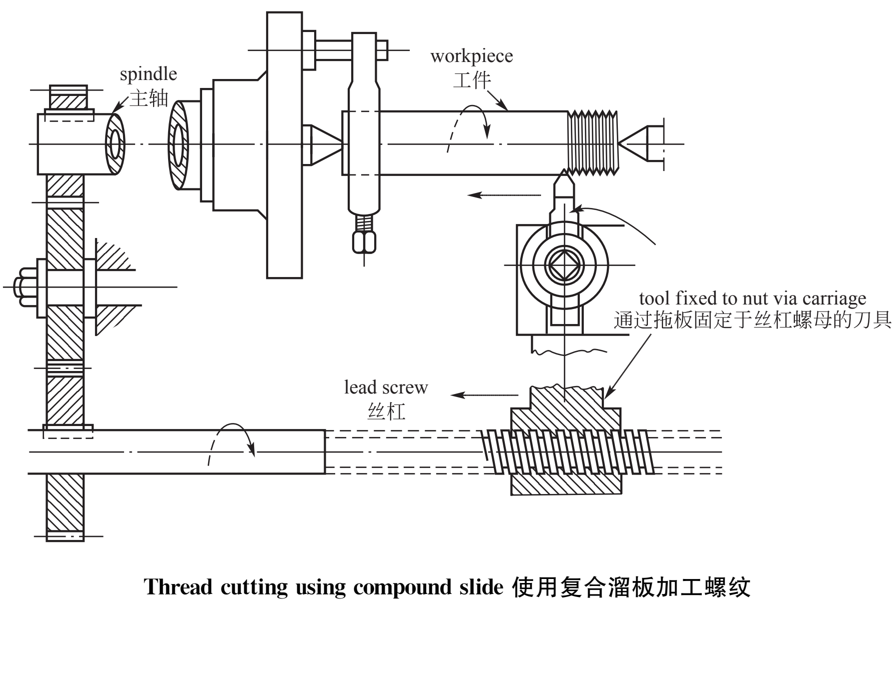


Carbide insert held by clamp screw for cutting tool 螺钉压板固定刀粒

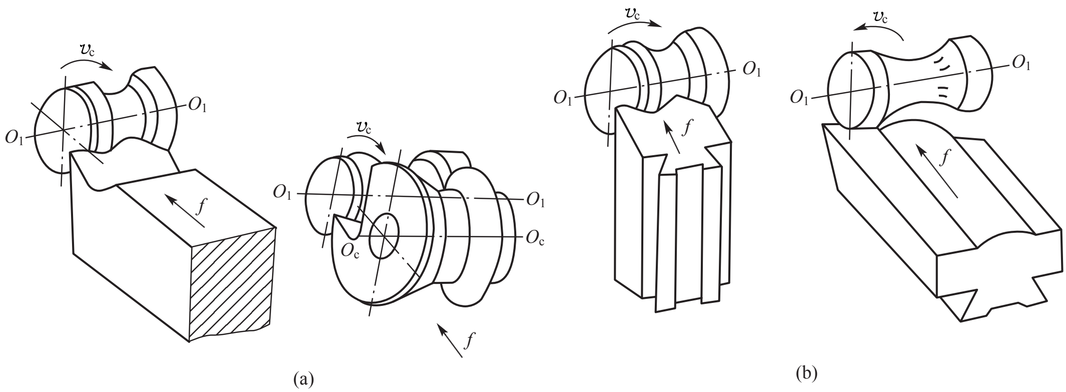


Different kinds of tools and cutting operations used on a lathe 不同种类车刀及其用途

1 – recess or internal grooving 反向切槽 2 – internal threading 车内螺纹 3 – internal facing for blind hole 车内盲孔 4 – internal turning 车内表面 5，6 – facing 车端面 7 – fine turning with nose radius tool 圆弧车刀精车 8 – facing and turning 台阶车削 9 – thread cutting 车螺纹 10，11 – turning 车外表面 12 – threading 车螺纹 13 – left hand turning 左向车削 14 – parting or slotting 切断、切槽 15 – finish turning 光刀车削 16 – radius form turning 成形车削

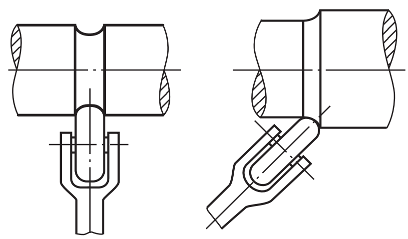


Thread cutting using compound slide 使用复合溜板加工螺纹

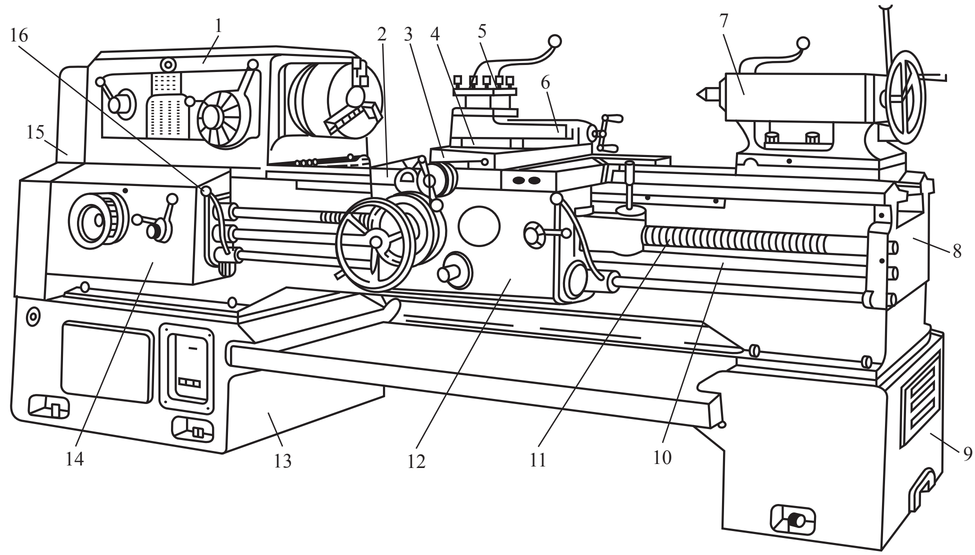


Types of lathe form tools 成形车刀的种类

(a) circular form tool 圆体成形车刀　(b) straight form tool 棱体成形车刀



Knurling 滚压



Layout of a general purpose horizontal lathe 卧式车床外形

1 – headstock 主轴箱　2 – saddle(carriage)床鞍(大拖板)　3 – cross-slide 中拖板　4 – rotary plate 转盘　5 – tool post 方刀架　6 – small slide 小拖板　7 – tailstock 尾座　8 – bed 床身　9 – right base 右床脚　10 – feed rod 光杆　11 – leadscrew 丝杠　12 – slide box(apron)溜板箱　13 – left base 左床脚　14 – feed change gear box 进给箱　15 – change gear box 挂轮架　16 – handle 操作手柄

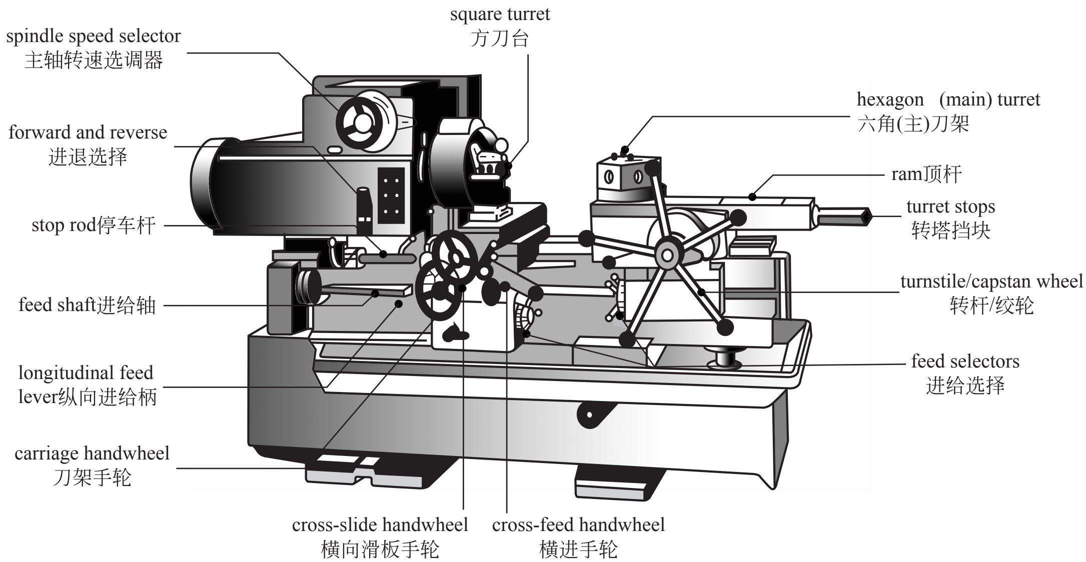
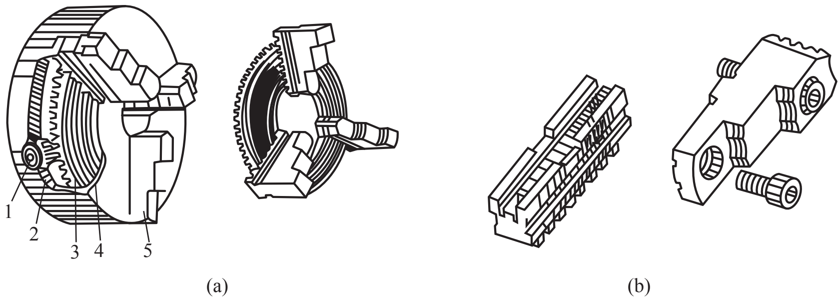
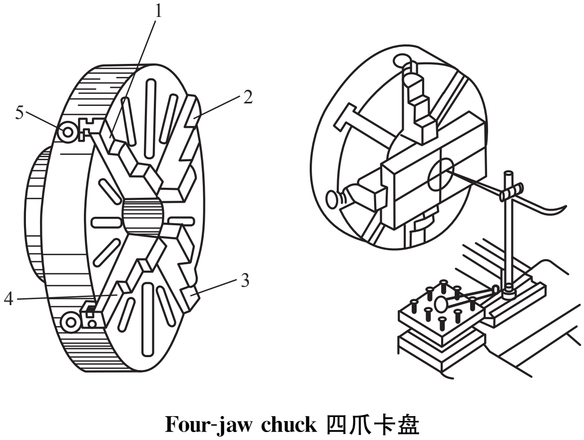


Illustration of the components of a turret lathe 转塔车床结构示意图



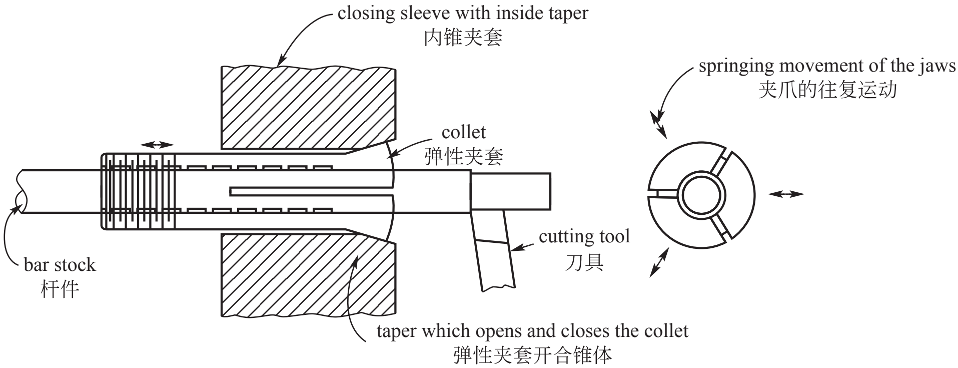
Three-jaw chuck 三爪卡盘

1 - rectangular hole 方孔　2 - bevel pinion 小锥齿轮　3 - bevel teeth on scroll plate 转盘大锥齿轮　4 - scroll plate 转盘　5 - jaw 卡爪

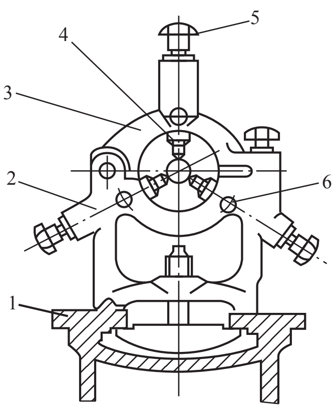


Four-jaw chuck 四爪卡盘

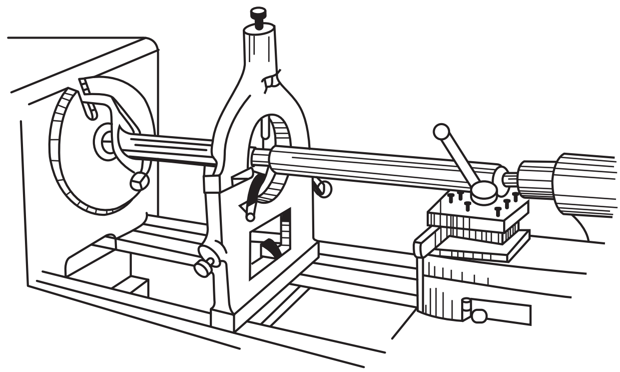
1～4 - jaw 卡爪　5 - jaw screw 螺杆



Collet chuck principle 弹性夹套夹紧原理

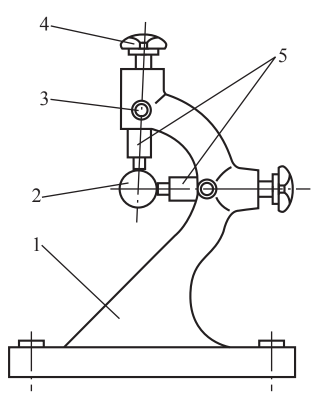


Construct of centre rest 中心架结构

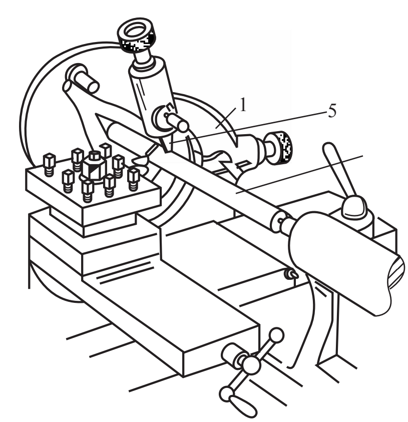


Application of center(steady)rest 中心架应用

1－slide way(guide way)导轨　2－base of centre rest 基座　3－live part 活动部分　4－movable support 移动支承　5－adjustment knob 调节旋钮　6－lock screw 锁紧螺钉



Structure of follower rest 跟刀架结构

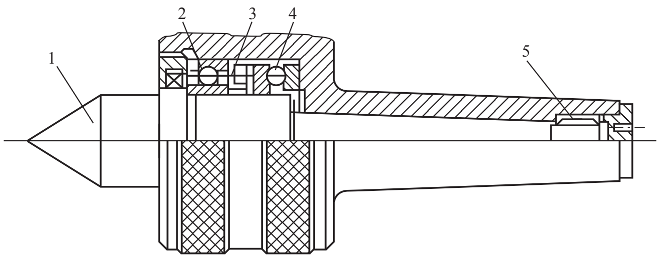


application for lengthy rod 用于长轴

Application of follower rest(movable support)跟刀架应用

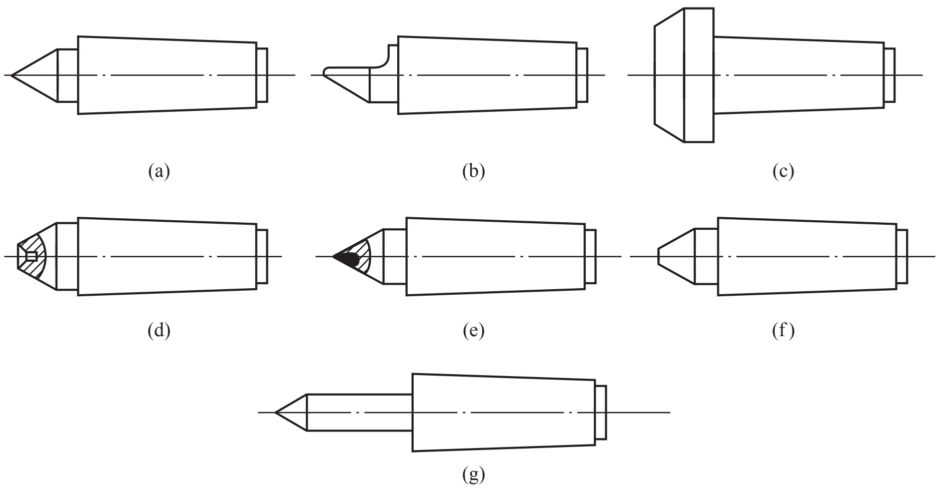
1－base 架座　2－workpiece 工件　3－clamping screw 紧固螺钉

4－adjustment hand wheel 调节手轮　5－support 支承爪

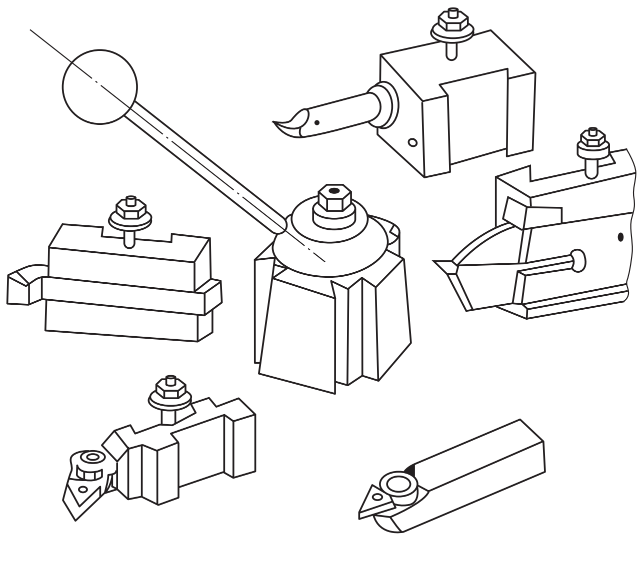


Construction of live centre 活顶针结构

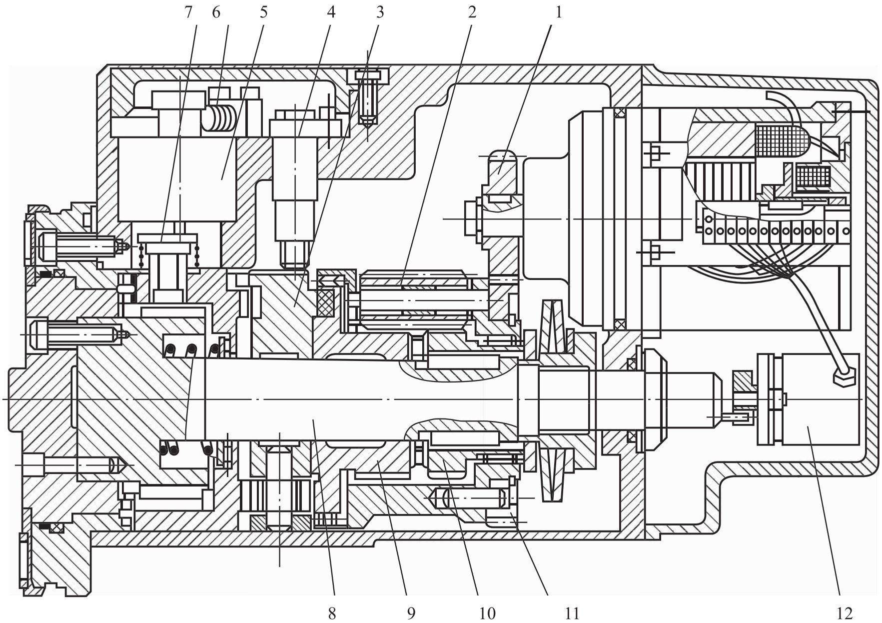
1 - centre 顶尖　2，4 - ball bearing 球轴承
3 - spacer bush 轴承隔套　5 - adjustment set 调整装置



Various types of centres 各种顶针结构

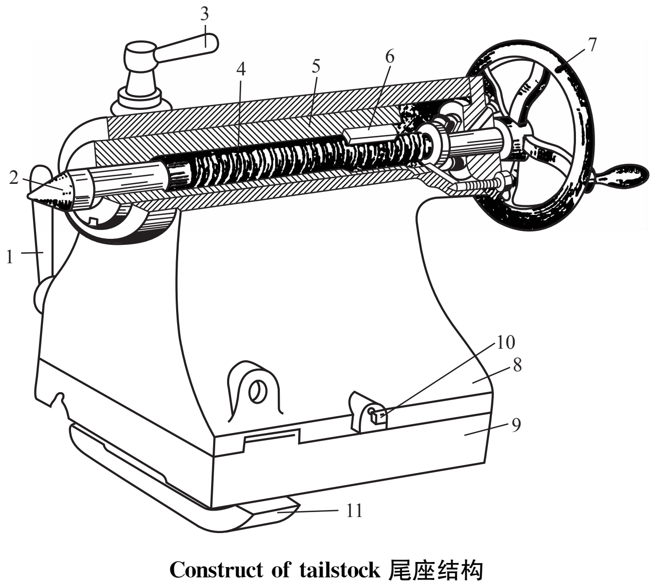


Quick change tool holder 快换刀架



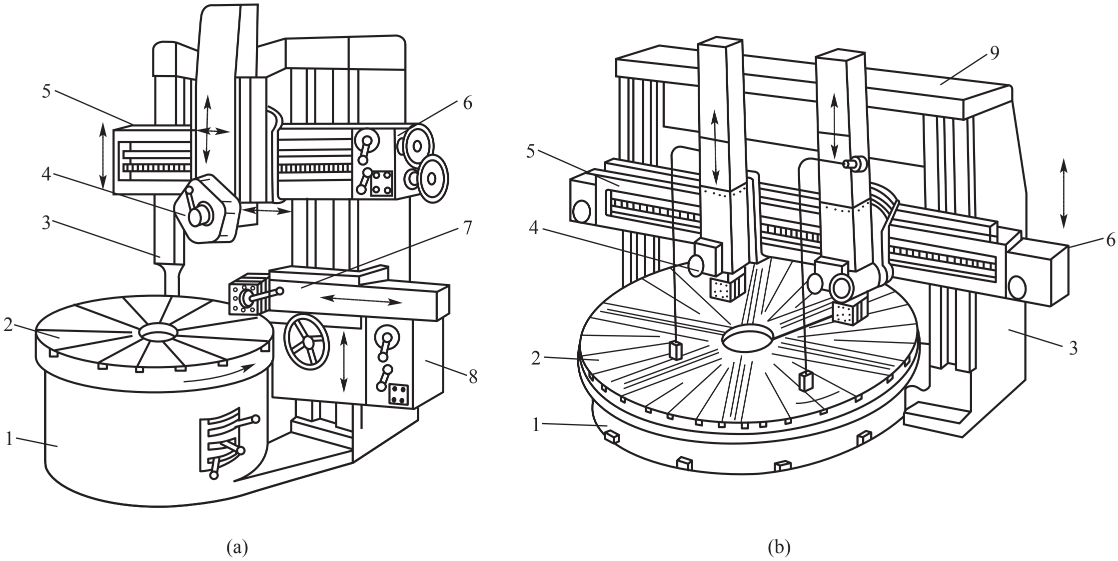
Construct of power-operated tool post 电动刀架结构

1，9，10，11 – gear 齿轮　2 – planet gear 行星齿轮　3 – rotary wheel 滚轮　4 – lock senor 锁紧传感器　5 – electromagnet 电磁铁　6 – pre-dividing sensor 预分度传感器　7 – insert pin 插销　8 – spindle 主轴　12 – pulse generator 脉冲发生器



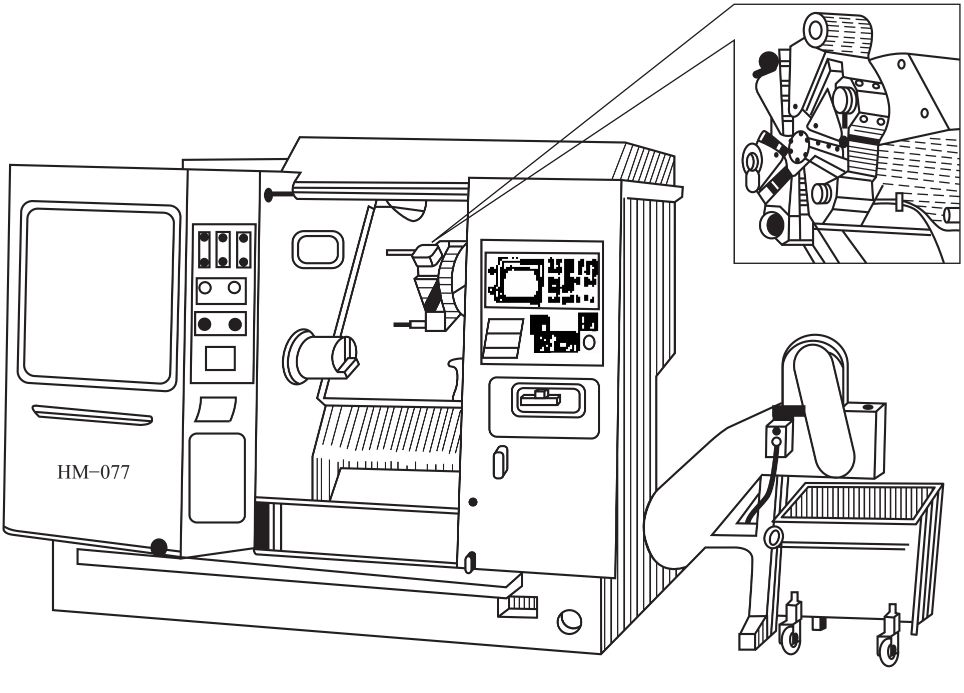
Construct of tailstock 尾座结构

1 – lock handle for tailstock 尾座锁紧手柄　2 – centre 顶针　3 – lock handle for centre 顶针锁紧手柄　4 – leadscrew 螺杆　5 – bush 套筒　6 – leadscrew nut 丝杠螺母　7 – handwheel 手轮　8 – base 尾座体　9 – connecting plate 连接底板　10 – adjustment screw for taper turning 车削锥度调节螺钉　11 – clamping plate 固定夹板

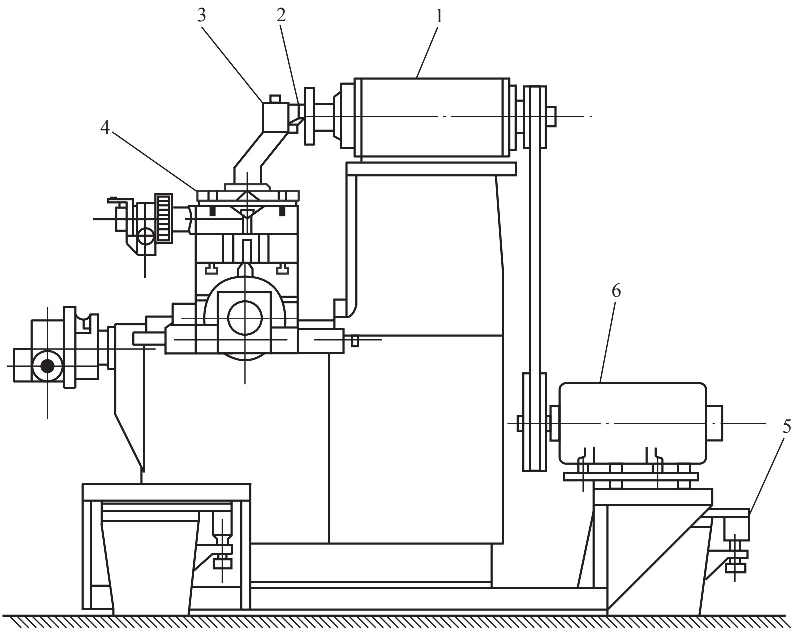


Layout of vertical lathe 立式车床

(a) single head 单头刀架 (b) double heads 双头刀架
1 - bed 底座 2 - worktable 工作台 3 - colunm 立柱 4 - vertical tool head 垂直刀架
5 - cross rail 横梁 6 - feed box 进给箱 7 - side tool post(head)侧刀架
8 - feed box for side head 侧刀架进给箱 9 - arch 顶梁



Layout of horizontal NC lathe 卧式数控车床外形



Moore precision lathe 摩尔精密车床

1 – spindle supported by air bearing 空气轴承主轴　2 – diamond tool 金刚石刀具
3 – tool holder 刀具夹持器　4 – precision rotary 精密回转台
5 – air cushion 气垫　6 – motor 电动机

Reading Materials

Passage 1: The Lathe

The lathe is one of the most useful and versatile machines in the workshop, and is capable of carrying out a wide variety of machining operations. The main components of the lathe are the headstock and tailstock at opposite ends of a bed, and a tool-post between them, which holds the cutting tool. The tool-post stands on a cross-slide which enables it to move sideward across the saddle or carriage as well as along it, depending on the kind of job it is doing.

The ordinary center lathe can accommodate, only one tool at a time on the tool-post, but a turret lathe is capable of holding six or more tools on the revolving turret. The lathe bed must be very solid to prevent the machine from bending or twisting under stress.

The headstock incorporates the driving and gear mechanism, and a spindle which holds the workpiece and causes it to rotate at a speed which depends largely on the diameter of the workpiece. A bar of large diameter should naturally rotate more slowly than a very thin bar, the cutting speed of the tool is what matters. Tapered centres in the hollow nose of the spindle and of the tailstock hold the work firmly between them. A feed-shaft from the headstock drives the tool-post along the saddle, either forwards or backwards, at a fixed and uniform speed. This enables the operator to make accurate cuts and to give the work a good finish. Gears between the spindle and the feed-shaft control the speed of rotation of the shaft, and therefore the forward or backward movement of the tool-post. The gear, which the operator will select, depends on the type of metal, which he is cutting, and the amount of metal he has to cut off. For a deep or roughing cut the forward movement of the tool should be less than for a finishing cut. Centers are not suitable for every job on the lathe. The operator can replace them by various types of chucks, which hold the work between jaws, or by a front-plate, depending on the shape of the work and the particular cutting operation. He will use a chuck, for example, to hold a short piece of work, or work for drilling, boring or screw-cutting. A transverse movement of the tool-post across the saddle enables the tool to cut across the face of the workpiece and give it a flat surface.

For screw cutting, the operator engages the leadscrew, a long screwed shaft which runs along in front of the bed and which rotates with the spindle. The lead-screw drives the tool-post, forwards along the carriage at the correct speed, and this ensures that the threads on the screw are of exactly the right pitch. The operator can select different gear speeds, and this will alter the ratio of spindle and leadscrew speeds and therefore alter the pitch of the threads. A reversing lever on the headstock enables him to reverse the movement of the carriage and so bring the tool back to its original position.

Passage 2: Lathe Chuck

Lathe chuck consists of a body with inserted workholding jaws that slide radially in slots and are actuated by various mechanisms such as screws, scrolls, levers, and cams, alone or in a variety of combinations. The number of jaws varies. Chucks in which all the jaws move together are self centering and are used primarily for round work. Two-jaw chucks operate somewhat like a vise, and may be used for round and for irregular shaped workpieces by the use of suitably shaped jaws or jaw inserts.

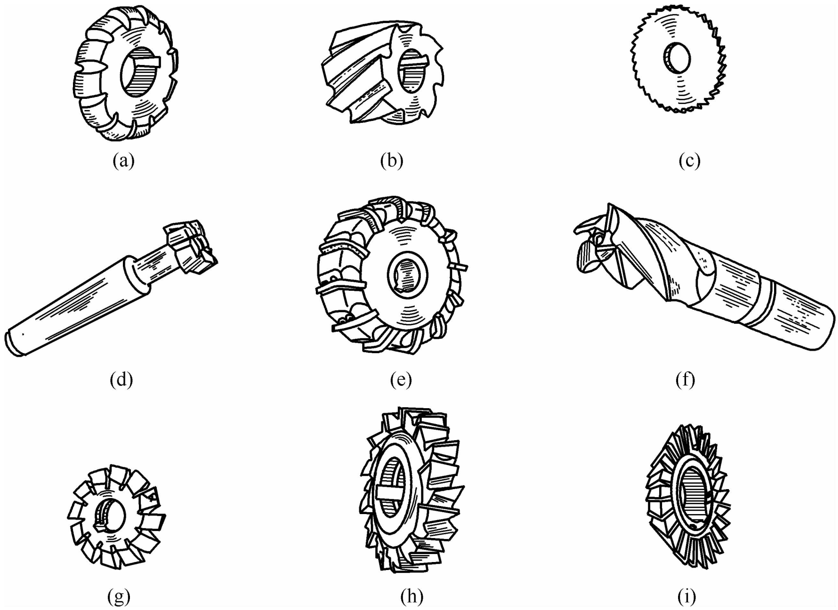
The accuracy of a chuck deteriorates with usage owing to wear, dirt, and deformation caused by excessive tightening. Independent jaw chucks permit each jaw to move independently for chucking irregular-shaped workpieces or to center a round workpiece.

The jaws of most lathe chucks can be reversed to switch from external to internal chucking. Jaws may be adapted to fit workpiece shapes that are not round. The means of attaching a lathe chuck to different machine tools have been well standardized, so that chucks made by different manufacturers can be easily interchanged.

In addition to their standard jaws, lathe chucks may also be fitted with a variety of special purpose jaws to accommodate different types of workpiece surfaces and configurations. The principal types of chuck jaws used for these purposes are called softjaws and are generally made of cast aluminum.

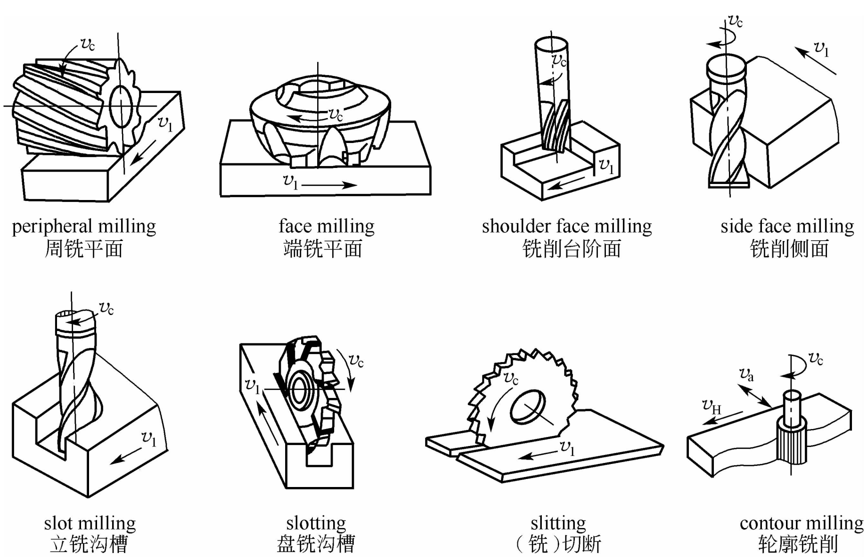
3.2 Milling and Boring 铣削、镗削加工及其装备

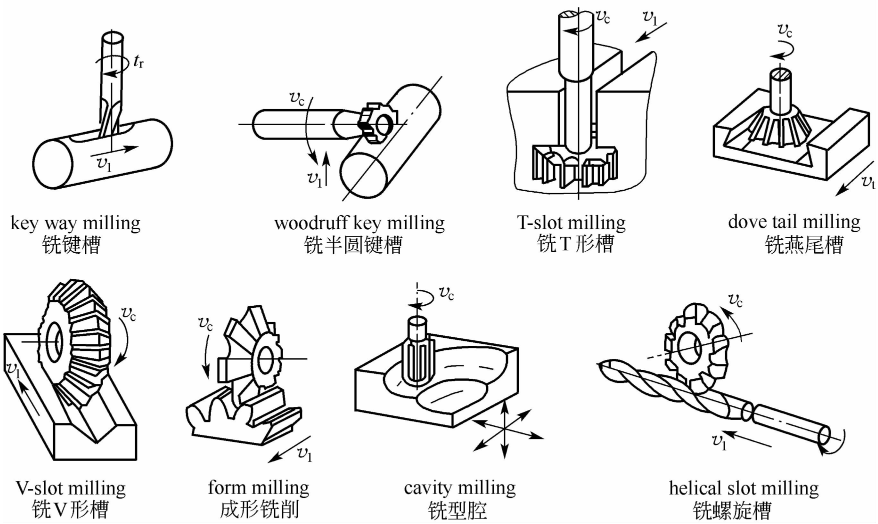
Milling Process 铣削加工



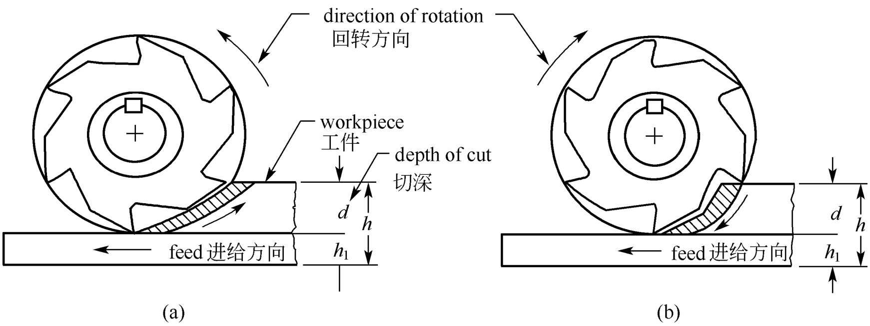
Various types of milling cutters 各种形式的铣刀

（a）form relieved circular cutter 铲背圆弧成形铣刀 （b）helical peripheral cutter 螺旋圆周铣刀
（c）slitting saw cutter 锯切铣刀 （d）shell end milling cutter 整体端面铣刀 （e）face cutter 端面铣刀
（f）multi flute end milling cutter 多槽端铣刀 （g）angle milling cutter 角度铣刀
（h）staggered tooth cutter 交错齿铣刀 （i）angle milling cutter 角度铣刀



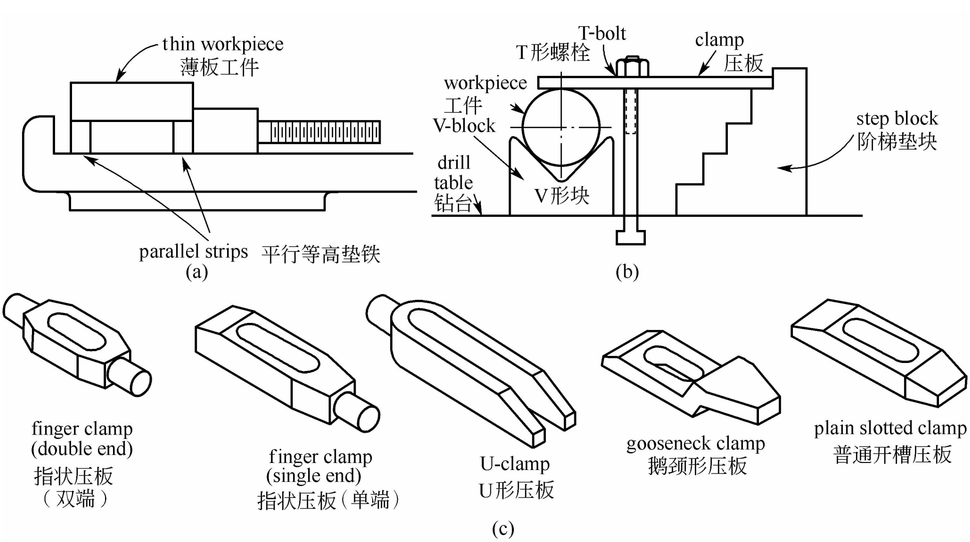


Operations on milling process 铣削加工应用类型

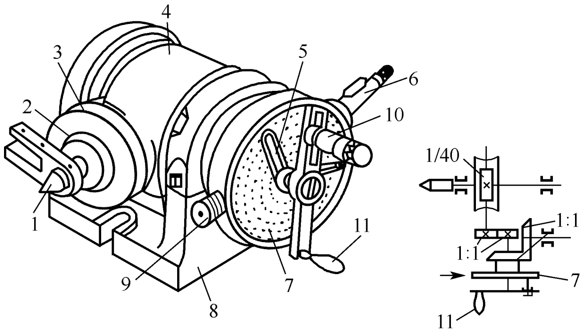


Up milling and down milling 逆铣和顺铣

（a）up milling 逆铣 （b）down milling 顺铣



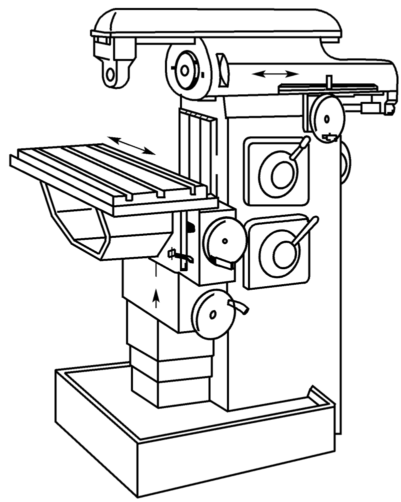
Various clamps for milling machine 铣床夹具和多种压板



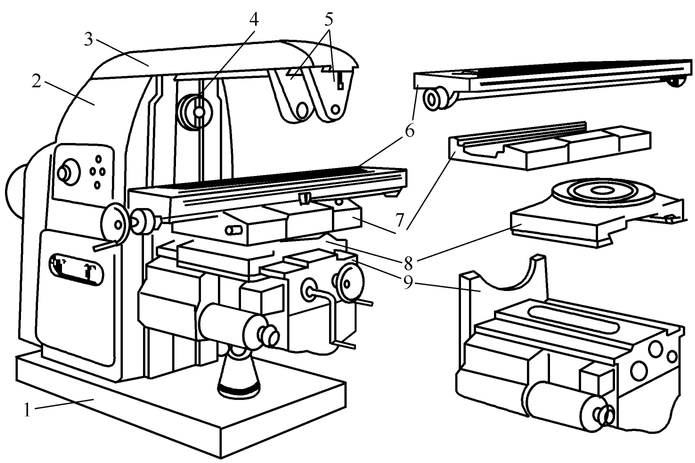
(a)　　(b)

Dividing head　分度头

1 - centre 顶针　2 - index head spindle 分度头主轴　3 - dial plate 刻度盘　4 - shell body 壳体　5 - sector arm 分度叉　6 - protrude spindle 外伸轴　7 - index plate 分度盘　8 - base 基座　9 - lock screw 锁紧螺钉　10 - index pin 插销　11 - handle 分度头手柄

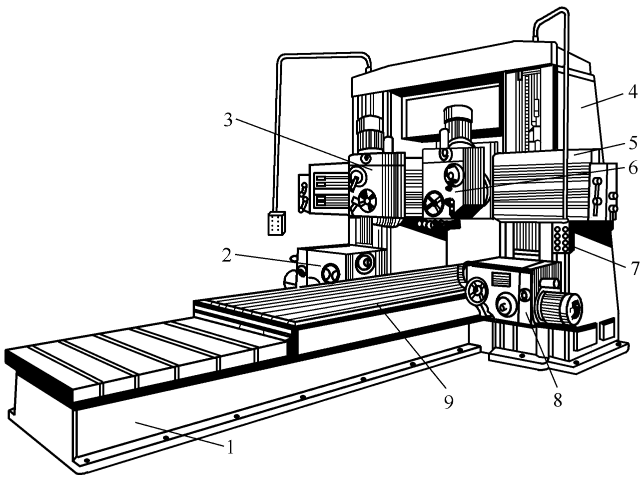


Multi-purpose tool milling machine
万能工具铣床



Horizontal knee and column type milling machine 卧式升降台铣床

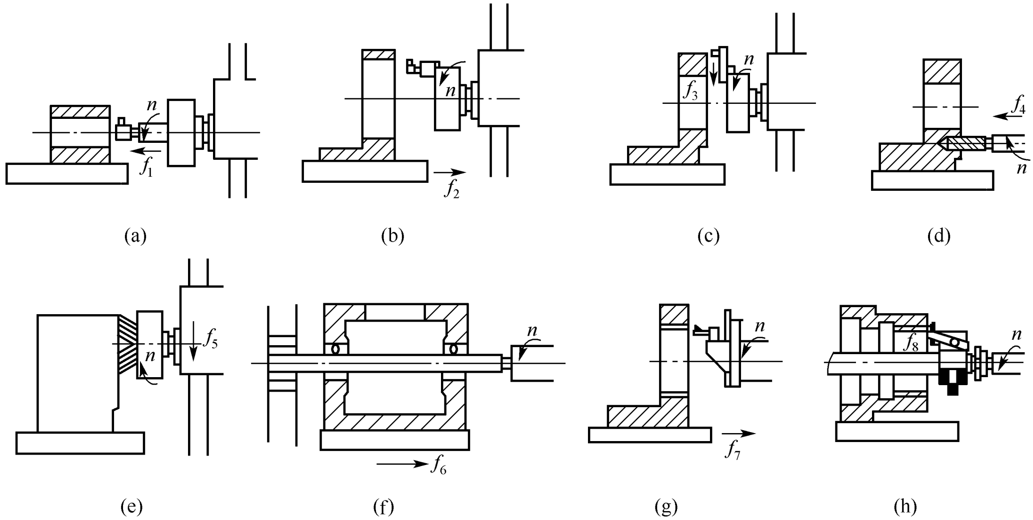
1 - base 基座　2 - vertical column 立柱　3 - overarm 悬梁　4 - spindle 主轴　5 - support frame 支架　6 - T slot table T 槽工作台　7 - rotary base 回转座　8 - saddle 床鞍　9 - knee 升降台



H-frame milling machine 龙门铣床结构

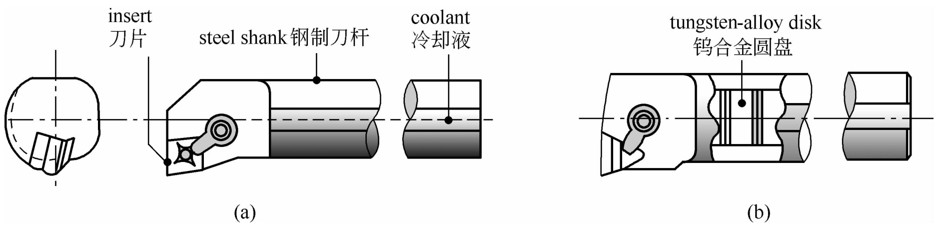
1 - bed 床身　2，8 - horizontal milling head 卧式铣头
3，6 - vertical milling head(spindle carrier)立式铣头(主轴箱)
4 - column 立柱　5 - beam 横梁　7 - manual
panel 操控箱　9 - table 工作台

Boring Process 镗削加工

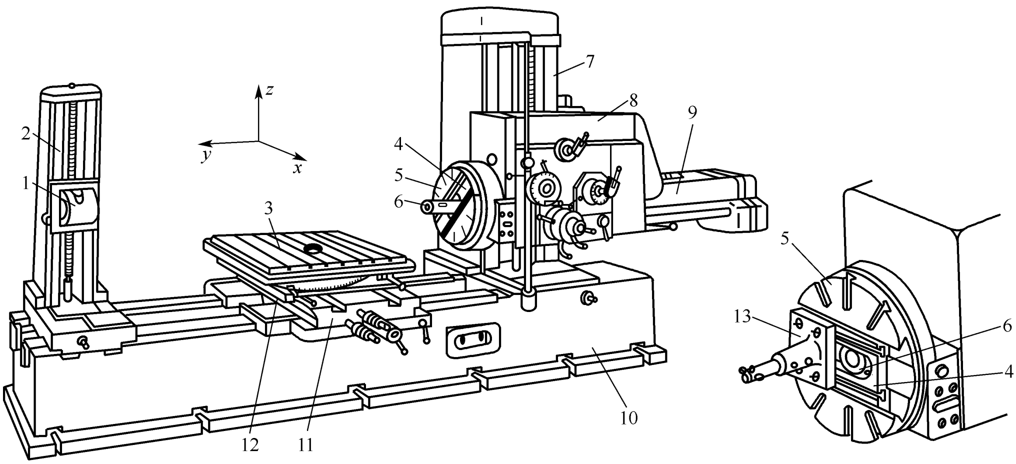


Main operations for horizontal boring machine 卧式镗床主要加工方法

(a) boring with boring bar 镗刀杆镗孔　(b) boring large hole with rotary plate 平旋盘镗大孔
(c) face cutting with rotary plate 平旋盘切端面　(d) drilling 钻孔　(e) face milling
铣刀铣端面　(f) two hole boring with bar on rear column 利用后立柱双孔同时镗
(g) threading 加工螺纹　(h) internal groove cutting 加工内孔沟槽

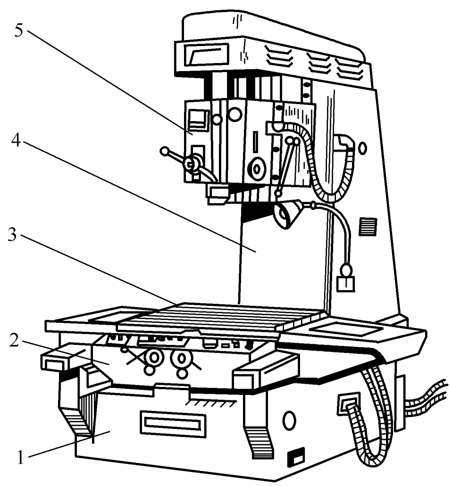


Boring bar structure 镗刀杆结构



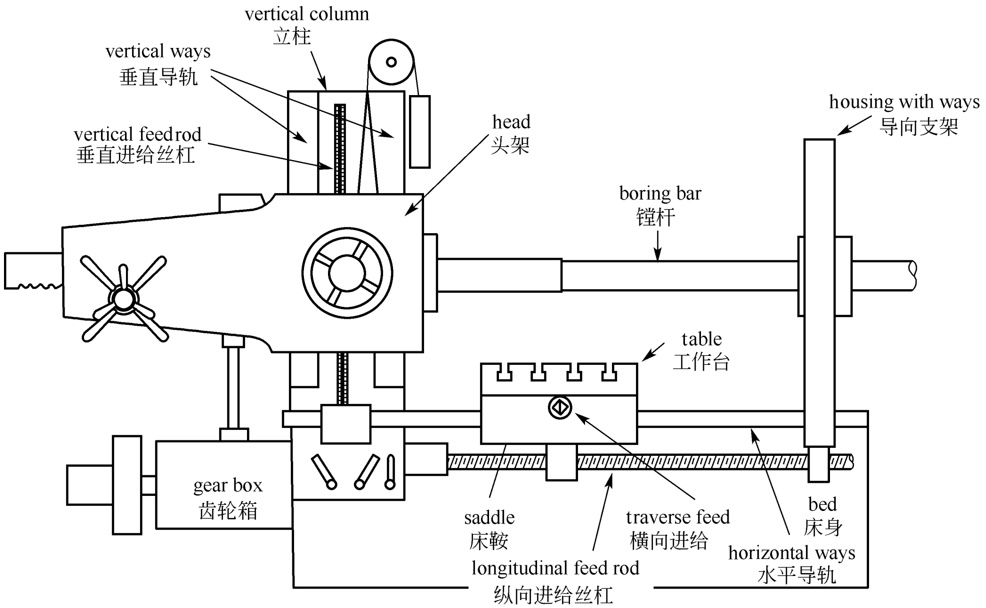
Structure of horizontal boring machine 卧式镗床结构

1 - housing with ways 活动支架　2 - rear column(pillar)后立柱　3 - table 工作台　4 - radial tool holder 径向刀架　5 - rotary plate 平旋盘　6 - spindle 主轴　7 - front column 前立柱　8 - spindle box 主轴箱　9 - rear cover 后尾筒　10 - bed 床身　11 - lower saddle 下滑座　12 - upper saddle 上滑座　13 - tool base 刀座



Vertical simplex column coordinate boring machine 立式单轴坐标镗床

1 - base 底座　2 - slide saddle 滑座　3 - table 工作台
4 - column 立柱　5 - spindle box 主轴箱



Schematic diagram of boring machine 镗床图解

Reading Materials

Passage 1: Milling Process and Milling Cutter

Milling is a basic machining process by which a surface is generated by progressive chip removal. The workpiece is fed into a rotating cutting tool. Sometimes the workpiece remains stationary, and the cutter is fed to the work. In nearly all cases, a multiple-tooth cutter is used so that the material removal rate is high. Often the desired surface is obtained in a single pass of the cutter or work, and because very good surface finish can be obtained, milling is particularly well suited and widely used for mass-production work. Many types of milling machines are used, ranging from relatively simple and versatile machines that are used for general-purpose machining in job shops and tool-and-die work on highly specialized machines for mass production. Unquestionably, more flat surfaces are produced by milling than by any other machining process.

The cutting tool used in milling is known as a milling cutter. Equally spaced peripheral teeth will intermittently engage and machine the workpiece. This is called interrupted cutting.

Milling operations can be classified into two broad categories called peripheral milling and face milling. Each has many variations. In peripheral milling the surface is generated by teeth located on the periphery of the cutter body. The surface is parallel with the axis of rotation of the cutter. Both flat and formed surfaces can be produced by this method, the cross section on the resulting surface corresponding to the axial contour of the cutter. This process, often called slab milling, is usually performed on horizontal spindle milling machines.

There are two modes of operation for milling cutters. In conventional (up) milling the workpiece motion opposes the rotation of the cutter, while in climb (down) milling the rotational and feed motions are in the same direction. Climb milling is preferred wherever it can be used since it provides a more favorable metal-cutting action and generally yields a better surface finish. Climb milling requires more rigid equipment and there must be no looseness in the workpiece feeding mechanism since the cutter will tend to pull the workpiece.

Index milling cutters have precision ground carbide inserts positioned around the cutter body and are held in pins or wedges which can be released for indexing. Some milling cutters may have either profile-sharpened or form-relieved teeth. Profile-sharpened cutters are those, which are sharpened on the relief surface using a conventional cutter grinding machine. Form-relieved cutters are made with uniform radial relief behind the cutting edge. They are sharpened by grinding the face of the teeth. The profile style provides greater flexibility in adjusting relief angles for the job to be done, but it is necessary that any form on the cutter be reproduced during each resharpening. In the form-relieved style, the relief angle cannot be changed since it is fixed in the manufacture of the cutter. However, the form-relieved construction is well adapted to cutters with intricate profiles since the profile is not changed by resharpening.

Most large milling cutters are provided with an axial hole for mounting on an adapter or arbor, and usually have a drive key slot. Certain small-diameter cutters and some cutters for specialized applications are made using an integral shank construction where the cutting section is at the end of a straight or tapered shank which fits into the machine tool spindle or adapter. Also, some large facing cutters are designed to mount directly on the machine tool spindle nose.

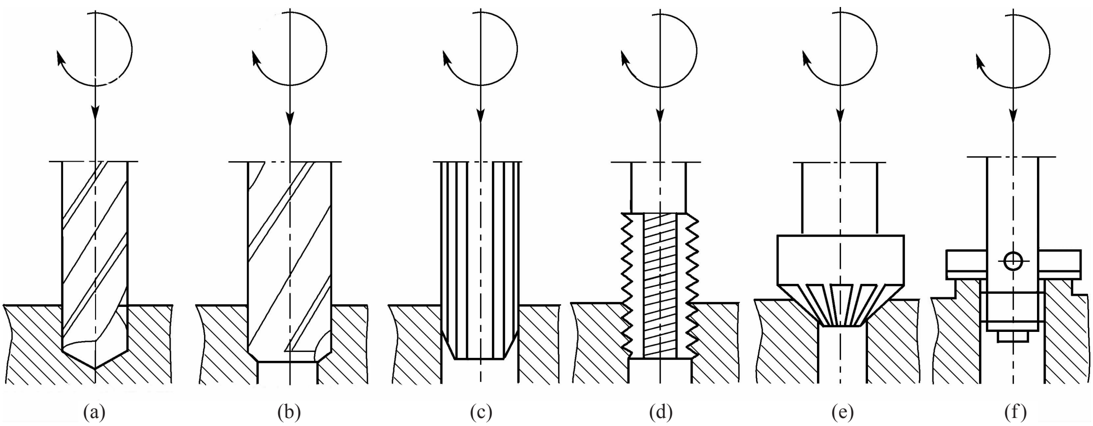
Passage 2: Boring

Boring is an operation of enlarging a hole. Generally the single point tool bit is mounted in the boring bar of suitable diameter commensurate with the diameter to be bored. The overhang of the tool is to be made as small as possible to reduce the chatter which is very common in boring.

The workpiece where a hole is already existing is mounted on the table of a horizontal boring machine. The table of a horizontal boring machine has accurate guideways to move the table in two perpendicular directions (X and Y in horizontal plane). Generally heavy workpieces and heavy bores which are difficult to be handled in drilling machines are bored in horizontal boring machines. A drilled hole, which is not properly located, can be made concentric with the axis of rotation of the spindle by the boring operation. It is also possible to carry out the boring operation in a lathe for limited applications while in drilling and milling machines a large range of holes can be bored using the multiple point cutting tools in addition to the single point tool as explained earlier. Boring with a single point cutting tool being a semi-finishing operation, very small amount of stock is left out to be removed.

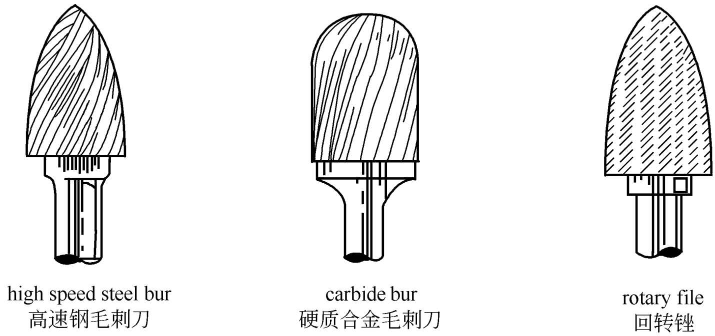
The major problem of boring with a boring bar with a single point turning tool is the lack of rigidity of the boring bar. The size of the boring bar is dictated by the size of the hole to be bored, while its length depends upon the geometry of the hole. A simple boring bar whose length equals five times its diameter would be suitable for the required purpose. However beyond this length, chatter becomes predominant reducing the finish of the hole produced. It is necessary to use special damped boring bars for boring bars above this range.

3.3 Drilling and Reaming Processes 钻削、铰削加工及其装备

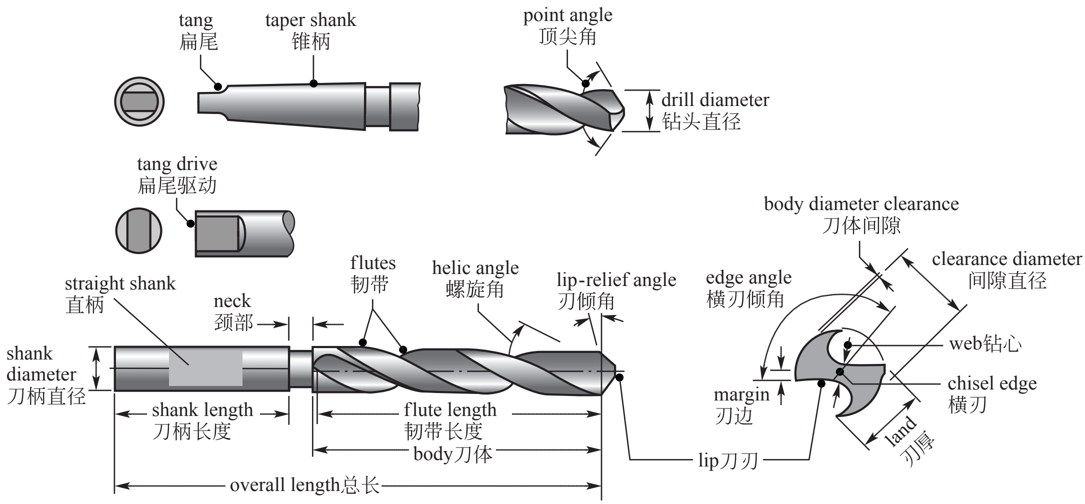


Operations on a drilling machine 钻床加工类型

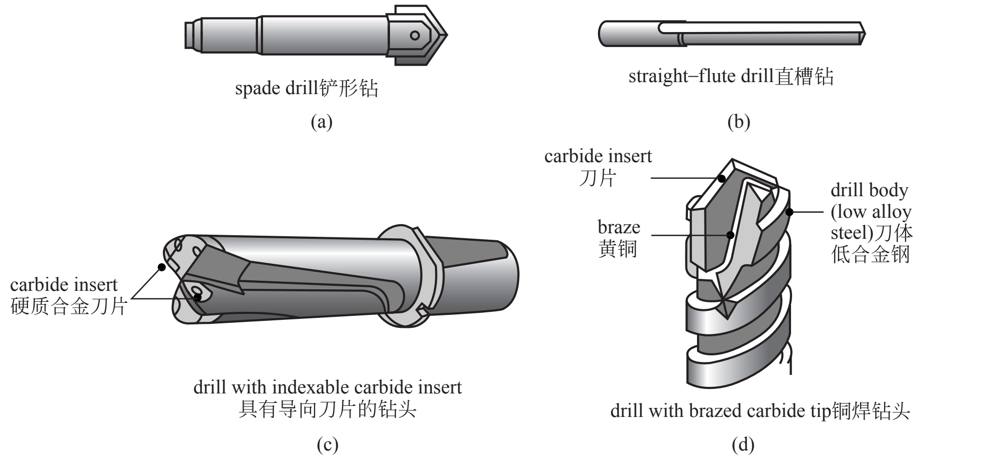
(a) hole drilling 钻孔 (b) core drilling 扩孔 (c) reaming 铰孔 (d) threading 攻螺纹
(e) counter sinking 锪锥孔 (f) spot facing 锪端面



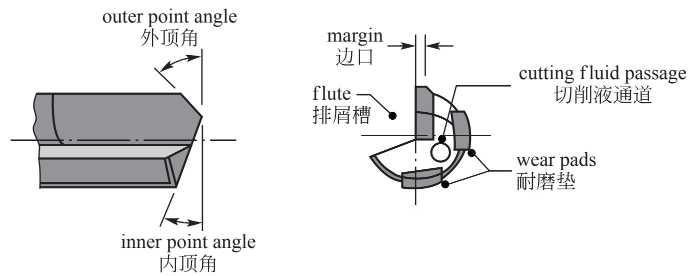
Various types of burs 去毛刺刀类别



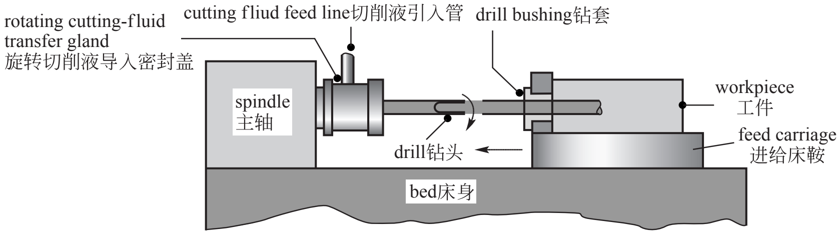
Structure of twist drill 麻花钻结构



Various types of drills 钻头种类

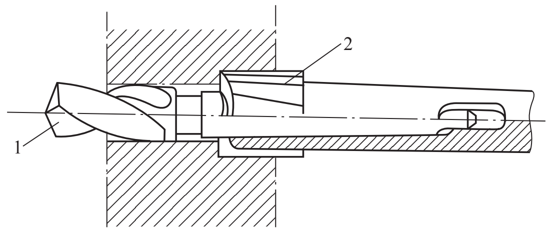


(a)



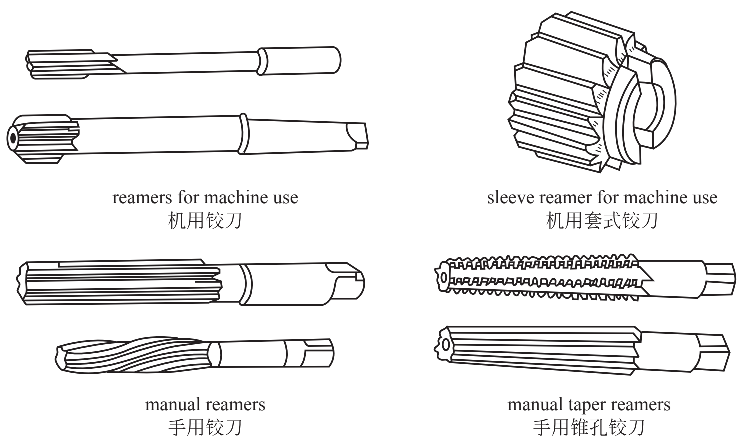
(b)

A gun drill features and gun-drilling operation 枪钻特点及其加工应用

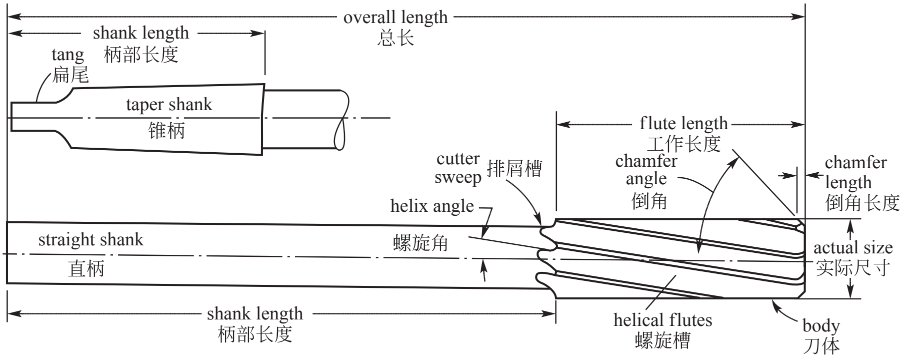


Complex tool for drilling and enlarging 钻-扩复合刀具

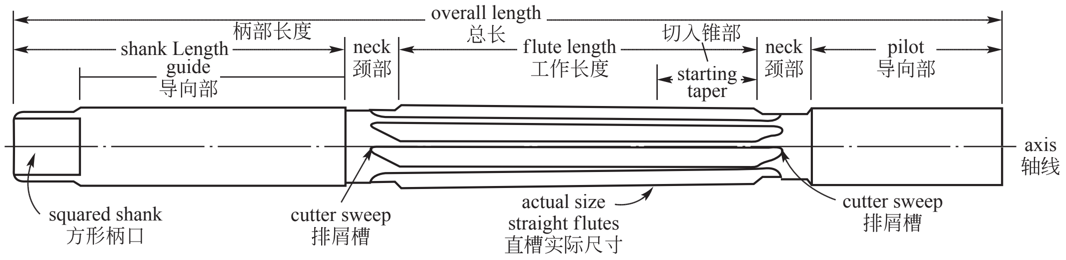
1 – twist drill 麻花钻头 2 – enlarging tool 扩孔刀



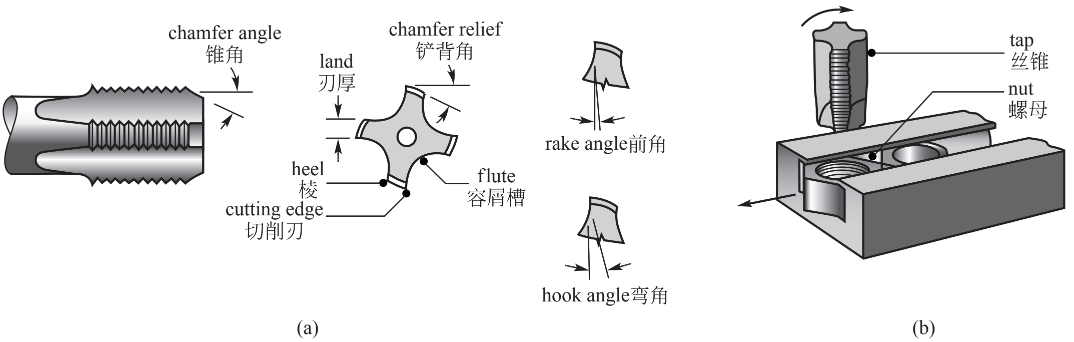
Types of reamers 铰刀种类



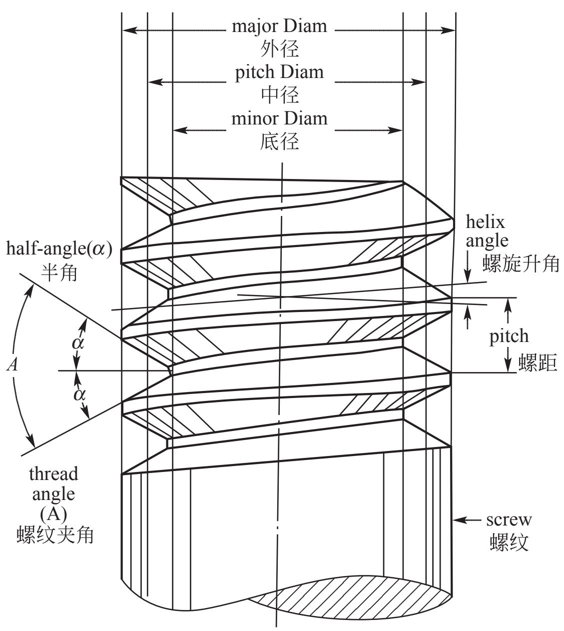
Chuck reamer with straight or taper shank 卡夹式机用直柄或锥柄铰刀



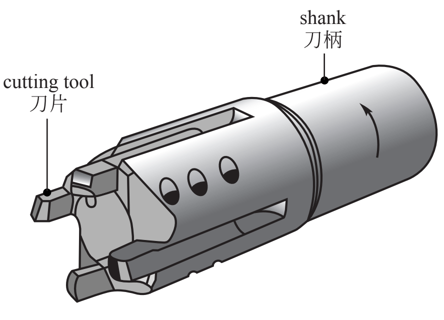
Head reamer with pilot and guide 手动导向铰刀

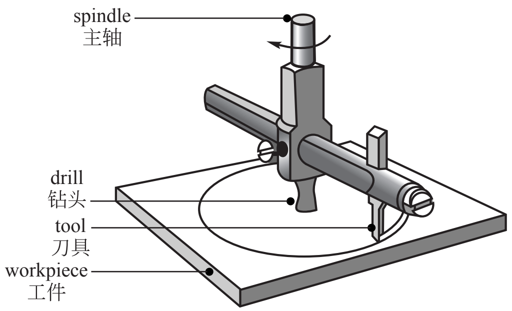


Terminology of a taper and tapping of steel nuts 丝锥术语及钢制螺母攻丝



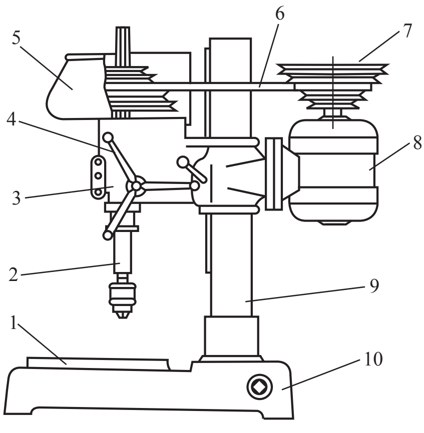
Terminology of screw 螺纹术语





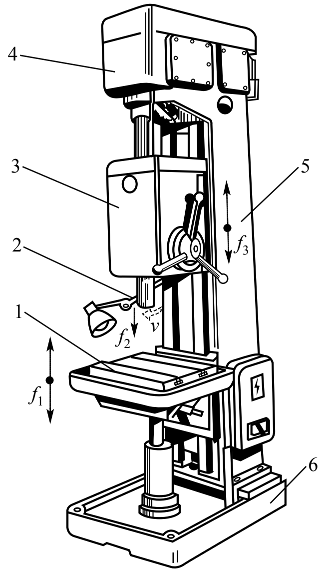
Trepanning machining 套料加工刀具

（a）trepanning tool 套料刀 （b）trepanning with a drill-mounted single cutter 钻头安装单刀套料加工



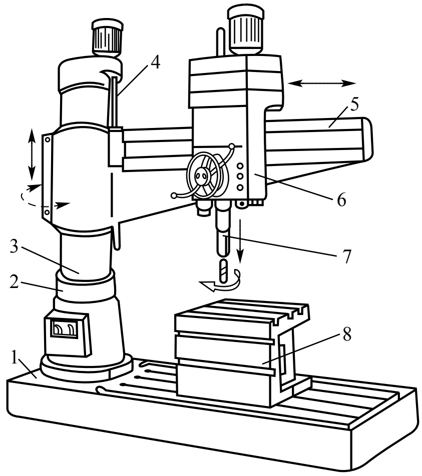
Drill press used on bench 台式钻床

1 – table 工作台 2 – spindle 主轴 3 – spindle box 主轴箱 4 – feed hand wheel 进给手轮 5 – safety cover 安全护罩 6 – V-belt 三角带 7 – pulley 皮带轮 8 – motor 电动机 9 – vertical column 立柱 10 – base 底座



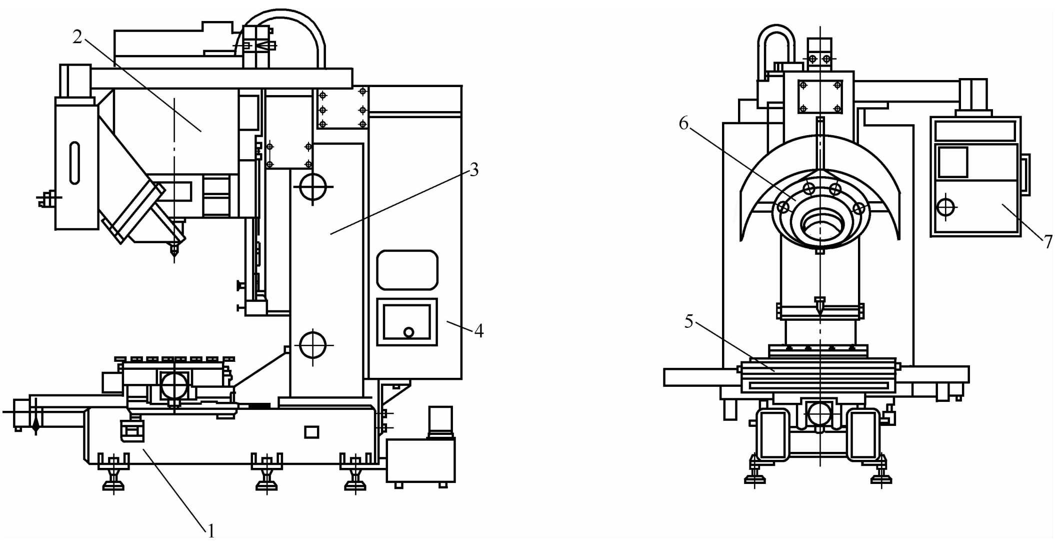
Vertical drill press 立式钻床

1 – table 工作台 2 – spindle 主轴 3 – feed box 进给箱 4 – gear box 主轴箱 5 – vertical column 立柱 6 – base 底座



A radial drilling machine 摇臂钻床

1 – base 底座　2 – external column 外立柱　3 – internal column 内立柱　4 – leadscrew for radial arm moving up/down 摇臂升降丝杠　5 – radial arm 摇臂　6 – spindle box 主轴箱　7 – spindle 主轴　8 – table 工作台



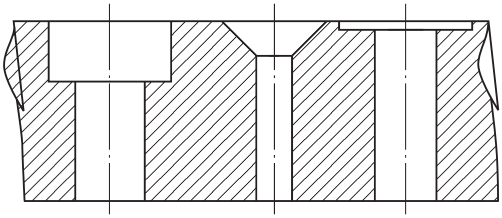
Numerical control drilling center 数控钻削中心

1 – bed 床身　2 – spindle box 主轴箱　3 – vertical column 立柱　4 – electrical control case 电控箱　5 – X-Y table X-Y 工作台　6 – turret 转塔刀库　7 – manual panel 操控面板

Reading Materials

Passage 1:　Other Hole Making Operations

Counter boring　Already existing holes in the components can be further machined by counter boring. The counter boring can be done by a tool similar to the shell end mill with the cutting edges present along the side as well as the end while a pilot portion is present for the tool to enter the already machined hole to provide the concentricity with the hole. In the counter boring operation, the hole is enlarged with a flat bottom to provide a proper seating for the bolt head or a nut, which is flushed from the outer surface.



Spot facing Spot facing is similar to counter boring, but removes only a very small portion of material around the existing hole to provide a flat surface square to the hole axis. This is normally done to provide a bearing surface for a washer or a nut or the head of a bolt. This has to be done only in case where the existing surface is not smooth. The tool used can be same as that for counter boring.

Counter sinking Counter sinking is also similar to counter boring, except that the additional machining done on a hole is conical to accommodate the counter sunk machine screw head. Again the depth of counter sinking should be large enough to accommodate the screw head to fully flush with the surface.

Passage 2: Reaming

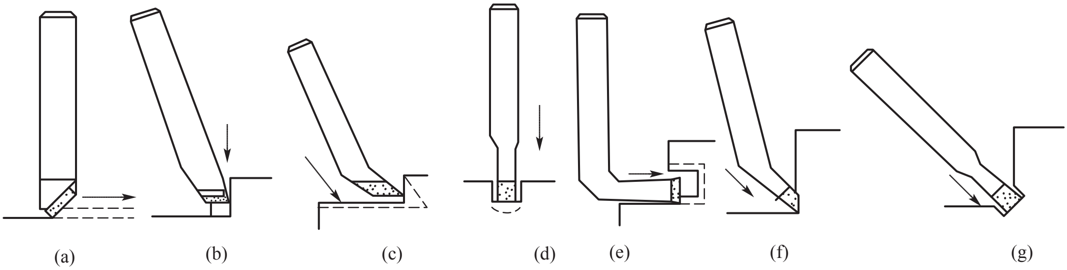
Jig design for reaming is basically the same as for drilling, whose difference is the need to hold closer tolerances on the jigs and bushings, and provide additional support to guide the reamer. For long holes, it is essential to guide the reamer at both ends, using special piloted reamers designed for this purpose. Jigs should be designed so that the pilot enters the bushing before the reamer enters the workpiece, and remains piloted until the reaming operation is completed. For short holes, the reamer is usually guided at one end, with the bushing sized to fit the outer diameter of the reamer. Additionally, bushings for reaming are generally longer than for drilling, usually three or four times the reamer diameter. Chip clearance is also generally less for reaming than for drilling, varying from one-fourth to one-half the tool diameter down to a maximum of 0.125～0.24″regardless of the reamer diameter:

Bushing bores must be closely controlled. Bushings that are too small can cause tool seizure and breakage. Bushings that are too large will result in bell-mouthed or out-of-round holes. Data in the Handbook of Jig and Fixture Design can be used, as a guide.

Carbide bushings should be considered for long production runs or where abrasive conditions are present. Roller or ball bearing, rotary-type bushings also provide maximum wear while maintaining close tolerances under high loads.

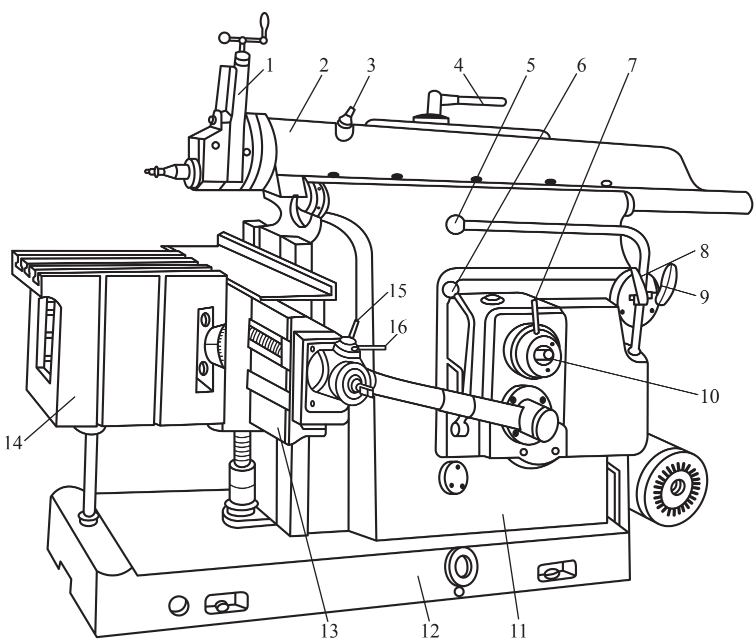
3. 4 Reciprocating Machining Processes 往复式加工

Shaping Process 刨削加工



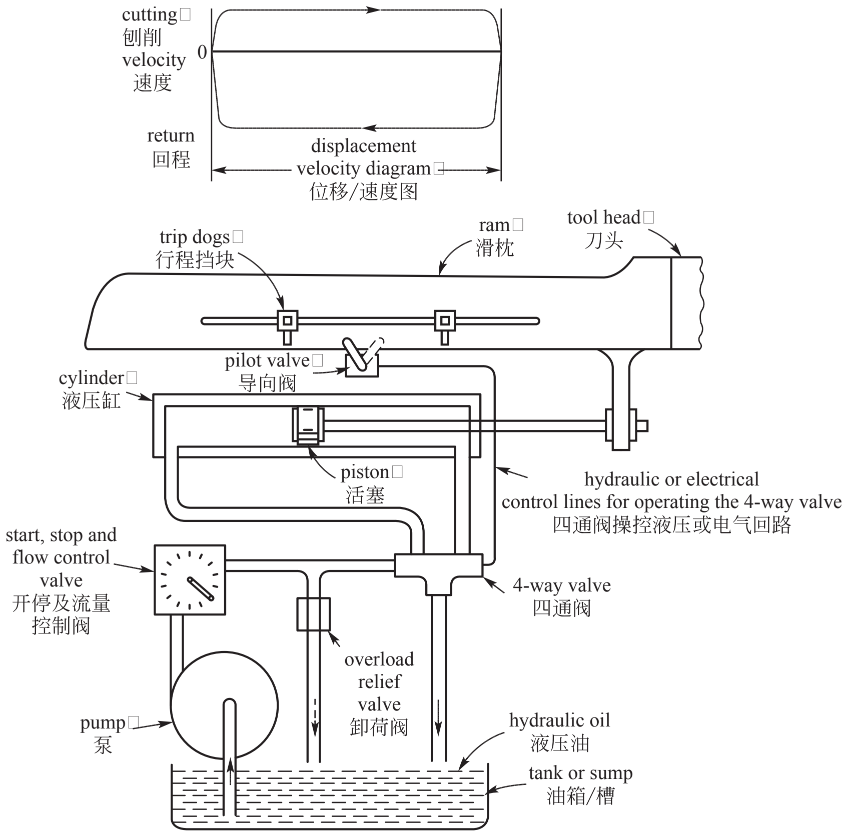
Shaping tools and various shaping types 刨刀与刨削加工类型

（a）flat shaping 刨平面 （b）shoulder shaping 刨台阶 （c）angle shaping 刨角度
（d），（g）slitting shaping 刨沟槽 （e），（f）side slot shaping 刨侧槽

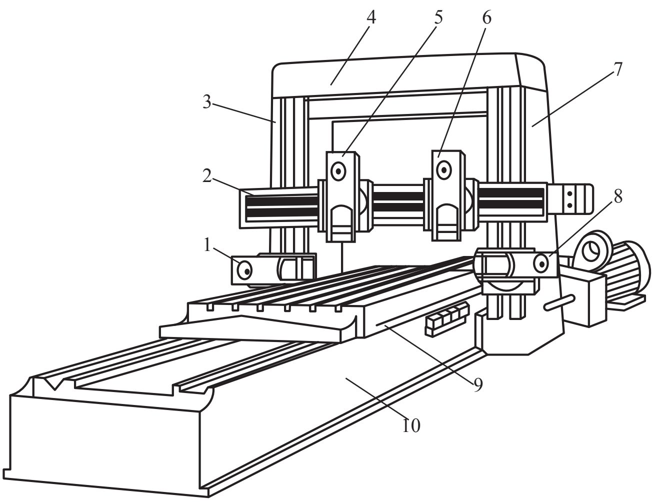


Structure of a shaper 牛头刨床结构

1 - clapper box 刀架 2 - ram 滑枕 3 - crank for positioning the ram 滑枕位置调节手柄 4 - crank for locking 紧定手把 5 - handling crank 操纵手柄 6 - crank for rapid movement of table 工作台快移手把 7 - feed adjusting handle 进给量调节手柄 8，9 - velocity adjustment set 速度调节手柄 10 - stroke handle 行程手柄 11 - bed 床身 12 - base 基座 13 - beam 横梁 14 - table 工作台 15 - handle for table movement direction 工作台移动方向手柄 16 - direction switch handle for feed movement 进给运动换向手柄



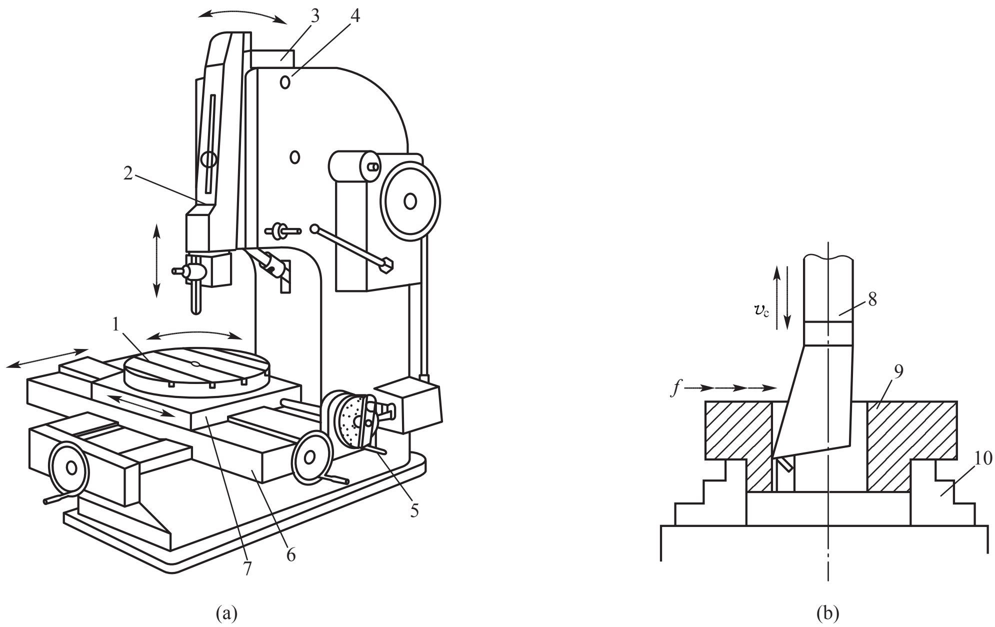
Hydraulic shaper 液压牛头刨床



H-frame construction of a planning machine 龙门刨床结构

1 - left side head 左侧刀架　2 - cross rail 横梁　3 - left column 左立柱　4 - arch 顶梁
5 - left rail head 左垂直刀架　6 - right rail head 右垂直刀架　7 - right column 右立柱
8 - right side head 右侧刀架　9 - table 工作台　10 - bed 床身

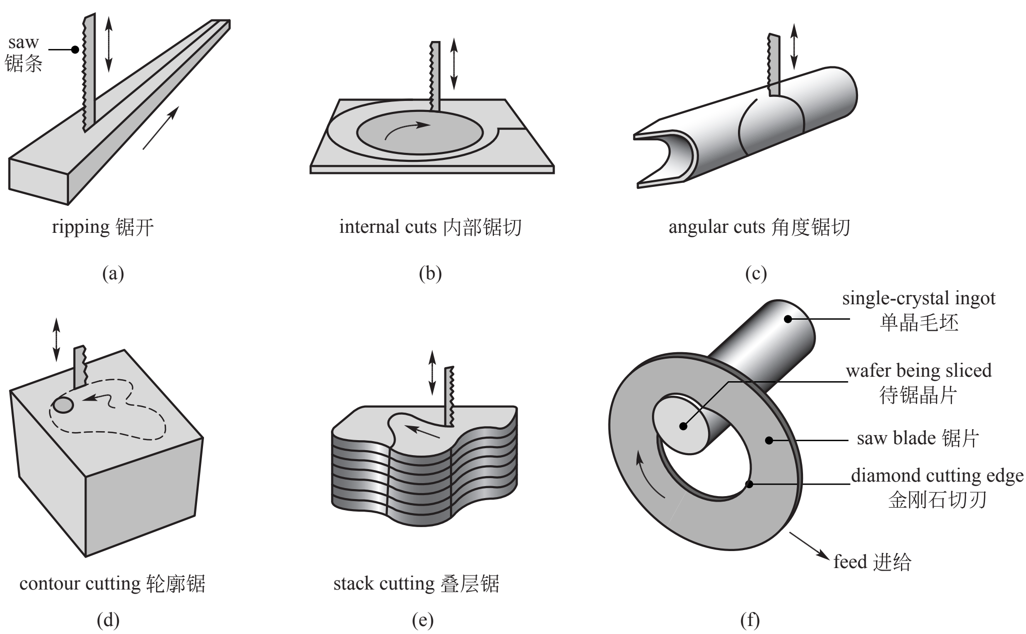
Slotting Process 插削加工



Slotter and slotting process 插床与插削加工

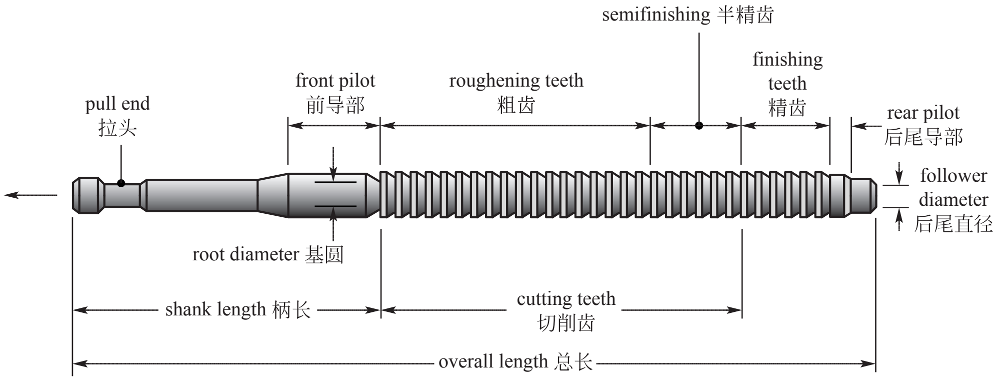
（a）layout of a slotter 插床外形 （b）slotting process for key way 插削键槽

1 - rotary table 回转工作台 2 - vertical ram 立式滑枕 3 - base for ram way 滑枕导轨座
4 - bed 床身 5 - dividing head 分度头 6 - saddle 床鞍 7 - slide 溜板
8 - slotting tool 插刀 9 - workpiece 工件 10 - chuck 卡盘

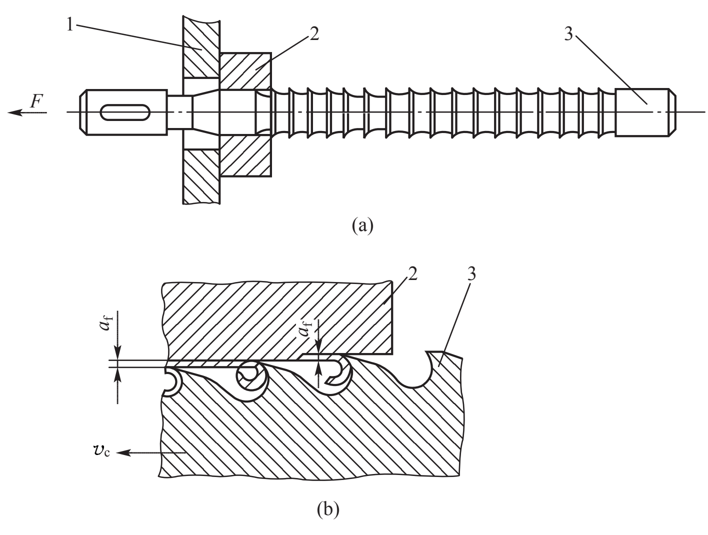


Various examples of sawing operations 锯切操作

Broaching Process 拉削加工

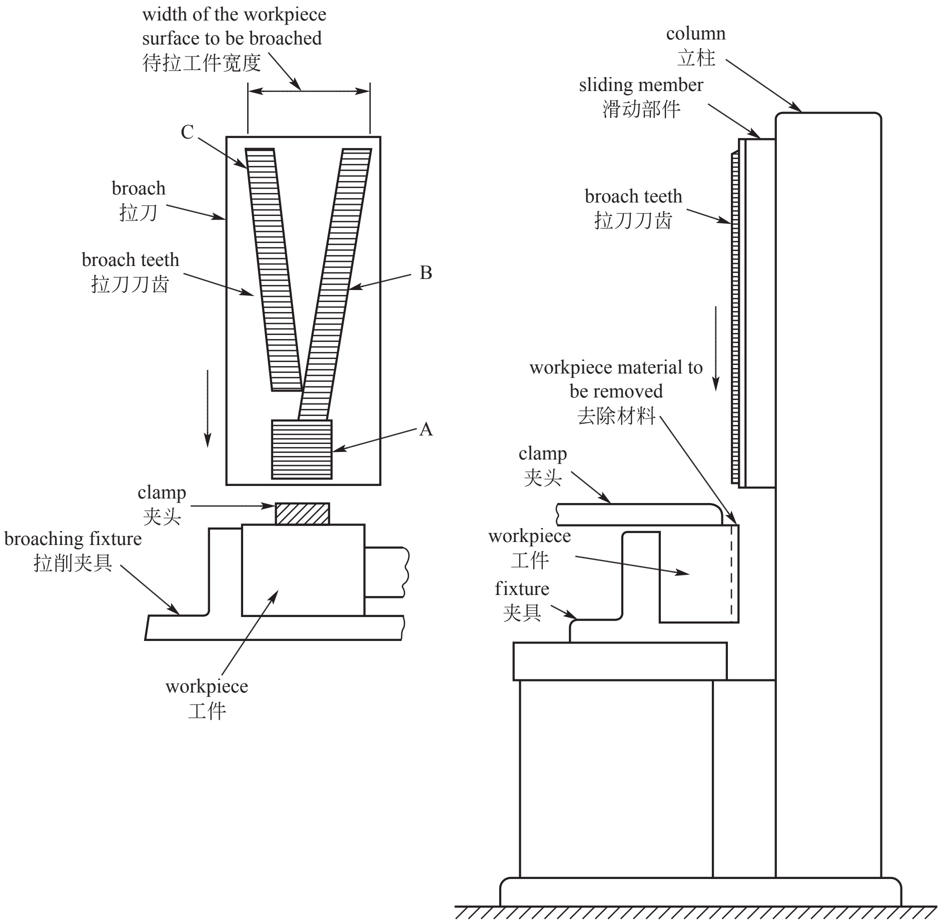


Typical construction of a pull broach 拉刀结构

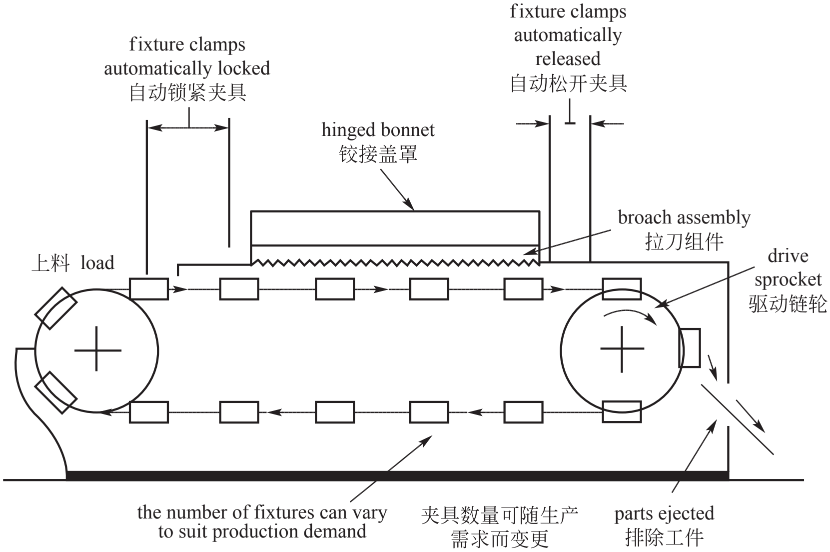


Broach process 拉削过程

1 – choke plate 挡板　2 – workpiece 工件　3 – pull broach 拉刀



A surface broaching machine 平面拉床



Continuous broaching of flats 多个工件平面的连续拉削

Reading Materials

Passage 1: **Shaper**

Shaper is a relatively slow machine tool with very low metal removal capability. Hence it is increasingly being replaced by more versatile milling machines. The shaper is a low cost machine tool used for initial rough machining of the blanks. It is rarely used in production operations. The shaper uses a single point tool similar to a lathe which is clamped to a tool post mounted to a clapper box which in turn is mounted to a reciprocating ram. The ram while undertaking the cutting stroke pushes the cutting tool through the workpiece to remove the material. When the ram returns, no cutting takes place. In between the return and cutting strokes, the table moves in the total direction perpendicular to the cutting direction, which is termed as the feed direction.

The single point cutting tool is clamped in the tool head. The tool head has the ability to swivel the cutting tool in any angle while clamping the tool with any overhang, depending the requirement. The swivelling ability is important for the tool to machine surfaces that are not in a horizontal plane. Further, the tool should be firmly supported during the forward motion to carry out material removal. During the return stroke, the cutting tool will not be doing the cutting and hence will be an idle stroke. If the tool is held firmly as in the cutting stroke, the tool will be rubbing the already machined workpiece and also the flank surface of the tool will wear out quickly. To reduce this, the tool is lifted during the return stroke by the clapper box arrangement.

Passage 2: **Planer**

The planer is very similar to the shaper in terms of the surface that can be generated. A planer is generally used machining large workpiece which can not be held in a shaper. In a shaper the cutting tool reciprocates during the cutting motion, which in the case of a planer the work table reciprocates. The feeding motion in a planer is given to the cutting tool, which remains stationary during the cutting motion.

The tool head in a construction similar to the clapper box of a shaper is mounted on the cross rail. The tool head can be moved along the cross rail for the feeding action while the depth of cut can be controlled by moving the tool downwards. It is possible to mount more than one tool head on the cross rail as well as on the columns on both sides, so that multiple surfaces can be completed simultaneously. This helps in reducing the total machining time since planing is a relatively slow operation like shaping. Like shapers, planers can also be mechanically or hydraulically driven.

Passage 3: **Slotter**

The slotting machine is basically a vertical axis shaper. The workpieces which cannot be conveniently held in a shaper can be machined in a slotter. Generally keyways, splines, serrations, rectangular grooves and similar shapes are machined in a slotting machine. The stroke of the ram is smaller in slotting machines than in shapers to account for the type of the work that is handled in them.

The type of tools used in a slotter is very similar to that of a shaper except that the cutting actually takes place in the direction of cutting. However in view of the type of surfaces that are possible in the case of a slotter, a large variety of boring bars or single point tools along with shanks are used.

Passage 4: Broaching Machines

There are basically four different types of broaching machines such as:

(1) Push broaching machines,

(2) Pull broaching machines,

(3) Surface broaching machines,

(4) Continuous surface broaching machines.

Push broaching machines These are generally used for internal surfaces where the broach movement is guided by a ram. These machines are simple, since the broach only needs to be pushed through the component for cutting and then retracted. The workpiece is fixed into a boring fixture on the table. Even simple arbour presses can be used for push broaching.

Pull broaching machines These are a little more complex in terms of operation. These consist of a work holding mechanism, and a broach pulling mechanism along with a broach elevator to help in the removal and threading of the broach through the workpiece. The workpiece is mounted in the broaching fixture and the broach is inserted through the hole present in the workpiece. Then the broach is pulled through the workpiece completely and the workpiece is then removed from the table. Afterwards the broach is brought back to the starting point before a new workpiece is located on the table. The same cycle is then repeated.

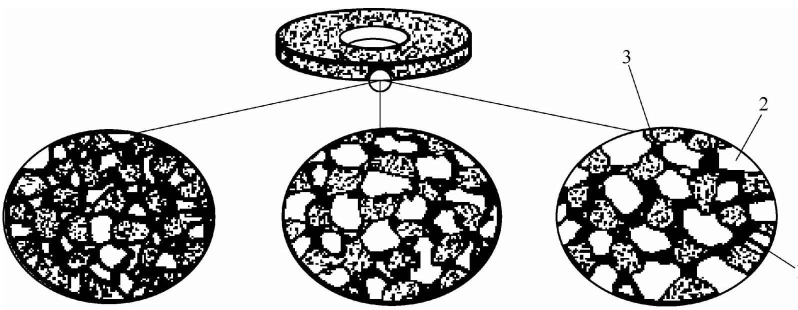
The power for the pulling mechanism and the movement of the broach is generally provided by a hydraulic fluid. Because of the inner surface broaching, it is necessary to remove the broach from the pulling mechanism to thread it through the workpiece hole in every cycle.

Surface broaching machine Surface broaching is relatively simple since the broach can be continuously held and then it will carry out only a reciprocating action. The workpiece is held in the fixture while the surface broach is reciprocated with the ram on the vertical guide-ways on the column. The progressive action surface broach with the teeth segments distributed into three areas A, B and C. The progressive action reduces the maximum broaching force, but results in a longer broach.

Continuous broaching machine The reciprocation of the broach always involves an unproductive return stroke, which is eliminated in a continuous surface broaching machine. In this the small workpieces are mounted on the broaching fixtures which are in turn fixed to a continuously moving conveyor. Broaches which are normally stationary, are kept above the workpieces. The workpieces are pushed past the stationary broaches by means of the conveyor for cutting. The workpieces can be loaded and unloaded onto the conveyor manually or automatically. These machines are used for mass production.

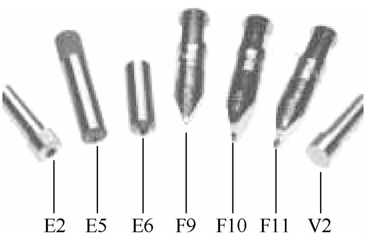
3.5 Abrasives Processes 磨削加工及其装备

Common Abrasive Process 普通磨削加工

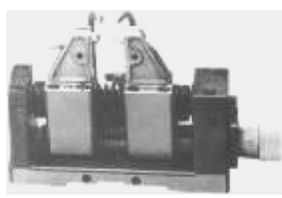


Grinding wheel structure 砂轮组织

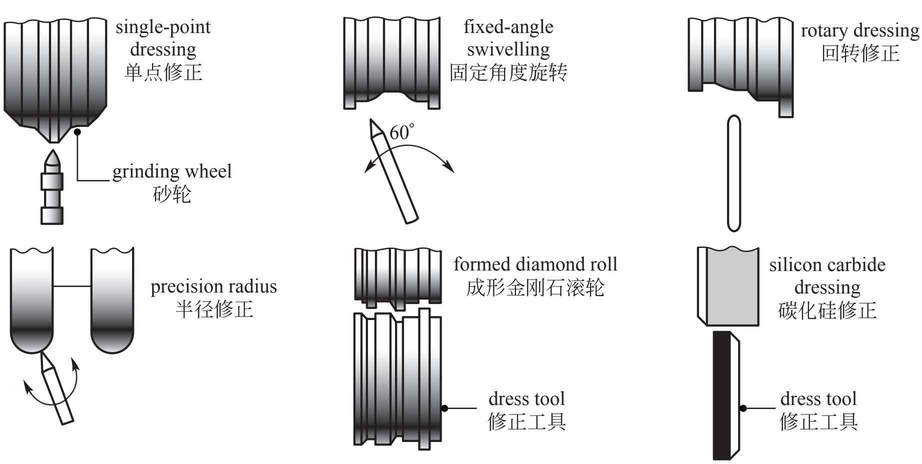
1 – bond 结合剂、粘接剂 2 – grain 磨粒、粒度 3 – porosity 气孔、空隙



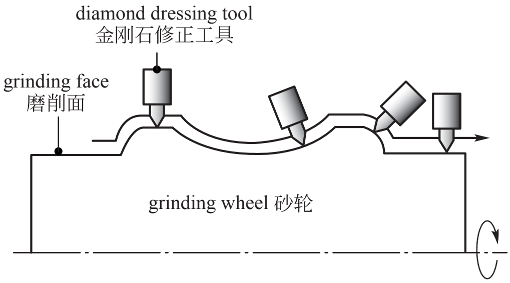
Diamond dressing pen 砂轮修正金刚笔



Wheel dressing set 砂轮修正器

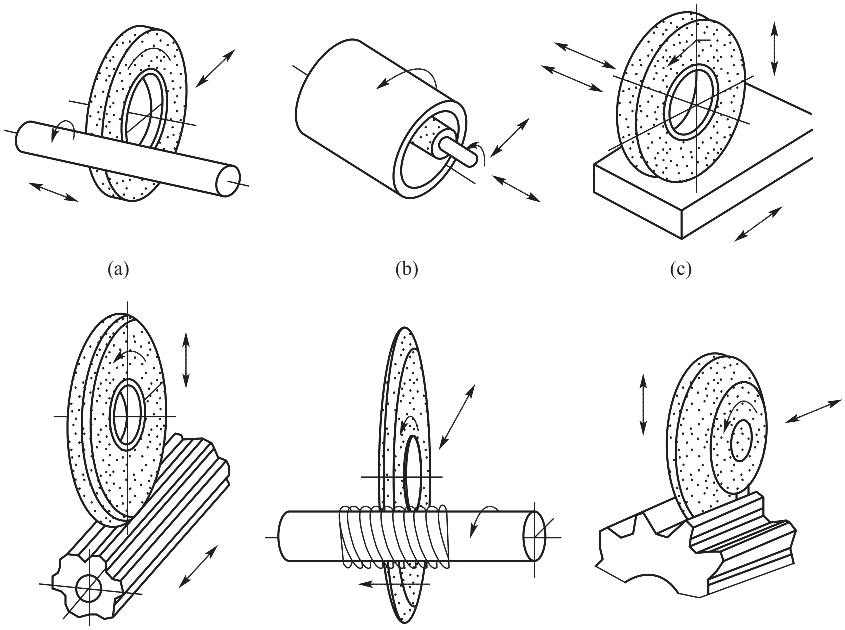


(a)



(b)

Forms of grinding wheel dressing 砂轮修正方式

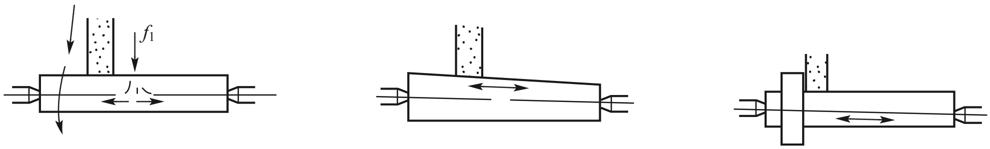


(a)　(b)　(c)

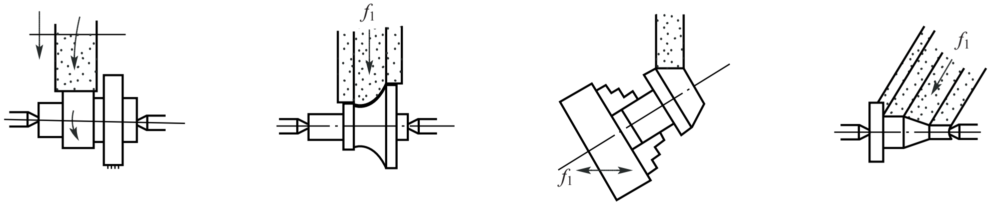
(d)　(e)　(f)

Various applications of wheel grinding 砂轮磨削的应用

（a）cylindrical grinding 磨削外圆　（b）internal grinding 磨削内圆　（c）plate grinding 磨削平面　（d）key way grinding 磨削花键　（e）helical grinding 磨削螺纹　（f）gear tooth grinding 磨削齿形



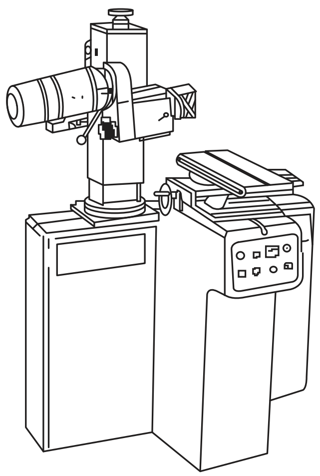
(a)　(b)　(c)



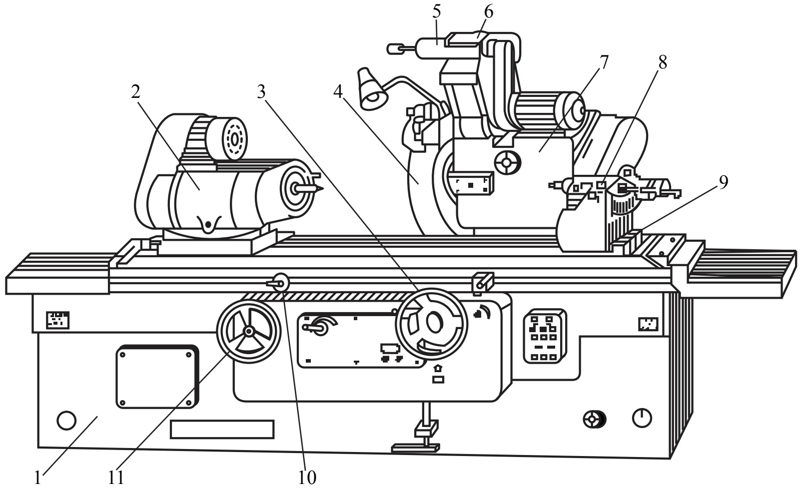
(d) (e) (f) (g)

Various operations of cylindrical grinding 纵磨法的各种应用

（a）cylindrical grinding via axial feed 纵磨法磨外圆 （b）conical surface grinding 磨削锥面 （c）cylindrical and surface grinding via axial feed 纵磨法磨外圆及端面 （d）plunge grinding 横磨法磨外圆 （e）plunge form(profile)grinding 横磨法磨成形面 （f）short tap grinding 磨短锥面 （g）form grinding via oblique feed 斜向横磨成形面

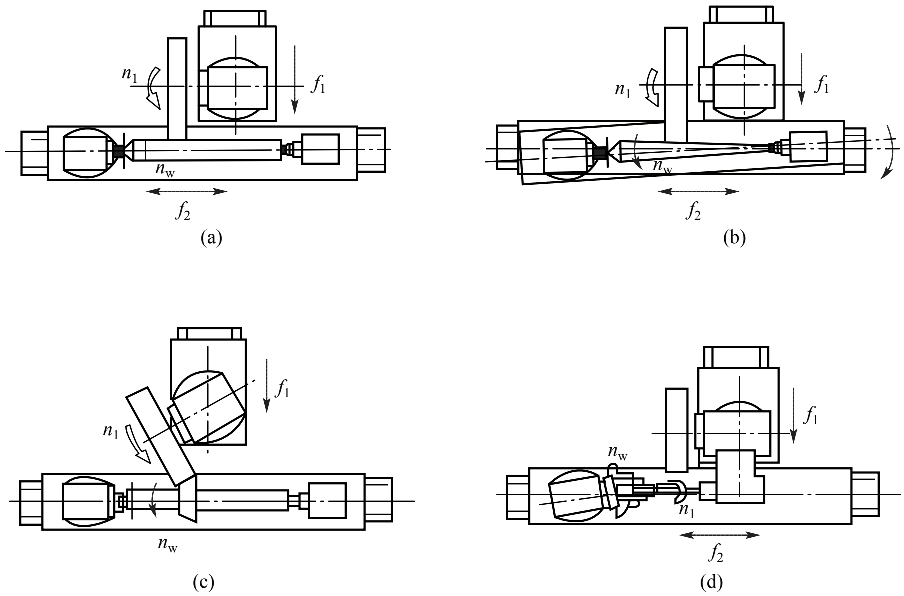


Multi-purpose grinding machine for tools 万能工具磨床



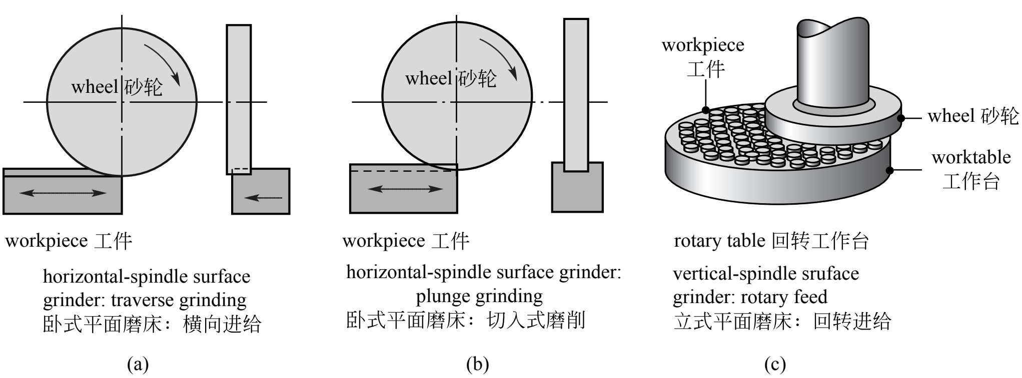
Multi-purpose grinding machine for cylinder 万能外圆磨床

1 – bed 床身 2 – headstock 头架 3，11 – hand wheel 手轮 4 – abrasive(grinding)wheel 砂轮 5 – inner surface abrasive 内圆磨具 6 – support frame 支架 7 – wheel supporting frame 砂轮架 8 – tailstock 尾架 9 –(work)table 工作台 10 – stroke choke 行程挡块

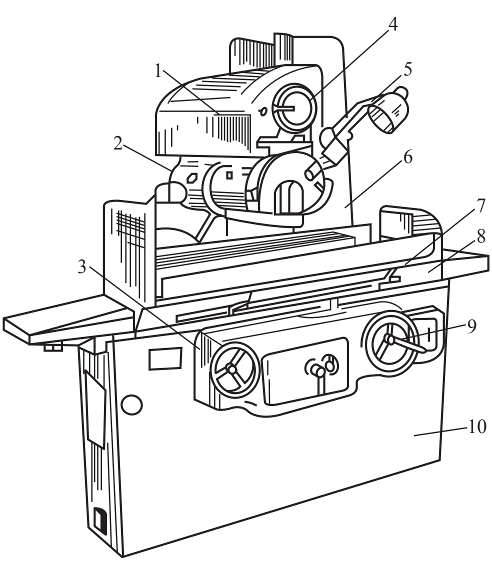


Typical operations on multi-purpose grinding machine for cylinder 外圆磨床的典型应用

（a）cylindrical grinding via axial feed 纵磨法磨外圆面 （b）long tap grinding via work table oblique 板转工作台磨削长锥面 （c）short tap grinding via wheel head oblique 板转砂轮头架磨短锥面 （d）inner tap grinding via wheel head oblique 板转砂轮头架磨削内锥面

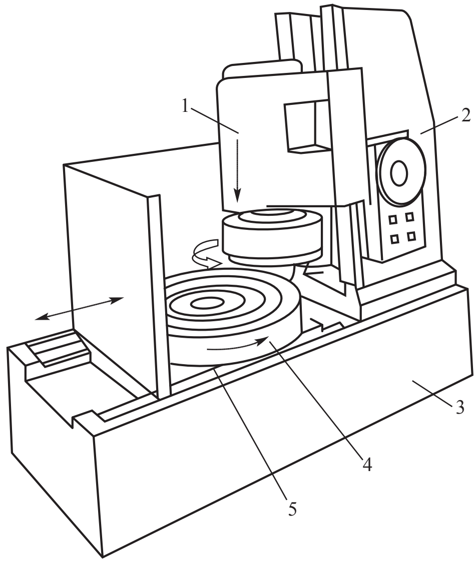


Various surface-grinding operations 平面磨削实施操作



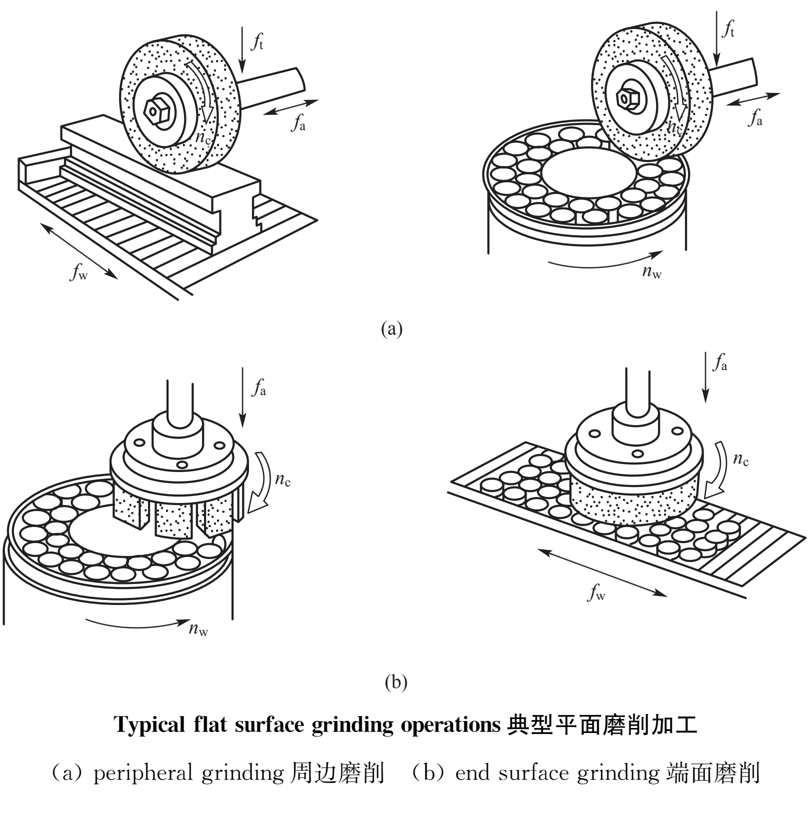
Flat surface grinder 平面磨床

1-hand wheel(for moving table feed)(工作台移动)手轮 2-grinding wheel head 磨头 3-slide plate 拖板 4, 9-hand wheel(for moving wheel head)磨头移动手轮 5-wheel dresser 砂轮修正器 6-column 立柱 7-stroke choke 行程挡块 8-worktable(saddle)工作台 10-bed 床身



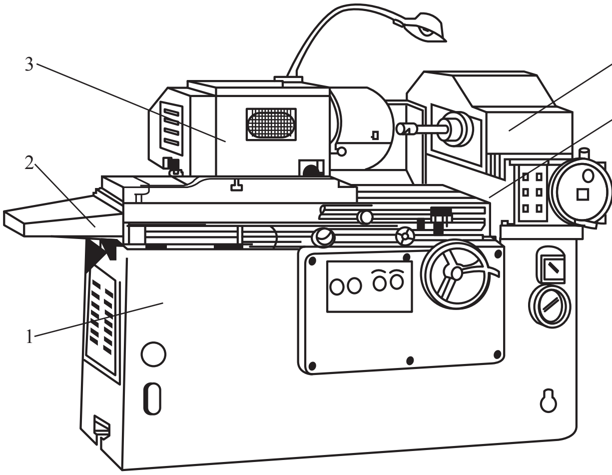
Vertical spindle surface grinder 立轴平面磨床

1-grinding wheel head 磨头
2-column 立柱 3-bed 床身
4-worktable 工作台
5-saddle 床鞍



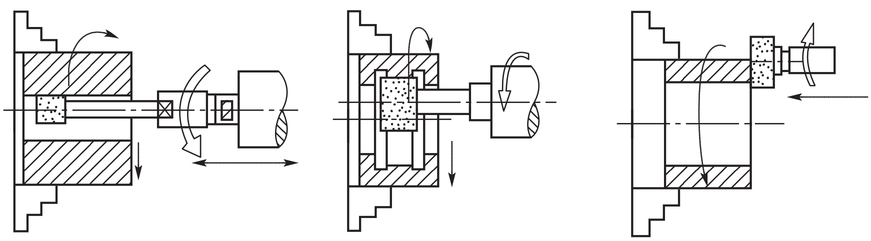
Typical flat surface grinding operations 典型平面磨削加工

(a) peripheral grinding 周边磨削 (b) end surface grinding 端面磨削



Internal surface grinding machine 内圆磨床

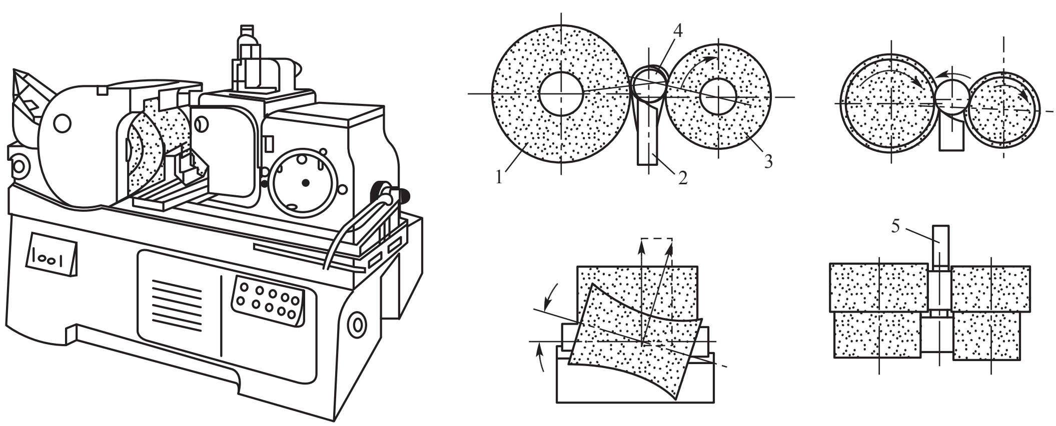
1 - bed 床身　2 - worktable 工作台　3 - work head 头架
4 - wheel head 砂轮头架　5 - saddle 床鞍



(a)　　　　(b)　　　　(c)

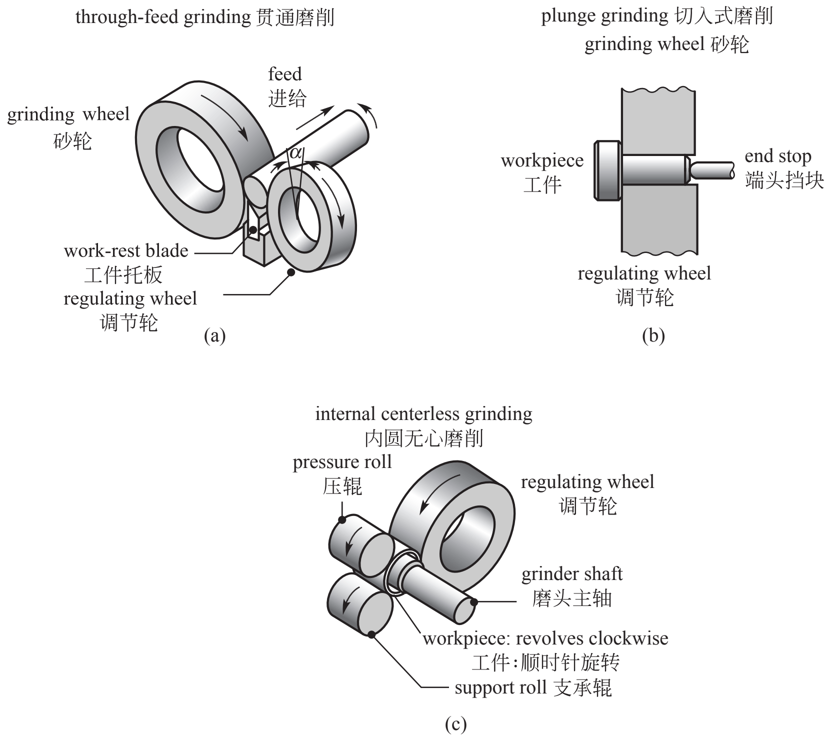
Operations for inner surface grinding machine 内圆磨削方法

(a) hole grinding via axial feed 纵磨法磨内孔　(b) plunge internal grinding via traverse feed 横磨法磨内孔　(c) end surface grinding 磨削端面

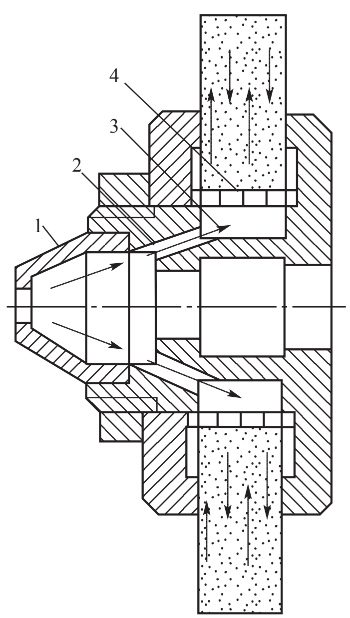


Centreless grinding operations 无心磨削

1 - grinding wheel 砂轮　2 - work rest blade 托板　3 - regulating wheel 调节轮　4 - workpiece 工件　5 - end stop 挡块

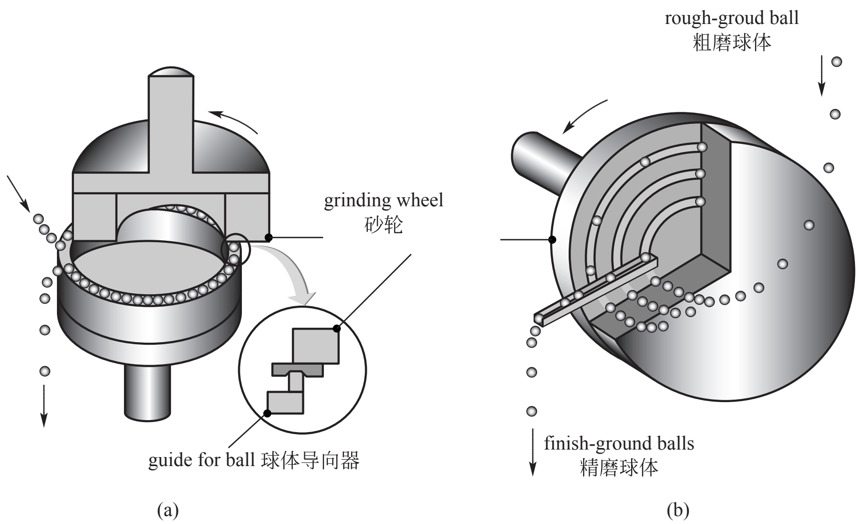


Forms of centerless grinding 无心磨削形式

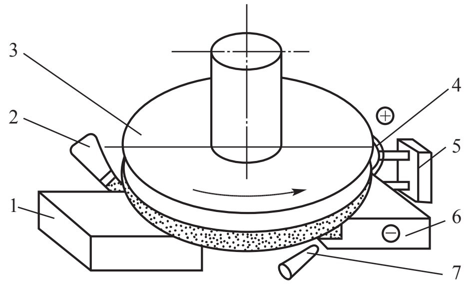


Internal cooling wheel structure 内部冷却砂轮结构

1 - tapped cover 锥形盖　2 - coolant hole 冷却液通孔　3 - wheel cavity 砂轮中心腔　4 - thin sleeve with radial hole 带径向小孔的薄壁套筒



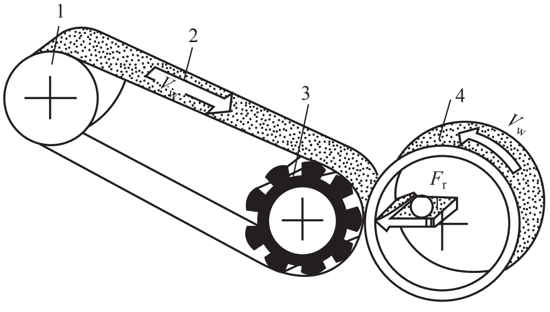
Steel-ball grinding 钢球磨削



Electrolytic in-process dressing(ELID)电解在线砂轮修正

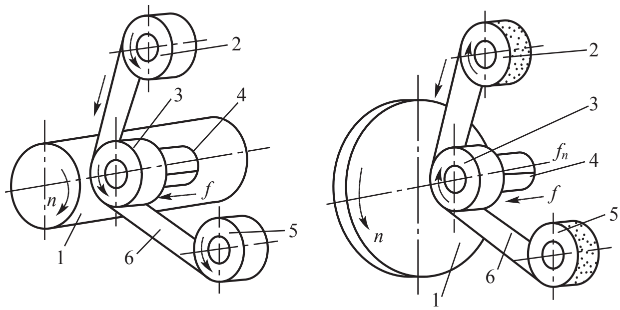
1 - workpiece 工件　2 - coolant 冷却液　3 - super hard abrasive wheel 超硬磨料砂轮　4 - electrical(connection)brush 电刷　5 - frame 支架　6 - cathode 负极　7 - electrolysis 电解液

Coated Abrasive Process 涂覆磨具磨削加工



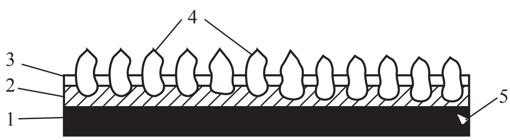
Coated abrasive belt grinding set structure 砂带磨削装置构成

1 - tension wheel 张紧轮　2 - abrasive belt 砂带　3 - contact wheel 接触轮　4 - workpiece 工件



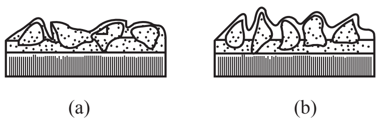
Open-loop belt precision lapping 开式砂带精密研抛

1 - workpiece 工件　2 - belt coil 砂带卷　3 - contact wheel 接触轮
4 - vibrator 激振器　5 - belt pulling wheel 砂带收卷轮　6 - belt 砂带
n - revolution speed of spindle 主轴转速　f - feed 进给速度
f_n - vibration frequency 振动频率



Cross section structure of abrasive belt 砂带截面图

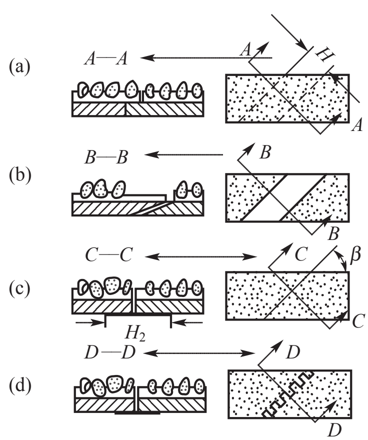
1 - backing 底材　2 - make coat 底胶层
3 - size coat 覆胶　4 - abrasive grain
(grit)磨粒　5 - addatives 添加剂



Comparison of belt structures by different grain planting processes 不同的植砂方式砂带结构比较

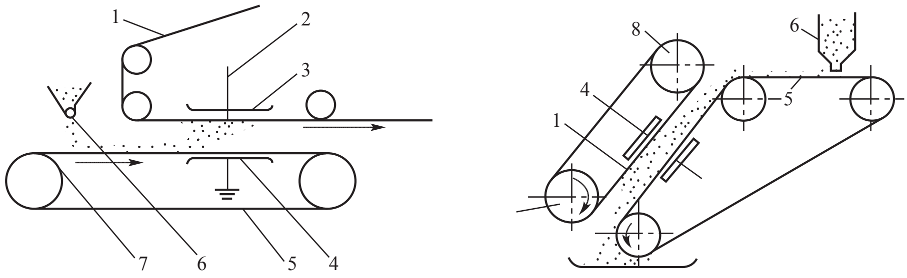
(a) gravity grain planting 重力植砂
(b) electrostatic microreplication planting 静电植砂

Various forms of abrasives from coated abrasive belt 各种形式的涂覆磨具



Belt joint forms 砂带接头形式

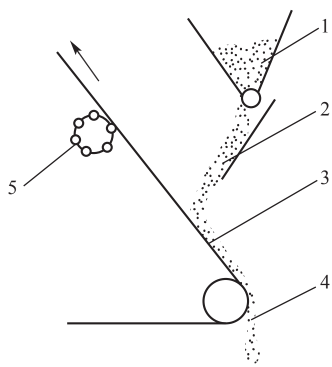
(a) overlapping joint 搭接　(b) overlapping joint with grain removed 去除磨料的搭结　(c) flat joint 平接
(d) flat joint with sine wave lateral 正弦边口平接



(a)　　(b)

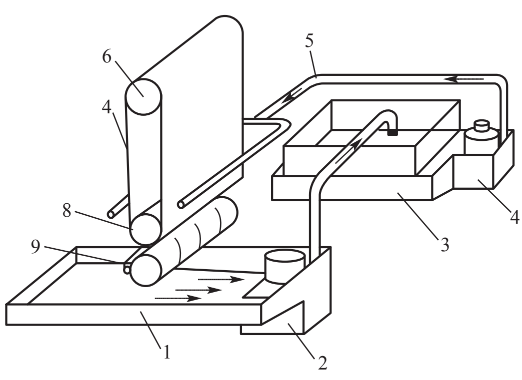
Theoretical scheme of electrostatic microreplication abrasive grain planting 静电植砂原理

1 - backing 底材　2 - high voltage wire 高压线　3 - cathode 负极　4 - anode 正极
5 - convey belt 传送带　6 - abrasive gain 磨料（粒）　7 - driving wheel 驱动轮
8 - tension wheel 张紧轮



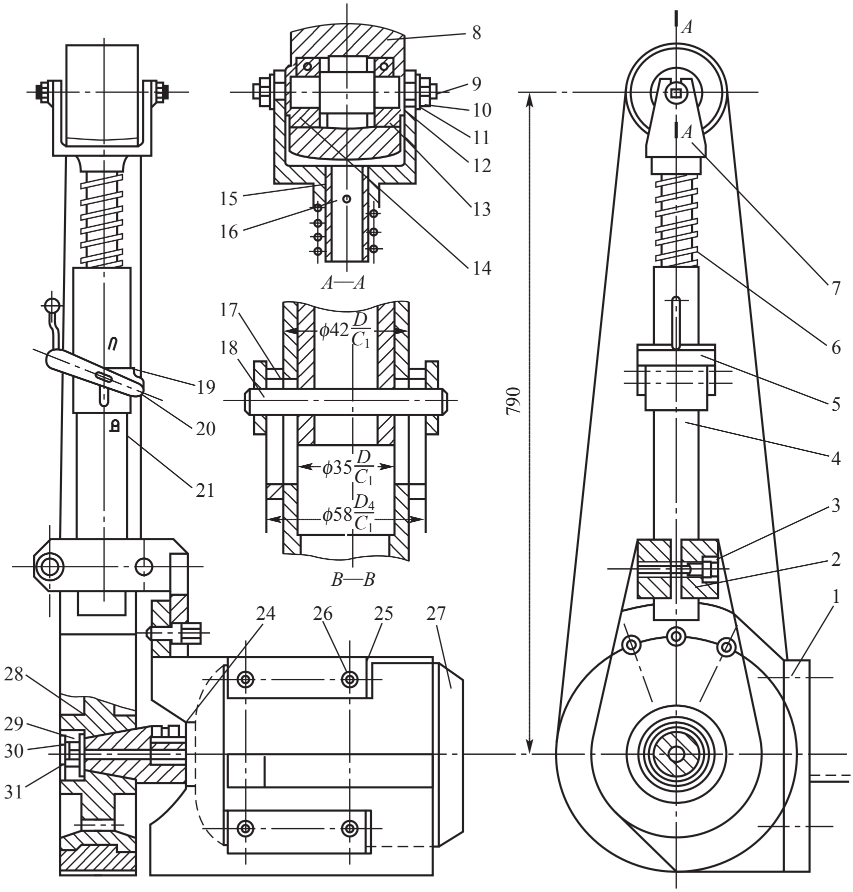
Grain planting by gravity 重力植砂简图

1 - grain tank 砂箱　2 - choke plate 挡板　3 - backing 底材
4 - grain 磨粒　5 - press roller 压辊



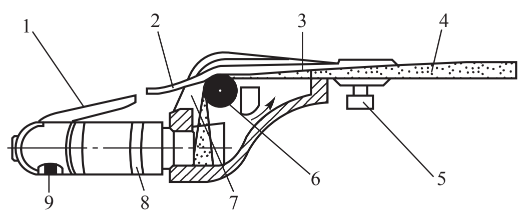
Cooling and lubricating set for wide belt application 宽砂带冷却润滑装置

1 - collecting tank 集收槽　2，4 - reserve tank 储蓄槽　3 - filter 过滤器
5 - ejection pipe 喷管　6 - tension wheel 张紧轮　7 - belt 砂带
8 - contact wheel 接触轮　9 - workpiece 工件



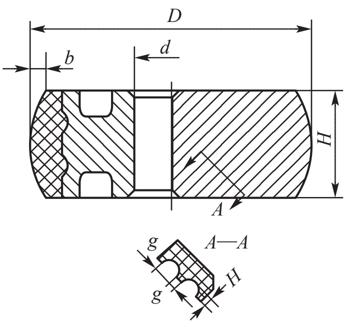
General belt grinding head 通用砂带磨头

1 - clamp base 夹座　2 - revolution frame 转架　3 - bolt 螺栓　4，15 - supporting rod 支承杆
5 - knob 手把　6 - spring 弹簧　7 - support 支承叉　8 - tension wheel 张紧轮　9 - shaft 轴
10，29，31 - nut 螺母　11，13，30 - washer 垫片　12 - sleeve 衬套　14 - bearing 轴承
16，18，20 - pin 销　17 - slot frame 叉架　19，22，25 - screw 螺钉　21 - belt 砂带
23 - tapper bushing 锥套　24 - key 键　26 - rubber cushion 橡胶垫
27 - motor 电机　28 - contact wheel 接触轮

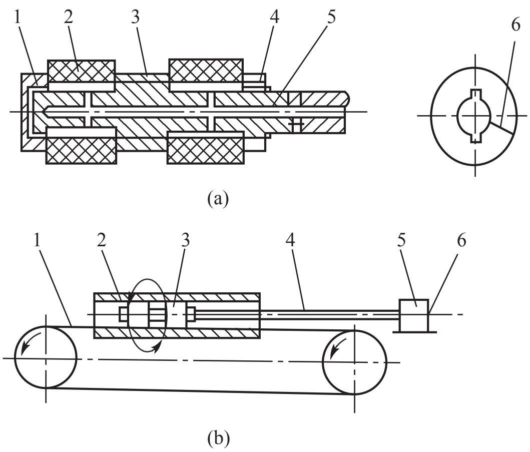


Pneumatic pistol-like portable belt grinder 气动手枪式砂带机

1 - switch 开关　2 - tension adjusting bar 调节杆　3 - belt 砂带
4 - contact arm 接触臂　5 - adjusting knob 调节钮　6 - idle wheel 惰轮
7 - driving wheel 驱动轮　8 - pneumatic propel wheel 气动叶轮
9 - revolution speed adjust knob 速度调节旋钮



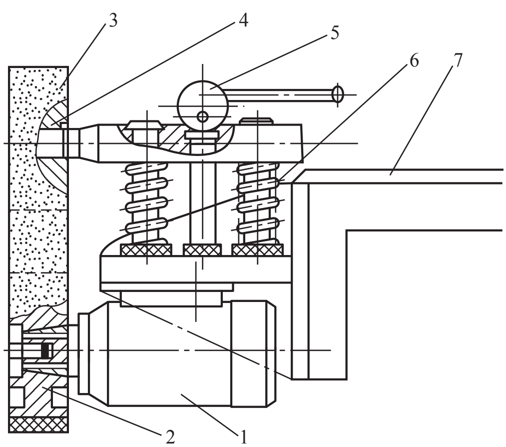
Design of contact wheel 接触轮结构设计



Contact gasbag structure for deep hole machining 深孔加工用接触气囊结构

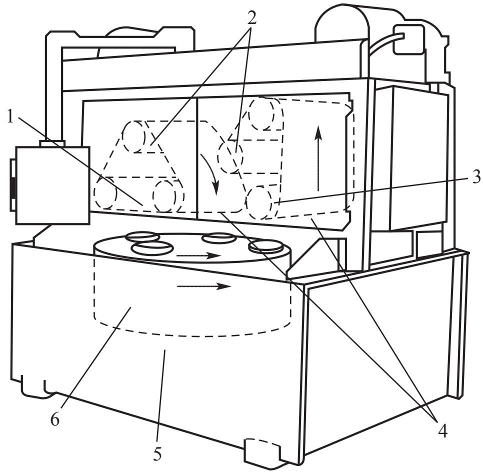
（a）gasbag 气囊：1，4 – nut 螺母　2 – gasbag 气囊　3 – separating sleeve 隔离套　5 – pressurized air 压缩空气　6 – rubber loop cut 橡胶环开口

（b）machining strategy 加工策略(方案)：1 – belt 砂带　2 – workpiece 工件　3 – gasbag 气囊　4 – push rod 推杆　5 – air inlet 进气口　6 – pressurized air 压缩空气



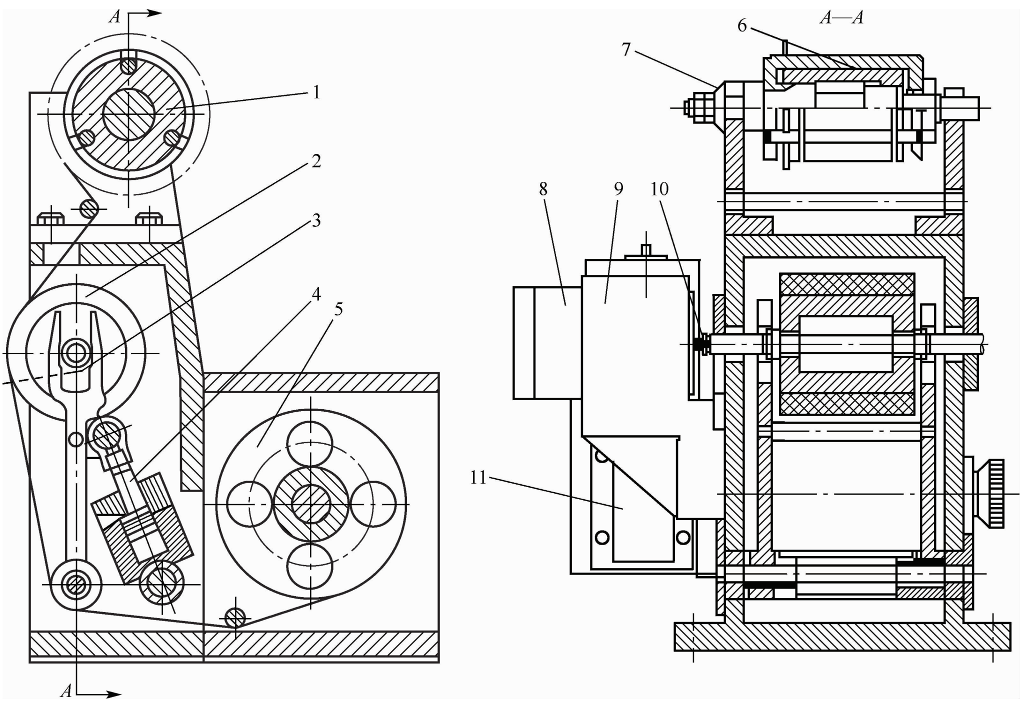
Internal surface grinding head 内圆砂带磨削头架

1 – motor 电动机　2 – driving wheel 驱动轮　3 – belt 砂带　4 – contact wheel 接触轮　5 – tension cam 张紧凸轮　6 – press spring 压缩弹簧　7 – holding base 夹持座



Flat surface grinding machine 平面砂带磨床

1 - wide belt 宽砂带 2 - tension roller 张紧辊 3 - contact roller 接触辊
4 - grinding area 磨削区域 5 - bed 床身 6 - rotary table 回转工作台



Open-loop belt grinding(lapping)head set 开式砂带磨削(研磨)头架

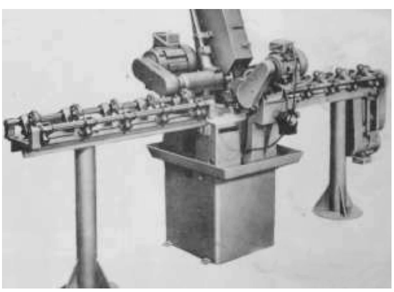
1 - belt coil 砂带卷 2 - contact wheel 接触轮 3 - level 杠杆 4 - sliding oil cylinder 移动油缸
5 - belt pulling wheel 砂带收卷轮 6 - belt tension mechanism 砂带张紧机构 7 - spring 弹簧
8 - vibrator 激振器 9 - DC motor 直流电机 10 - shaft coupling 联轴器 11 - gear box 变速箱

Coated abrasive belt 砂带产品

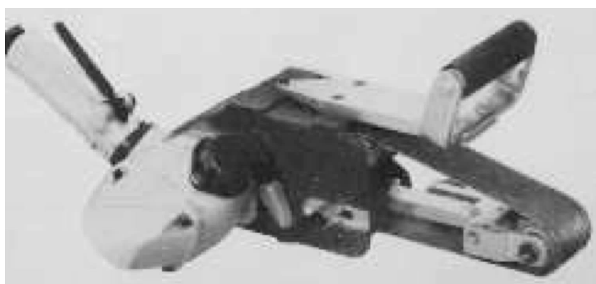
Grinding disc 磨盘、砂盘

Polishing cloth wheel 抛光布轮

Elastic grinding and polishing wheel 弹性磨抛轮

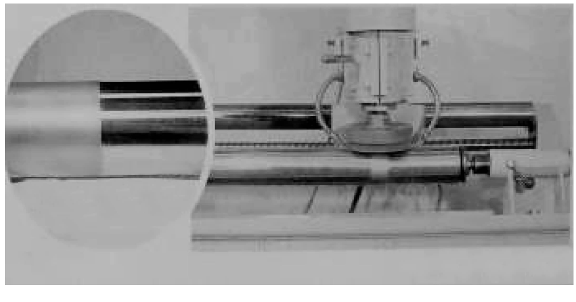


Centreless belt grinding machine
无心砂带磨床

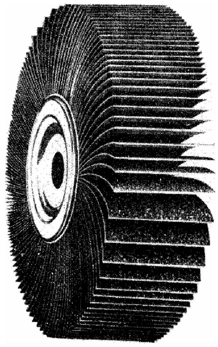


Portable grinder 手提式砂带机

Portable welding seam polisher
手提式焊缝打磨机

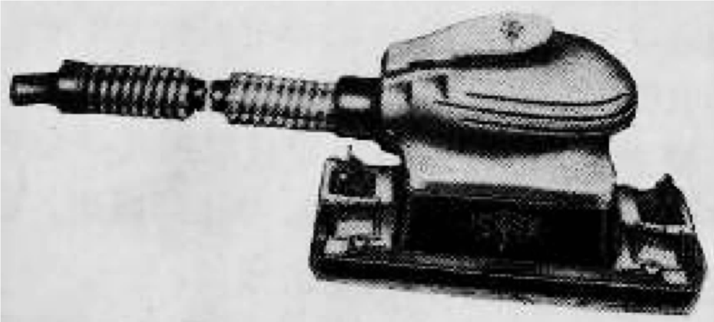


Abrasive disc precision polisher 圆盘精密抛光机



Flap(page)wheel(千)页轮

Abrasive disc grinder 圆盘打磨机



Reciprocating vibration flat grinder 往复振动平面磨光机

Reading Materials

Passage 1: Abrasive Process

Grinding is a process carried out with a grinding wheel made up of abrasive grains for removing very fine quantities of material from the workpiece surface. The required size of abrasive grains are thoroughly mixed with the bonding material and then pressed into a disc shape of given diameter and thickness. This can be compared to a milling process with an infinite number of cutting edges.

Grinding is a process used for the following purposes:

(1) Machining materials which are too hard for other machining processes such as tool and die steels and hardened steel materials,

(2) Close dimensional accuracy of the order of 0.3 to 0.5 micron and,

(3) High degree of surface smoothness such as Ra=0.15 to 1.25 micron.

This accounts for 25% of all the machining processes used for roughing and finishing.

The abrasive grains are basically spherical in shape with large sharp points which act as cutting edges. All the grains are of random orientations and as such the rake angle presented to the work material can vary from positive to a large negative value. Sometimes grits slide rather than cut because of its orientation.

The depth of cut taken by each of the grain is very small. However a large number of grits act simultaneously and hence the material removed is large. The cutting Speeds employed are also relatively higher. As result the chips produced are very small and are red hot, they get often welded easily to the abrasive grain or to the workpiece. Thus the grinding process is a very inefficient one compared to the other conventional metal cutting processes.

Various types of abrasives are hard materials with adequate toughness which act as cutting edges for a sufficiently long time. They also have the ability to fracture into smaller pieces when the force increases, which is termed as friability. This property gives the abrasives the necessary self-sharpening capability. The abrasives that are generally used are:

(1) Aluminum Oxide (Al_2O_3). This is a natural abrasive, also known as corundum and emery. Natural abrasives generally have impurities and as a result their performance is inconsistent. Hence the abrasive used in grinding wheels is generally manufactured from the aluminum ore bauxite.

(2) Silicon Carbide (SiC). Silicon carbide is made from silica sand and coke with small amounts of common salt.

(3) Cubic Boron Nitride (CBN). Cubic Boron Nitride (CBN) is next in hardness only to diamond. It is not a natural material but produced in the laboratory using a high temperature/high pressure process similar to the making of artificial diamond. CBN is less reactive with materials like hardened steels, hard chill cast iron, and nickel base and cobalt based super alloys. This is very expensive, 10 to 20 times that of a conventional abrasive such as aluminum oxide.

(4) Diamond. Diamond is the hardest known material that can be used as a cutting tool material. It has a very high chemical resistance capacity along with a low coefficient of thermal expansion. It is inert towards iron.

Passage 2: Grinding Wheel Balancing and Dressing

Wheel Balancing A new grinding wheel when used should be properly balanced. In view of the high rotational speeds used, any residual unbalance left would be harmful for the machine part and also produces a poor surface finish. Such wheels are provided with movable balance weights for adjusting the balance mass location. The balancing operation can be carried in two ways:

(1) Static balancing,

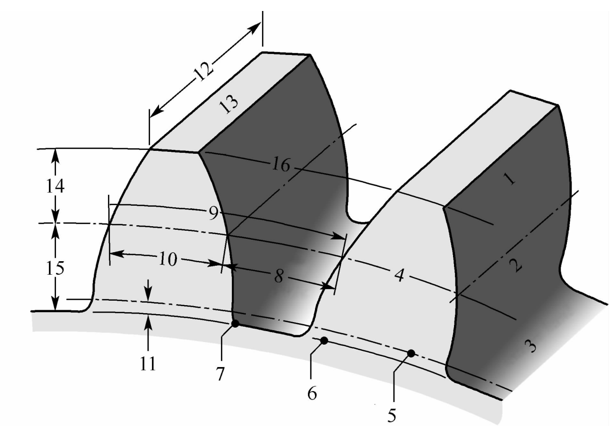
(2) Dynamic balancing.

In static balancing the grinding wheel is rotated on an arbour and the balance weights adjusted until the wheel no longer stops its rotation in any one specific position.

Dressing and Truing With continuous use a grinding wheel becomes dull with the sharp abrasive grains becoming rounded. This condition of a dull grinding wheel with worn out grains is termed as glazing. Further some grinding chips get lodged into the spaces between the grit resulting in a condition known as loaded wheel. Loading is generally caused during the grinding of soft and ductile materials. A loaded grinding wheel cannot cut properly. Such a grinding wheel can be cleaned and sharpened by means of a process called dressing. A simple dressing is done by means of small steel disks which are free to rotate at the end of a stick. These disks when contacting the grinding wheel face sharpen the wheel by removing a small portion of the face of wheel. Though this process is a simple one，since the dressing is done manually it does not produce a concentric surface.

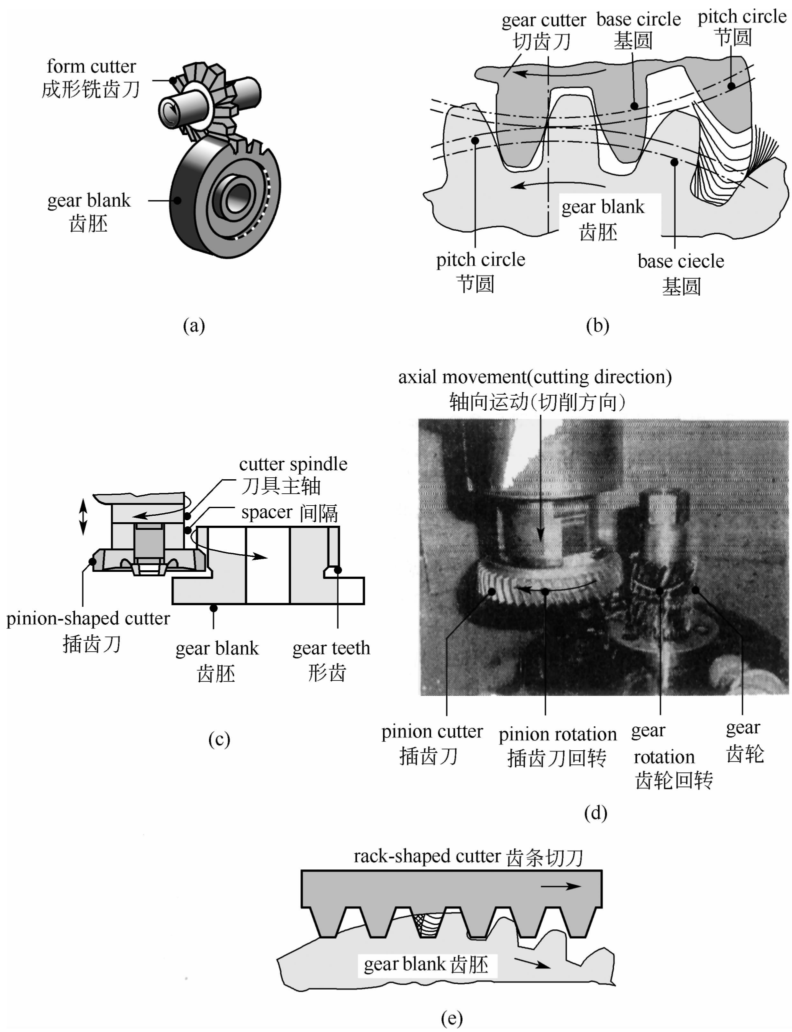
To obtain a true surface of the grind wheel in terms of either the form or concentricity a diamond dressing tool can be used. A diamond used for truing is set in a close fitting hole at the end of a short steel bar and is brazed. To do the truing operation，the grinding wheel is rotated at its normal speed and a small depth of 0.025mm is given while moving the dressing tool across the face of the grinding wheel in an automatic feed. Diamond dressing is also used to generate the necessary form other than the straight form. Diamond dressing on CNC grinding machines can generate any form of wheel.

3.6 Gear Cutting，Nontraditional Processes and Other Processes 齿轮加工、其他工艺及特种加工及其装备



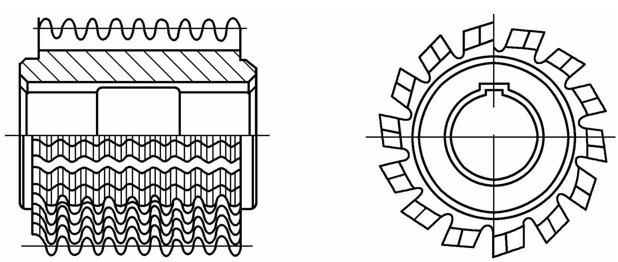
Nomenclature for an involute spur gear 渐开线直齿专门术语

1 - face 齿顶面 2 - flank 齿根面 3 - bottom land 齿根 4 - pitch circle 节圆 5 - clearance circle 顶隙圆 6 - dedendum circle 齿根圆 7 - fillet radius 过渡圆半径 8 - width of space 齿槽宽度 9 - circular pitch 圆弧节距 10 - tooth thickness 齿厚 11 - clearance 顶隙 12 - face width 齿宽 13 - top land 齿顶面 14 - addendum 齿顶高 15 - dedendum 齿根高 16 - outside circle 齿顶圆

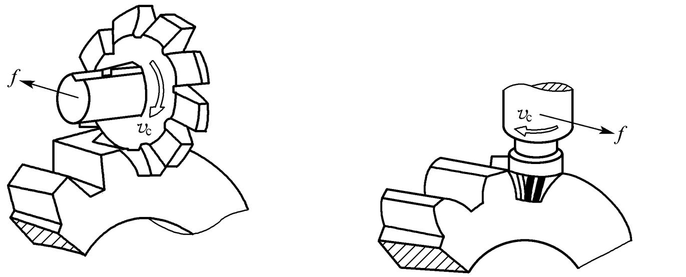


Methods for gear teeth machining 形齿加工方法

(a) form cutting 成形铣削 (b) gear generating with a pinion-shaped gear cutter 滚齿 (c), (d) gear generating 插齿 (e) rack-shoped cutter machining 齿条刀具插齿



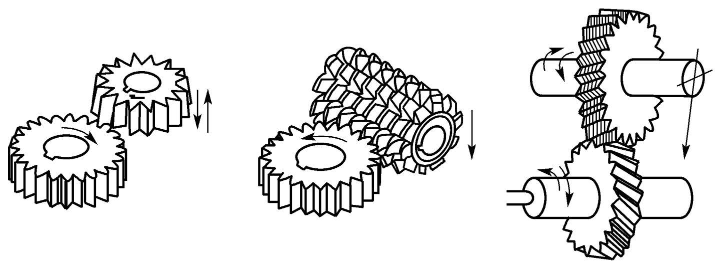
Gear hob滚刀



(a) (b)

Gear form milling 齿轮的成形铣削

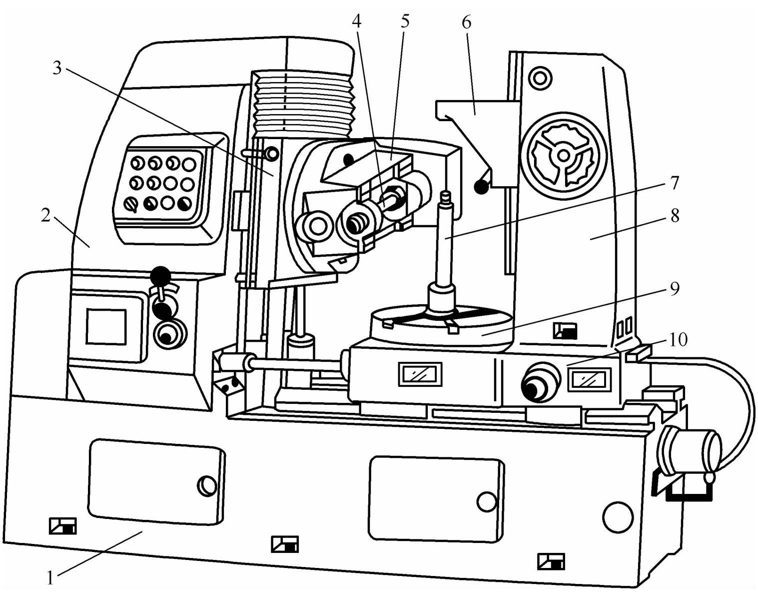
(a) disk milling cutter 盘状铣刀 (b) finger type milling cutter 指状铣刀



(a) (b) (c)

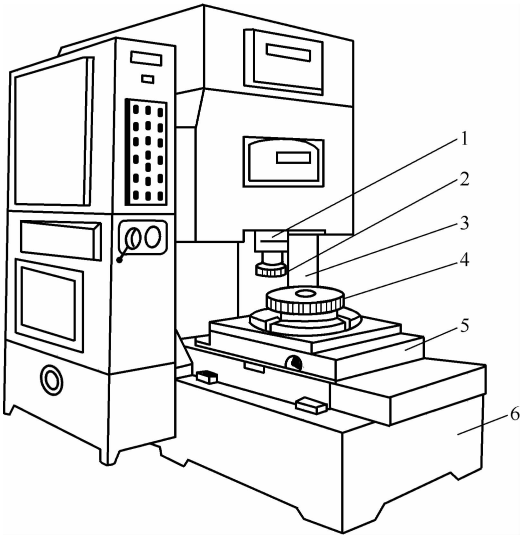
Gear generating machining 齿轮展成加工

(a) gear shaping/planning 插齿 (b) gear hobbing 滚齿 (c) gear shaving 剃齿



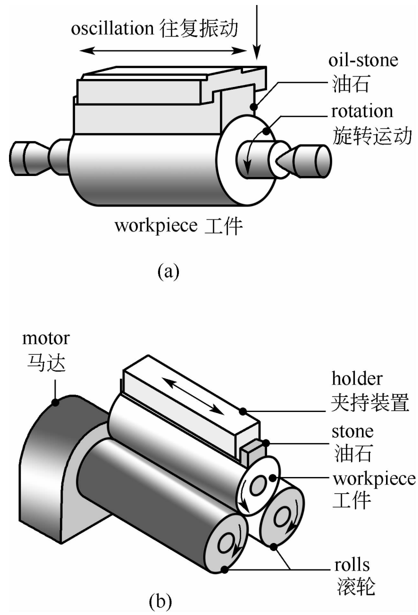
Gear hobbing machine 滚齿机

1- bed 床身 2 - column 立柱 3 - tool post slide 刀架溜板 4 - tool arbor 刀杆 5 - tool post 刀架
6 - support 支架 7 - mandrel 心轴 8 - rear column 后立柱 9 - table 工作台 10 - saddle 床鞍

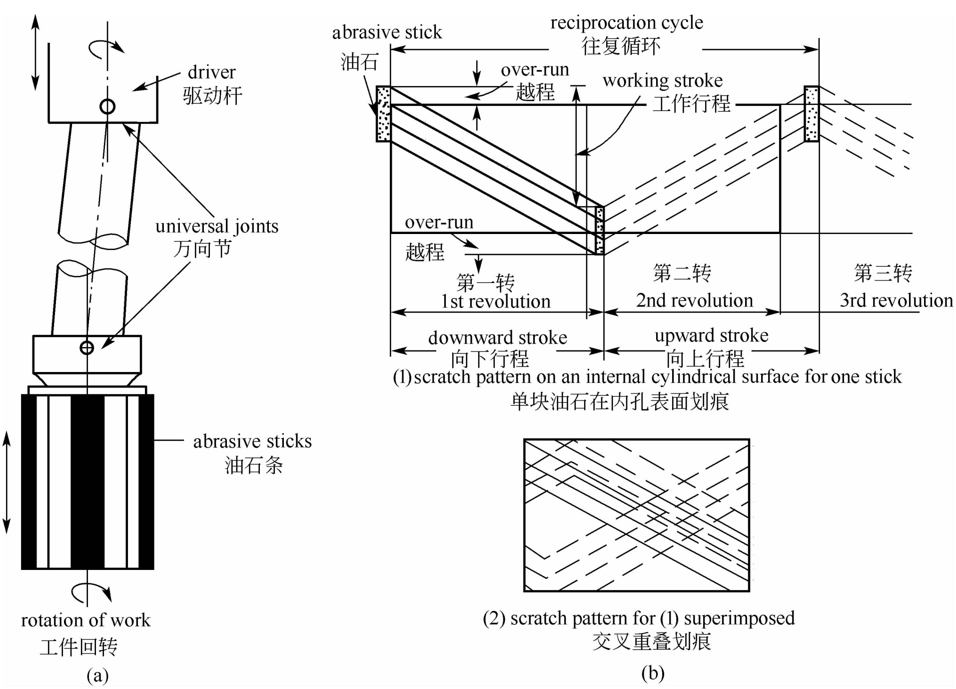


A gear shaper 插齿机

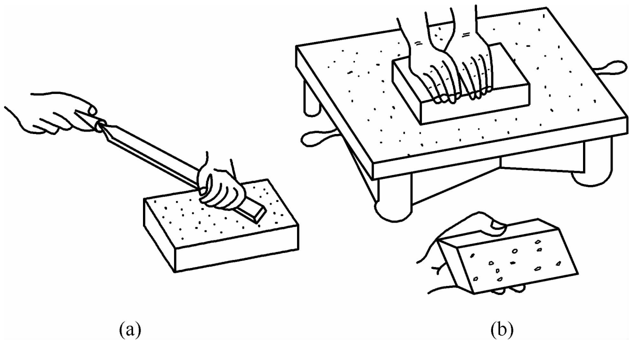
1 – spindle 主轴　2 – pinion cutter 插齿刀
3 – column 立柱　4 – workpiece 工件
5 – table 工作台　6 – bed 床身



Typical motions in a super finishing operation 典型的超精加工运动

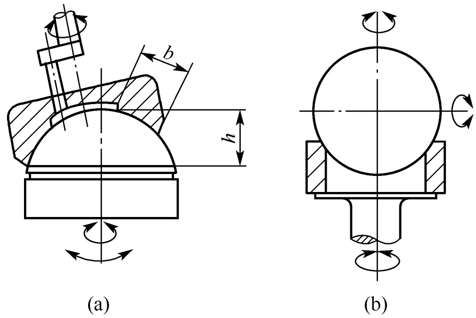


Honing operation and its scratch pattern 珩磨工艺及表面形貌



Flat scraping and lapping 平面刮研

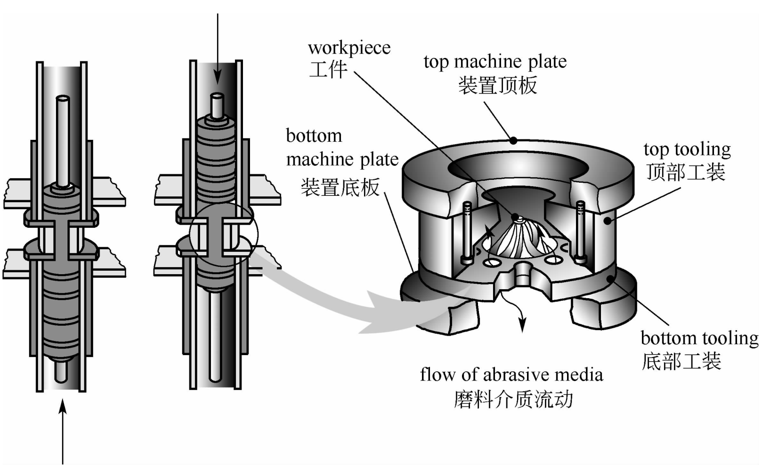
（a）scraping 刮削 （b）lapping 研磨



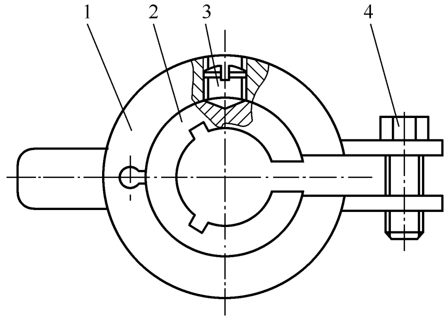
Sphere surface lapping 球面研磨

（a）semisphere surface lapping 半球面研磨

（b）whole sphere surface lapping 整球面研磨

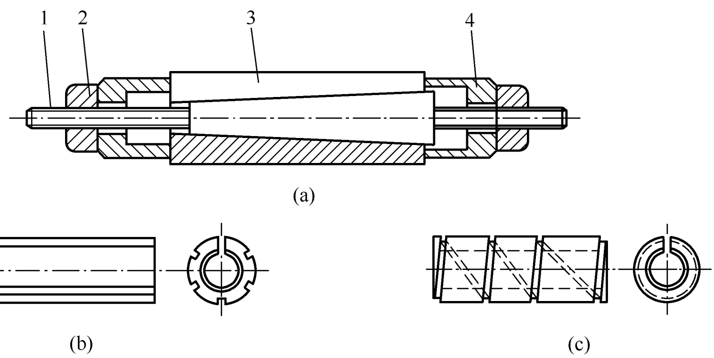


Abrasive-flow lapping（deburing）流动磨粒研磨(去毛刺)



Cylindrical lapping operation 研磨外圆

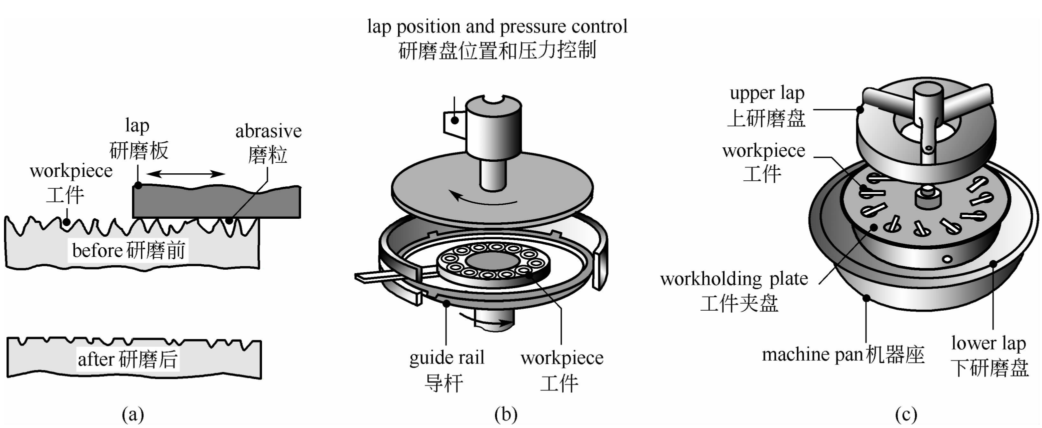
1 - lap sleeve 研磨套　2 - lap ring 研磨环　3 - positioning screw 定位螺钉　4 - adjusting screw 调节螺钉



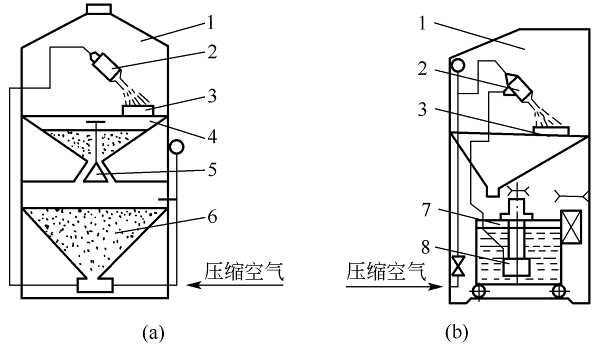
Internal surface lapping operation 内圆研磨

（a）adjustable lapping mandrel 可调研磨芯棒　（b）lapping sleeve with straight groove 直槽研磨套　（c）lapping sleeve with spiral groove 螺旋槽研磨套

1- taper mandrel 锥度芯棒　2 - screw 螺母　3 - lapping sleeve 研磨套　4 - face cap 端盖



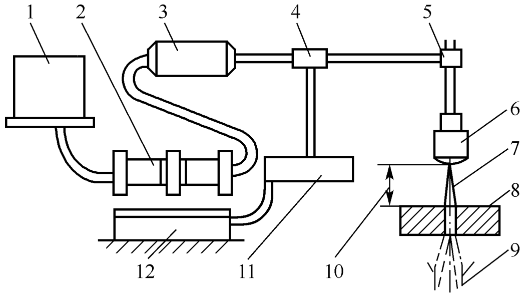
Flat lapping process 平面研磨工艺



Sand blasting (abrasive-jet) setup 喷砂装置

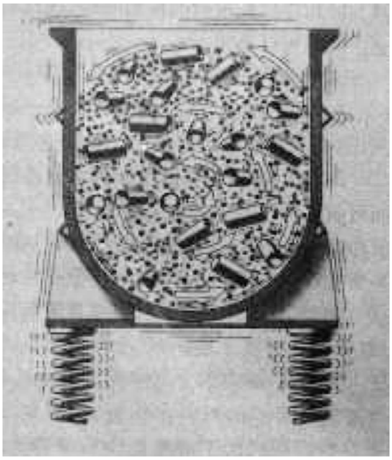
(a) dry 干式 (b) wet 湿式

1 - blasting chamber 喷射室 2 - nozzle 喷嘴 3 - workpiece 工件 4 - funnel 漏斗 5 - automation valve 自动阀 6 - abrasive tank 磨料箱 7 - fluidized abrasive (slurry) tank 流化磨料箱 8 - pump 泵

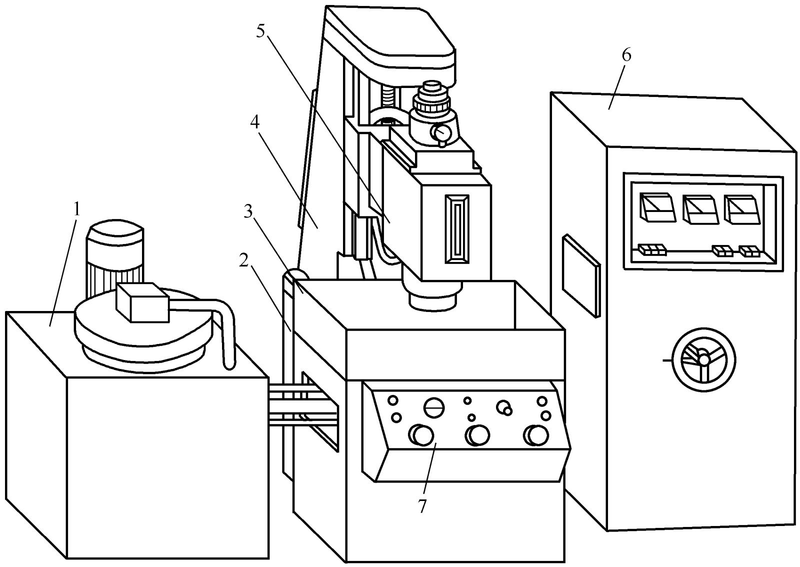


Scheme of abrasive water jet cutting 磨料水射流切割示意图

1 - water tank 水箱 2 - pump 水泵 3 - accumulator 蓄能器 4 - controller 控制器 5 - valve 阀 6 - sapphire nozzle 宝石喷嘴 7 - jet 射流束 8 - workpiece 工件 9 - drain 结水槽 10 - work distance 靶距 11 - hydraulic system 液压系统 12 - intensifier 增压器

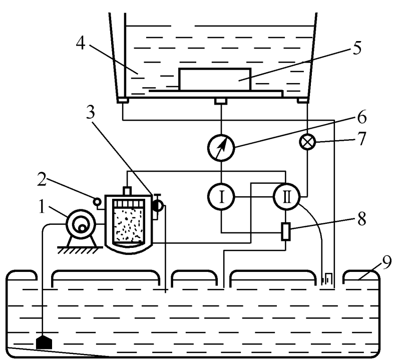


Vibration deburring machine 振动去毛刺机



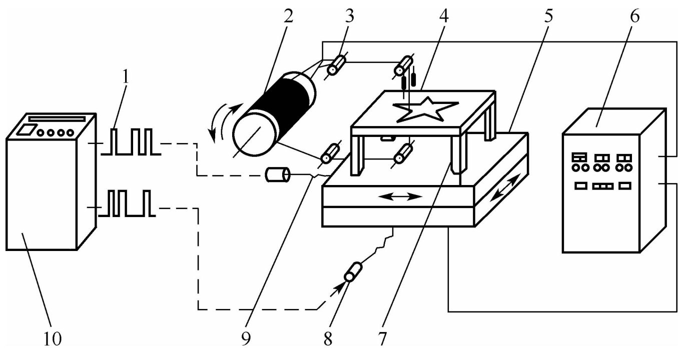
Electro discharge machine 电火花机床

1－hydraulic pump and oil tank 液压泵油箱　2－bed 床身
3－dielectric collector 工作液箱　4－column 立柱　5－spindle 主轴
6－pulse power supply 脉冲电源　7－control panel 控制板



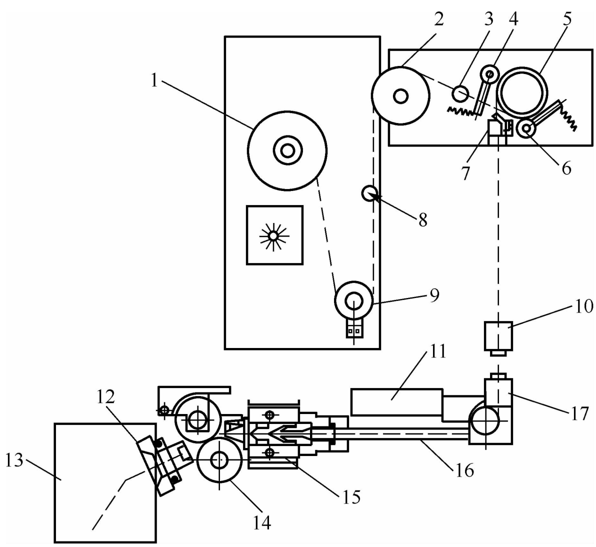
Dielectric recycling system 工作液循环系统

1－pump 液压泵　2－filter 过滤器　3－overflow valve 溢流阀
4－dielectric fluid tank 工作液槽　5－oil cup 油杯
6－pressure meter 压力表　7－throttle valve 节流阀
8－jet tube 射流管　9－reservoir 储液箱



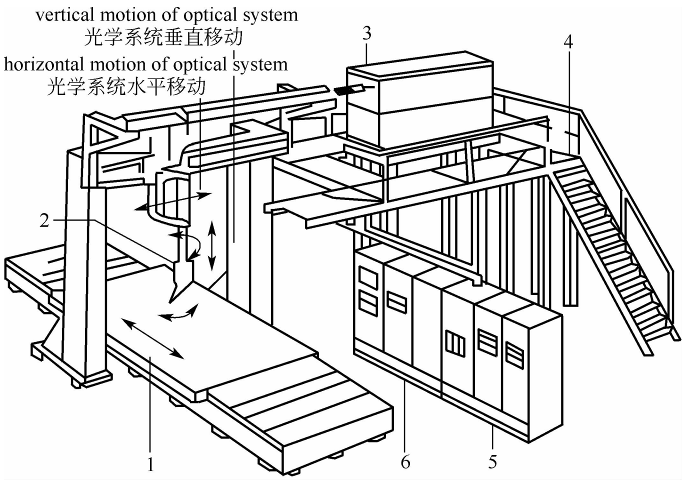
Principle of NC wire EDM process 数控线切割工作原理

1 – electric pulse signal 电脉冲信号 2 – wire spool 储丝筒
3 – guide wheel 导轮 4 – workpiece 工件 5 – table 工作台
6 – pulse power 脉冲电源 7 – pad 垫铁
8 – stepped motor 步进电机 9 – leading screw 丝杆
10 – computer controller 计算机控制器



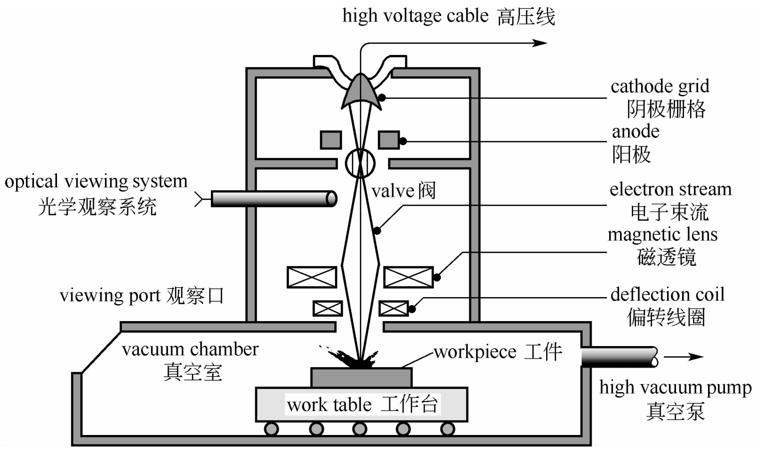
Lower speed wire feeding mechanism 低速走丝机构

1 – wire spool 丝筒 2 – pulley 滑轮 3 – felt roller 毡轮 4 – press wheel 压轮
5 – tension controller 张紧机构 6 – press wheel 压轮 7 – wire breakage detector 断丝检测器 8 – guide hook 导向钩 9 – spindle bushing 轴套 10 – upper wire guide 上导向器 11 – wire dismantling arm 线丝拆除臂 12 – exit of used wire 线丝排除口 13 – used wire spool 废丝筒 14 – roller 滚轮
15 – pull part 牵引部件 16 – guide tube for wire exit 出丝导管
17 – lower wire guide 下导向器

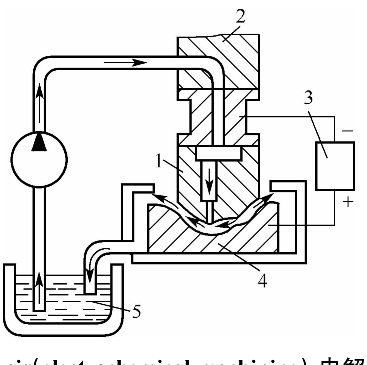


Laser beam machine 激光加工机

1 - moving table 移动工作台　2 - cutting head 切割头　3 - laser head　激光头
4 - platform 平台　5 - power 电源　6 - NC system 数控系统

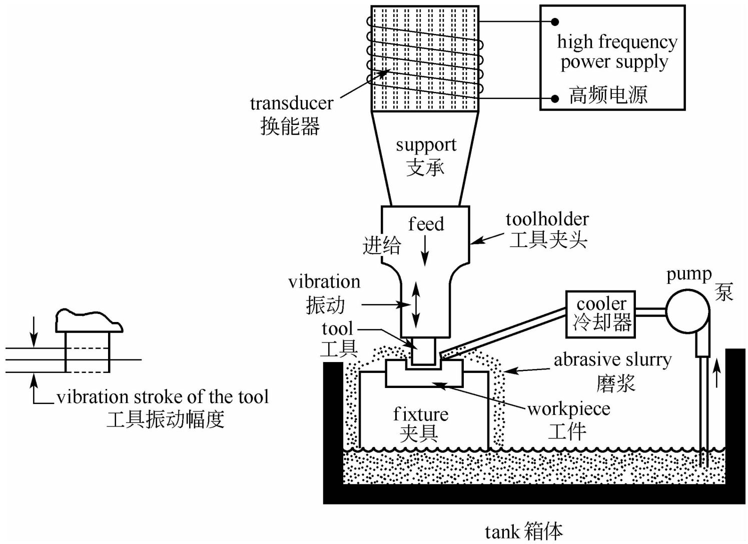


Schematic illustration of the electron-beam process 电子束加工示意图

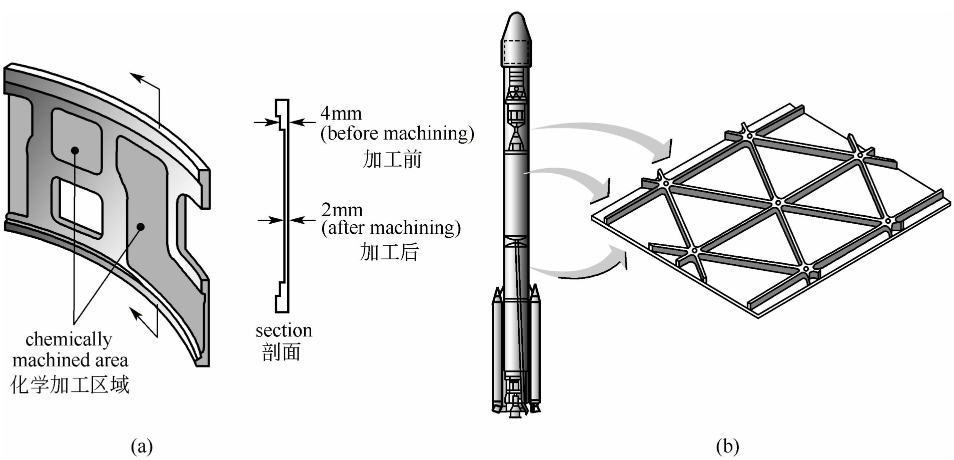


Principle of electrolysis(electrochemical machining) 电解(电化学)加工原理

1 - tool cathode 工具电极(阴极)　2 - feed set 进给机构　3 - DC power
直流电源　4 - workpiece (anode)工件(阳极)　5 - electrolyte 电解液

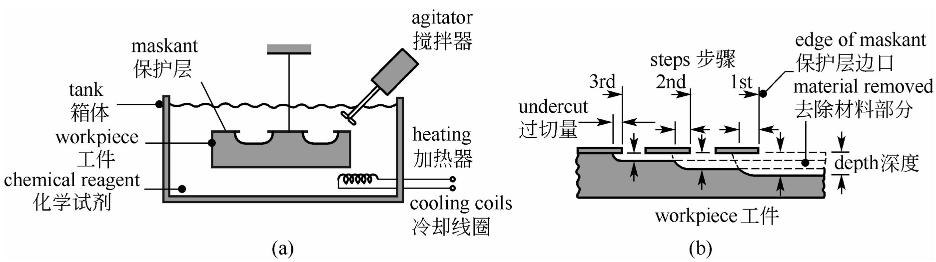


Schematic diagram of an ultrasonic machining operation 超声加工原理图

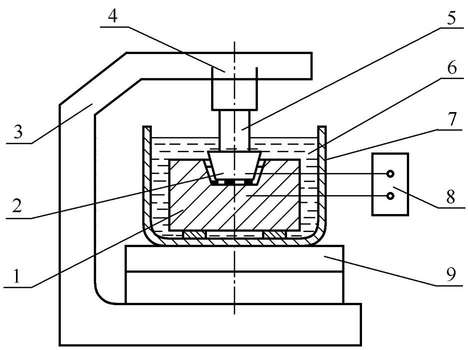


Examples of chemical milling 化学铣削例子

（a）missile skin-panel section 导弹薄壳剖面 （b）space-launch 太空飞船

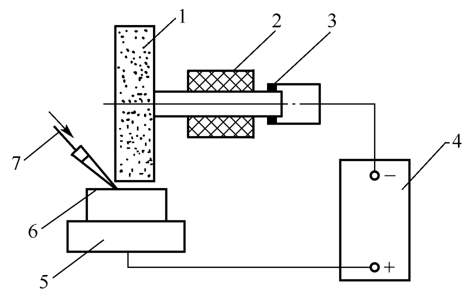


Chemical process 化学加工



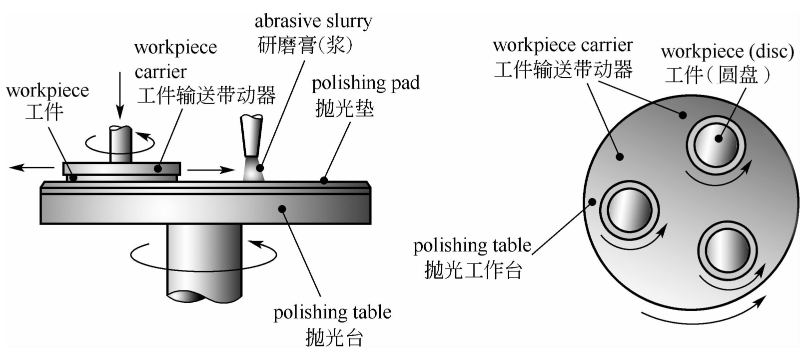
Schematic diagram of electrochemical polishing 电化学抛光示意图

1 - workpiece(anode)工件(阳极) 2 - tool (cathode)工具(阴极) 3 - support 支架 4 - servo 伺服机构 5 - feed spindle 进给主轴 6 - electrolyte 电解液 7 - electrolyte tank 电解液槽 8 - DC power 直流电源 9 - table 工作台

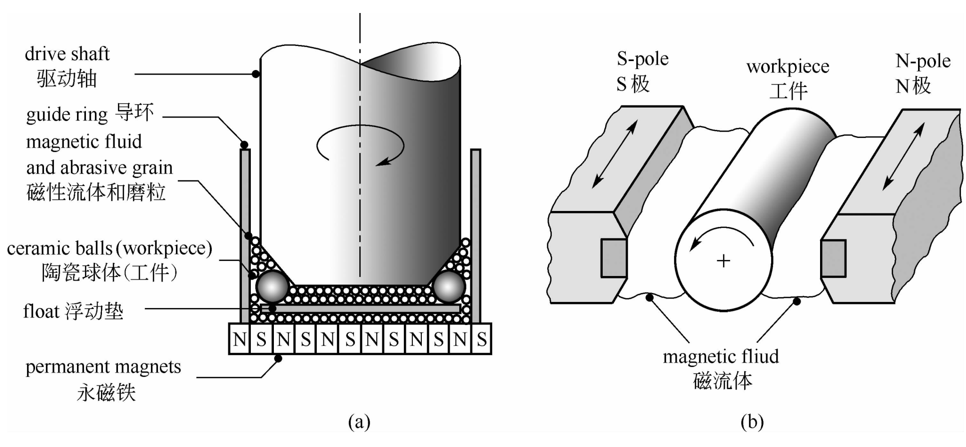


Schematic diagram of an electrochemical grinding operation 电解(电化学)磨削示意图

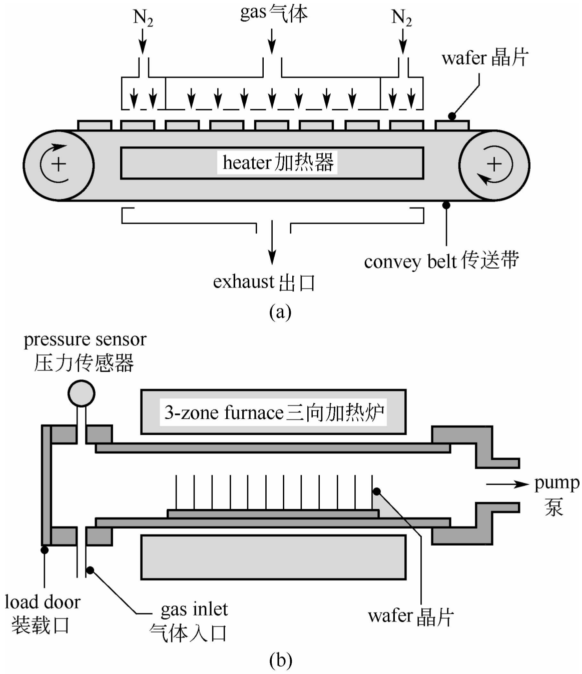
1 - electrically conducting grinding wheel 导电砂轮 2 - insulating bushing 绝缘套 3 - electricity conducting ring 电导环(电刷) 4 - DC power 直流电源 5 - table 工作台 6 - workpiece 工件 7 - electrolyte 电解液



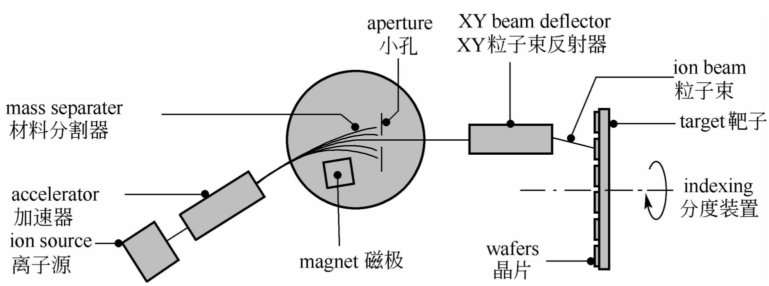
Chemical-mechanical polishing process(CMP) 化学机械抛光



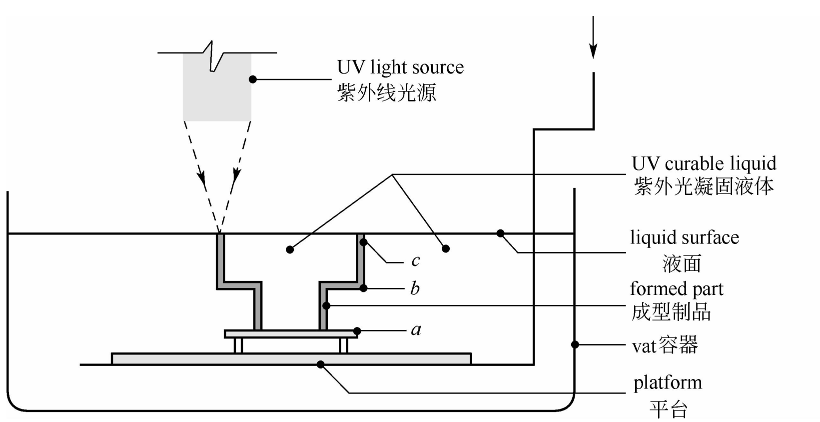
Magnetic fluid and abrasive polishing 磁磨粒抛磨球体和辊柱



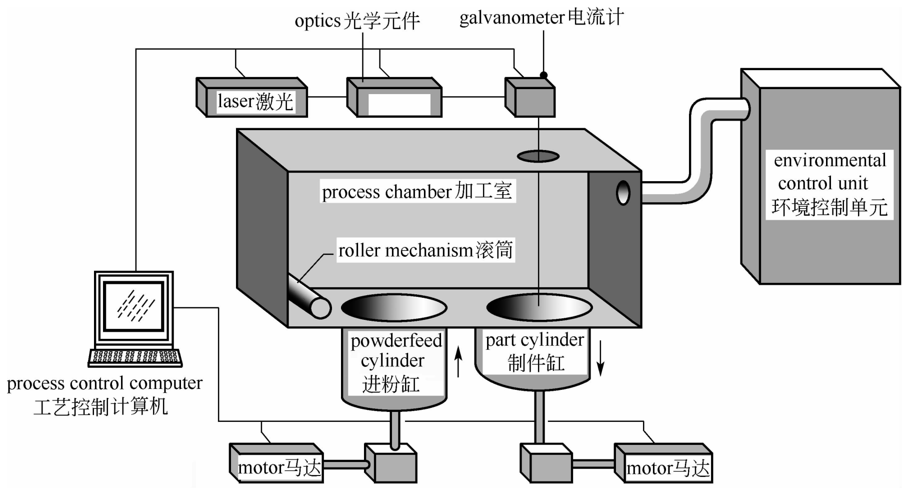
Coating with Chemical vaporization deposit (CVD)化学气相沉积涂层



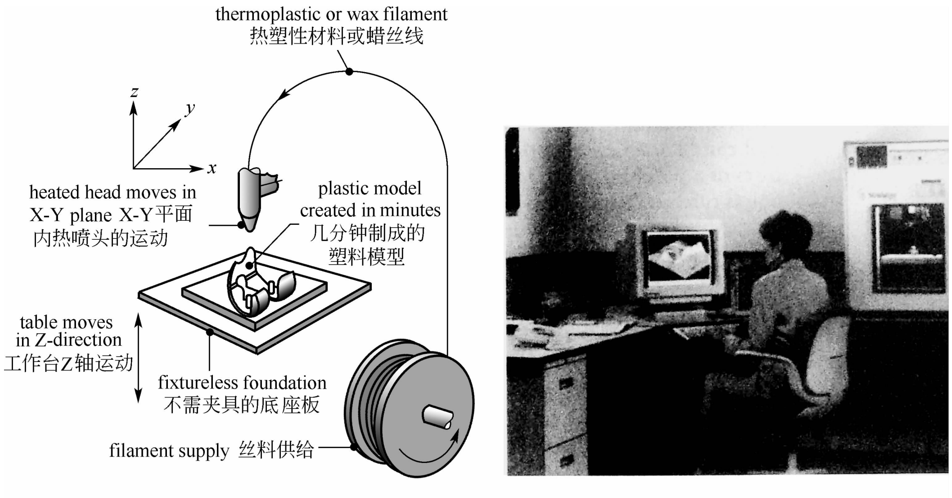
Apparatus for ion implantation 离子注入装置



Stereolithography process(SL)液相固化立体成形工艺

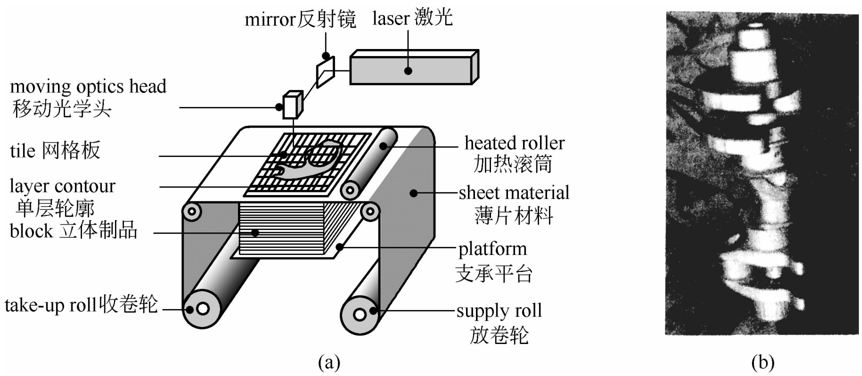


Selective-laser-sintering process (SLS)选择性激光烧结成形工艺



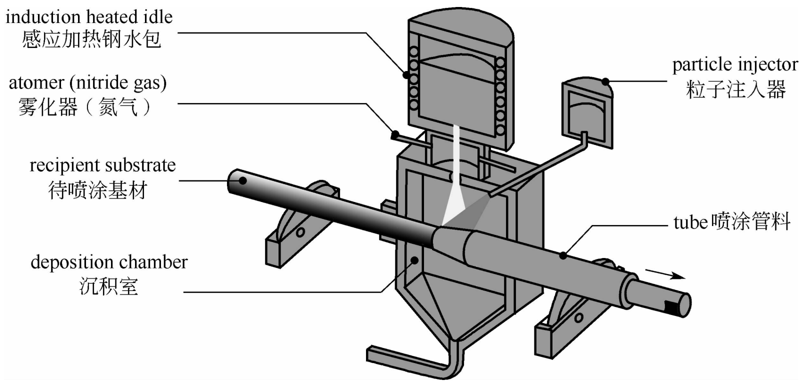
(a)　　(b)

Fused-deposition-modeling process (FDM)熔丝堆积成形工艺

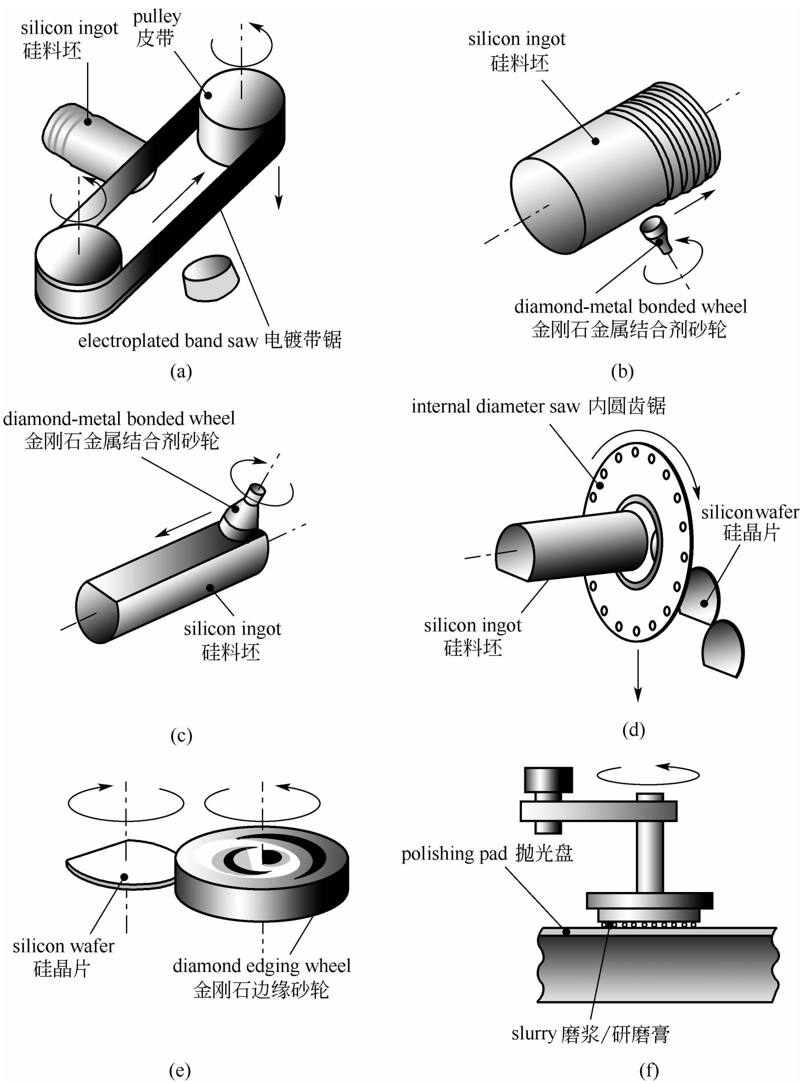


(a)　　(b)

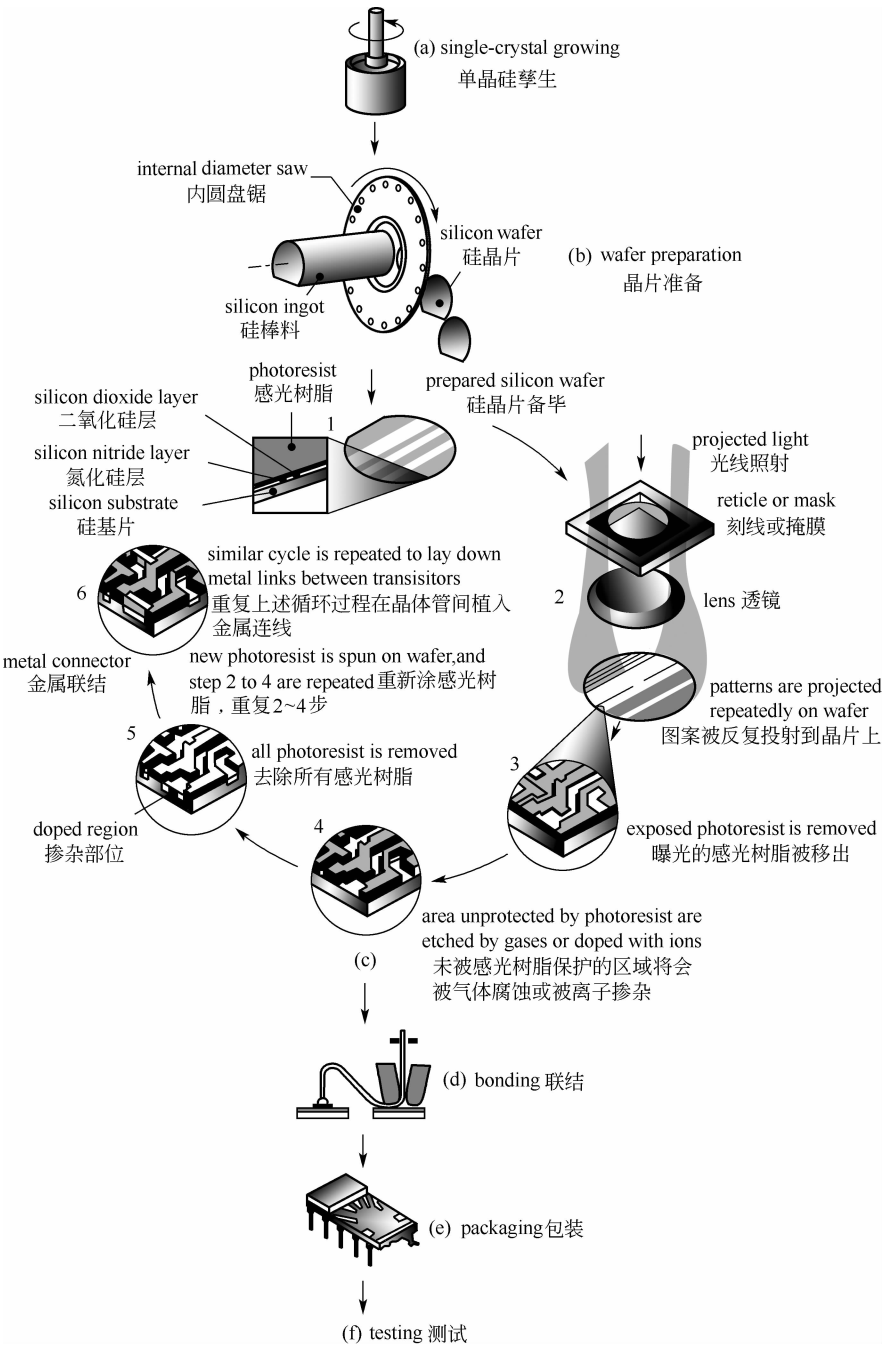
Laminated-object-manufacturing process (LOM)薄片分层叠层制造



Seamless tube or pipe production with Spray deposition 无缝钢管的喷涂成形工艺



Finishing operation on a silicon ingot to produce wafer 硅棒制造硅晶片的精密加工



The general fabrication sequence for integrated circus 集成电路的通用制作方法

Reading materials

Passage 1: **Gear Cutting Methods**

Gear forming This is a process of machining gears using a form milling cutter in a milling machine. Gears can be cut using a form milling cutter, which has the shape of the gear teeth. The form milling cutter called DP (diametral pitch, used in inch systems which is equivalent to the inverse of a module) cutters have the shape of the teeth similar to the tooth space with the involute form of the corresponding size gear. Commercial gear milling cutters are available as a set for a given module or diametral pitch. These can be used on either horizontal axis or vertical axis milling machines, though horizontal axis is more common. The vertical axis cutters are similar to end mills with the tooth profile on the cutting edge.

The tooth space actually depends upon the number of teeth. Accordingly a range of cutters with numbers 1 to 8 are available to cover the entire range of gears to be machined as shown in the following table. This is made possible by approximating the tooth profile by considering the fact that profile variation is relatively small between the gears with close range teeth. For achieving closer accuracy, additional 7 cutters are also available to account for the intermediate range of gears as shown in the Table in the third and fourth columns.

DP cutters used for form milling

Cutter number	Range of teeth that can be cut	Cutter number	Range of teeth that can be cut
1	135～Rack	1.5	80～134
2	55～134	2.5	42～54
3	35～54	3.5	30～34
4	26～34	4.5	23～25
5	21～25	5.5	19～20
6	17～20	6.5	15～16
7	14～16	7.5	13
8	12～13		

Though form milling of gears is a relatively common process in machine shops, it is suitable for small volume production, in particular for one off quantities. With a smaller number of cutters, it is possible to produce a large range of gears. The process is also suitable for producing spur, helical and worm gears. This process is economical for small volumes.

However, the accuracy of the gear is dependent upon the accuracy of the dividing head as well as the profile accuracy of the cutter for the given gear. Thus it is not to be used for very high accuracy requirements. Further, this is a slow process. Internal gears cannot be produced by this process.

Gear Generation To obtain more accurate gears, the gear is generally generated using a cutter, which is similar to the gear with which it meshes by following the general gear theory. As a result, one cutter theoretically generates all gears regardless of the number of teeth present in the manufactured gear. All the teeth have the correct profile and mesh correctly. The gears produced by generation are more accurate and the manufacturing process is also fast. These are used for large volume production. There are two types of gear generation methods that are commonly used, i. e. gear shaping, and gear bobbing.

Gear Shaping and Planning To understand the concept of gear shaping, imagine a gear blank which has a periphery that is very soft and is easily deformable. An ordinary involute gear is pressed into the rim of the gear blank until the two pitch circles are in contact. Then the gear blank is rolled together with the gear such that the pitch circles roll on each other without slipping. Since the rim of the gear blank is soft, the gear teeth is pressed and theoretically correct teeth is formed on the gear blank. The teeth so formed meshes with any other involute gear of the same module regardless of the number of teeth.

The gear shaper cutter is mounted on a vertical ram and is rotated about its axis as it performs the reciprocating action. The workpiece is also mounted on a vertical spindle and rotates in mesh with the shaping cutter during the cutting operation. The relative rotary motions of the shaping cutter and the gear blank are calculated as per the requirement and incorporated with the change gears.

The cutter slowly moves into the gear blank surface with incremental depths of cut, till it reaches the full depth. The cutter and gear blank are separated during the return (up) stroke and come to the correct position during the cutting (down) stroke.

Gear shaping can cut internal gears, splines and continuous herringbone gears that cannot be cut by other processes. This process can also cut gears close to a shoulder with very small clearance. The length of stroke of a gear shaper limits the maximum width of a gear that can be produced. However since the approach and over travel are small, this process is fast for narrow gears. Otherwise, the production rate of a gear shaper is lower compared to the other generating process, i. e. gear hobbing. For producing helical gears special oscillating motion has to be provided on a gear shaper for the reciprocating of the cutter.

Gear Hobbing Gear hobbing is a continuous process eliminating the unproductive return motion of the gear shaping operation. To understand the concept of gear hobbing, an analogy similar to that used in gear shaping can be taken. Imagine an involute rack being pressed into the gear blank with a very soft rim up to the point when the pitch circles of the rack and the gear blank meet. During this process the rack is moved lengthwise while the gear blank is rotated such that it rolls with the rack without slipping. Theoretically correct tooth profiles are formed on the gear blank rim as it is very soft. The number of teeth formed depends upon the size of the gear blank used.

The above procedure may be difficult to implement practically. It therefore is modified in the form a gear cutter called hob, where the rack is wound round the cylinder in a helix like a worm . Since the involute rack teeth are straight lines, the hob threads are easier to produce and inspect. Gashes are cut across the threads to provide the cutting edges. These cutting edges are relieved behind, for the clearance similar to a form milling cutter. Rotation of the hob causes the theoretical rack to move along a straight line.

The workpiece is mounted on a vertical axis and rotates about its axis. The hob is mounted on an inclined axis whose inclination is equal to the helix angle of the hob. This makes the gear blank teeth in the same plane as that of the gear hob teeth, which is termed as the generating plane. The hob is rotated in synchronization with the rotation of the blank and is slowly moved into the gear blank till the required tooth depth is reached in a plane above the gear blank. Then the hob is fed slowly in the axial direction of the gear blank till the complete tooth face width is achieved.

For hobbing helical gears, the hob is swivelled by an additional angle of the helix angle of the gear to be made. The hobbing process though used for gears and splines more frequently, is also suitable for other shapes such as ratchets and sprockets.

Since hobbing is a continuous process, it is fast, economical and the most productive gear machining process. It is also possible to mount more than one gear blank in the work axis to increase the production rate. However, this process cannot be used for machining internal gears or gears with shoulders and flanges because of the clearance needed for the hob.

Passage 2: Electric Discharge Machining (EDM)

A powerful spark causes pitting or erosion of the metal at both the anode (+) and cathode (−), e. g. automobile battery terminals, loose plug points, etc. This process is utilized in Electric Discharge Machining (EDM). This process is also called spark machining or spark erosion machining. The EDM process involves a controlled erosion of electrically conductive materials by the initiation of rapid and repetitive spark discharges between the tool and workpiece separated by a small gap of about 0.01 to 0.50 mm. This spark gap is either flooded or immersed in a dielectric fluid. The controlled pulsing of the direct current between the tool and the work produces the spark discharge.

Initially the gap between the tool and the workpiece, which consists of the dielectric fluid, is not conductive. However, the dielectric fluid in the gap is ionized under pulsed application of DC, thus enabling the spark discharge to pass between the tool and the work. Heat transfer from the spark to both the tool and the workpiece makes the latter to melt and partially vaporize and partially ionize the metal in a thin surface layer. Due to the inertia of the surrounding fluid, the pressure within the spark becomes quite large and may possibly assist in 'blasting' the molten material from the surface leaving a fairly flat and shallow crater. The amount of metal removed per spark depends upon the electrical energy expended per spark and the period over which it is expended.

The temperature of the arc reaches about 10000℃. The vapor of the metal is quenched by the dielectric medium when the arc is terminated by the electric pulse and thus the wear debris is always spherical in nature. The wear debris is carried away by the dielectric fluid, which is in continuous circulation. The same process as described above is continued a number of times per second with each pulse removing a small wear particle from the workpiece thereby causing the material to take the shape of the electrode. The arc is always struck at a point between the workpiece which is closest from the tool (electrode). Thus the complimentary tool surface will be reproduced in the workpiece.

Passage 3: Laser Beam Cutting

Laser cutting uses the erosion effect of high-energy light beams. As in the case of electron-beam cutting, the work material is vaporized at the point of impact. According to the laser material used, differentiation is made between solid and gas lasers. With solid lasers (e.g. ruby, neodymium-yttrium-aluminum-garnet), the excitement of a light emission is achieved with the use of a flash light (pump light), and when using a gas laser (e.g. CO_2, He-Ne) through the provision of a high voltage. A lens system focuses the monochromatic high-energy light. The power density achievable at the point of contact with the work may be up to 107 kW/cm^2.

Passage 4: Wire-EDM Machining

As with all electrical discharge machining, the actual metal removal is the result of a spark discharge jumping the gap from a tool through a dielectric to the workpiece. Upon striking the workpiece, the spark generates an intense localized heat that vaporizes a microscopic portion of the workpiece surface. In time the workpiece is simply eroded away. The traveling-wire method employs a reel of copper wire that is slowly fed past the workpiece and functions much the same as a band saw except the wire is used only once. In jumping from the wire to the workpiece, the sparks erode away a clearly defined path, which can be very closely controlled with NC. Hardened tool steels and carbides are effectively machined with this method. There is only one requirement the workpiece must be electrically conductive.

Passage 5: Chemical Etching

In contrast to the electrochemical processes, the chemical etching process does not use a forming tool nor an external electric power. The work material is mainly removed as a result of differences of potential at the grain boundaries according to the particular material being worked. A variety of acids are used as activators. Filters or centrifuges separate the removed material from the etching medium.

The work is carried out either in a bath of the etching medium (dip etching) or by spraying the etching medium on to the work (spray etching). In order to obtain a particular work geometry, the parts of the surface which are not to be machined are protected by masking. Frequently, a photographic film technique is employed, whereby the workpiece is covered with a light-sensitive film by rolling it on or dipping. A photographic image of the desired work geometry is then projected on to the work surface, so that the illuminated areas of the work become sensitive to the acid attack and the remaining areas are suitably masked.

Passage 6: Ultrasonic Machining

Ultrasonic machining (USM) is a mechanical metal removal process for brittle materials which uses high frequency oscillations of a shaped tool using an abrasive slurry. The term ultrasonic refers to the frequency range above the audible range and is above 16kHz.

Ultrasonic machining installations are mainly used for machining electrically non-conductive, brittle materials (such as glass, ceramic oxides, precious stones, carbides, germanium, silicons, graphite and hard metals). A high frequency generator activates the magnetostrictive oscillator, which transmits the high-frequency oscillations to the tool soldered to the tapered bronze transformer. The tool itself is only indirectly active in the actual metal removal process. The work material is removed through abrasive grains suspended in a slurry, which acts in a manner similar to that of the lapping process-like a number of simultaneously acting chisel points. The slurry suspension is externally applied to the work area and sucked up through the transformer.

In many installations, no separate feeding mechanism is provided. By a vertical arrangement of the tool-work system, the tool advances into the work as a result of its own weight.

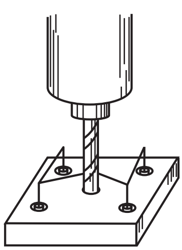
Passage 7: Electrochemical Grinding (ECG)

Electrochemical grinding (ECG) is a process that combines the electrochemical machining with the mechanical grinding operation to remove material. It uses a grinding wheel with an electrically conductive abrasive bonding agent. The electrolyte is introduced into the gap between the wheel and the workpiece in a manner similar to the application of grinding fluid in the conventional grinding operation. The ECG wheel is negatively charged while the workpiece acts as an anode.

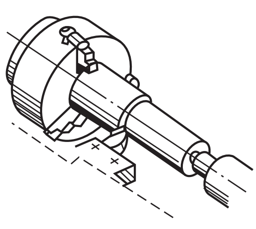
The material is removed by a combination of electrochemical action as well as grinding, The rotation of the grinding wheel draws the electrolyte into the gap. Within the contact area of the wheel and the workpiece, the material is removed by the electrochemical action in the beginning. But as the wheel advances the electrolyte becomes weak and the electrochemical action reduces where the abrasive grains are able to remove the material by mechanical action.

The material removal rates are high compared to conventional grinding processes by as much as 10 times to an average of about 1.6cm^3/min/1000 amperes. The surface finish ranges at about 0.15-0.40 μm. Tolerances are not as good as conventional grinding and range in the order 0.012 mm to 0.025 mm. The most common application of ECG is the grinding of tungsten carbide tool inserts.

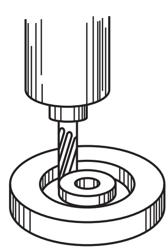
3.7 Numerical Control and Machining Center
数控加工/加工中心及其装备



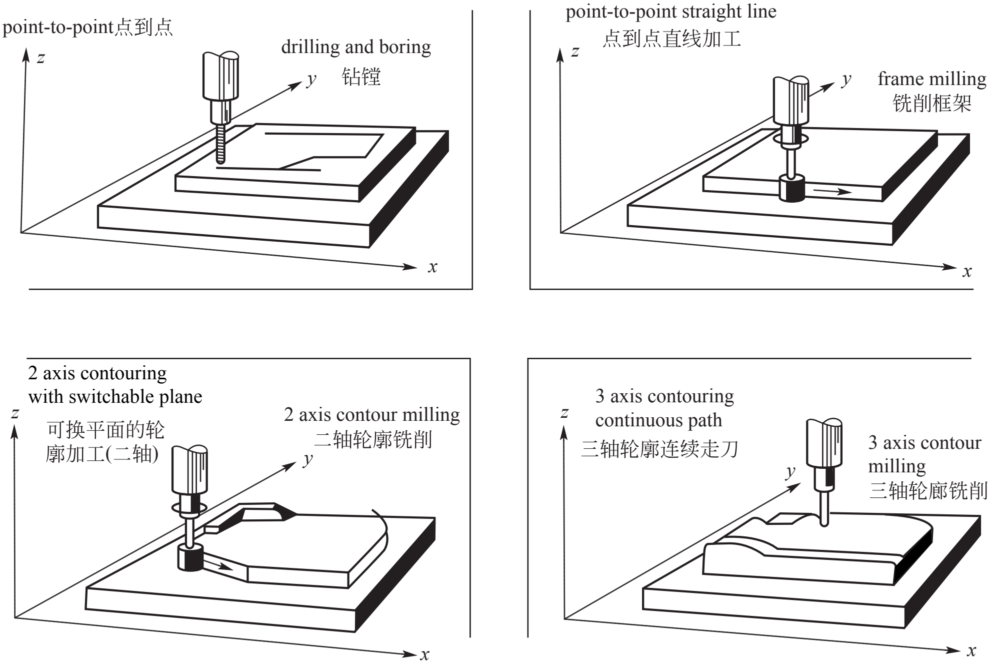
point-to-point hole machining(drilling)
点位加工



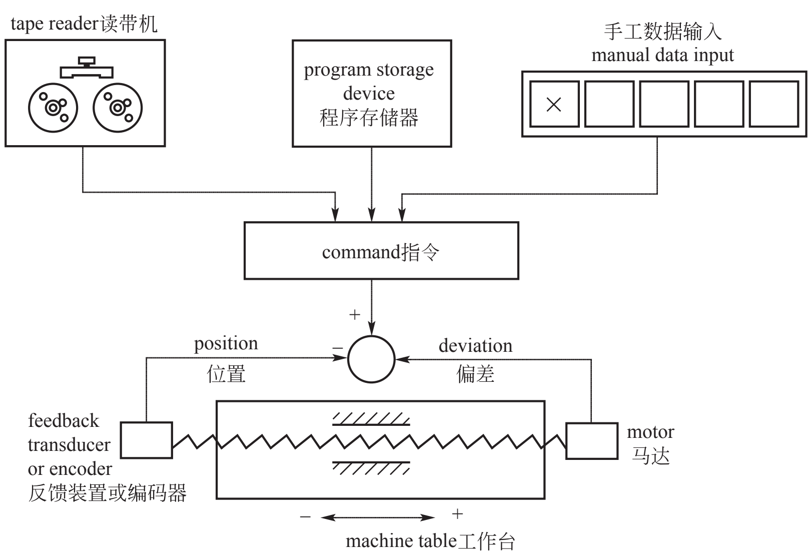
linear machining
直线加工



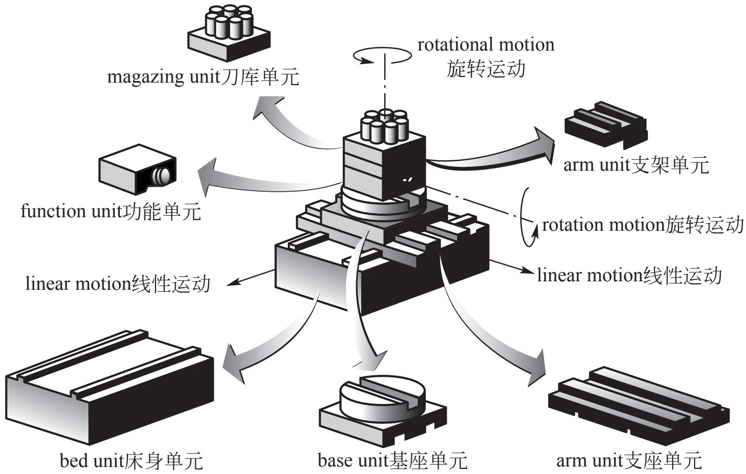
contour machining
轮廓加工



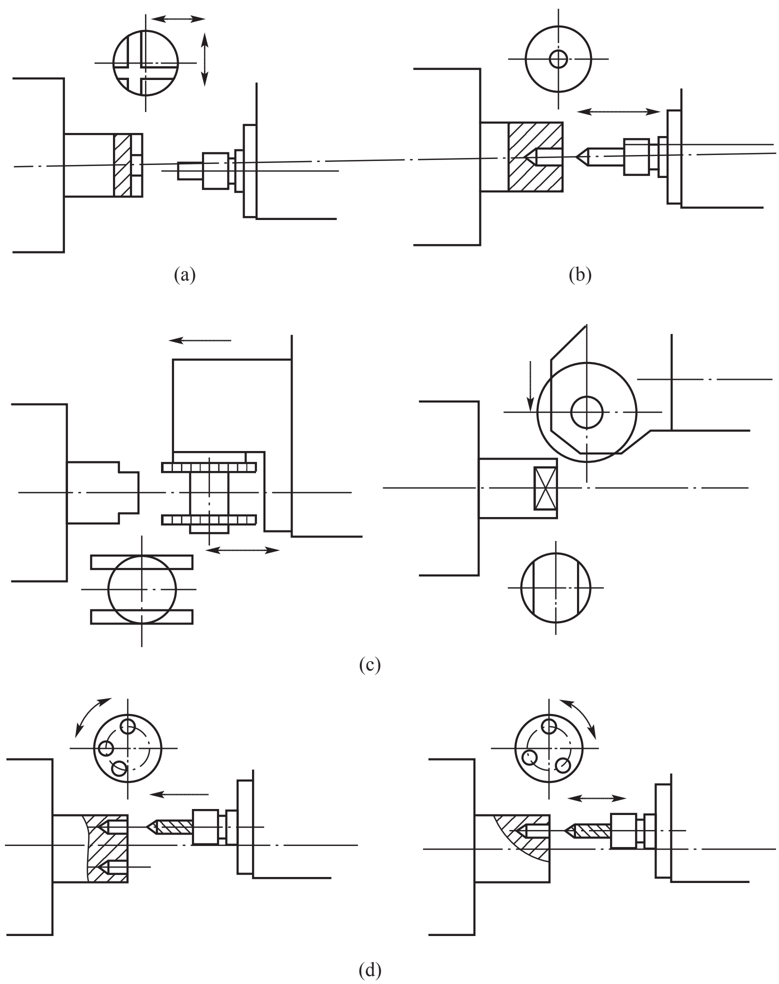
Types of NC(numerical control)machining 数控加工的类型

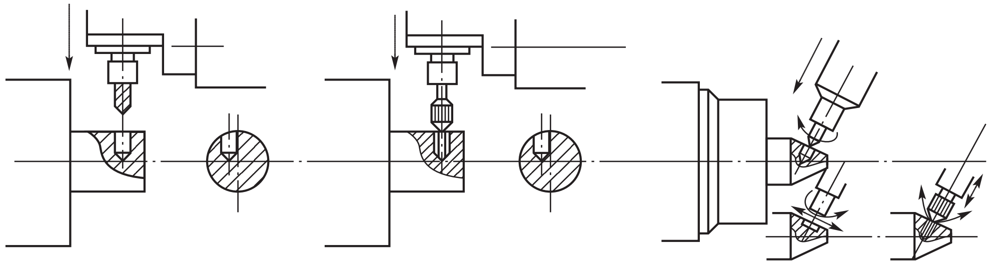


Data processing in CNC machining tool in a closed loop control
闭环 CNC 机床的数据处理



The assembly of different components of a reconfigurable machining center
可重构的加工中心不同部件的组合

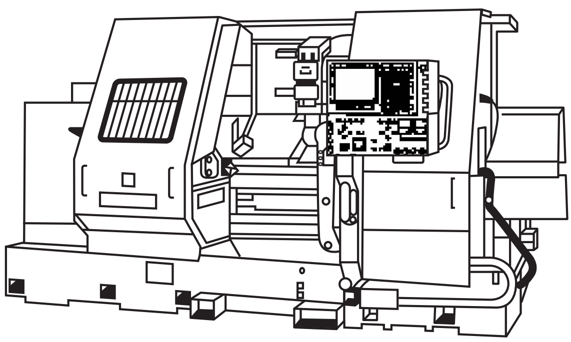




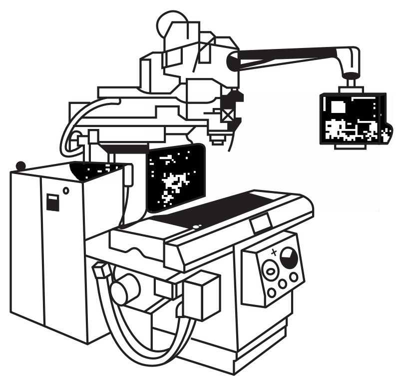
(e) (f) (g)

Application of turning centre 车削中心的应用

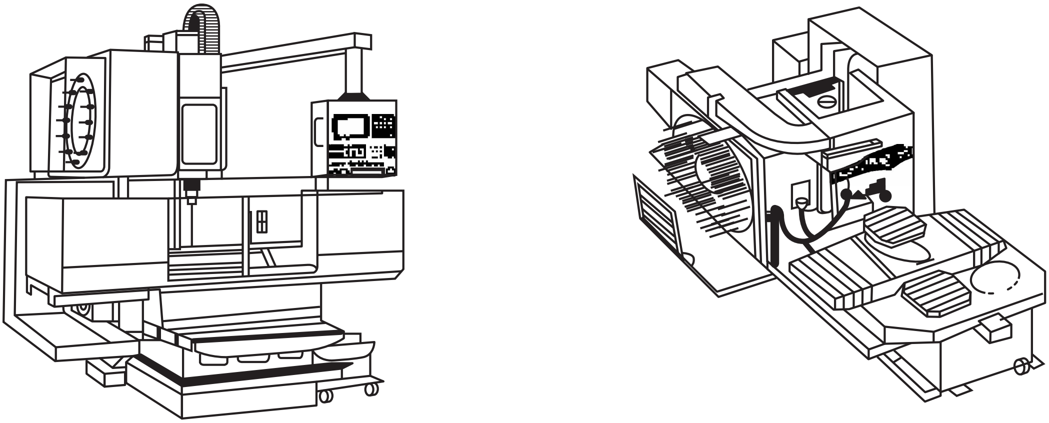
（a）facing 铣端面 （b）drilling and threading 钻孔、攻螺纹 （c）flat milling 铣削扁口平面 （d）dividing and threading 分度、攻螺纹 （e）radial drilling 横向钻孔 （f）radial threading 横向攻螺纹 （f）drilling，slotting and threading on taper 锥面上钻孔、铣槽、攻螺纹



NC lathe
数控车床



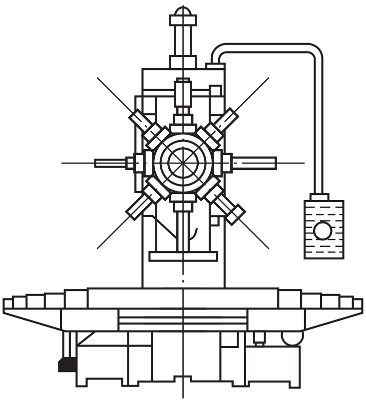
NC milling machine
数控铣床



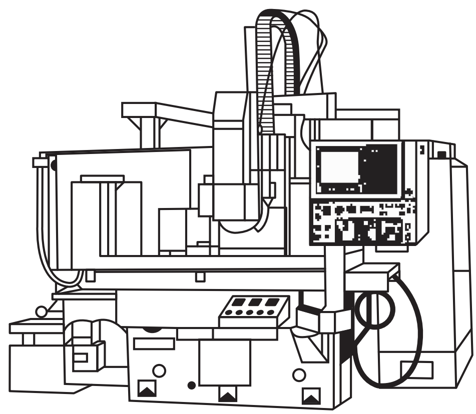
(a) (b)

Machining centre 加工中心

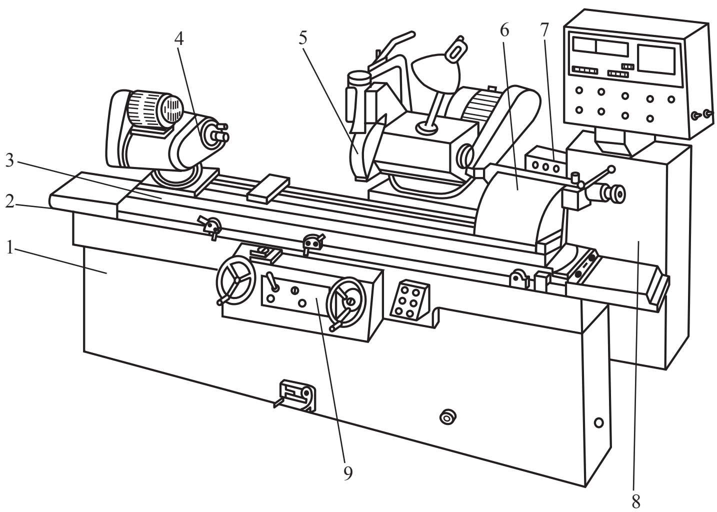
（a）vertical machining centre 立式加工中心 （b）horizontal machining centre 卧式加工中心



NC drilling machine 数控钻床

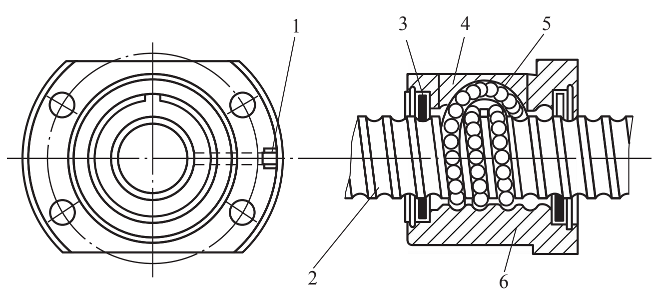


NC flat grinding machine 数控平面磨床



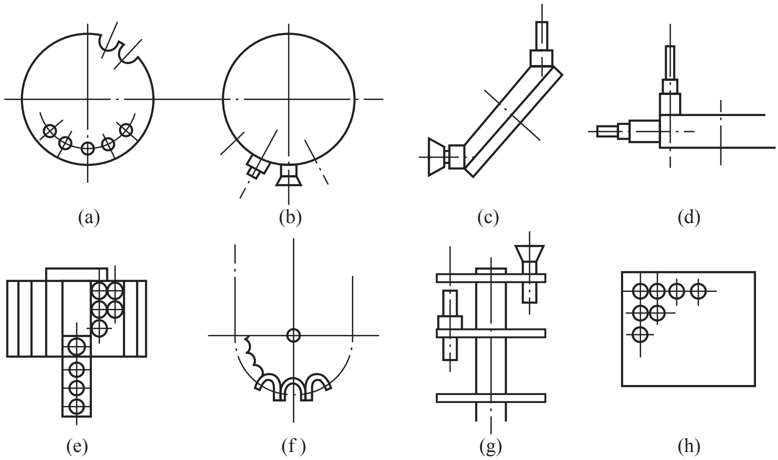
NC cylindrical grinding machine 数控外圆磨床

1 – bed 床身　2 – lower table 下工作台　3 – upper table 上工作台　4 – headstock 头架
5 – wheel spindle 砂轮主轴　6 – tailstock 尾座　7 – control panel 控制箱
8 – measure box 检测箱　9 – handle box 操作台

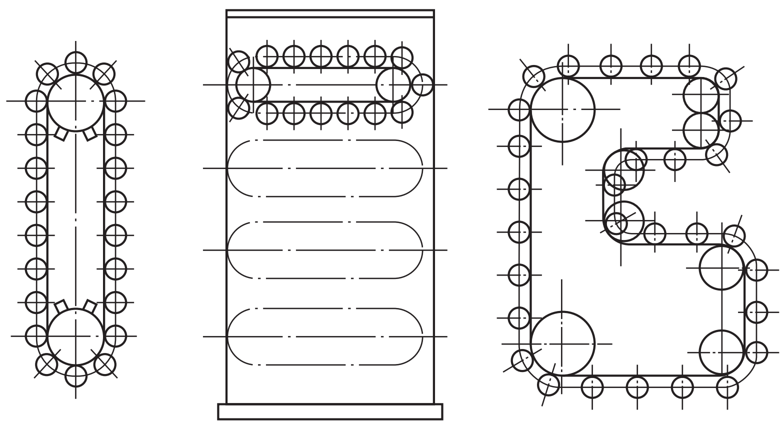


Construct of ball-screw pair with nut 滚珠丝杠螺母副结构

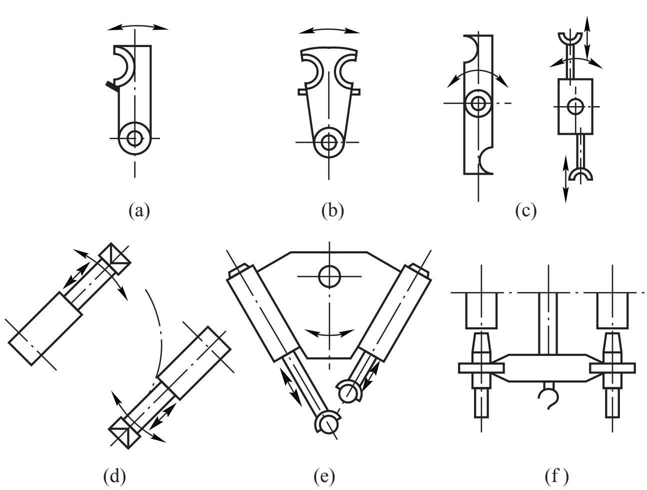
1 – oil hole 油孔　2 – ball screw 滚珠丝杠　3 – seal ring 密封圈
4 – oil cover 油罩　5 – ball path 滚珠通道　6 – nut 螺母



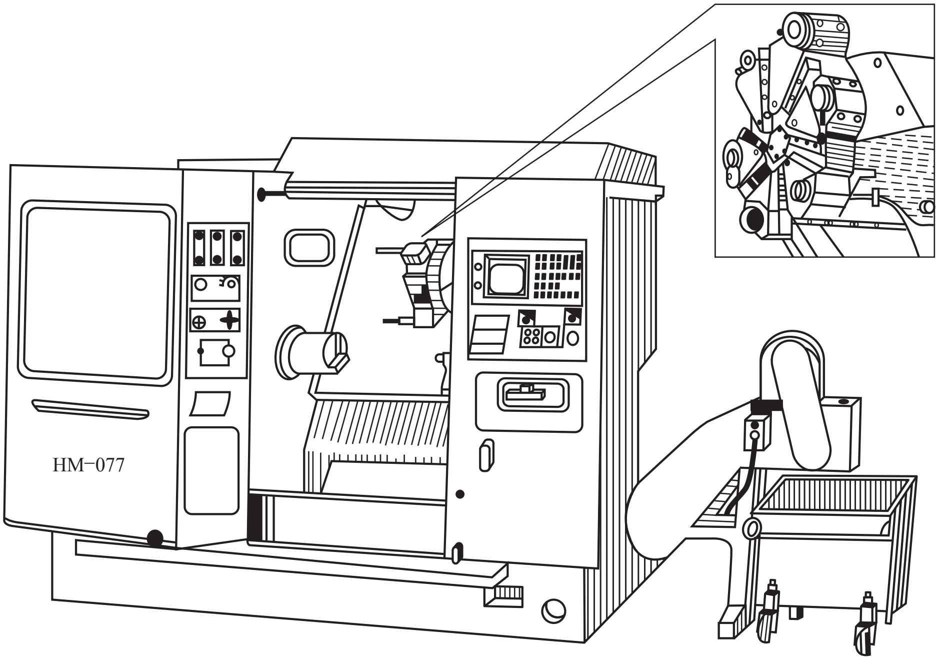
Various forms of plate-type tool changer 盘式刀库的不同形式



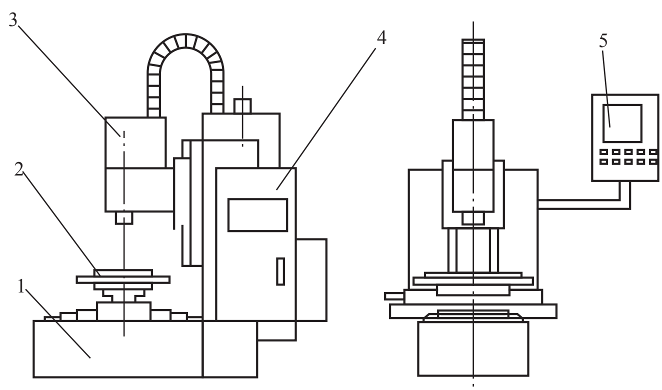
Various forms of chain-type tool changer 链式刀库的不同形式



Various forms of manipulators for tool changing 各种形式的换刀机械手

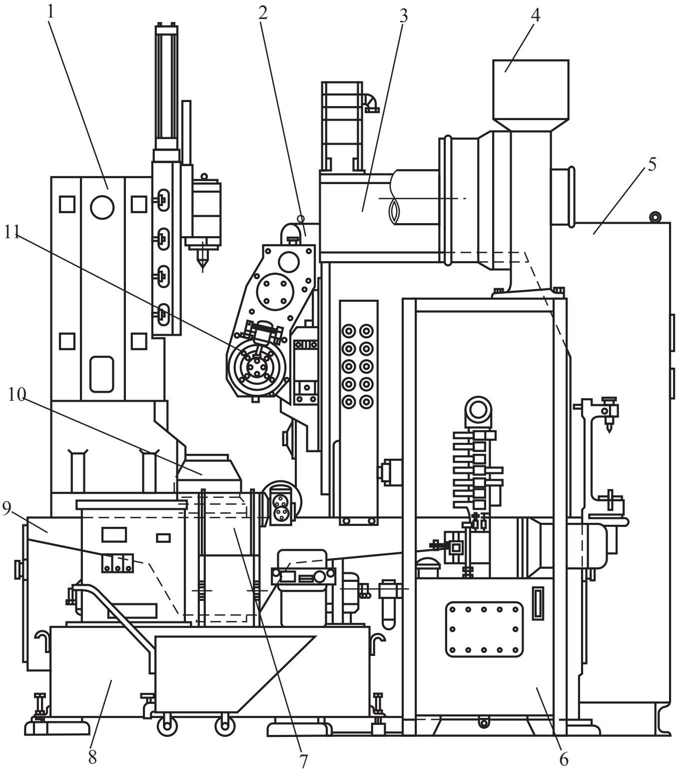


Layout of horizontal NC lathe 卧式数控车床外形



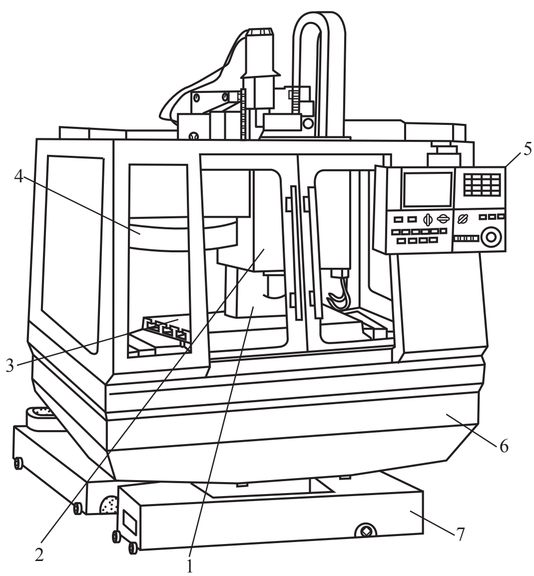
Layout of vertical NC milling, boring, drilling complex machine
立式数控铣、镗、钻复合机床

1 - bed 床身　2 - table 工作台　3 - spindle case 主轴箱
4 - control box 控制箱　5 - handle panel 控制面板



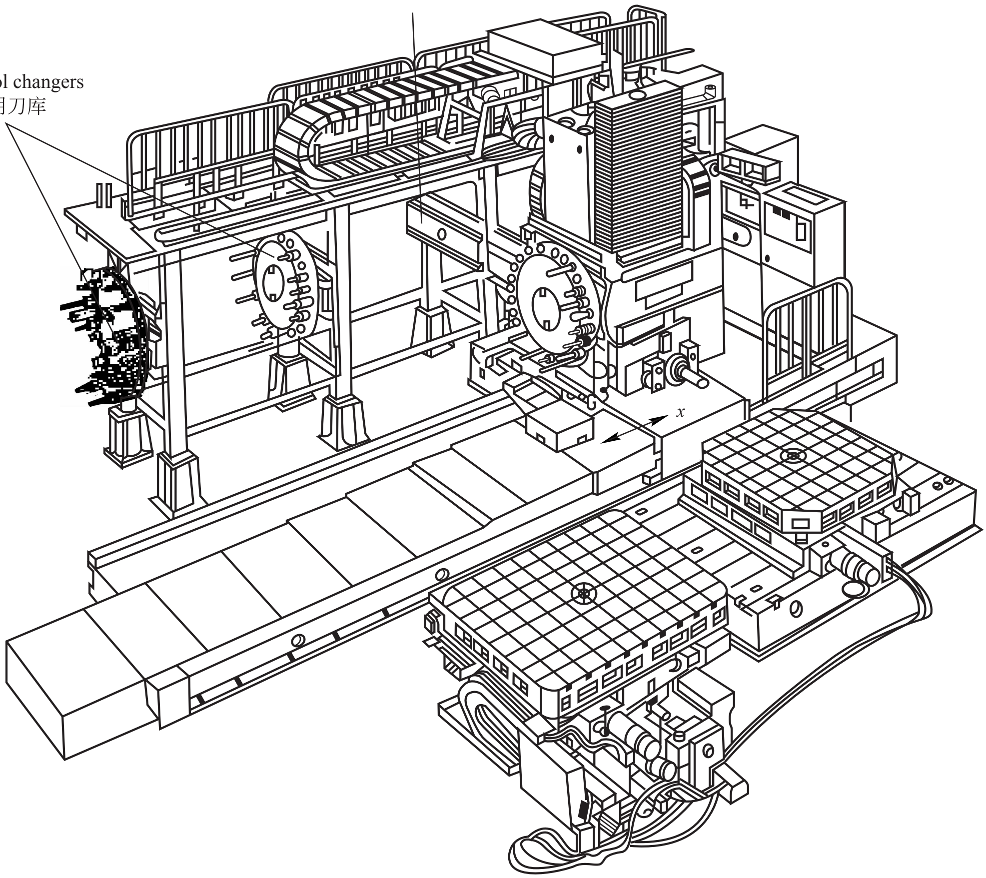
NC high speed gear cutting machine 数控高速滚齿机外形

1 – rear column 后立柱　2 – slide 滑板　3 – main column 主立柱　4 – oil frog absorber 抽油烟机
5 – electrical apparatus box 电气柜　6 – bed 床身　7 – chip excavator 排屑器　8 – cooling box 冷却箱
9 – hydraulic oil tank 液压油箱　10 – table 工作台　11 – cutter head 刀架

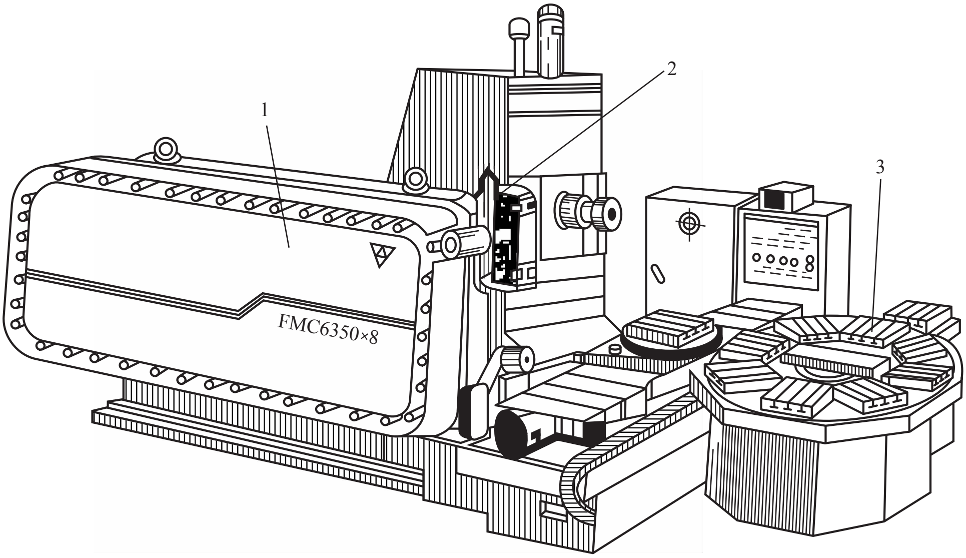


Vertical machining centre 立式加工中心

1 – column 立柱　2 – spindle component 主轴部件　3 – table and saddle 工作台和床鞍部件
4 – tool changer 刀库　5 – manual panel 操作面板　6 – bed 床身　7 – cooling system 冷却系统



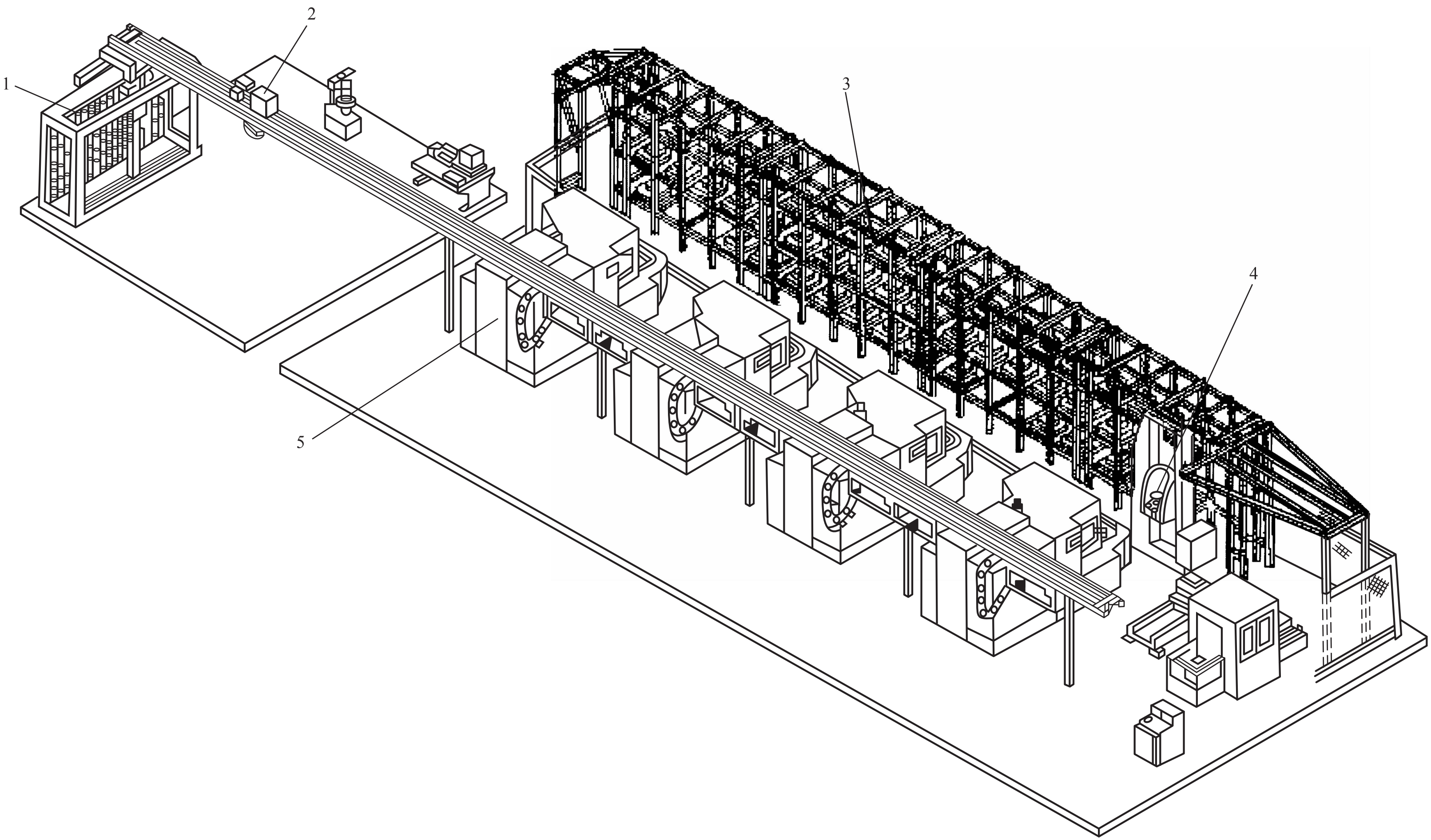
Horizontal machining centre with exchangeable tool changer 有可换刀库的卧式加工中心



Flexible manufacturing cell consisting of single machining center with pallets

由托盘和单台加工中心构成的柔性加工单元

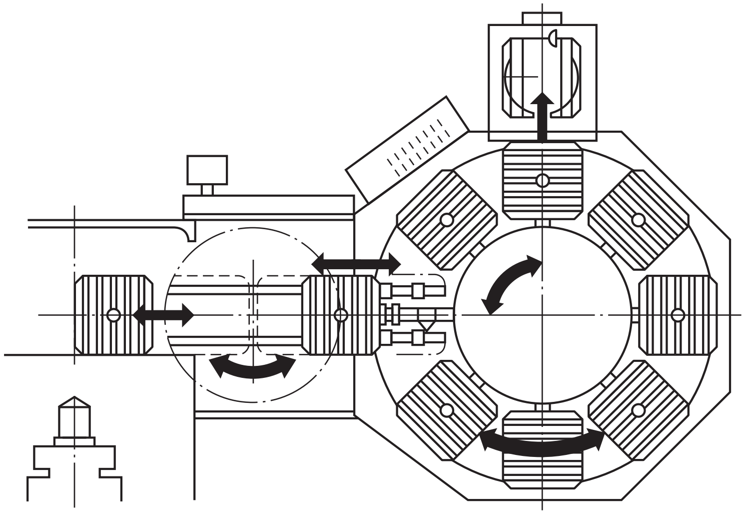
1 - tool changer 刀库 2 - manipulator 机械手 3 - pallet storage 托盘库



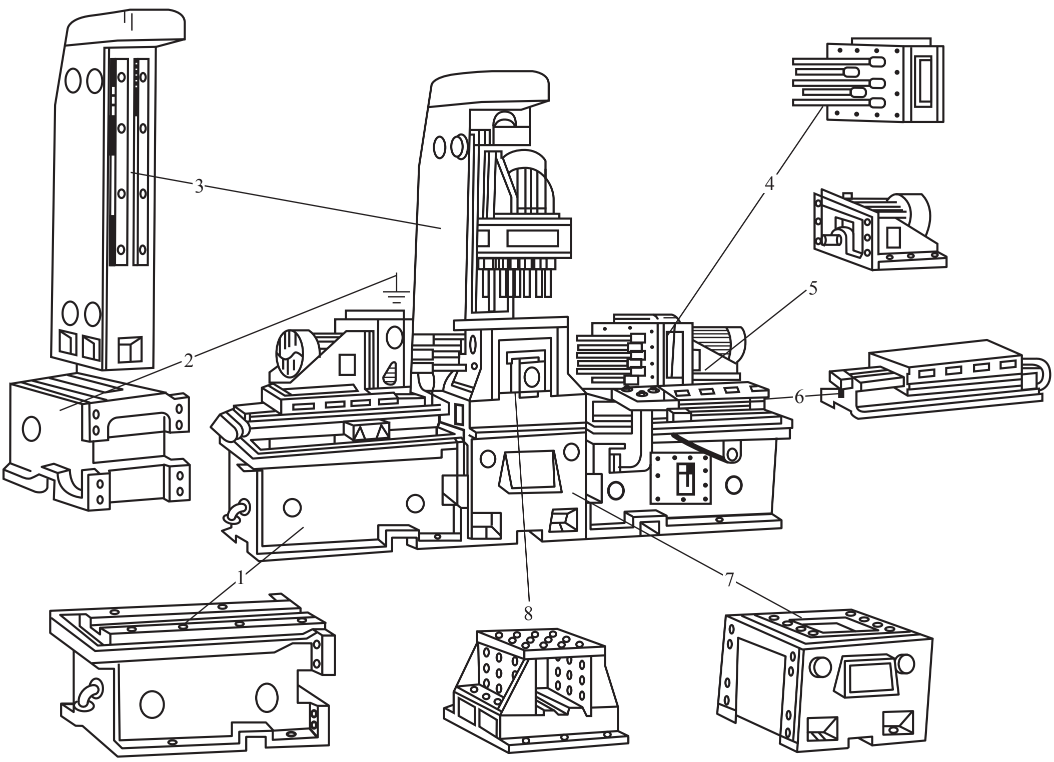
Pallet storage and central tool changer in flexible manufacturing system(FMS)柔性制造系统中的托盘库和中央刀库

1 - central tool changer 中央刀库　2 - tool convey set 刀具移送装置　3 - pallet storage 托盘库

4 - pallet convey set 托盘移送装置　5 - machining centre 加工中心

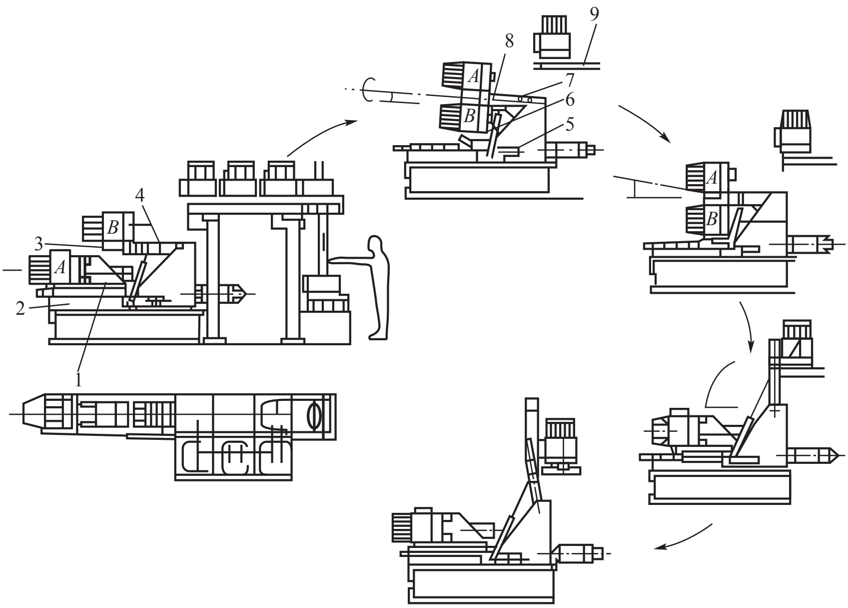


Rotary pallet exchanger 回转式托盘交换器



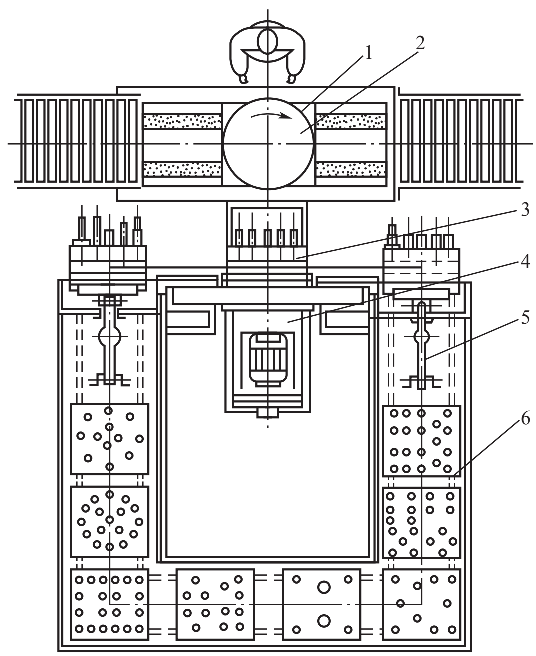
Components of modular machine 模块组合机床的组成

1 - left base 左底座　2 - base for column 立柱底座　3 - right base 右底座
4 - spindles box 主轴箱　5 - power driving box 动力箱　6 - sliding table 滑台
7 - central base 中央底座　8 - jig and fixture 夹具



Modular machine with changeable driving box 动力头可换式组合机床

1 - driving box 动力箱　2 - sliding table 滑台　3 - clamp 抓手　4 - lifting set 升降装置　5 - hydraulic cylinder 液压缸　6 - side lifting hydraulic cylinders 侧面升降油缸　7 - rotary hydraulic cylinder 回转液压缸　8 - clamping head 夹头　9 - storage for multi-spindle box 多轴箱库



Modular machine with changeable multi-spindle box by tipping set 带翻转装置的卧式多轴可换箱组合机床

1 - moveable table 移动工作台　2 - rotary table 回转工作台　3 - multi-spindle box 多轴主轴箱
4 - driving head 动力箱　5 - tipping set for multi-spindle box 主轴箱翻转装置
6 - storage for multi-spindle boxes 主轴箱库

Reading Materials

Passage 1: Numerical Control

Numerical control of machine tools may be defined as a method of automation in which various functions of machine tools are controlled by letters, numbers and symbols. Basically a NC machine runs on a program fed to it. The program consists of precise instructions about the manufacturing methodology as well as the movements. For example, what tool is to be used, at what speed, at what feed and to move from which point to which point in what path, all these instructions are given. Since the program is the controlling point for product manufacture, the machine becomes versatile and can be used for any part. All the functions of an NC machine tool are therefore controlled electronically, hydraulically or pneumatically.

In NC machine tools one or more of the following functions may be automatic:

(1) Starting and stopping of the machine tool spindle.

(2) Controlling the spindle speed.

(3) Positioning the tool tip at desired locations and guiding it along. Desired paths by automatic control of the motion of slides.

(4) Controlling the rate of movement of the tool tip (i. e. feed rate).

(5) Changing of tools in the spindle.

Initially the need of NC machines was felt for machining complex shaped small batch components as those belonging to an aircraft. However, this spectrum currently encompasses practically all activities of manufacturing, in particular capital goods and white goods. Thus the range covered is very wide. Besides machining with which we are concerned in this book, NC has been used in a variety of manufacturing situations. The majority of applications of NC are in metal cutting machine tools such as milling machines, lathes, drilling machines, grinding machines and gear generating machines. Besides a number of metal forming machine tools such as presses, flame cutting machines, pipe bending and forming machines, folding and shearing machines also use NC for their program control. The inspection machines called Co-ordinate Measuring Machines (CMM) are also based on NC. Lastly the robots basically may be material handling units, but their control principles are very close to the NC. Besides these applications listed for manufacturing, other applications such as filament winding or assembly machines based on the NC principles can also be seen in the industry.

NC machines have been found suitable for the following:

(1) Parts having complex contours, that cannot be manufactured by conventional machine tools.

(2) Small lot production, often for even single (one off) job production, such as for prototyping, tool manufacturing, etc.

(3) Jobs requiring very high accuracy and repeatability.

(4) Jobs requiring many set-ups and/or when the set-ups are expensive.

(5) Parts that are subjected to frequent design changes and consequently require more expensive manufacturing methods.

(6) The inspection cost, which is a significant portion of the total manufacturing cost.

One or more of the above considerations would justify the processing of a part by an NC machine tool.

Numerical Control is superior to conventional manufacturing in a number of ways. The superiority comes because of the programmability. These are as follows:

(1) Parts can be produced in less time and therefore are likely to be less expensive. The idle (non-cutting) time is reduced to minimum. This of course depends on the way the part program for the part is written. The endeavor of the machine tool builder is to provide a facility whereby the non-cutting time can be brought to the minimum. It is possible to reduce the non-productive time in NC machine tools in the following ways:

① by reducing the number of set-ups,

② by reducing set-up time,

③ by reducing workpiece-handling time,

④ by reducing tool-changing time.

These make NC machines highly productive.

(2) Parts can be produced more accurately even for smaller batches. In conventional machine tools, precision is largely determined by human skill. NC machines, because of automation and the absence of interrelated human factors, provide much higher precision and thereby promise a product of consistent quality for the entire batch.

(3) The operator involvement in part manufacture is reduced to a minimum and as a result less scrap is generated due to operator errors. No operator skill is needed, except in setting up of the tools and the work. Even here, the set-up has been simplified to a great extent.

(4) Since the part program takes care of the geometry generated, the need for expensive jigs and fixtures is reduced or eliminated, depending upon the part geometry. Even when a fixture is to be used, it is very simple compared to a conventional machine tool. It is far easier to make and store part programs (tapes).

(5) Inspection time is reduced, since all the parts in a batch are identical, provided proper care is taken about tool compensations and tool wear in part program preparation and operation. With the use of inspection probes in the case of some advanced CNC controllers, the measurement function also becomes part of the program.

(6) The need for certain types of form tools is completely eliminated in NC machines. This is because the profile generated can be programmed, even if it involves three dimensions.

(7) Lead times needed before the job can be put on the machine tool are reduced to a great extent, depending upon the complexity of the job. More complex jobs may require

fixtures or templates if they are to be machined in conventional machine tools, which can be reduced to a large extent.

(8) CNC machining centres can perform a variety of machining operations that have to be carried out on several conventional machine tools, thus reducing the number of machine tools on the shop floor. This would save floor space and result in less lead-time in manufacture. This would also result in an overall reduction in production costs.

(9) The set-up times are reduced, since the set-up involves simple location of the datum surface and position. Further, the number of set-ups needed can also be reduced. All this translates into lower processing times. A component can be fully machined in a single machining centre or turning centre, each of which having wider machining capabilities. In conventional manufacture if the part has to be processed through a number of machine tools which are located in different departments, the time involved in completion and the resultant in process inventory would be large. This would be greatly eliminated by the use of NC machine tools.

(10) Machining times and costs are more accurately predictable since all the elements involved in manufacturing have to be thoroughly analyzed before a part program is prepared.

(11) Operator fatigue does not come into picture in the manufacturing of a part. NC machine tool can be utilized continuously since it is more rigid than conventional machine tools.

(12) Tools can be utilized at optimum feeds and speeds that can be programmed.

(13) The modification to part design can be very easily translated into manufacture by the simple changes in part programs without expensive and time consuming changes in jigs, fixtures and tooling. This will add to the flexibility of manufacture.

(14) The capability (metal removal) of NC machines is generally high because of the very rigid construction employed in machine tool design compared to conventional machine tools.

Though NC machines have a number of advantages, there are certain limitations which one should keep in mind while making use of them.

(1) The cost of an NC machine tool is much high compared to an equivalent conventional machine tool. The cost is often 5 to 10 times higher. The cost of tooling is also high. This requires a very high initial investment. All this makes the machine hourly rate high. As a result, it is necessary to utilize the machine tool for a large percentage of time.

(2) The skill required to operate an NC machine is generally high in view of the complex and sophisticated technology involved. This requires part programmers, tool setters, punch operators and maintenance staff (electronics and hydraulics) who are more educated and trained than conventional machine operators.

(3) Special training is required for the personnel manning NC machine tools. NC manufacturing requires training of personnel both for software as well as hardware. Part

programmers are trained to write instructions in desired languages for the machines on the shop floor. They also have to be acquainted with the manufacturing process. Similarly, machine operators have to be prepared for the new NC culture. These factors are important for the successful adoption and growth of NC technology.

(4) As NC is a complex and sophisticated technology, it also requires higher investments for maintenance in terms of wages of highly skilled personnel and expensive spares. The need for maintenance engineers trained in all the subsystems present such as mechanical, hydraulic, pneumatic and electronics makes the job more difficult. Though the latest machines are equipped with a large number of diagnostic facilities, maintenance is still one major limitation.

(5) The automatic operation of NC machines implies relatively higher running costs, Moreover, the requirements of a conditioned environment for operating NC technology adds to the costs.

Passage 2: NC Machine Tools

At present, the CNC machining centre appears to be the most capable and versatile automatic machine tool that can perform drilling, milling, boring, reaming and tapping operations. The general objective behind the development of NC machine tools continues to remain the reduction of cost of production by reducing the production time. This in turn is directed towards the avoidance of non-productive time which is mainly due to the number of setups, setup time, workpiece handling time, tool change time and lead time. The performance of a variety of machining operations on the same machining centre eliminates the non-productive waiting time that occurs if such operations are performed on different machines. Provision of automatic tool changing, indexing of tables and several pallets add to the productivity of the machining centres.

The basic information that has to be input into the system consists of the part geometry and cutting process parameters followed by the cutting tools used. This part program is then entered into the controller of the machine, which in turn runs the machine tool to make the part.

The command received from the operator is communicated to the corresponding axis driving system for execution. The axis motion control system operates in a feed back loop with suitable transducers such as linear scales and/or rotary encoders to get the appropriate position or velocity feed back. Most of these systems have a very high response with good resolution of the order of 1 micron or less.

The controllers have a number of modes in which they operate. There can be four possible modes in which the controller can function in relation to a machining centre. The first shows a typical drilling machine operation, termed as point-to-point mode. In this, the control has the capability to operate all the three axes, but not necessarily simultaneously. As a result, it would be possible to move the tool to any point (in X and Y-axes) in the fastest possible speed and carry out the machining operation in one axis (Z-axis) at that point. This would be useful for drilling and punching machines. The second type is an improvement over this in which in addition to the point to point mode, the machine tool has the capability to carry out a continuous motion in each of the axis direction. This would help in obtaining the milling in a straight line along any of the axes. The third type shows a control system, which improves the previous type by adding the simultaneous motion capability in any two axes. This is what is required in most of the cases. Any 3D profiles to be machined can be completed using the concept of 2.5D mode, in view of the limitation of the machine.

The last one is the highest form of control that is generally found in most of the current day control systems. This gives the capability of simultaneous three or more axes motion. This would be useful for machining most of the complex 3D profiles encountered in industrial practice such as aerospace components, moulds and dies.

Passage 3: Computer Aided Process Planning (CAPP)

Traditionally process planning is performed manually by highly experienced planners who possess an in-depth knowledge of the manufacturing processes involved and the capabilities of the shop floor facilities. Because of the experience factor involved in planning for the physical reality of the product and in the absence of standardization of the process, conventional process planning has largely been subjective. Moreover, this activity is highly labor intensive and often becomes tedious when dealing with a large number of process plans and revisions to those plans. Rather than carrying out an exhaustive analysis and arriving at optimal values which would be time consuming, process planners often tend to play safe by using conservative values and this situation would invariably leads to non-optimal utilization of the manufacturing facilities and longer lead times. They would also not be in a position to see whether a similar component has already been planned in view of the difficulties involved in going through all the old process plans.

The need for shorter lead times, satisfying varied customer demands on the product variety and the optimum use of manufacturing facilities prompted research organizations and industries to automate many functions in the product cycle. Harnessing the power of the computer is extremely advantageous in process planning since vast amount of data needs to be used for arriving at the right decision for planning the manufacturing operations.

Computer Aided Process Planning (CAPP) is a means to automatically develop the process plan from the geometric image of the component. The key to development of such CAPP systems is to structure the data concerning part design, manufacturing facilities and capabilities into categories and logical relationships. CAPP thus appears to fully integrate CAD and CAM.

Passage 4: Characteristics and Selection of Machining Centers

The major characteristics of machining centers are summarized here:

(1) Machining centers are capable of handling a wide variety of part sizes and shapes efficiently, economically, repetitively, and with high dimensional accuracy with tolerances in the order of +0.0025mm.

(2) These machines are versatile and capable of quick changeover from one type of product to another.

(3) The time required for loading and unloading workpieces, changing tools, gauging of the part, and troubleshooting is reduced. Therefore productivity is improved, thus reducing labor requirements (particularly skilled labor) and minimizing production costs.

(4) These machines are equipped with tool-condition monitoring devices for the detection of tool breakage and wear as well as probes for tool-wear compensation and for tool positioning. In-process and post-process gauging and inspection of machined workpieces are now features of machining centers.

(5) These machines are relatively compact and highly automated and have advanced control systems, so one operator can attend to two or more machining centers at the same time, thus reducing labor costs.

Because of the high productivity of machining centers, large amounts of chips are produced and must be collected and disposed of properly; this is referred to as chip management. Several designs are available for chip collection with one or more spiral (screw) or chain conveyors that collect the chips along troughs in the machine and deliver them to a collecting point.

Machining centers are available in a wide variety of sizes and features, and their costs range from about \$50000 to \$1 million and higher. Typical capacities range up to 75kW. Maximum spindle speeds are usually in the range of 4000 to 8000rpm, and some are as high as 75000rpm for special applications using small-diameter cutters. Modern spindles can accelerate to a speed of 20000rpm in only 1.5 seconds. Some pallets are capable of supporting workpieces weighing as much as 7000kg, although even higher capacities are available for special applications.

Machining centers generally require significant capital expenditure, so to be cost effective, they may have to be used for more than one shift per day. Consequently, there must be a sufficient and continued demand for parts to justify this purchase. Because of their inherent versatility, however, machining centers can be used to produce a wide range of products, particularly for just-in-time manufacturing.

The selection of the type and size of machining centers depends on several factors, especially:

(1) Type of products, their size, and their shape complexity,

(2) Type of machining operations to be performed, and the type and number of cutting tools required,

(3) Dimensional accuracy required,

(4) Production rate required.

Appendix 附：

ISO Standard codes G 国际标准化组织标准 G 代码

Code 代码	Function 功能	Chinese translation 中译文
G00	Point-to-point positioning，rapid traverse	快速点定位
G01	Line interpolation	直线插补
G02	Circular interpolation，clockwise (CW)	圆弧插补(顺时针)
G03	Circular interpolation，anti-clockwise (CCW)	圆弧插补(逆时针)
G04	Dwell	暂停
G05	Hold/delay	保持/延时
G06	Parabolic interpolation	抛物线插补
G07	Unassigned	未指定
G08	Acceleration of feed rate	加速
G09	Deceleration of feed rate	减速
Gl0	Linear interpolation for ‘long dimensions’	“长尺寸”直线插补
G11	Linear interpolation for ‘short dimensions’	“短尺寸”直线插补
G12	Unassigned	未指定
G13～G16	Axis designation	轴选定
G17	XY plane designation	XY 平面选定
G18	ZX plane designation	ZX 平面选定
G19	YZ plane designation	YZ 平面选定
G20	Circular interpolation，CW for ‘long dimensions’	圆弧插补，CW 用于“长尺寸”
G21	Circular interpolation，CW for ‘short dimensions’	圆弧插补，CW 用于“短尺寸”
G22～G29	Unassigned	未指定
G30	Circular interpolation，CCW for ‘long dimensions’	圆弧插补，CCW 用于“长尺寸”
G31	Circular interpolation，CCW for ‘short dimensions’	圆弧插补，CCW 用于“短尺寸”
G32	Unassigned	未指定
G33	Thread cutting，constant lead	等导程螺纹加工
G34	Thread cutting，linearly increasing lead	导程线性增加螺纹加工
G35	Thread cutting，linearly decreasing lead	导程线性减小螺纹加工
G36～G39	Unassigned	未指定
G40	Cutter compensation—cancels to zero	取消刀补回零
G41	Cutter radius compensation—offset left	刀具半径补偿—左
G42	Cutter radius compensation—offset right	刀具半径补偿—右
G43	Cutter compensation—positive	刀具补偿—正
G44	Cutter compensation—negative	刀具补偿—负
G45～G52	Unassigned	未指定
G53	Deletion of zero offset	取消零偏移

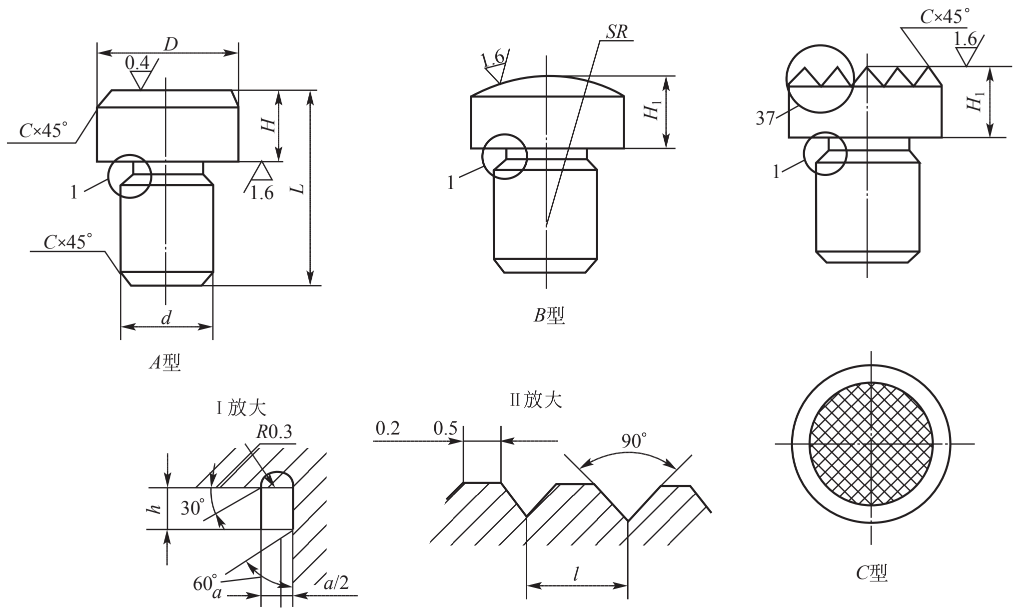
Code 代码	Function 功能	Chinese translation 中译文
G54～G59	Datum point/zero shift	基准点/零偏移
G60	Target value，positioning tolerance 1	定位公差目标值 1
G61	Target value，positioning tolerance 2，or loop cycle	定位公差目标值 2 或循环
G62	Rapid traverse positioning	快速横移定位
G63	Tapping cycle	攻螺纹循环
G64	Change in feed rate or speed	进给速度更改
G65～G69	Unassigned	未指定
G70	Dimensioning in inch units	英制尺寸
G71	Dimensioning in metric units	公制尺寸
G72～G79	Unassigned	未指定
G80	Canned cycle cancelled	取消固定循环
G81～G89	Canned drilling and boring cycles	固定钻孔、镗孔循环
G90	Specifies absolute input dimensions	指定绝对坐标输入尺寸
G91	Specifies incremental input dimensions	指定增量坐标输入尺寸
G92	Programmed reference point shift	预点寄存
G93	Unassigned	未指定
G94	Feed rate/min (inch units when combined with G70)	每分钟进给量(G70 英制)
G95	Feed rate/rev (metric units when combined with G71)	每转进给量(G71 公制)
G96	Spindle feed rate for constant surface feed	恒定主轴进给
G97	Spindle speed in revolutions per minute	主轴每分钟转速
G98～G99	Unassigned	未指定

ISO Standard M codes 国际标准化组织标准 M 代码

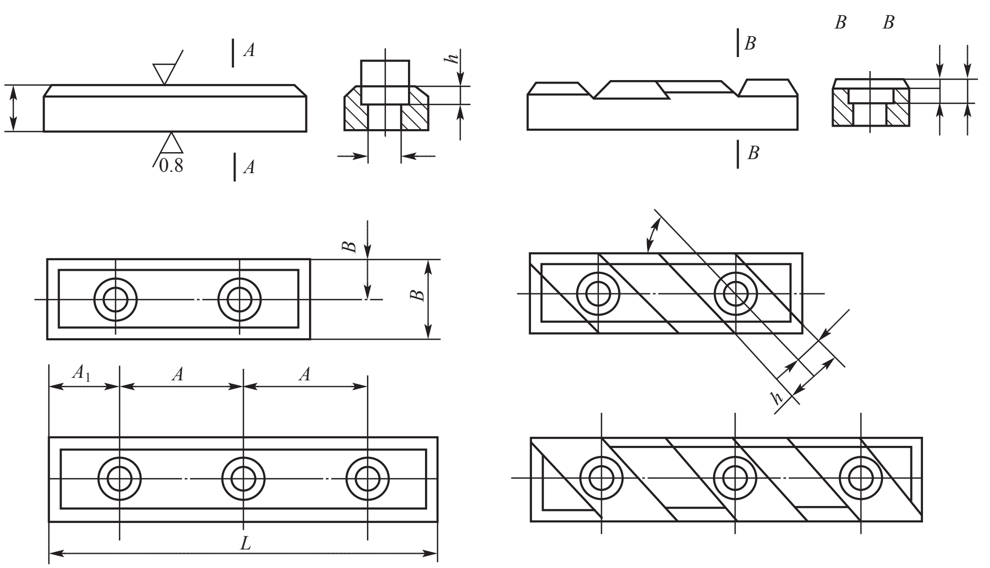
Code 代码	Function 功能	Chinese translation 中译文
M00	Program stop，spindle and coolant off	程序停止，主轴、冷却液关闭
M01	Optional programmable stop	选择可编程序停止
M02	End of program—often interchangeable with M30	程序结束与 M30 互换
M03	Spindle on，CW	主轴顺时针开启
M04	Spindle on，CCW	主轴逆时针开启
M05	Spindle stop	主轴停止
M06	Tool change	换刀
M07	Coolant supply No. 1 on	冷却液开启 1
M08	Coolant supply No. 2 on	冷却液开启 2
M09	Coolant off	冷却液关闭
M10	Clamp	夹紧
M11	Unclamp	松开夹具
M12	Unassigned	未指定

Code 代码	Function 功能	Chinese translation 中译文
M13	Spindle on，CW＋coolant on	主轴顺时针开启，冷却液开启
MI4	Spindle on，CCW＋coolant on	主轴逆时针开启，冷却液开启
M15	Rapid traverse in＋direction	正横向移动
M16	Rapid traverse in－direction	负横向移动
M17～M18	Unassigned	未指定
M19	Spindle stop at specified angular position	主轴指定角位停止
M20～M29	Unassigned	未指定
M30	Program stop at end tape ＋ tape rewind	纸带结束，倒纸带
M31	Interlock by-pass	互锁旁路
M32～M35	Constant cutting velocity	恒定切速
M36～M39	Unassigned	未指定
M40～M45	Gear changes；otherwise unassigned	齿轮换挡，否则，不指定
M46～M49	Unassigned	未指定
M50	Coolant supply No. 3 on	冷却液开启 3
M51	Coolant supply No. 4 on	冷却液开启 4
M52～M54	Unassigned	未指定
M55	Linear cutter offset No. 1 shift	刀具直线位移，位置 1
M56	Linear cutter offset No. 2 shift	刀具直线位移，位置 2
M57～M59	Unassigned	未指定
M60	Piece part change	更换工件
M61	Linear piece part shift，location 1	工件直线位移，位置 1
M62	Linear piece part shift，location 2	工件直线位移，位置 1
M63～M67	Unassigned	未指定
M68	Clamp piece part	夹紧工件
M69	Unclamp piece part	放松工件
M70	Unassigned	未指定
M71	Angular piece part shift，location 1	工件角度位移，位置 1
M72	Angular piece part shift，location 2	工件角度位移，位置 1
M73～M77	Unassigned	未指定
M78	Clamp non-activated machine bed-ways	夹紧非驱动导轨
M79	Unclamp non-activated machine bed-ways	放松非驱动导轨
M80～M99	Unassigned	未指定

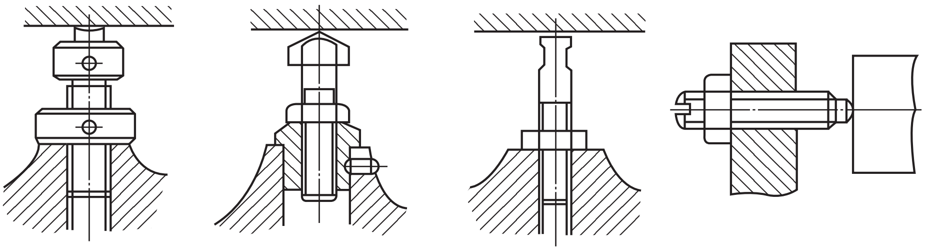
3.8　Jig and Fixture，Tooling 工装夹具



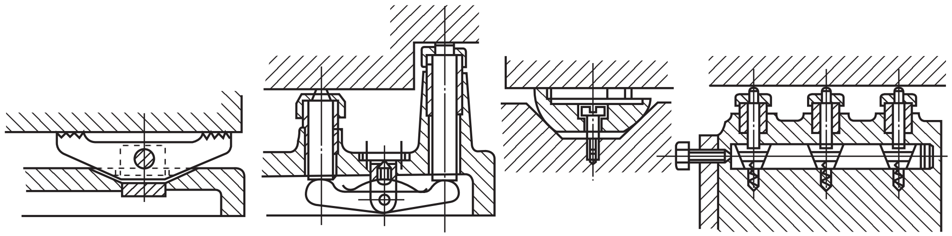
Various forms of rest buttons 支承钉的形式



Various forms of rest plates 支承板的形式

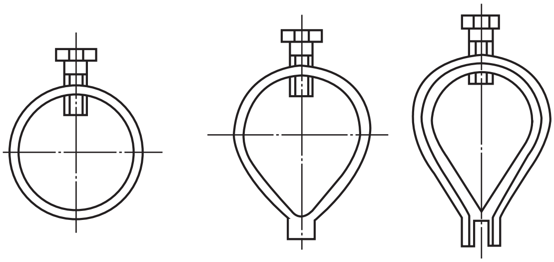


Various forms of adjustable rest buttons 可调支承钉的形式

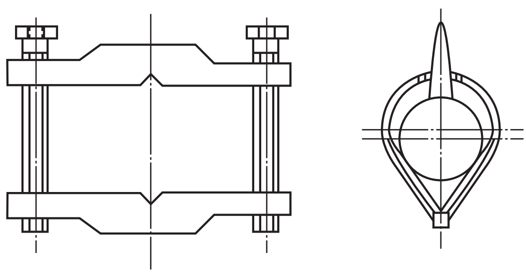


(a) (b) (c) (d)

Various forms of self-positioning rest buttons 自位支承钉的形式

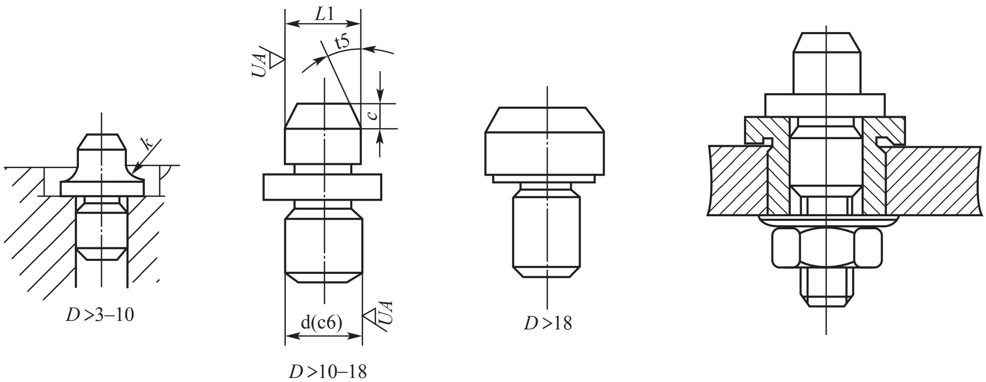


(a) (b) (c)



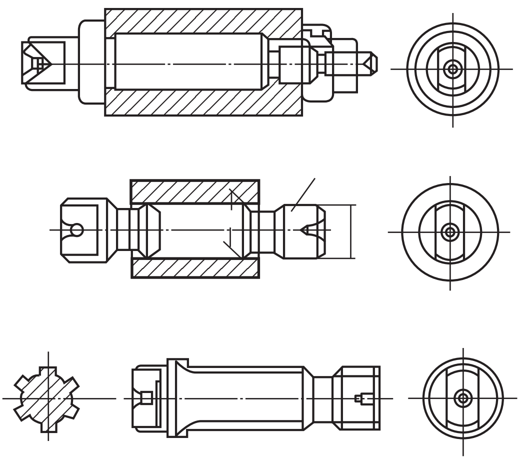
(d) (e)

Clamping dogs 夹头

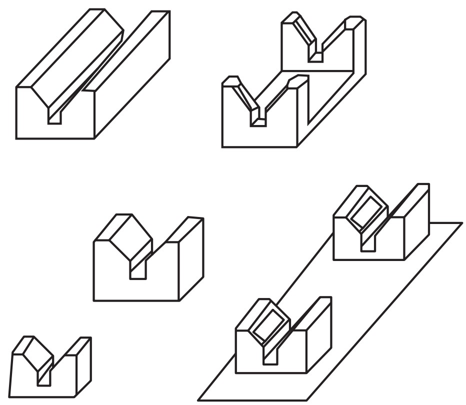


(a)　(b)　(c)　(d)

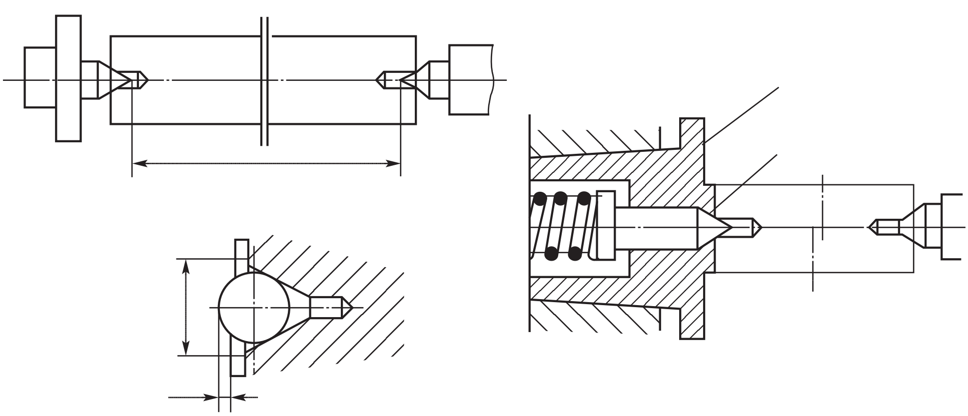
Cylindrical positioning pins 圆柱定位销



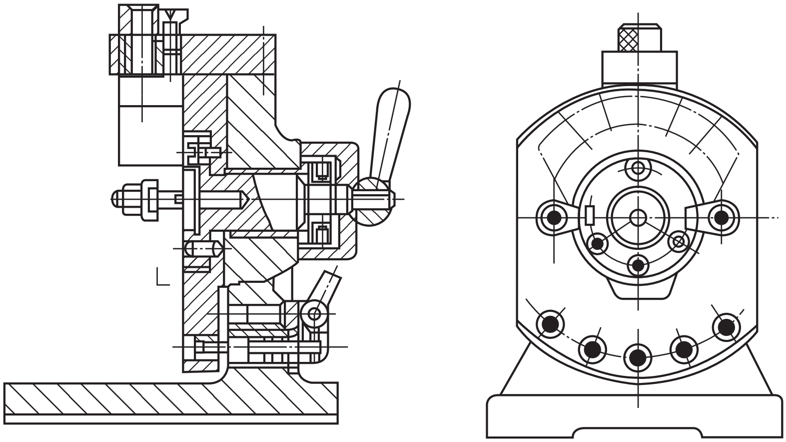
Cylindrical mandrel 圆柱心轴



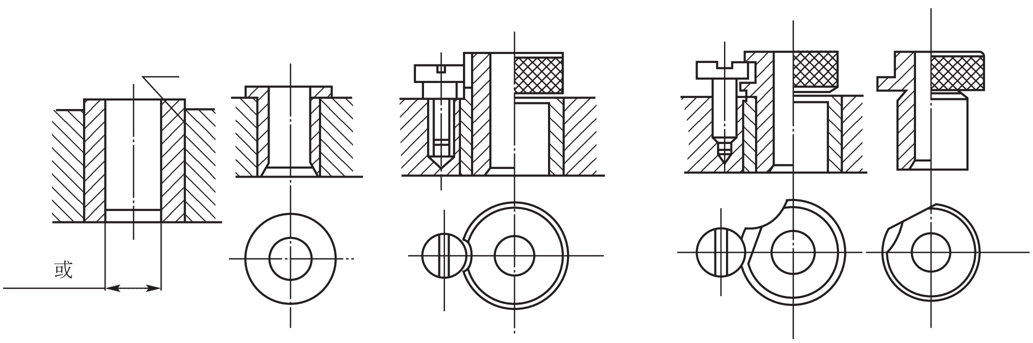
V positioning locating block V 形块



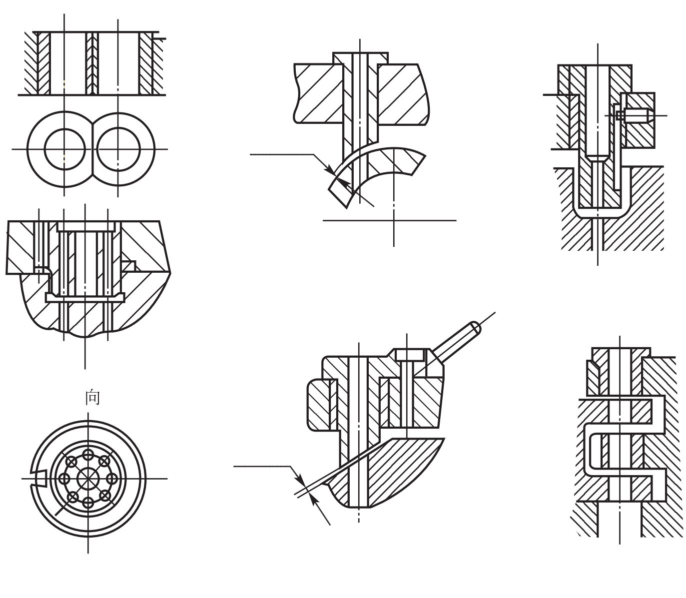
Positioning by centre holes 中心孔定位



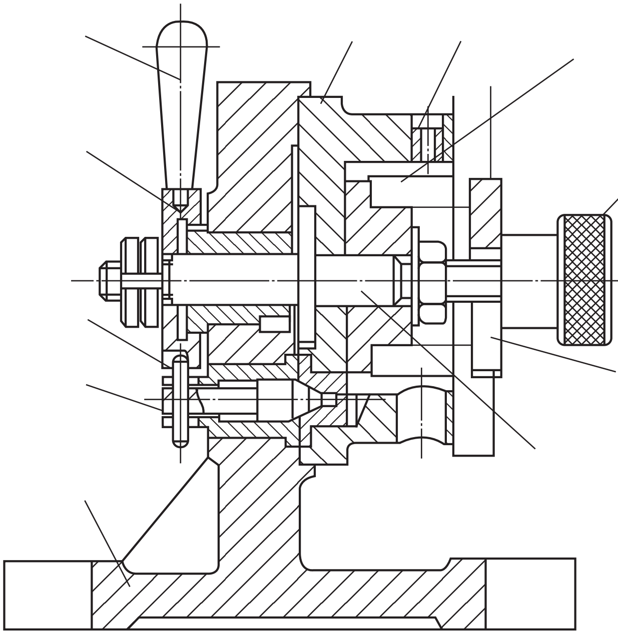
Dividing set with push-in pin 分度销插入式分度装置



Standard drill bushings 标准钻套

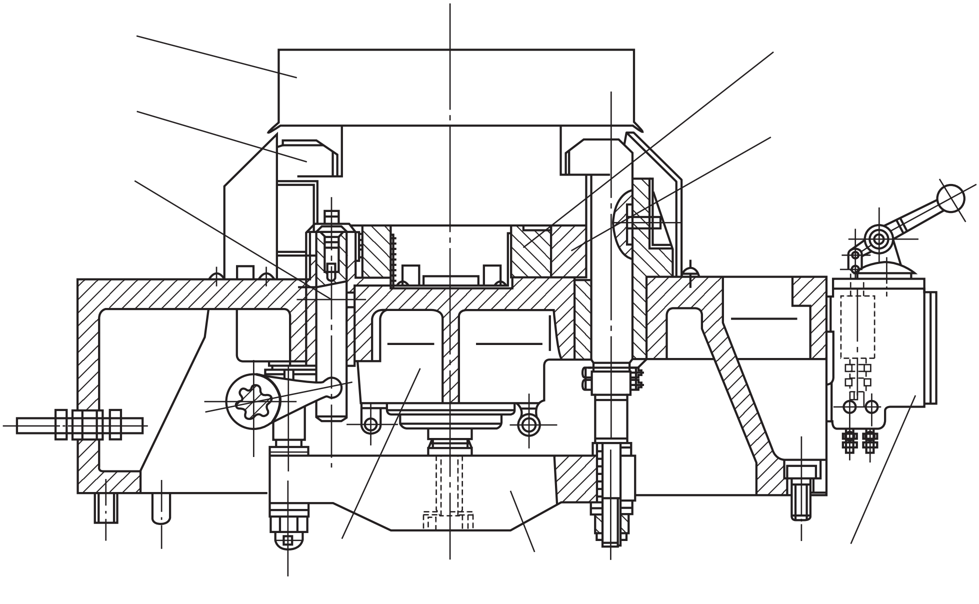


Special structure drill bushings 特殊钻套



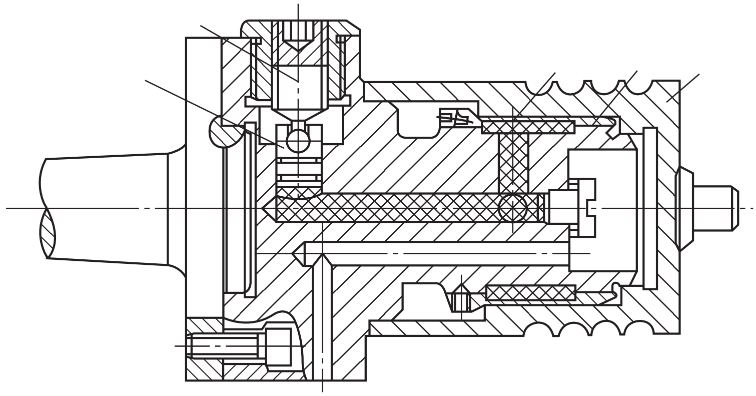
Rotary drill jig 回转式钻模

1－base 夹具体　2－push-in positioning pin 插销　3－pin 销　4－screw bush 螺纹套
5－handle 手把　6－rotary plate 转盘　7－drill bushing 钻套
8－positioning part 定位件　9－knurled nut 滚花螺母
10－snap washer 开口垫片　11－rotary spindle 转轴



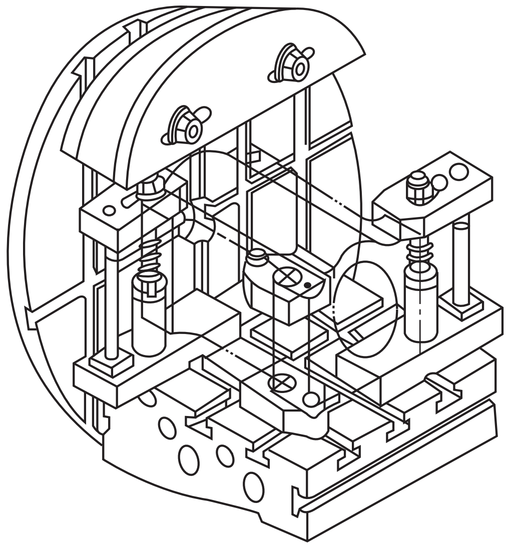
Follower jig and fixture on automation line 自动线上随行夹具

1－slide positioning pin 活动定位销　2－hook clamping plate 钩形压板　3－follower jig 随行夹具
4－convey support 输送支承　5－positioning rest plate 定位支承板
6－lubricating pump 润滑液压泵　7－lever 杠杆　8－hydraulic cylinder 液压缸

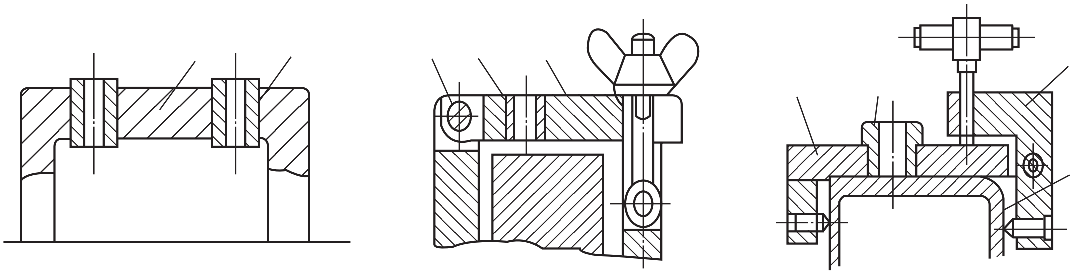


Positioning and clamping fixture with liquidized plastics 液性塑料定心夹紧夹具

1 – slide pin 滑柱　2 – clamp bolt 压紧螺钉　3 – liquid plastics 液性塑料
4 – thin-wall bushing 薄壁套筒　5 – workpiece 工件

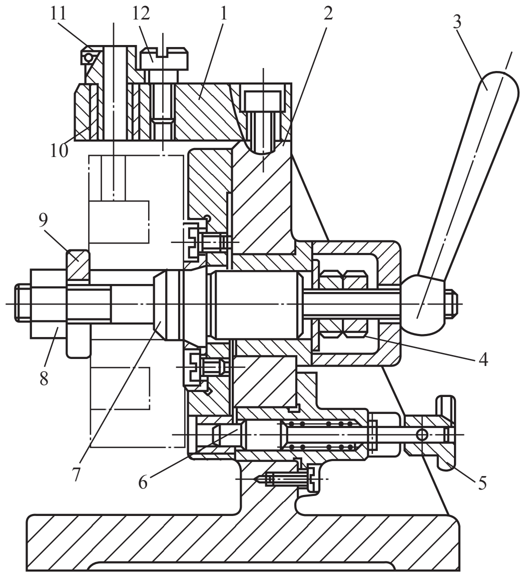


Modular jig 组合夹具



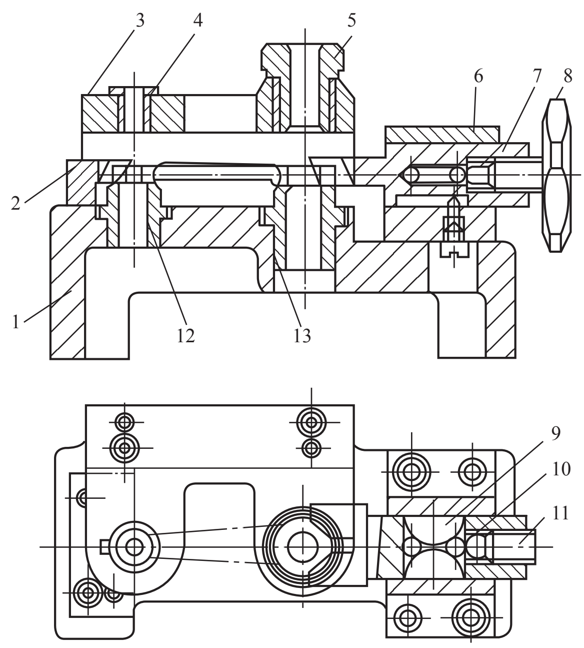
Drill jig plate 钻模板

1 – drill jig plate 钻模板　2 – drill bushing 钻套　3 – pivot 转轴
4 – clamping plate 压板　5 – workpiece 工件



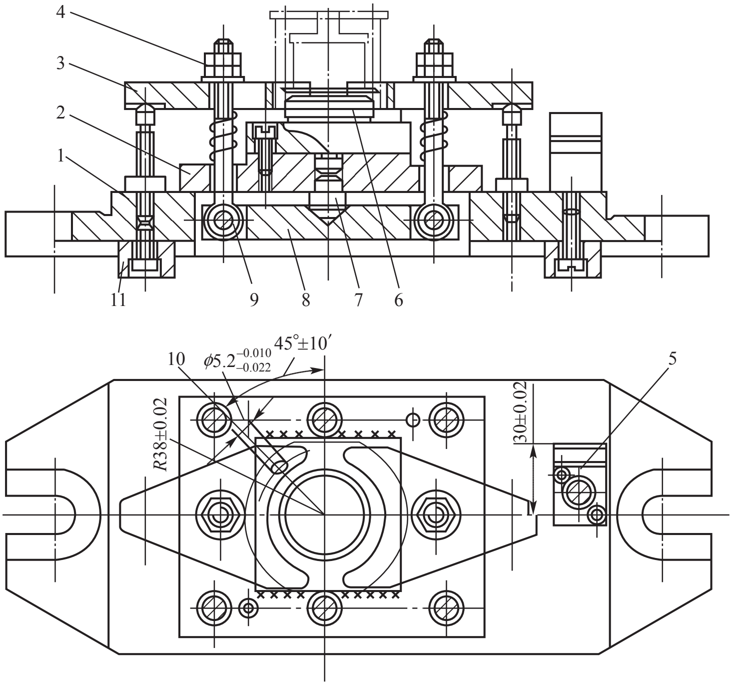
Special-purpose rotary drill jig 专用回转式钻模

1 – drill plate 钻模板　2 – body 夹具体　3 – handle 手柄　4，8 – nut 螺母　5 – knob 旋钮
6 – alignment pin 对定销　7 – cylinder pin 圆柱销　9 – quick change washer 快换垫圈
10 – sleeve 衬套　11 – drill bushing 钻套　12 – screw 螺钉



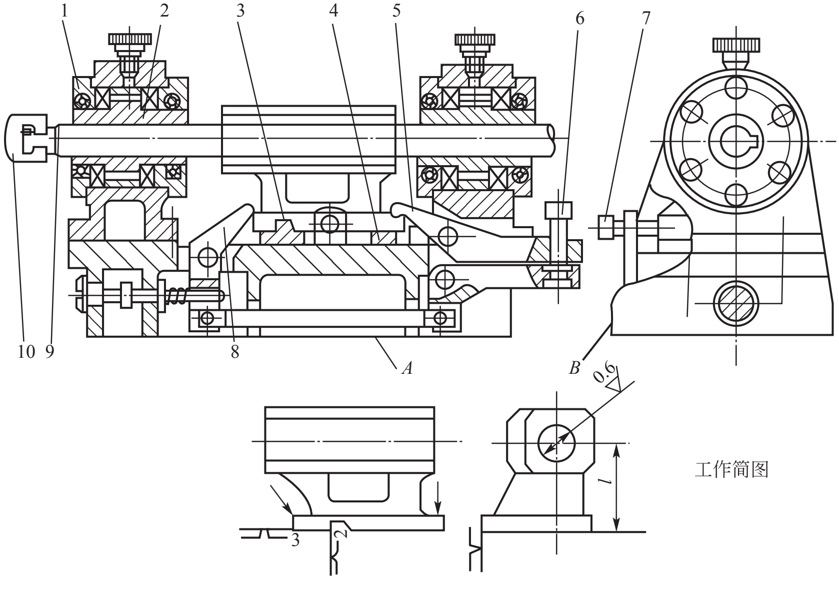
Shift drill jig 移动式钻模

1 – jig body 夹具体　2 – fixed V positioning block 固定式 V 形块　3 – drill plate 钻模板
4，5 – drill bushing 钻套　6 – support base 支座　7 – moveable V positioning block
活动式 V 形块　8 – handle knob 手轮　9 – woodruff key 半圆键
10 – ball 滚珠　11 – screw 螺钉　12，13 – positioning bushing 定位套



Milling jig for shell work machining 加工壳体的铣床夹具

1 - jig body 夹具体　2 - rest plate 支承板　3 - clamping bar 压板　4 - nut 螺母
5 - tool check block 对刀块　6 - positioning cylinder 定位销　7 - ball head pin 球头钉
8 - pivot plate 铰接板　9 - bolt bar 螺杆　10 - anti-rotation pin 防转销　11 - guide key 导向键



Boring jig for tailstock machining 尾座镗削夹具

1 - jig frame 镗模架　2 - boring bushing 镗套　3，4 - positioning plate 定位板
5，8 - clamping bar 压杆　6 - clamping screw 夹紧螺钉　7 - adjustable supporting 可调支承
9 - tool bar 镗刀杆　10 - floating couple 浮动接头

Reading Materials

Passage 1: Locating Elements

AS a rule, the chief locating elements of jigs and fixtures are stationary stops. The most widely used types of stationary stops are rest buttons .

Rest buttons with a rounded head are used for locating a rough surface. In this case, the area of contact between the button and workpiece will approach a point. This will result in mere definite location and will ensure a higher stability of the workpiece.

Flat rest buttons or pads are used for locating flat machined surfaces.

It is not advisable to use rounded-head rest buttons in this case for the following reasons:

(1) In point contact between the button and workpiece, the button surface wears rapidly and its height is changed. Usually when a workpiece is located on a machined surface, accurate location is required.

(2) If the area of contact on the workpiece surface is small, an impression or dent may remain on the surface due to the high specific pressures produced in work clamping.

A workpiece is located on a rough un-machined surface in a jig or fixture on three locating elements ("three points"). With more points the location will be indefinite since a surface which is not a true plane can only contact any three points simultaneously.

The locating (workpiece support) elements should be arranged so that the centre of gravity of the workpiece and the projections of the clamping forces are within the triangle formed by the elements. This will prevent the workpiece from turning over under the action of its own weight or due to the clamping forces. The clamps are positioned, if possible, so that their action is opposite the workpiece supports.

Sometimes, when a workpiece is located on fixed or stationary locators, a more stable position of the workpiece is required. This stability is provided for by adjustable locators. Adjustable locators are classified into three types: ①jackscrews, ②wedge-type jack pins, ③spring jack pins.

The first of these are screwed out of the body and into contact with the located workpiece. The second are pushed up by the wedge into contact with the workpiece, The third type, spring jack pins, are pushed down, compressing the spring, by the weight of the workpiece until the latter is located on the principal locating elements. The pin is then firmly locked in this position. Here, the spring ensures contact between the pin and work.

V-blocks are widely applied for locating external cylindrical surfaces in jigs and fixtures. This type of location will properly locate the longitudinal plane of symmetry of the cylinder. V-blocks usually have an angle of 90°, angles of 60°and 75° are much less frequent.

Housings and other parts are often located in jigs and fixtures on a flat surface and holes. A workpiece resting on a flat surface will be definitely located by two holes which fit over two locating pins in the jig or fixture.

Heavy workpieces are usually located on retractable locating pins which are extended into the locating holes after the workpiece has been loaded on the flat surface.

One of the locating pins is usually of the diamond type to reduce the effect of a dimensional variation between the holes on the setting-up accuracy, As an example, a certain workpiece is located on two straight (cylindrical) pins. It will be assumed that the workpiece may be loaded and removed from the jig or fixture if there is no clearance between locating holes and pins and if the distance between the holes is the nominal value. To load workpiece in which the centre-to-centre distance L varies within the tolerance 2a, the corresponding clearance will have to be provided between one of the locating pins and its hole in the workpiece. Otherwise, only workpiece, in which the deviation of the distance L corresponds to the clearance between none pin and its hole, can be located on the two pins.

The position of the workpiece, in the direction of a line passing through the hole centres, is fully determined by one locating pin. Angular location of the workpiece about the first pin is provided for by a second pin.

Therefore, if the second pin is of the diamond type, it will be possible to decrease the clearance between the diamond pin and hole in a direction important for proper location, i. e. , to increase the angular co-ordination accuracy.

Passage 2: Flexible Fixturing

In describing work-holding devices for the manufacturing operations throughout this book, the words clamp, jig, and fixture often are used interchangeably and sometimes in pairs, such as in jigs and fixtures. Clamps are simple multifunctional workholding devices, and jigs have various reference surfaces and points for accurate alignment of parts or tools. Fixtures generally are designed for specific purposes. Other work-holding devices also include chucks, collets, and mandrels, many which usually are operated manually. Workholding devices also are designed and operated at various levels of mechanization and automation (such as power chucks) and are driven by mechanical, hydraulic, or electrical means.

Work-holding devices generally have specific ranges of capacity. For example (1) a particular collet can accommodate bars only within a certain range of diameters; (2) four-jaw chucks can accommodate square or prismatic workpieces having certain dimensions; and (3) various other devices and fixtures are designed and made for specific workpiece shapes and dimensions and for specific tasks, called dedicated fixtures. If the part has curved surfaces, it is possible to shape the contacting surfaces of the jaws themselves by machining them (machinable jaws) to conform to the workpiece surfaces.

The emergence of flexible manufacturing systems has necessitated the design and use of workholding devices and fixtures which have built-in flexibility. There are several methods of flexible fixturing based on different principles that also are called intelligent fixturing systems. These devices are capable of quickly accommodating a range of part shapes and dimensions—without the necessity of extensive changes, adjustments, or requiring operator intervention—both of which would affect productivity adversely.

Modular fixturing Modular fixturing often is used for small or moderate lot sizes, especially when the cost of dedicated fixtures and the time required to produce are difficult to justify. Complex workpieces can be located within machines through fixtures produced quickly from standard components and can be disassembled when a production run is completed. Modular fixtures usually are based on, tooling plates or blocks configured with grid holes or T-slots upon which a fixture is constructed.

A number of other standard components (such as locating pins, adjustable stops, workpiece supports, V-blocks, clamps and springs) can be mounted onto the base plate or block to quickly produce a fixture. By computer-aided fixture planning specific applications, such fixtures can be assembled and modified using industrial robots. As compared with dedicated fixturing, modular fixturing has been shown to be low in cost, have a shorter lead time, easier to repair damaged components, and possess more intrinsic flexibility of application.

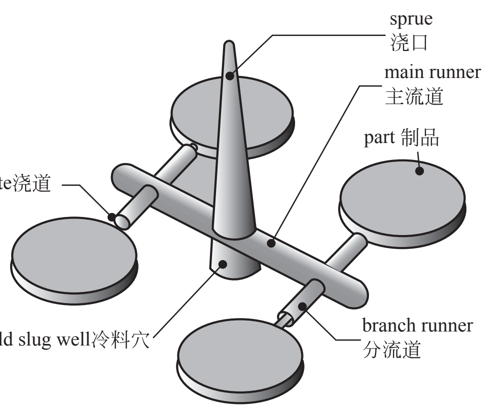
Bed-of-nails device This fixture consists of a series of air-actuated pins that conform to the shape of the external surfaces of the part. Each pin moves as necessary to conform to the shape at its point of contact with the part. The pins are then mechanically locked against the part. The device is compact, has high stiffness, and is configurable.

Adjustable-force clamping The strain gage mounted on the clamp senses the magnitude of the clamping force. The system then adjusts this force to keep the workpiece securely clamped to the workpiece for the particular application. It also can prevent excessive clamping forces that otherwise may damage the workpiece surface, particularly if it is soft or slender.

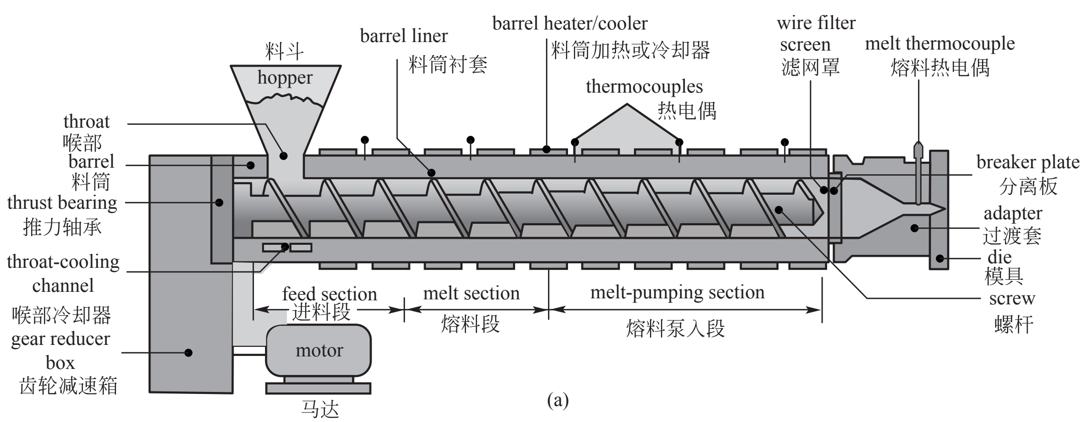
Phase-change materials There are two methods that can hold irregular-shaped or curved workpieces in a medium other than hard tooling. In the first and older method, a low-melting-point metal is used as the clamping medium. For example, an irregular-shaped workpiece is dipped into molten lead and allowed to set (like the wooden stick in a popsicle—a process similar to insert molding). After setting, the solified lead block is clamped in a simple fixture. The possibly adverse effect of such materials as lead on the workpiece to be clamped (liquid-metal embrittlement) must considered.

In the second method, the supporting medium is a magnetorbeological (MR) or electrorbeological (ER) fluid. In the MR application, the particles are ferromagnetic or paramagnetic, μm in size as well as using nano-particles, and in a nonmagnetic fluid. Surfactants are added to alleviate the particles from settling. After immersing, the workpiece in the fluid, an external magnetic field is applied, whereby the particles are polarized and the behavior of the fluid changes from a liquid to that of a solid. Afterwards, the workpiece is retrieved by removing the external magnetic field. The process is suitable particularly for nonferrous metal parts. In the ER application, fluid is a suspension of fine dielectric particles in a liquid of low dielectric constant. After the application of an electrical field, the liquid becomes a solid.

3.9 Die and Mould 模具结构



Mold features for injection molding 注射模具结构特征



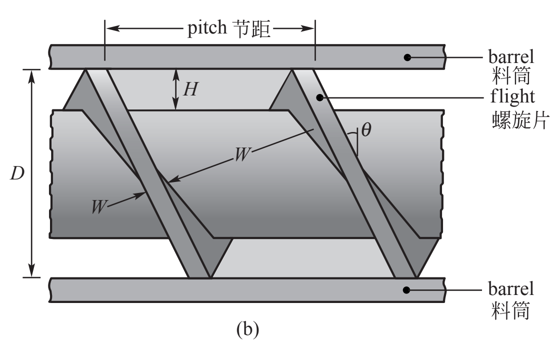
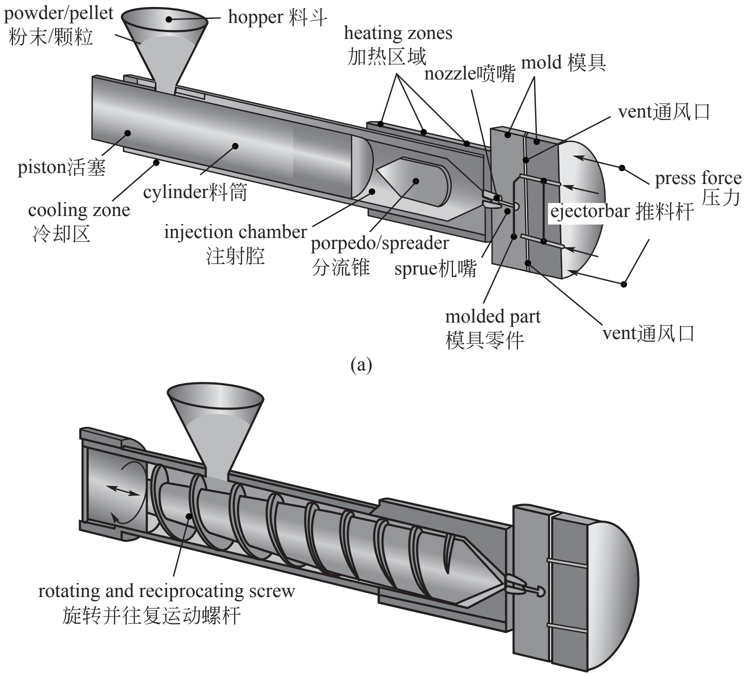


Illustration of a typical screw extruder 典型螺杆挤出示意图

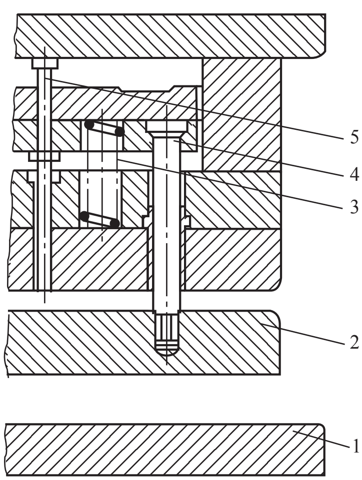


(a)

(b)

Illustration of injection molding with plunger(a)and reciprocating rotating screw(b)

柱塞(a)和旋转往复螺杆(b)注射模具



Three-plate injection mold 三板式注射模

1－plate 1 模板 1　2－plate 2 模板 2
3－spring 弹簧　4－ejector rod 顶料杆
5－ejector bar 推出杆

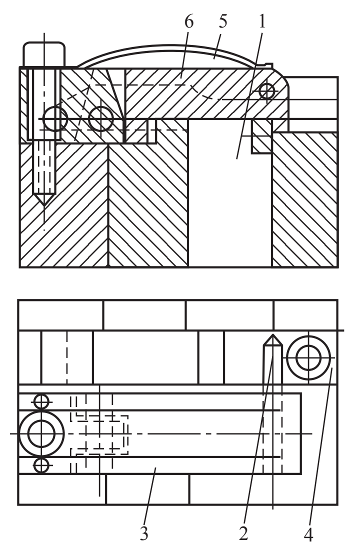
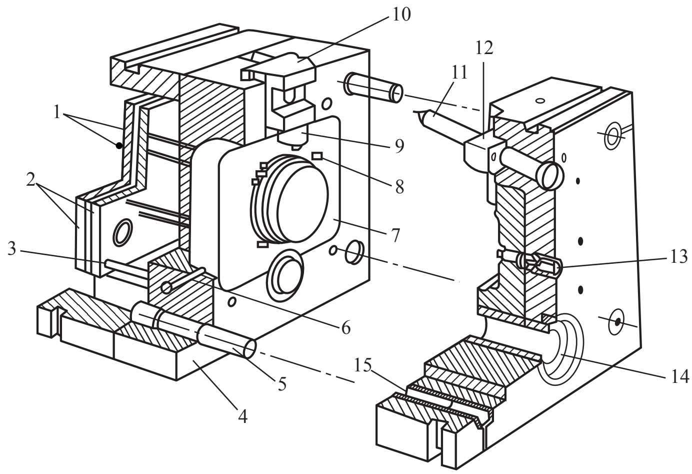


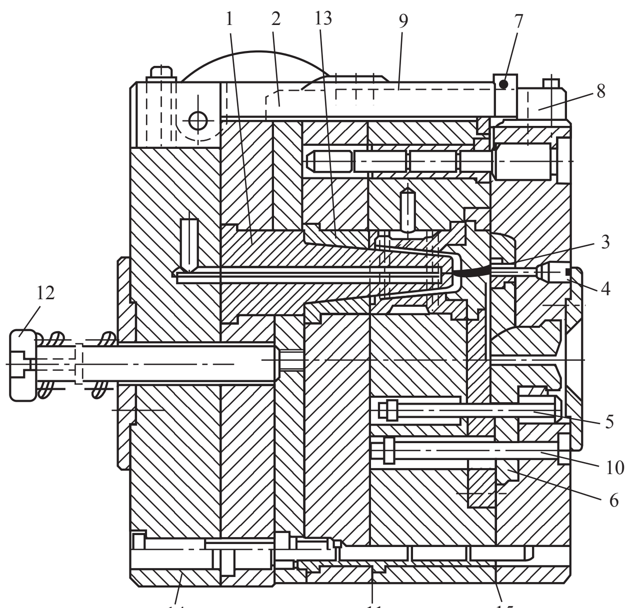
Plate movement 模板运动

1－plate 模板　2－pin 销　3－latch 插销
4－guide strip 导轨　5－leaf spring
片弹簧　6－waterway 冷却水道



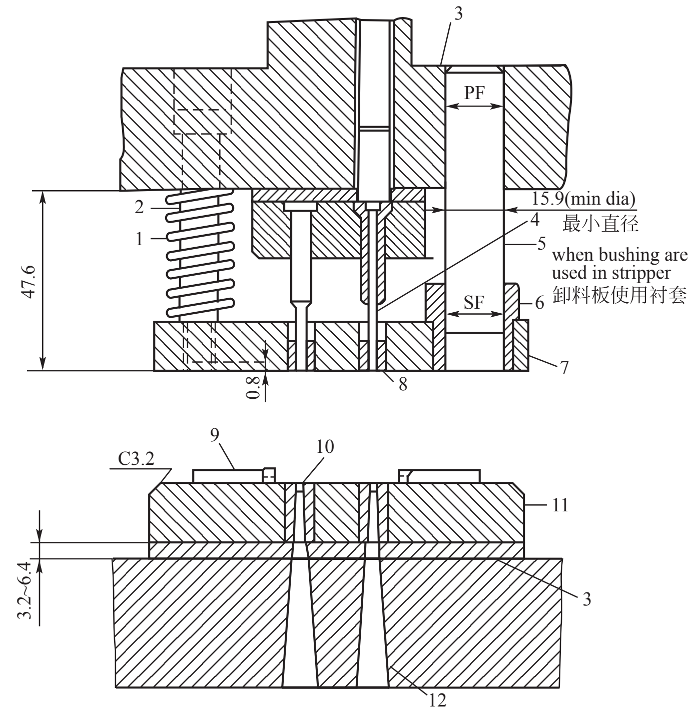
Typical die assembly 典型模具装配

1 – ejector pin 推杆　2 – ejector plate 推板　3 – ejector return pin 复位杆
4 – base support 支承底板　5 – guide pillar 导柱　6 – die insert waterway 镶块冷却水道
7 – die insert 镶块　8 – fixed core 固定型芯　9 – moving core 活动型
10 – moving core holder 活动型芯固定板　11 – angle pin 斜导柱
12 – core locking wedge 型芯楔压块　13 – cascade waterway 串联水道
14 – plunger bush 衬套　15 – guide bush 导套



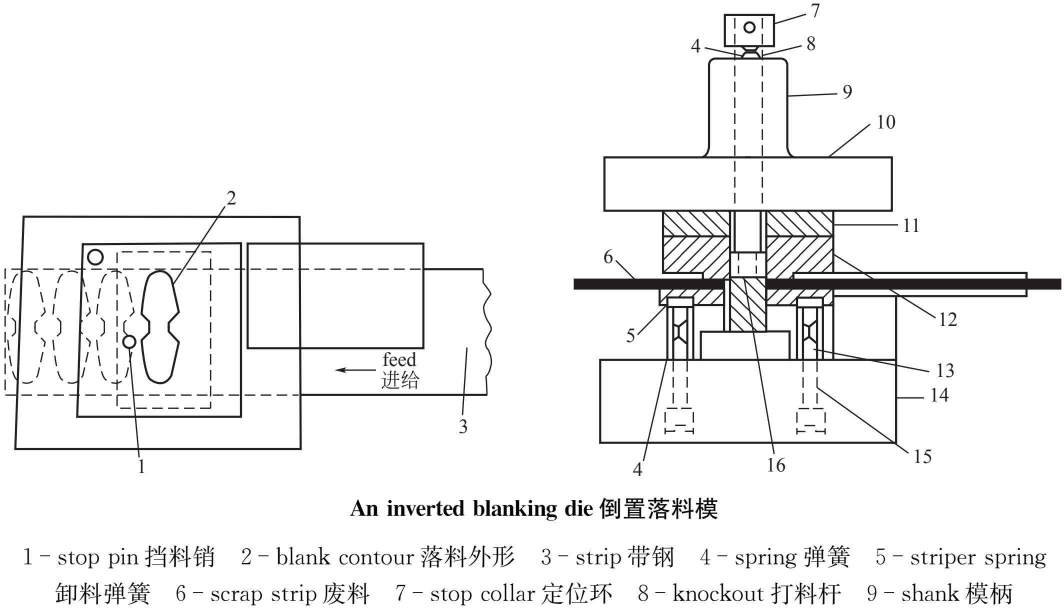
Typical degating tool 典型注塑模具

1 – sprue separating area 浇道分型面　2 – latch 插销　3 – sprue 直浇道　4 – retainer pin 固定销
5，10 – bolt head 插销头　6 – sprue-stripping plate 注料口分模板　7 – pin 销　8 – guide strip 导轨
9 – waterway 冷却水道　11 – main parting line 主要分型线　12 – ejector rod 推料杆
13 – stripper sleeve 分型套　14 – plate assembly 模板装置　15 – mold core 模具型芯



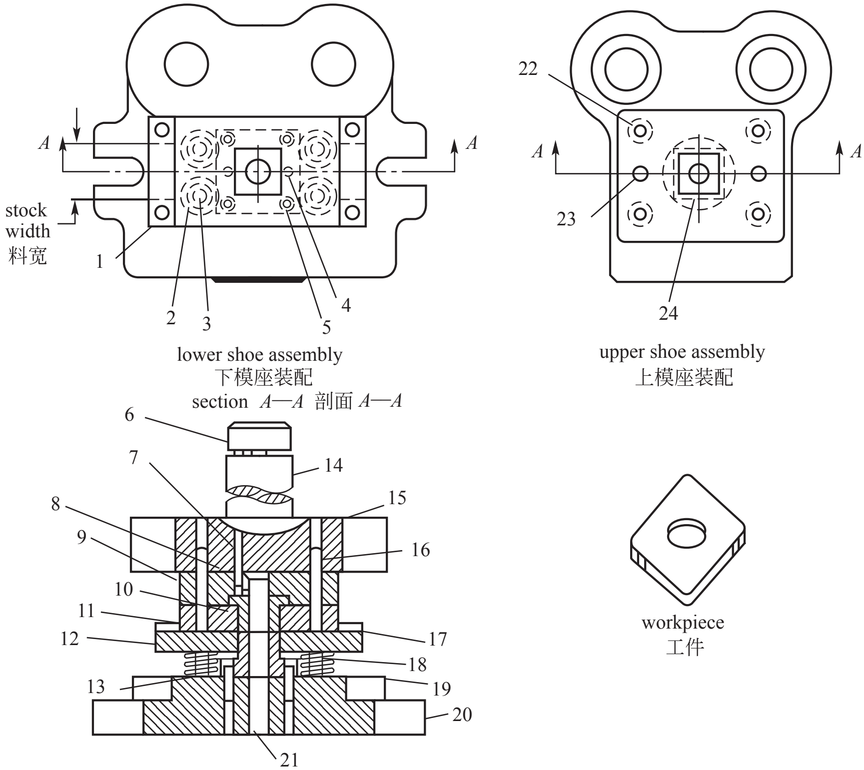
Typical single-station die for piecing holes 典型单工位冲孔模

1 - spring 弹簧　2 - stripper bolt 卸料螺钉　3 - base plate 支承板　4 - quill plate 凸模套管轴　5 - guide pin 导向销　6 - guide bushing 导套　7 - stripper 卸料板　8 - bushing for small punch 小冲头轴套　9 - nest 定位孔　10 - die bushing 模衬　11 - die block 凹模底板　12 - taper reamer 锥形孔



An inverted blanking die 倒置落料模

1 - stop pin 挡料销　2 - blank contour 落料外形　3 - strip 带钢　4 - spring 弹簧　5 - striper spring 卸料弹簧　6 - scrap strip 废料　7 - stop collar 定位环　8 - knockout 打料杆　9 - shank 模柄　10- upper shoe 上模座　11 - back plate 支承板　12 - die 凹模　13 - punch 凸模　14 - lower shoe 下模座　15 - striper bolt 卸料螺钉　16 - blank 落料件



A compound die 复合模

1 - stock guide 给料槽　2、19 - stripper spring 卸料弹簧　3、18 - stripper bolt 卸料螺钉　4 - 1/4 dowel 定位销　5 - cap screw 螺帽　6 - knockout collar 打料环　7 - knockout rod 打料杆　8 - headed piecing punch 冲头　9 - punch pad 冲头衬垫　10- shedder 卸料装置　11 - blanking die 落料模　12 - stripper 卸料板　13 - blanking punch and piecing die 落料模和冲孔模　14 - shank 模柄　15 - upper shoe 上模座　16- dowel 定位销　17 - stock guide 给料槽　20- lower shoe 下模座　21 - slug disposal hole 冷料处理孔　22 - cap screw 螺母　23 - dowel 定位销　24 - spring loaded shedder pin(oil seal breaker)弹簧式顶出销(油封开关)

Reading Materials

Passage 1: Injection Molds

The continuing development of injection-molding technology demands more and more of the processor. The most important problem in the process of injection molding is undoubtedly the correct design of injection mold, because the molding shop has little influence, if any, on the construction of the machine. Efficient production of the most diverse injection-molded parts depends primarily on the injection mold.

The durability of the molds depends on their care and treatment. Since the moving components and cavity of the mold are always hardened and ground, they should produce between 500000 and 1000000000 shots.

For ease of construction and to lower manufacturing cost, injection molds are becoming standardized. Some firms offer ready-made bases of square or round design as standard or stripper plate molds for immediate use. Only the inserts then have to be fitted into the bases.

Basically the injection mold consists of two halves. One mold half contains the sprue bushing and runner system, the other half houses the ejection system. The molded part is located at the parting line.

To set up a calculation conceiving the choice of cavities in an injection mold requires accurate knowledge of the material to be processed, of the injection-molding machine and of the molds. The mold costs increase with the rising number of cavities and the relative machine costs decrease. The production time required for a given molded part depends on the wall thickness, the injection speed, the recovery rate, the time required to cool the molded material, the cooling capacity of the mold and the necessary incidental times such as duration of pressure holding time, ejection time, delay times, etc.

Therefore the decision concerning the number of cavities to be determined depends on:

(1) size of the order (number of molded parts in connection with delivery time),

(2) shape of the molded parts(size, quality requirements),

(3) injection-molding machine (clamping force, plasticizing and injection capacity),

(4) mold costs.

There are several known procedures for calculating the economical number of cavities. Unfortunately they are so varied that it is impossible to condense them.

Passage 2: **Compound Die Design**

A compound die performs only cutting operations (usually blanking and piercing) which are completed during a single press stroke. A compound die can produce pierced blanks to close flatness and dimensional tolerances. A characteristic of compound dies is the inverted position of the blanking punch and blanking die. The die is fastened to the upper shoe and the blanking punch is mounted on the lower shoe. The blanking punch also functions as the piercing die, having a tapered hole in it and in the lower shoe for slug disposal.

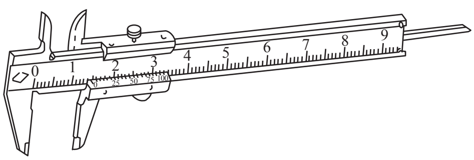
On the upstroke of the press slide, the knockout bar of the press strikes the knockout collar, forcing the knockout rods and shedder downward, thus pushing the finished workpiece out of the blanking die. The stock strip is guided by stock guides screwed to the spring-loaded stripper. On the upstroke the stock is stripped from the blanking die by the upward travel of the stripper. Before the cutting cycle starts, the strip stock is held flat between the stripper and the bottom surface of the blanking die.

Four special shoulder screws (stripper bolts), commercially available, guide the stripper in its travel and retain it against the preload of its springs.

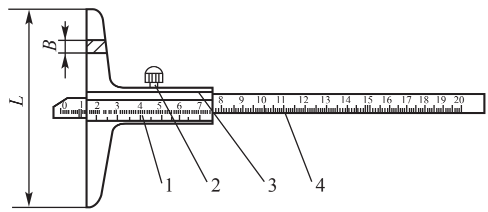
The blanking die as well as the punch pad is screwed and doweled to the upper shoe.

A spring-loaded shedder pin (oil-seal breaker) incorporated in the shedder is depressed when the shedder pushes the blanked part from the die. On this upstroke of the ram the shedder pin breaks the oil seal between the surfaces of the blanked part and shedder, allowing the part to fall out of the blanking (upper) die.

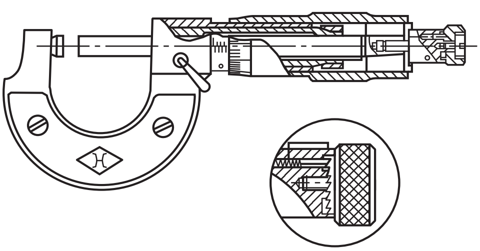
3.10 Engineering Metrology and Instrumentation 工程测量、计量仪器



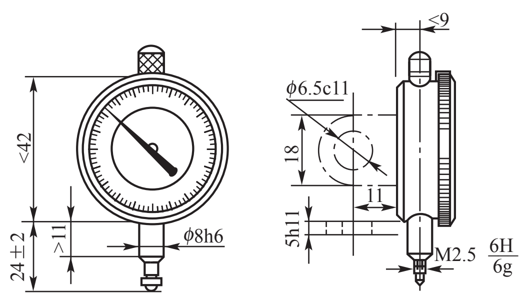
Vernier caliper 游标卡尺



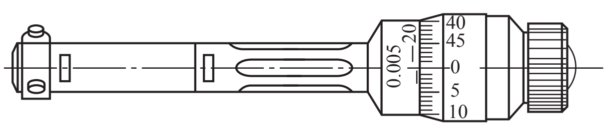
Vernier depth gauge 游标高(深)度尺



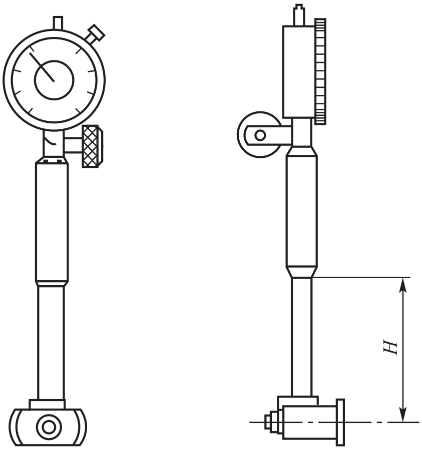
Micrometer for external diameter 外径千分尺



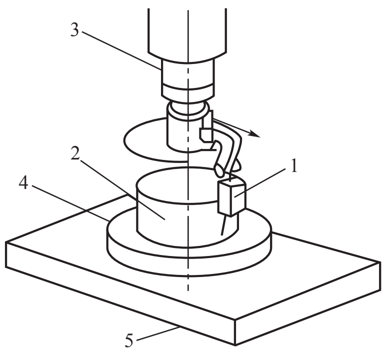
Centesimal dial indicator 百分表



Three-jaw micrometer for internal(inner/inside)diameter
三爪内径千分尺

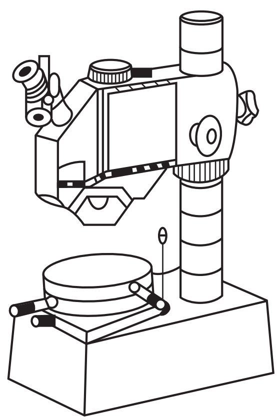


Centesimal dial indicator for internal diameter 内径百分表

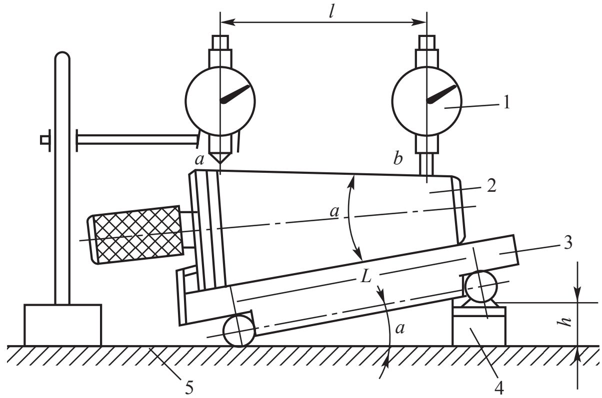


Roundness meter 圆度仪

1 - head 测量头　2 - workpiece 工件　3 - spindle 主轴　4 - moving table 移动工作台　5 - fixed table 固定工作台

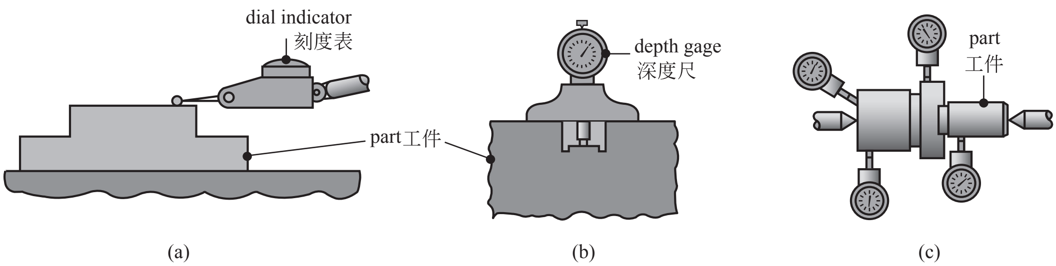


Binocular microscope 双管显微镜



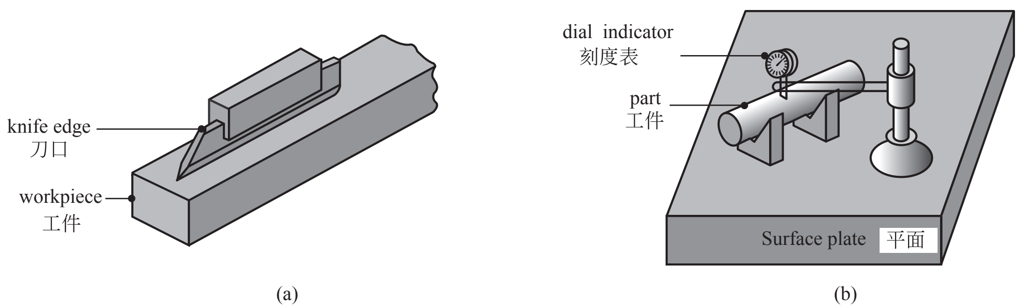
Angular measurement with a sine bar and dial indicator 正弦角度尺

1 - dial indicator 指示表　2 - part(taper)待测工件(锥体)　3 - sine bar 正弦尺　4 - gauge block 量块　5 - surface plate 平板



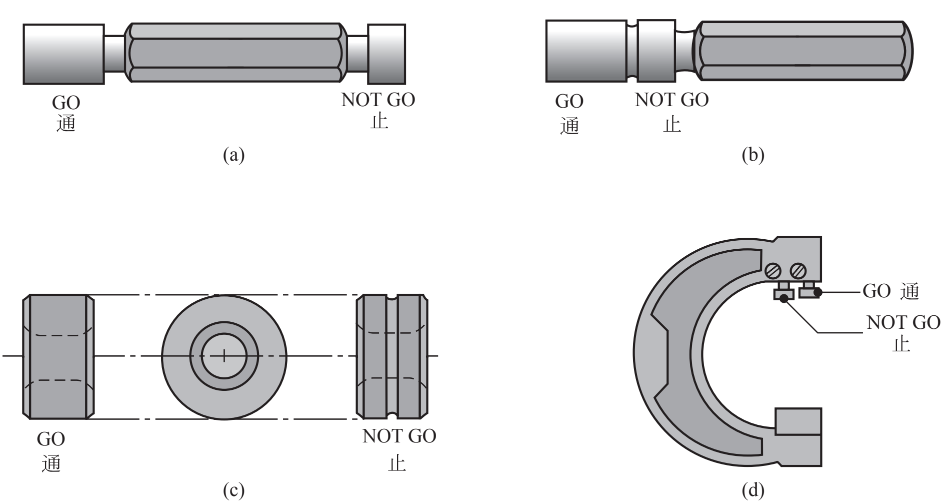
Three uses of dial indicator 刻度表(百分表、千分表)的三种用法

（a）roundness 圆度测量 （b）depth 深度测量 （c）multiple-dimension gauging 综合测量



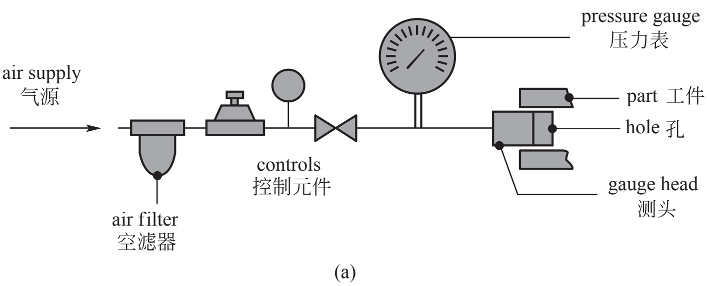
Measuring straightness manually 手工测量直线度

（a）with a knife-edge rule 用刀口尺 （b）with a dial indicator 用刻度表

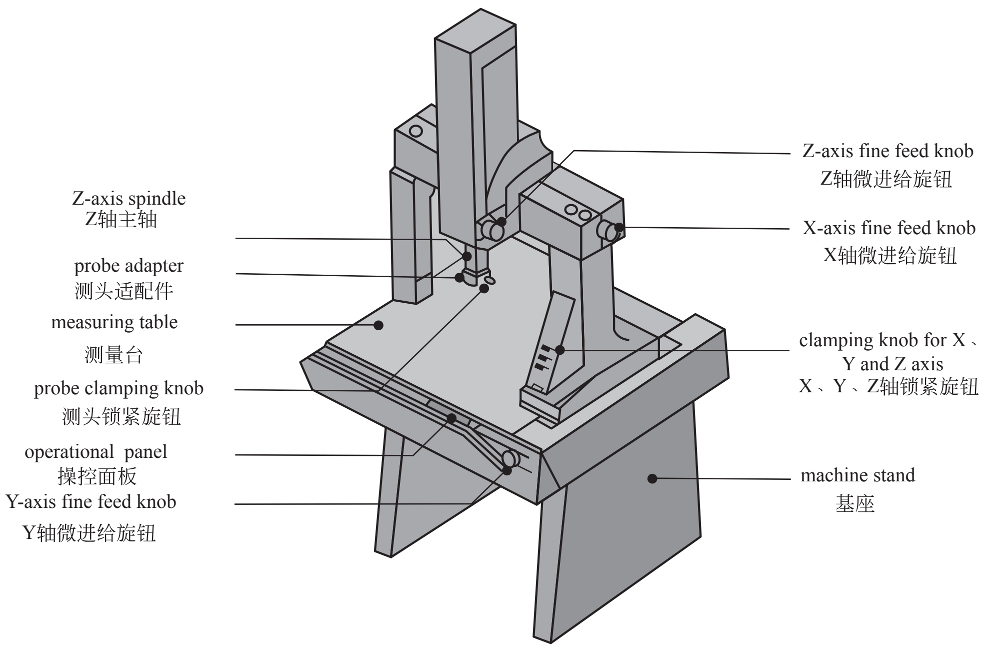


Fixed gage 光滑极限量规

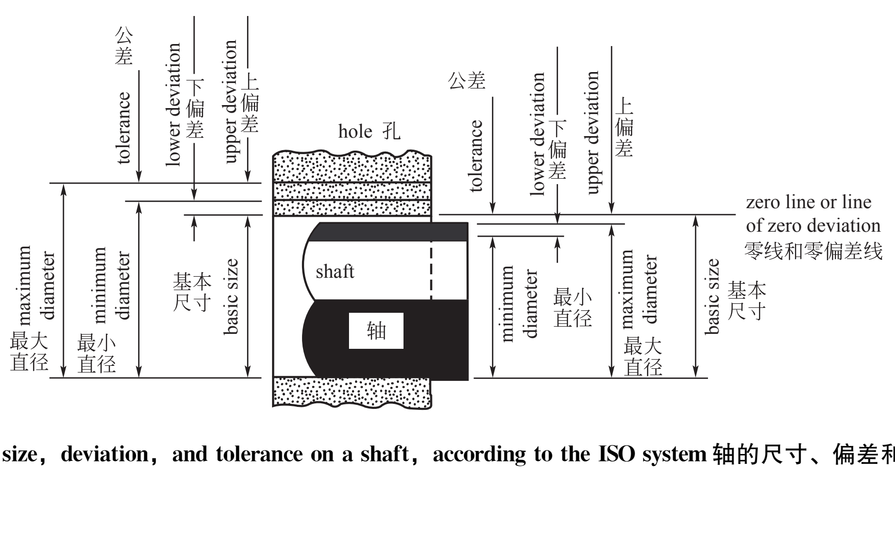
（a）and （b）plug gauge 塞规 （c）ring gauge 环规 （d）snap gauge 卡规



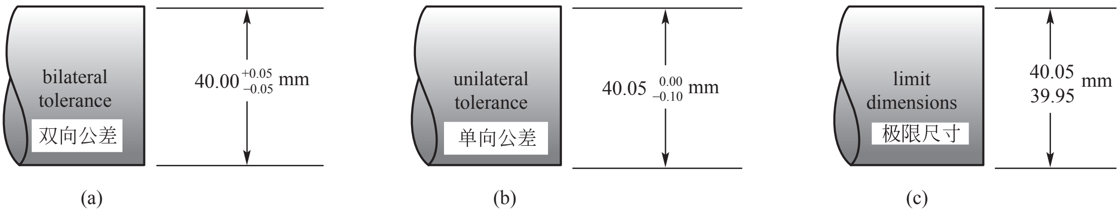
Air-gauge system 气动测量仪



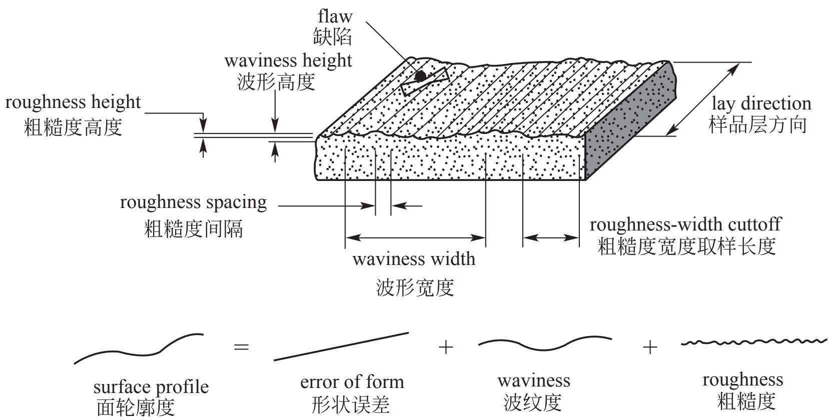
Coordinate-measuring machine 坐标测量机



Basic size，deviation，and tolerance on a shaft，according to the ISO system 轴的尺寸、偏差和公差



Various methods of assigning tolerance on a shaft 轴的尺寸标注方法



Standard terminology and symbols to describe surface finish 描述表面形貌的标准术语

type of feature 特征	type of tolerance 公差种类	characteristic 名称(性质)	symbol 符号
individual(no datum reference) 单个表面(无基准)	form 形状	flatness 平面度	▱
		straightness 直线度	—
		circularity(roundness)圆度	○
		cylindricity 圆柱度	⌭
individual or related 单个/相关	profile 轮廓	profile of a line 线轮廓度	⌒
		profile of a surface 面轮廓度	⌓
related(datum reference required) 相关(有基准作参考)	orientation 方向	perpendicularity 垂直度	⊥
		angularity 倾斜度	∠
		parallelism 平行度	//
	location 位置	position 位置度	⌖
		concentricity 同轴(心)度	◎
	runout 跳动	circular runout 圆(径向)跳动	↗
		total runout 全跳动	⌰

Geometric characteristic symbols to be indicated on engineering drawing of parts to be manufactured
加工零件工程图上标注的几何符号

Reading Materials

Passage 1: Gauges and Gauge Design

Adoption of limits and fits requires the production process to be designed to provide the necessary dimensions within the specified tolerances. It is also necessary to inspect all the parts to see whether they confirm to the requirements or not. Gauges or limit gauges are used for such purposes. Gauges are used for inspecting a given dimension whether it is within the tolerance limits specified or not. Thus a gauge is used for accepting a dimension rather than measuring it.

Consider a simple snap gauge used to inspect a shaft. The gauge consists of two elements, a 'GO' section which represents the maximum limit on the possible dimension of the shaft and a 'NOT GO' section that represents the minimum limit on the dimension of the shaft. If the shaft size is within the tolerance limit specified, then the condition will be satisfied, i. e. the part will go past the GO section and will not go beyond the NOT GO section.

The condition that the part dimension is larger than the maximum limit allowed and as a result the part will not go into the GO section. Similarly the condition that the part dimension is smaller than the lower limit of the part resulting in the part going through the NOT GO section.

All the gauges will have a similar arrangement, however the arrangement of the GO and NOT GO segments will have to be decided based on the profile dimension to be gauged. A variety of limit gauges are used in the industry. A few of them are mentioned below:

Snap gauge	—For gauging external dimensions
Plug gauge	—For gauging internal dimensions
Taper plug gauge	—For gauging taper holes
Ring gauge	—For gauging external diameters
Gap gauge	—For gauging gaps and grooves
Radius gauge	—For gauging radii
Thread pitch gauge	—For gauging external threads
Special gauges	—For specific applications such as alignment gauge, valve seat gauge, etc.

Gauges are high precision instruments used for acceptability of a given dimension of a part. However, gauges themselves have to be manufactured using any of the manufacturing processes. Whatever be the manufacturing process adopted and whatever care is exercised during manufacture, it is impossible to manufacture the gauges to the exact dimensions. Hence it is necessary to allocate tolerances on the gauge dimensions, particularly for the GO and NOT GO sections. Since the tolerance if applied outside the acceptable limits makes the gauge to allow the part with higher tolerance, the tolerance is generally applied inside the part tolerance. This will result in the components allowed by such a gauge being with in the tolerance limits. Generally a total of 10% of workpiece tolerance is assumed to be for the gauge tolerance. This is then equally distributed between the GO and NOT GO sections. This value is generally very small in view of the small tolerance of the parts and is rounded off to the nearest 0.001mm. With such an arrangement some good parts which are within the tolerance specified in the part print, but outside the limits of the gauge are likely to be rejected.

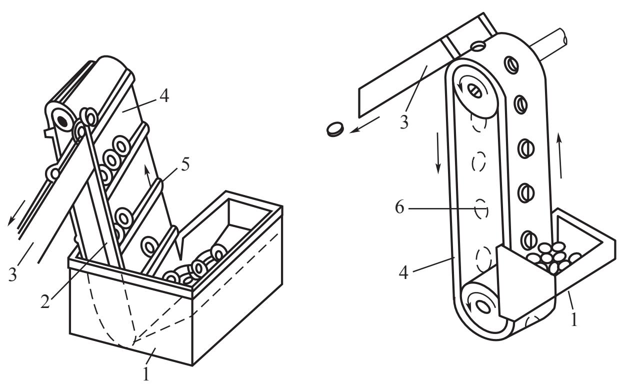
Another aspect to be considered in the design of gauges is the contact surfaces which are likely to wear out. The gauges are made with hard surfaces, which resist abrasion. But with continued usage over longer periods, the GO section, which experiences the relative movement with the part, is likely to be made bigger initially, to allow for the wear. About 5% of the work tolerance is normally allowed for this.

Passage 2: Coordinate Measuring Machines

A coordinate-measuring machine (CMM) basically consists of a platform on which the workpiece being measured is placed and then is moved linearly or rotated. A probe is attached to a head (capable of various movements) and records all measurements. In addition to the tactile probe shown, other types of probes are scanning, laser and vision probes, all of which are nontactile.

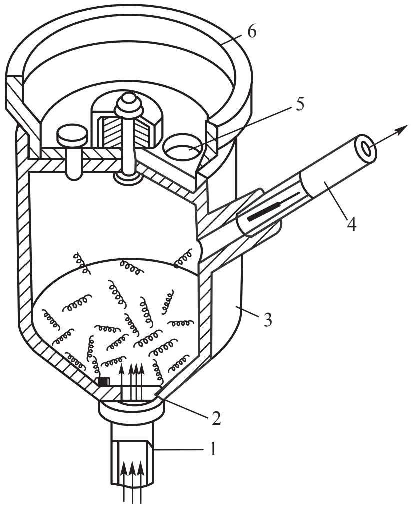
Coordinate-measuring machines are very versatile and capable of recording measurements of complex profiles with high resolution (0.25μm) and high speed. They are built rigidly and ruggedly to resist environmental effects in manufacturing plants, such as temperature variations and vibration. They can be placed close to machine tools for efficient inspection and rapid feedback; this way, processing parameters are corrected before the next part is made. Although large CMMs can be expensive, most machines with a touch probe and computer controlled three-dimensional movements are suitable for use in small shops and generally cost under $20000.

3.11 Convey Setups 物料装置



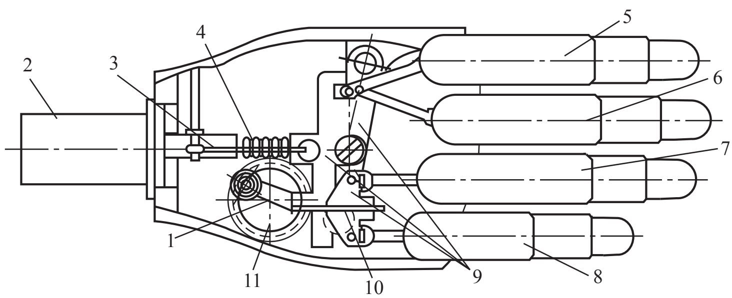
Hopper of plate chain form 板链式料斗

1 - hopper 料斗 2 - workpiece choke 挡板 3 - work way 料道
4 - belt 带 5 - work catcher 取料板 6 - magnet block 磁铁



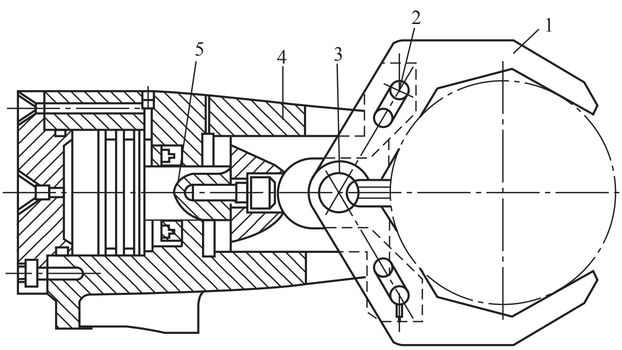
Gas-blast hopper 气吹式料斗

1 – gas tube 气管　2 – nozzle 喷嘴　3 – body 斗体　4 – work alignment way 排料滑道　5 – inlet 投料口　6 – upper part 上斗



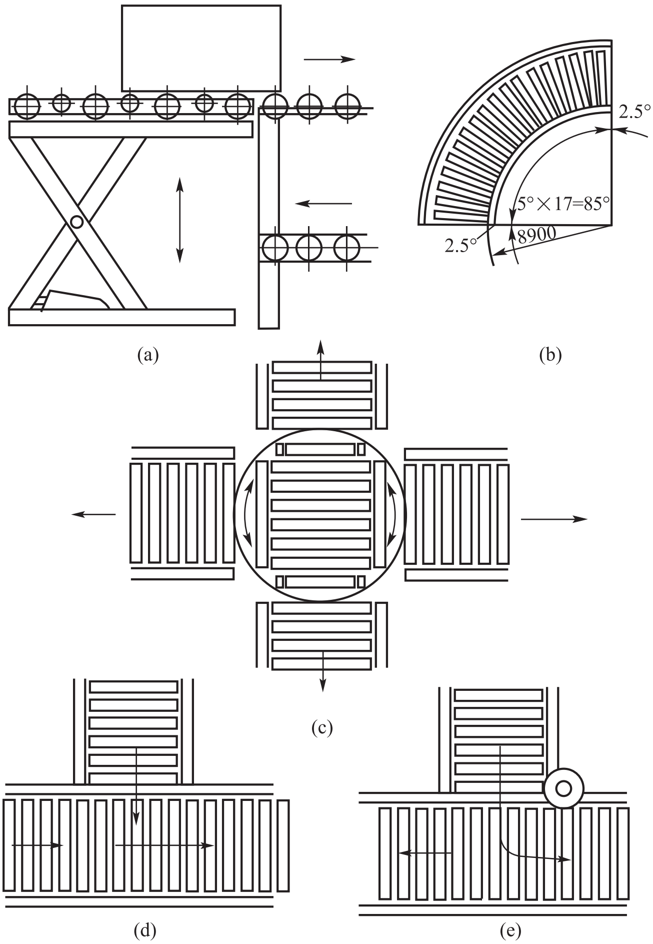
Imitating jaws of human hand 仿人手手爪

1 – driving bar 驱动杆　2 – motor 马达　3，10 – blade spring 弹簧片　4 – worm 蜗杆　5 – index finger 食指　6 – mid finger 中指　7 – ring finger 无名指　8 – small finger 小指　9 – bar 杆　11 – worm wheel(gear)蜗轮



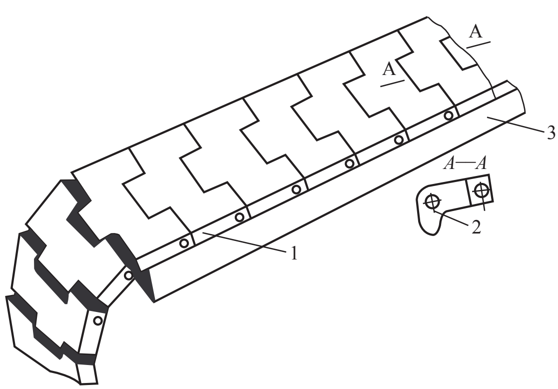
Rotary clamping jaws 回转型夹持手爪

1 – finger 手指　2，3 – cylindrical pin 圆柱销　4 – support 支架　5 – piston rod 活塞杆



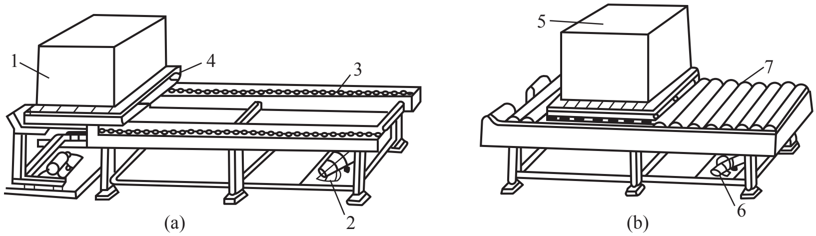
Assistant setup for auto-roller conveyor 自动输送辊道的辅助装置

（a）elevator 升降机 （b）circular way 弯轨 （c）rotary equipment 回转装置
（d）perpendicular convey 垂直传输 （e）perpendicular rotation 直角回转



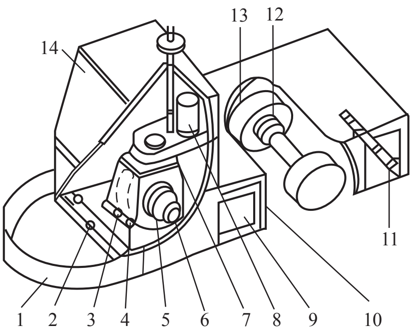
Caterpillar chain conveyor 链板履带传输辊道

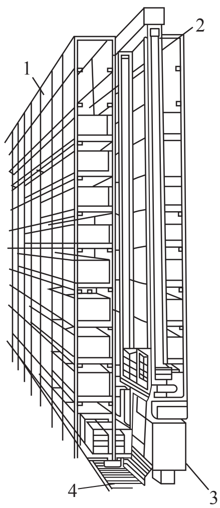
1 - caterpillar 履带链板 2 - tooth 齿形 3 - bracket 托架

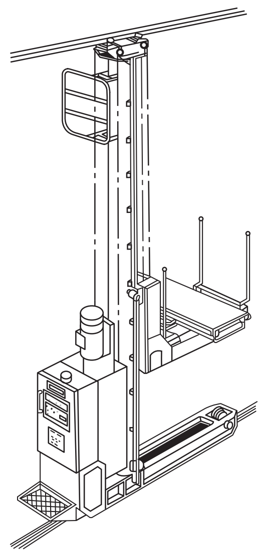


Power-driven roller conveyor 驱动传输辊道

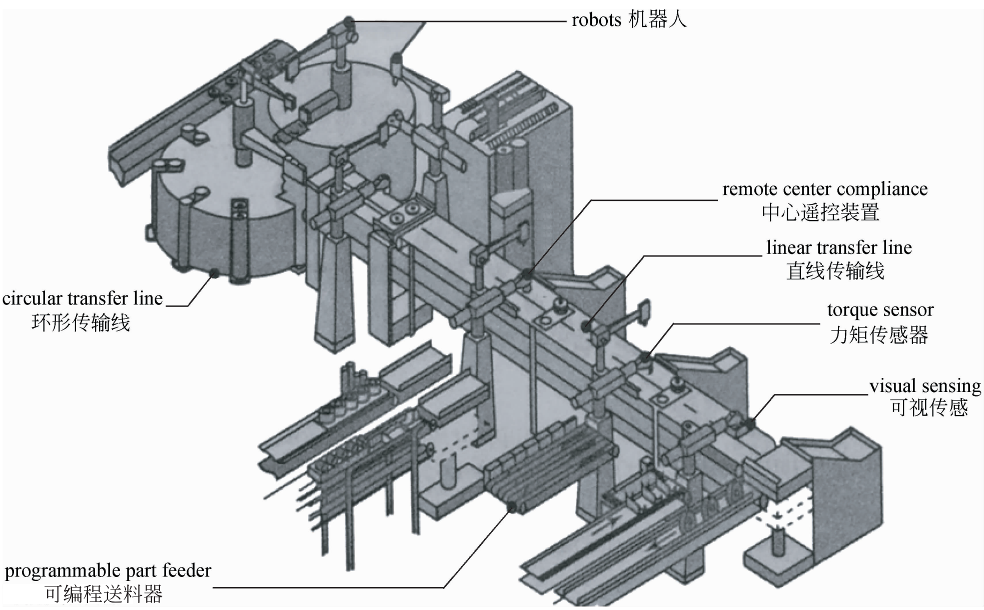
1，5 - workpiece 工件　2，6 - motor 电机　3 - chain 链条　4 - pallet 托板　7 - roller 辊轮





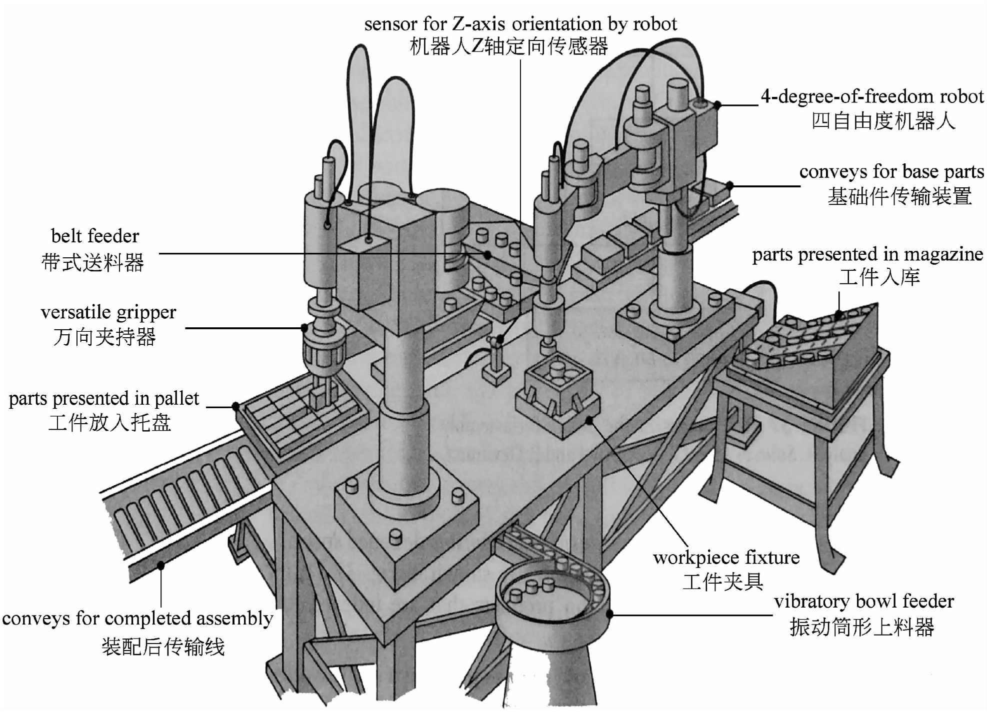


Auto-guide vehicle(AGV)自动导向车　Auto-warehouse 自动立体仓库　Hay stacker 堆跺机



Automated assembly operations using industrial robot and circular and linear transfer lines

使用机器人、回转传输线和直线传输线的自动操作装配线



A two-arm robot assembly station 双臂机器人装配站

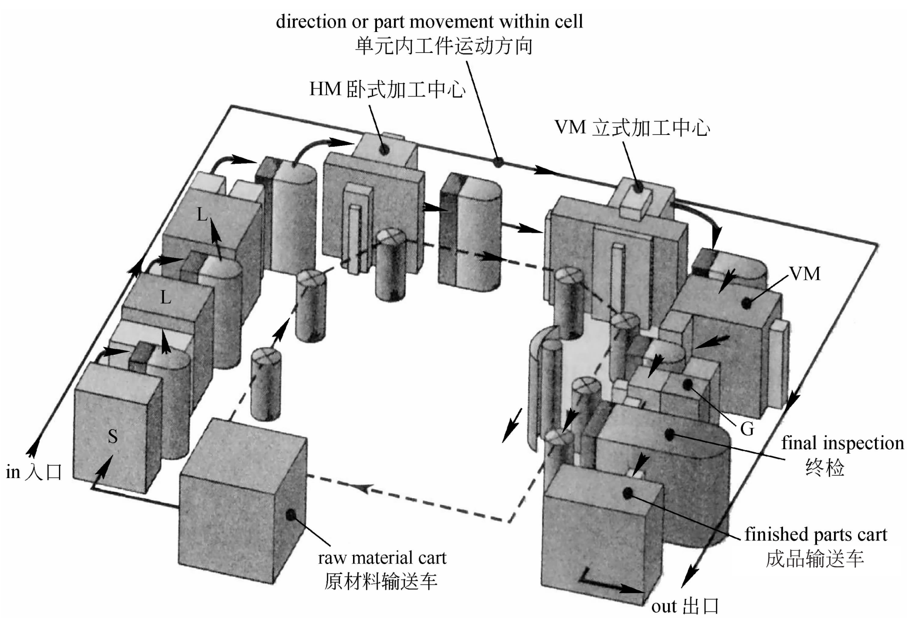
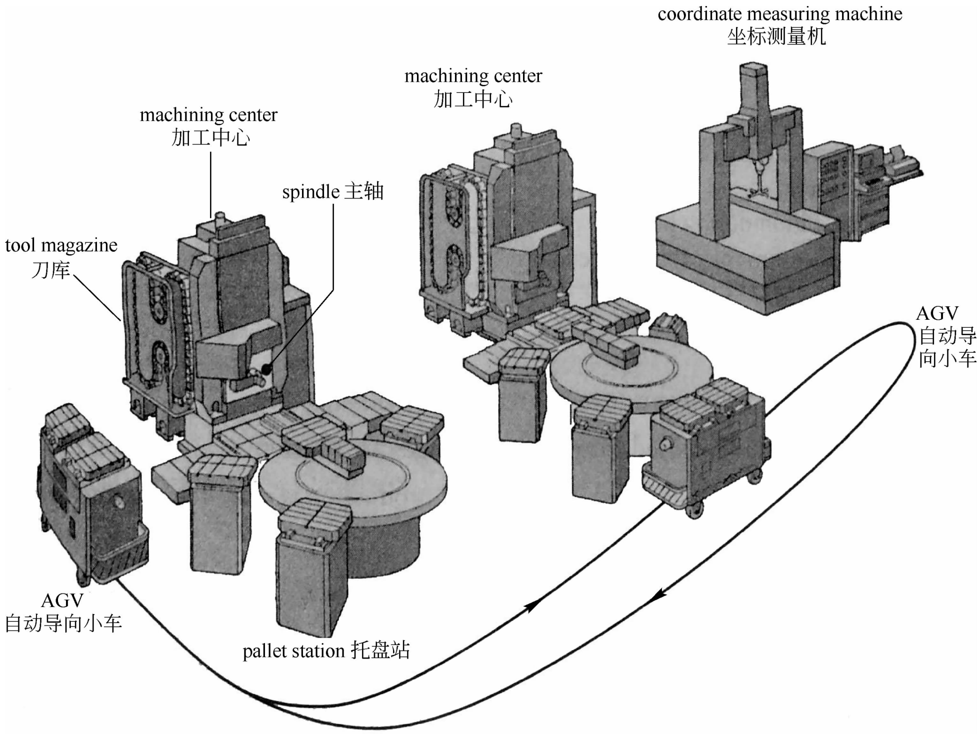


Illustration of a manned，flexible manufacturing cell 人力辅助柔性制造单元



A flexible manufacturing system showing machining centers 加工中心构建的柔性制造系统

Reading Materials

Passage 1:　Transfer Mechanisms and Transfer Lines.

Transfer mechanisms are used to move the workpiece from one station to another in the machine or from one machine to another to enable various operations to be performed on the part. Workpieces are transferred by methods, including (1) rails along which the parts (which usually are placed on pallets) are pushed or pulled by various mechanisms, (2) rotary indexing tables, and (3) overhead conveyors.

The transfer of parts from station to station usually is controlled by sensors and other devices. Tools on transfer machines easily can be changed using tool-holders with quick-change features, and the machines can be equipped with various automatic gauging and inspection systems. These systems are utilized between operations to ensure that the dimensions of a part produced in one station are within acceptable tolerances before that part is transferred to the next station. Transfer machines also are used extensively in automated assembly.

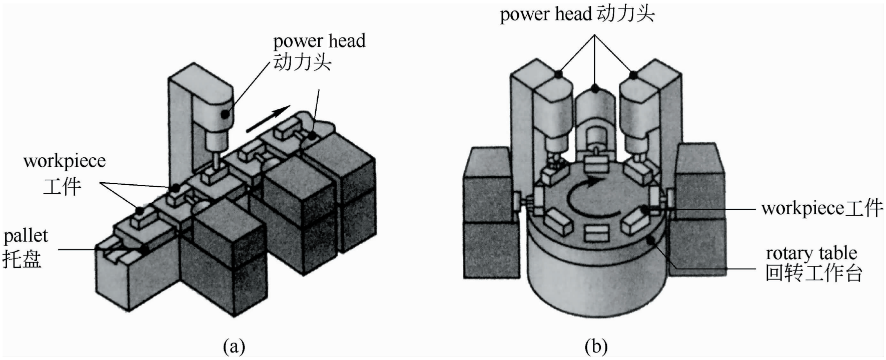


Fig. Two types of transfer mechanism: (a) straight rail and (b) circular or rotary pattern
两种传输机构：(a)直线传输；(b)环形(回转)方式

Passage 2: Evolution of Automation

Some metalworking processes were developed as early as 4000 B.C.. However, it was not until the beginning of the Industrial Revolution in the 1750s (also referred to as the First Industrial Revolution) that automation began to be introduced in the production of goods. Machine tools (such as turret lathes, automatic screw machines, and automatic bottle-making equipment) began to be developed in the late 1890s. Mass-production techniques and transfer machines were developed in the 1920s. These machines had fixed automatic mechanisms and were designed to produce specific products best represented by the automobile industry which produced passenger cars at a high production rate and low cost.

The major breakthrough in automation began with numerical control (NC) of machine tools. Since this historic development, rapid progress has been made in automating most aspects of manufacturing. These developments involve the introduction of computers into automation, computerized numerical control (CNC), adaptive control (AC), industrial robots, computer-aided design, engineering, and manufacturing (CAD/CAE/CAM), and computer-integrated manufacturing (CIM) systems.

Manufacturing involves various levels of automation, depending on the processes used, the product desired, and production volumes. Manufacturing systems in order of increasing automation include the following classifications:

Job shops These facilities use general-purpose machines and machining centers with high levels of human labor involvement.

Stand-alone NC production This uses numerically controlled machines but with significant operator/machine interaction.

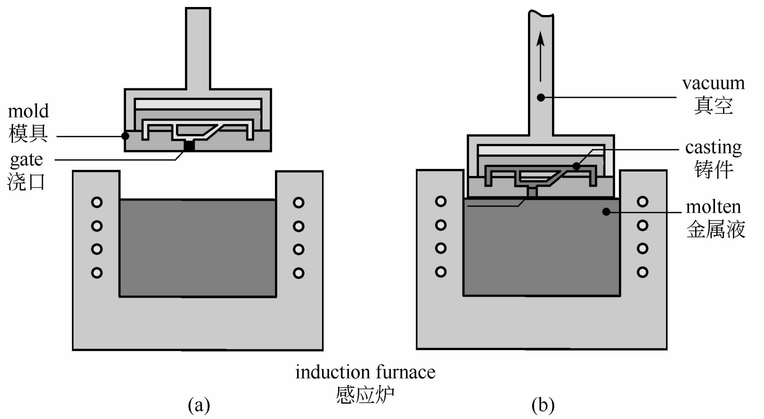
Manufacturing cells These use a designed cluster of machines with integrated computer control and flexible material handling-often with industrial robots

Flexible manufacturing systems These use computer control of all aspects of manufacturing, the simultaneous incorporation of a number of manufacturing cells, and automated material-handling systems.

Flexible manufacturing lines　Organize computer-controlled machinery in production lines instead of cells. Part transfer is through hard automation, product flow is more limited than in flexible manufacturing systems, but the through-put is larger for higher production quantities.

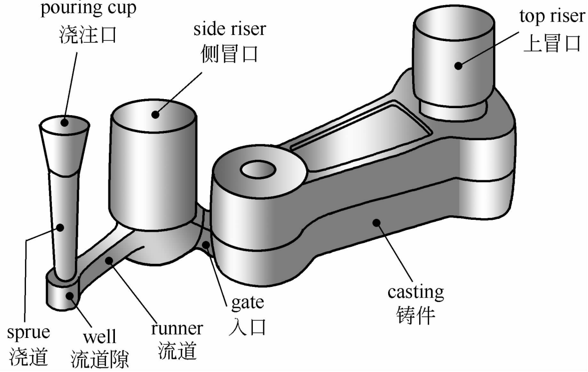
Flowlines and transfer lines　Consist of organized groupings of machinery with automated material handling between machines. The manufacturing line is designed with limited or no flexibility, since the goal is to produce a single part.

3.12　Casting, Forging, Welding and Stamping 铸造、锻压、焊接、压力加工

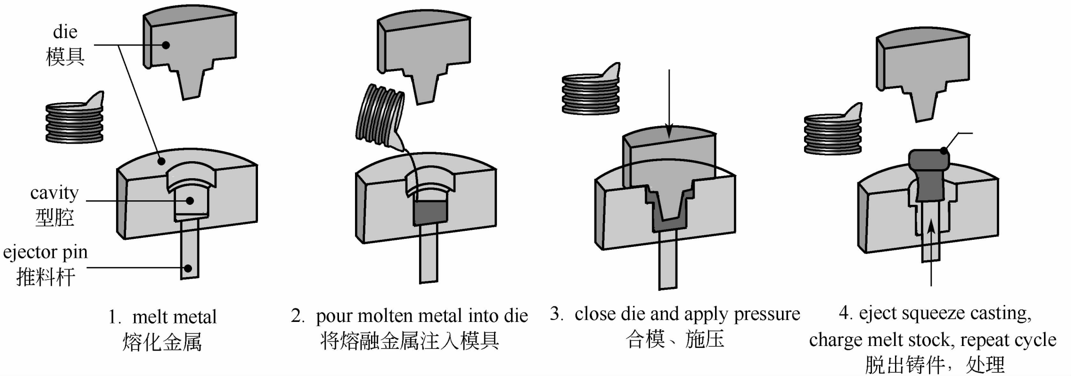


vacuum casting process 真空铸造

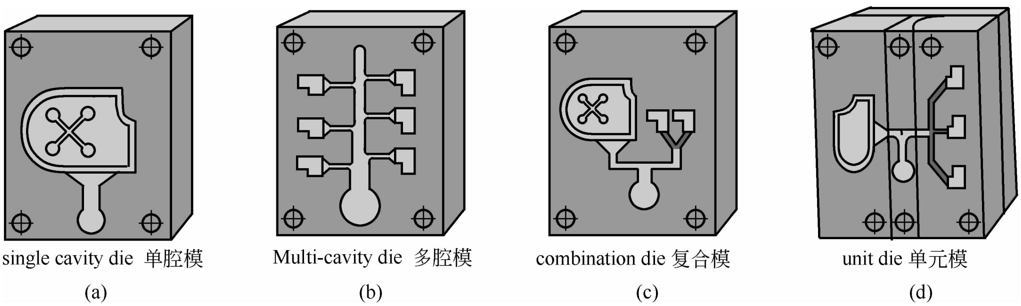
(a) before 铸前　(b) after 铸后



Typical riser-gated casting 典型浇-冒口铸造



Operations of the squeeze casting process 挤压铸造工艺操作过程



Various types of cavities in a die-casting die 压铸模具模腔结构

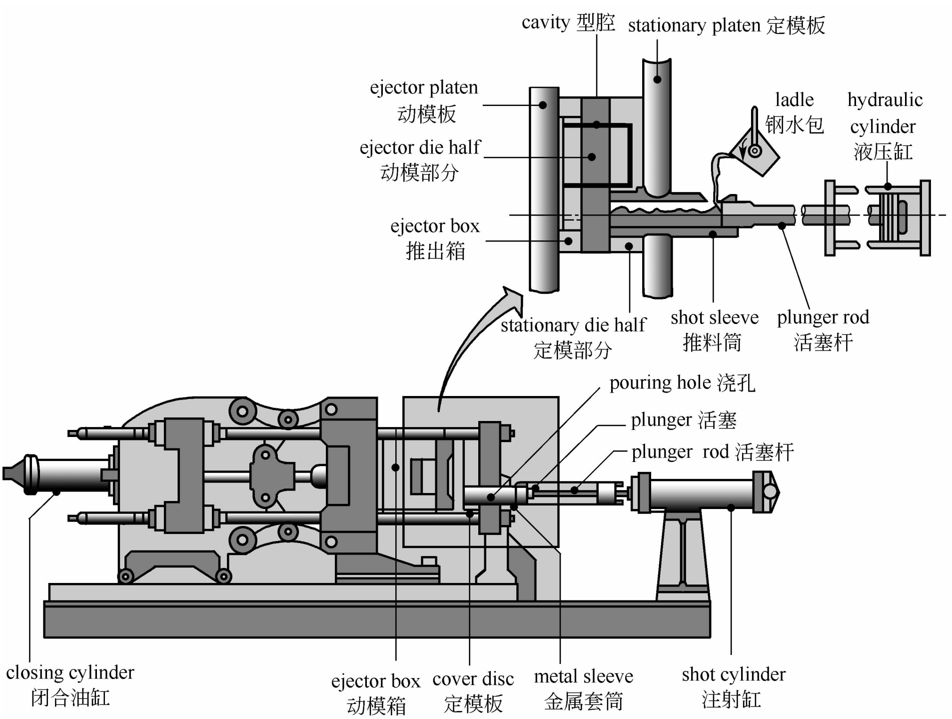


Illustration of the cold-chamber die-casting process 冷室压铸工艺示意图

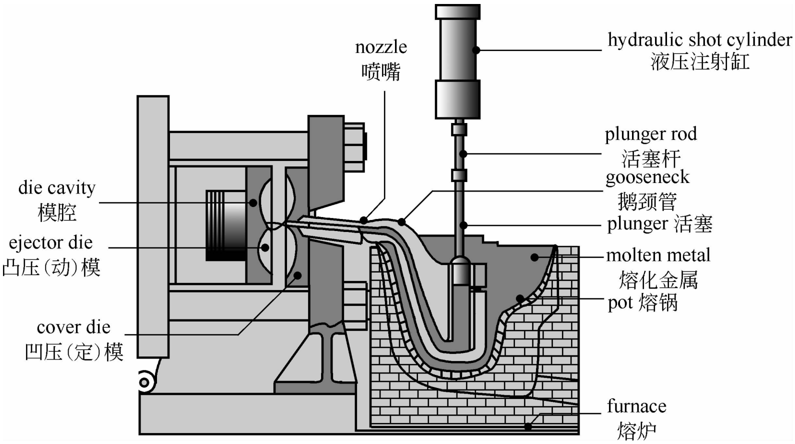


Illustration of the hot-chamber 热室压铸工艺

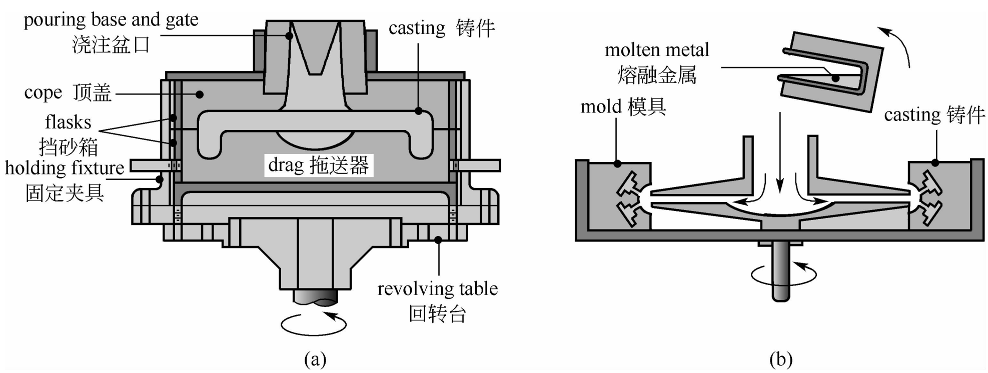
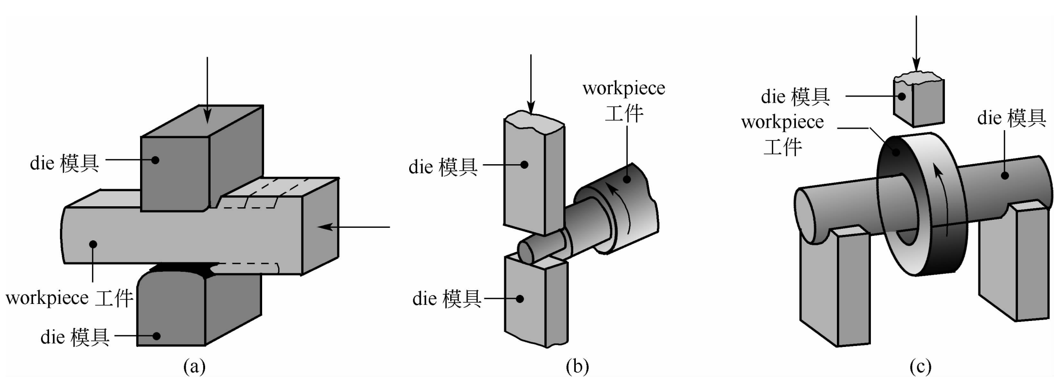
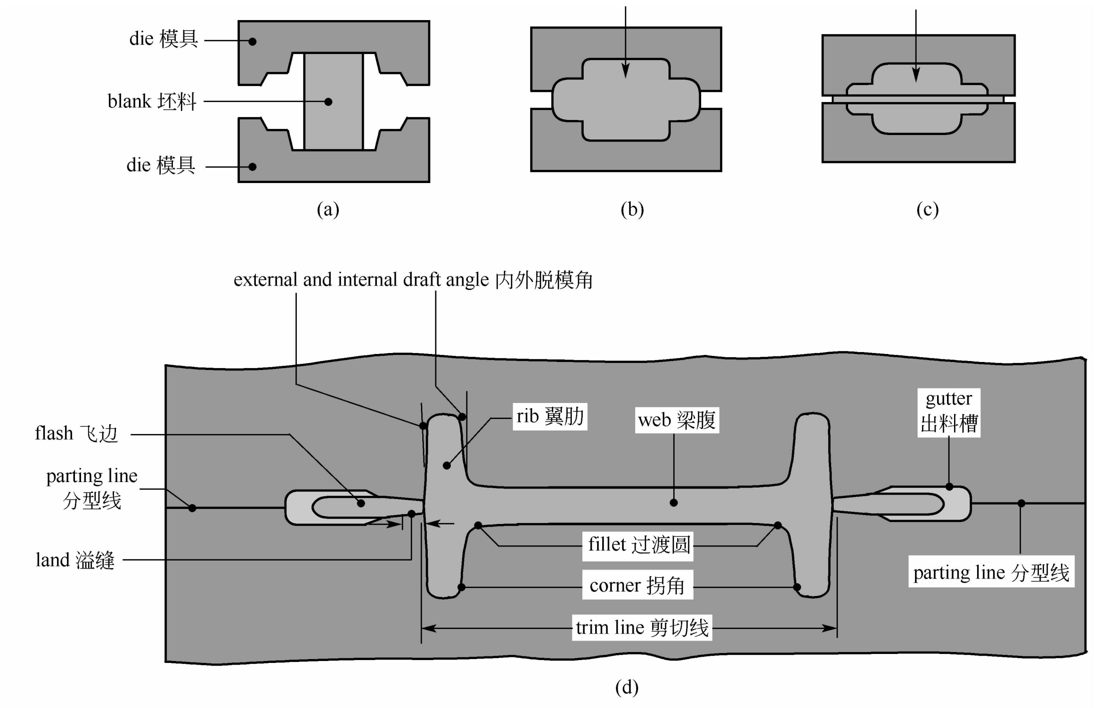


Illustration of centrifugal or semi-centrifugal casting process 离心和半离心铸造

（a）the semi-centrifugal casting process 半离心　（b）the centrifugal casting process 离心

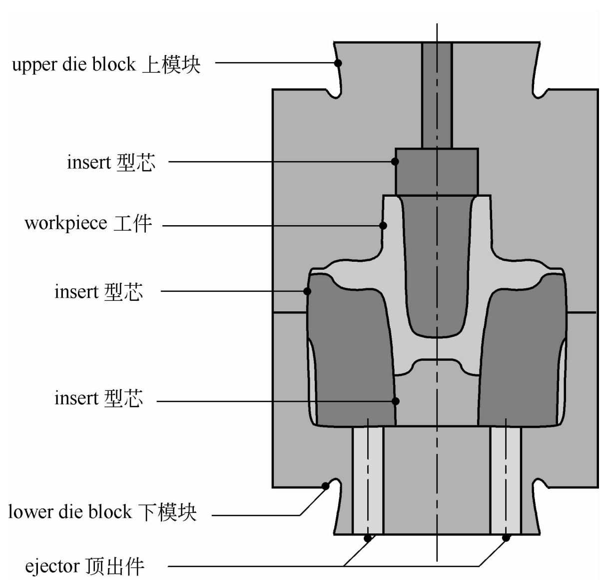


Various operations of forging process with open-die 自由锻压加工操作

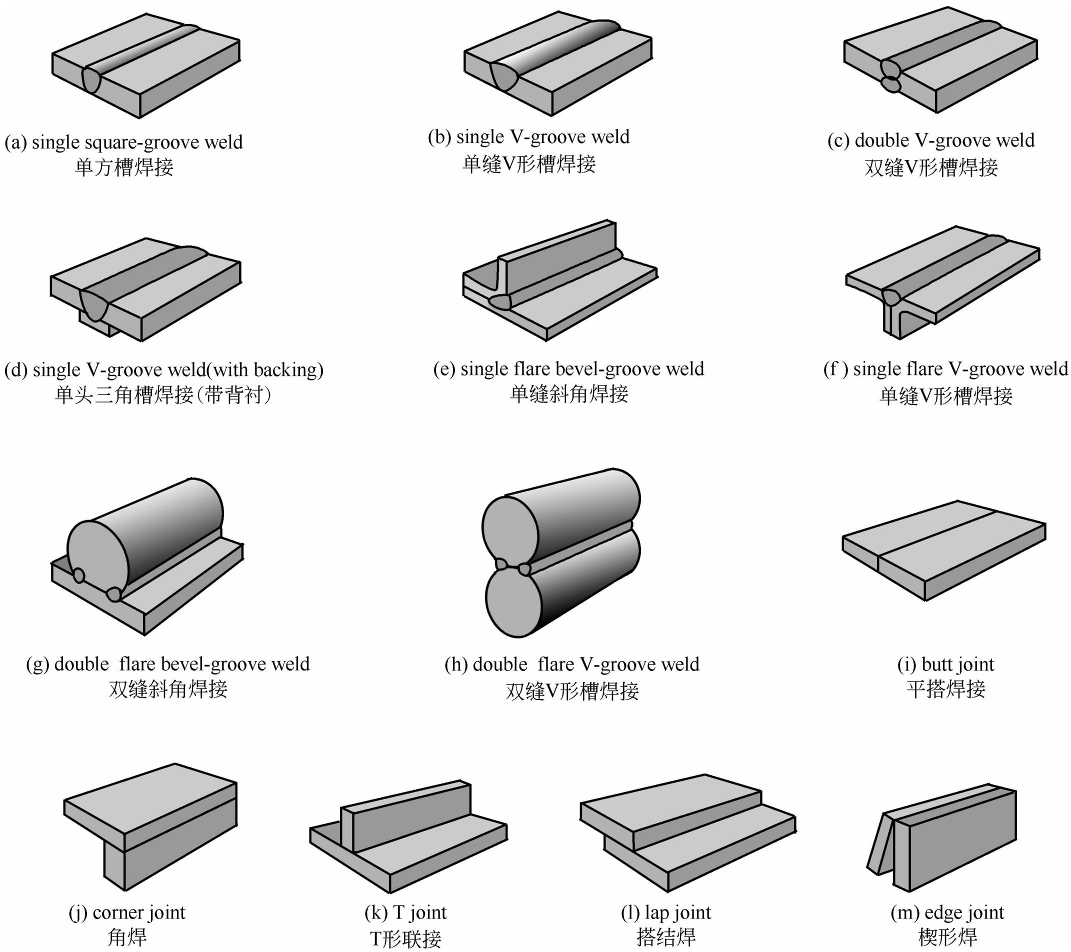


Die forging 模锻

(a) through (c) stages of impress-die forging of a solid round billet 从(a)到(c)锻打过程
(d) standard terminology of various features of a forging die 模锻标准术语



Die insert used in forging an automotive axle housing
汽车轴套型芯锻造



Examples of welded joints and their terminology 焊接头形式及其术语

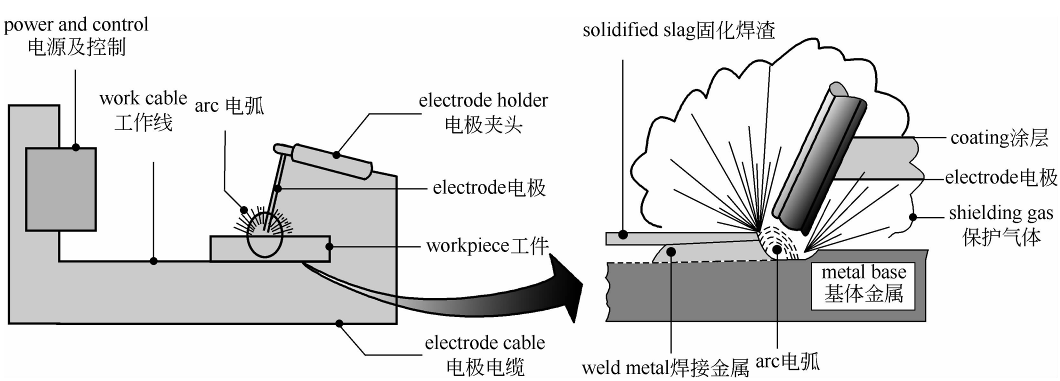
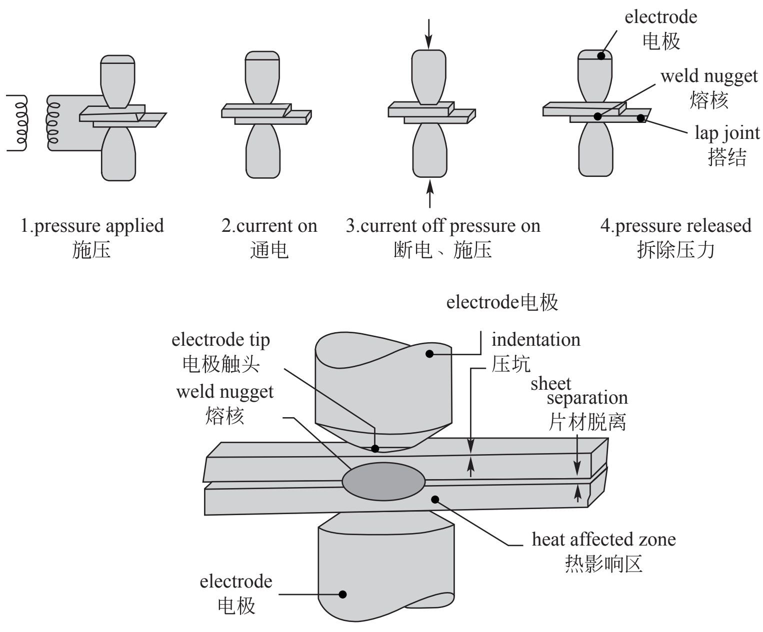


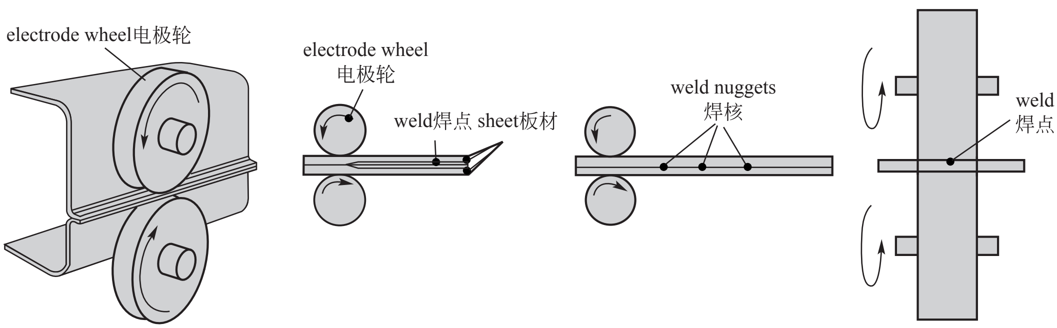
Illustration of shielding metal-arc welding process 金属引弧保护焊



(b)

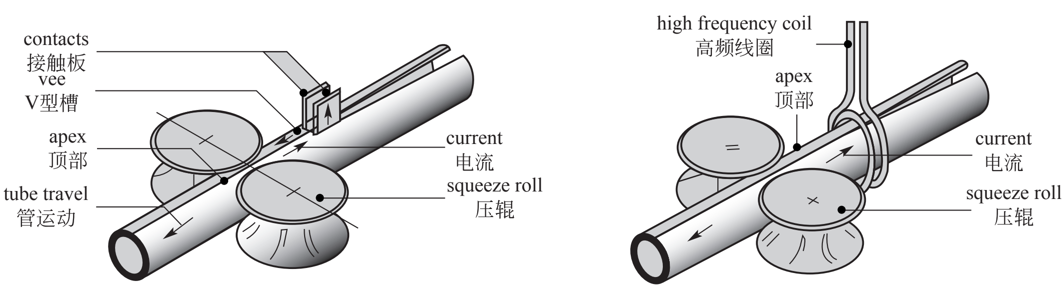
Process of spot welding 点焊

（a）sequence 步骤 （b）cross-section 断面图



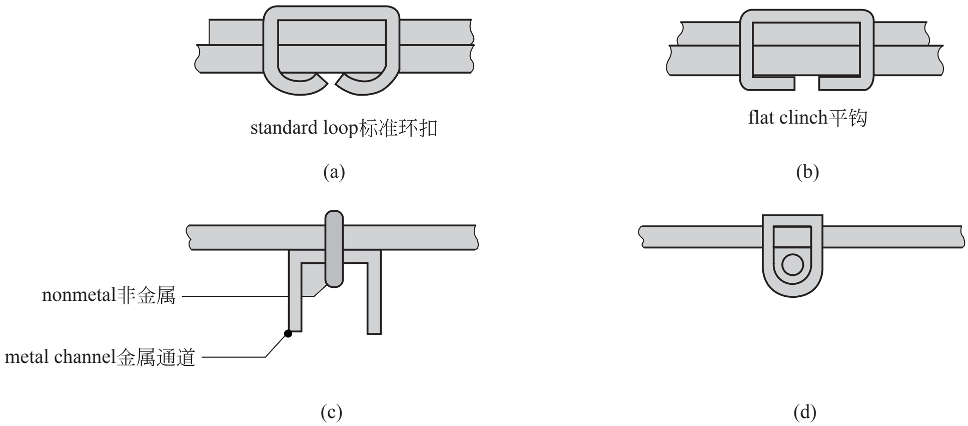
(a) (b) (c) (d)

Seam spot-welding process 缝隙的点焊



(a) (b)

Two methods of high-frequency continuous butt welding of tube 管的两种高频连续对焊方法



Typical examples of metal stitching 板扣联结的例子

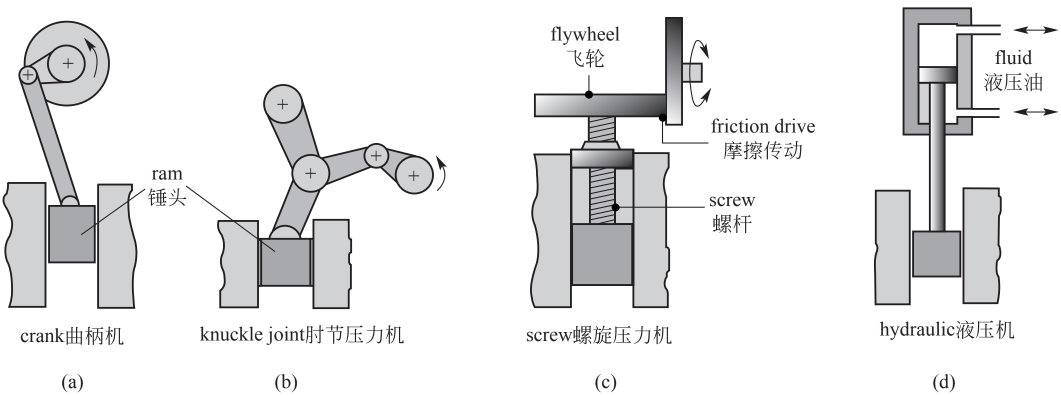
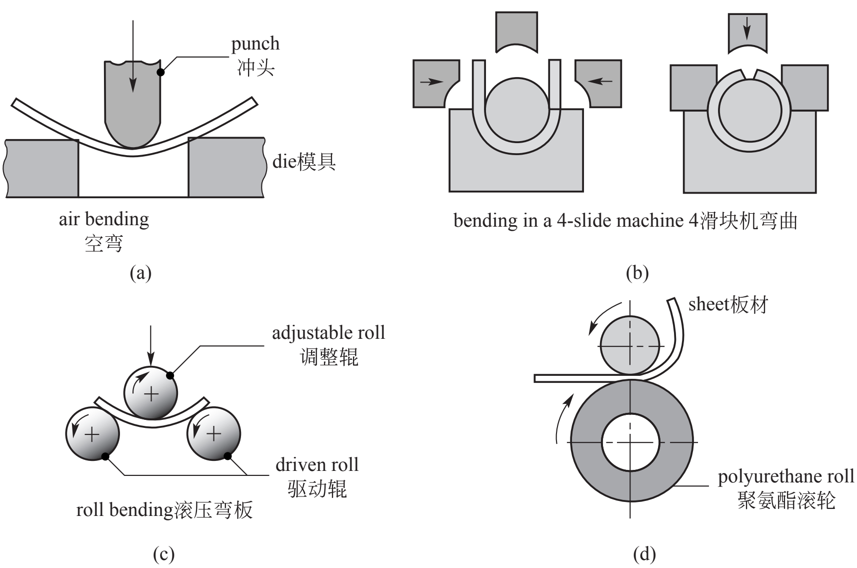
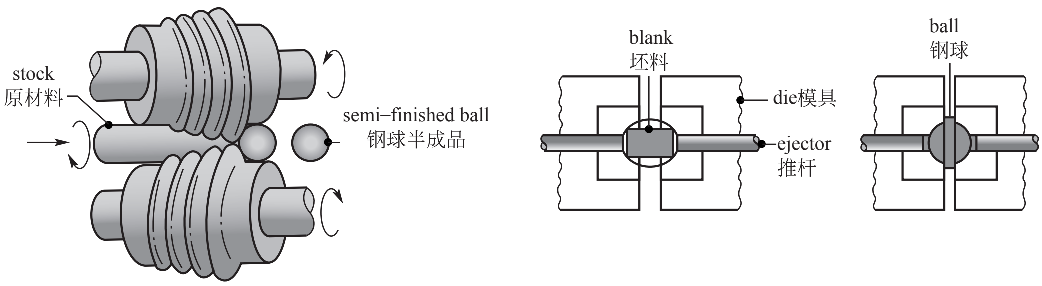


Illustration of the principles of various forging machines 锻压机床的工作原理



Examples of various bending operations 几种弯曲工艺技术

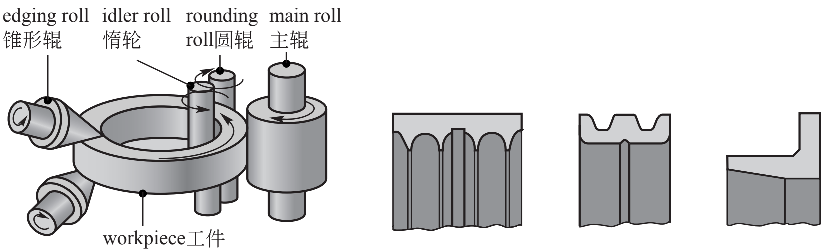


(a) (b)

Steel ball machined by dies 模具加工钢球

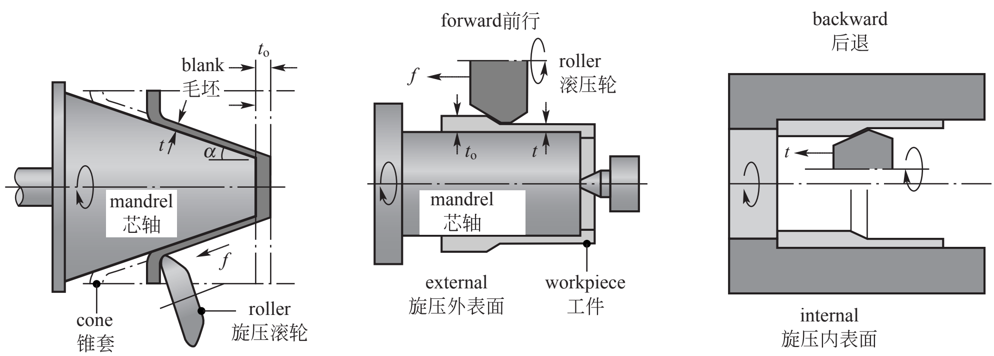
（a）production of steel balls by skew-rolling process 斜轧钢球

（b）production of steel balls by upsetting a cylindrical blank 圆柱坯料模压



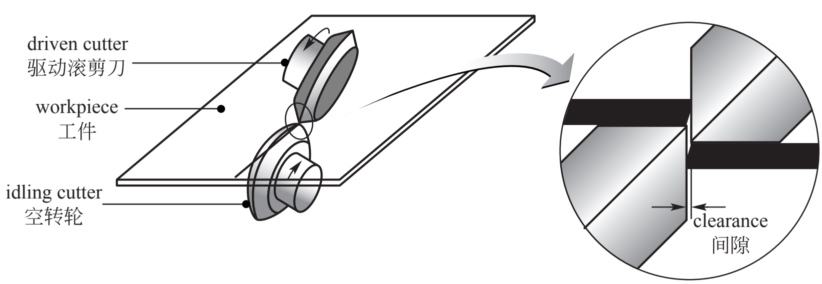
(a) (b) (c) (d)

Ring rolling operations 环件的滚压加工



(a) (b) (c)

Shear-spinning process 剪旋工艺



Slitting with rotary knives 旋转刀具剪切

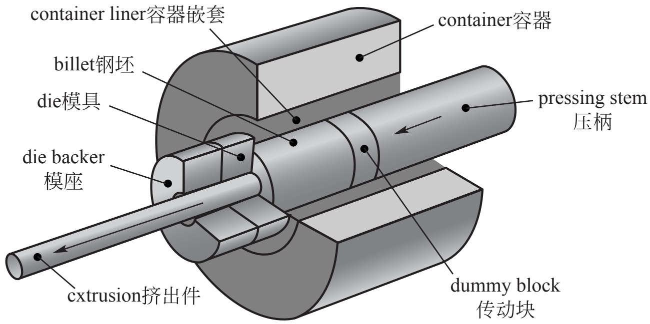
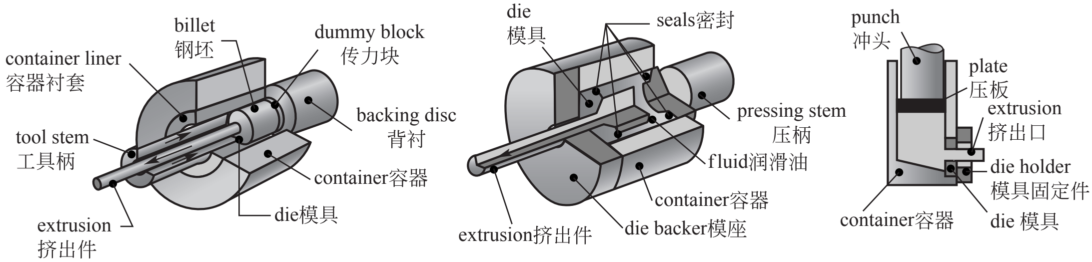


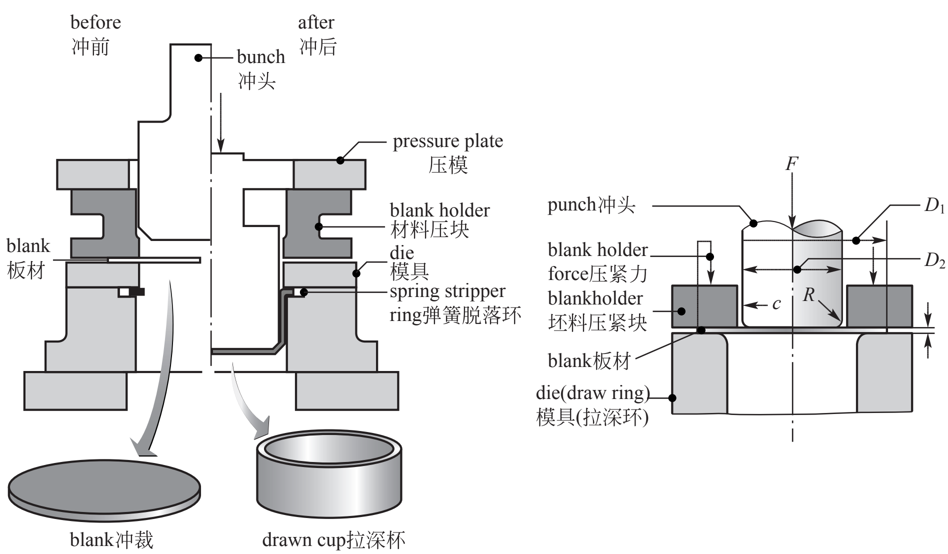
Illustration of the direct-extrusion process 直接挤出工艺



(a) (b) (c)

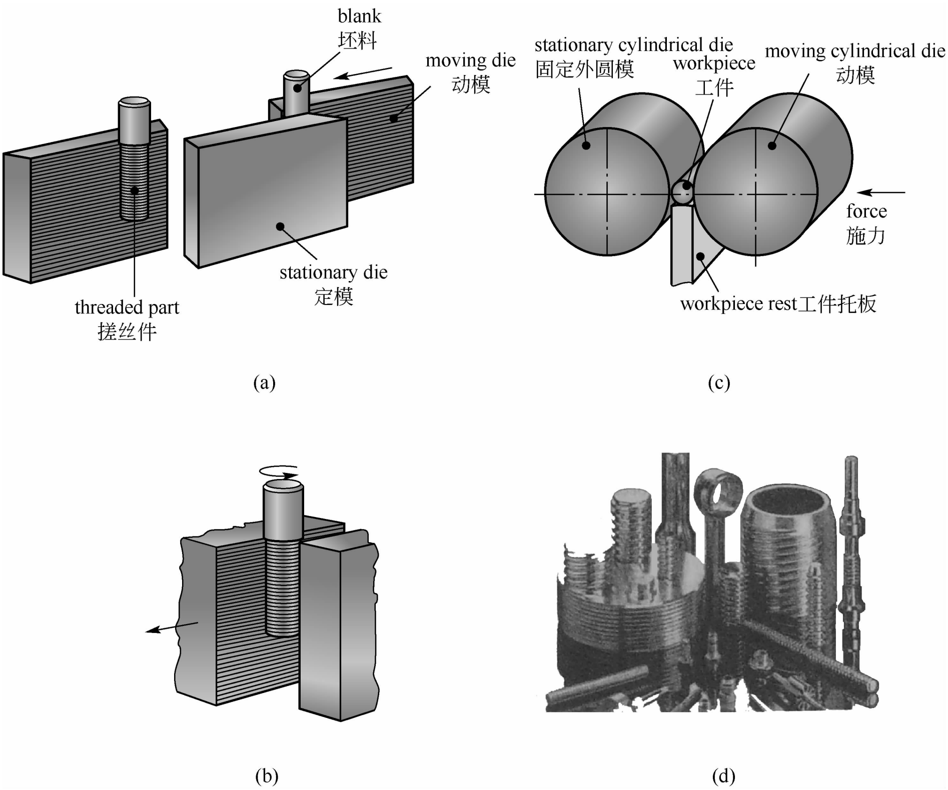
Types of extrusion 挤出工艺的类别

(a) indirection 间接挤出　(b) hydrostatic 静压挤出　(c) lateral 侧边挤出



(a) (b)

Illustration of the deep-drawing process 拉深工艺示意图



Thread rolling process 螺纹滚压工艺

(a) and (b) reciprocating flat die 往复平板模具 (c) two roller dies 双滚轮模具

(d) a collection of thread-rolled parts economically at high production rate 高效经济滚压系列螺纹件

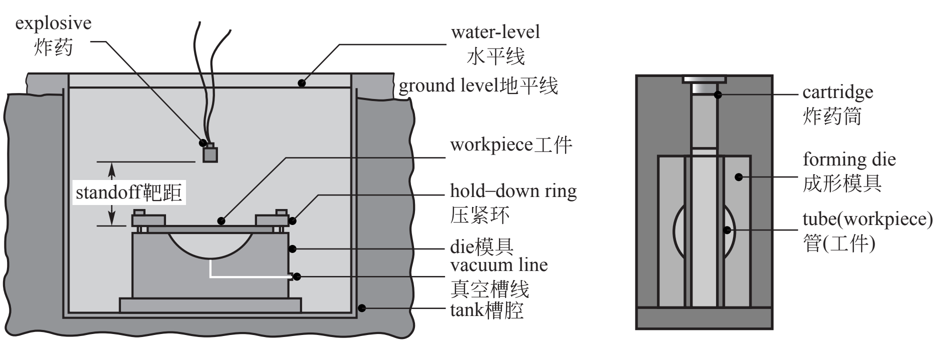
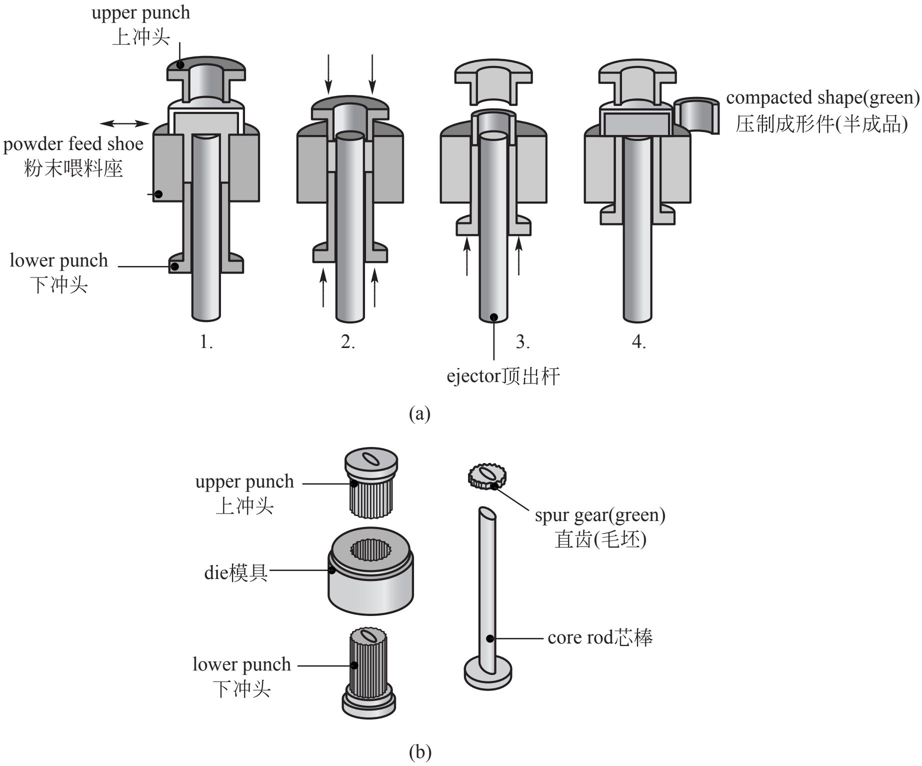


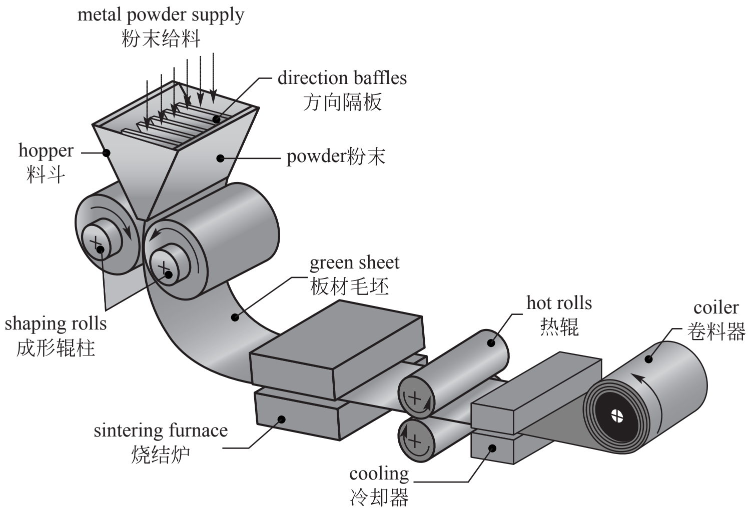
Illustration of the explosive forming process 爆炸成形技术



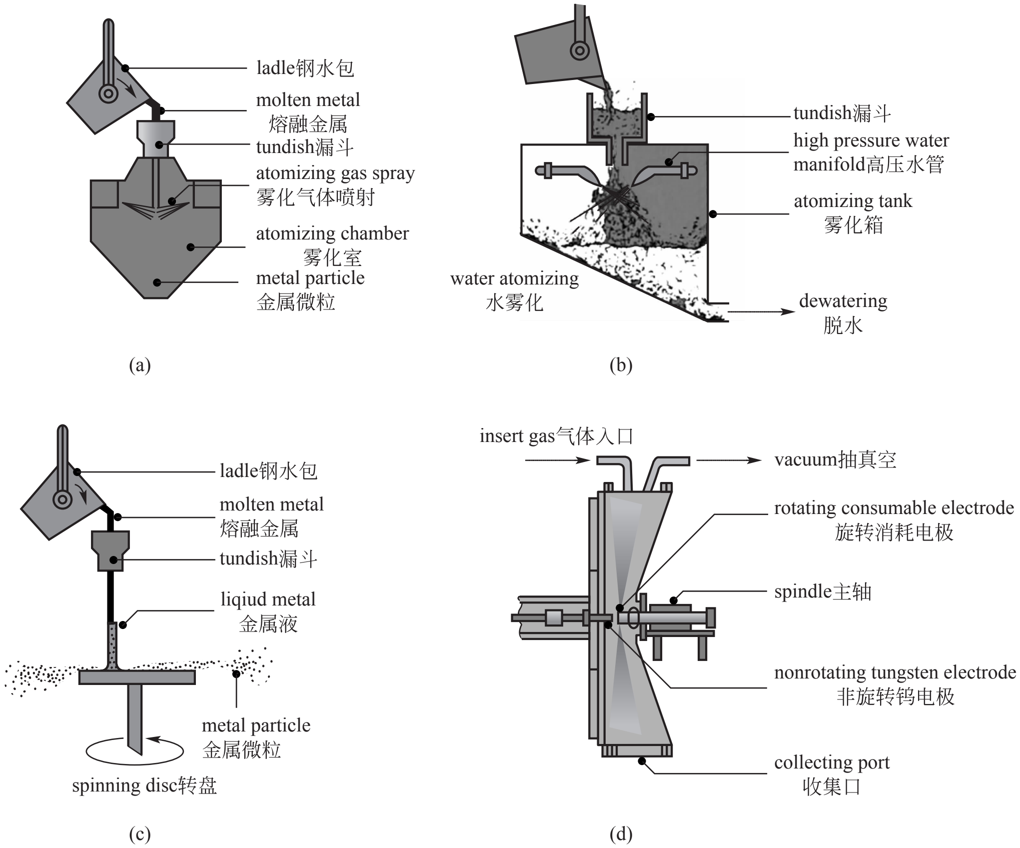
Powder metallurgy process 粉末冶金成形工艺

(a) compaction of metal powder to form a bushing(green part)粉末压制衬套(半成品)

(b) typical tool and die for a spur gear 直齿零件的典型(工)模具

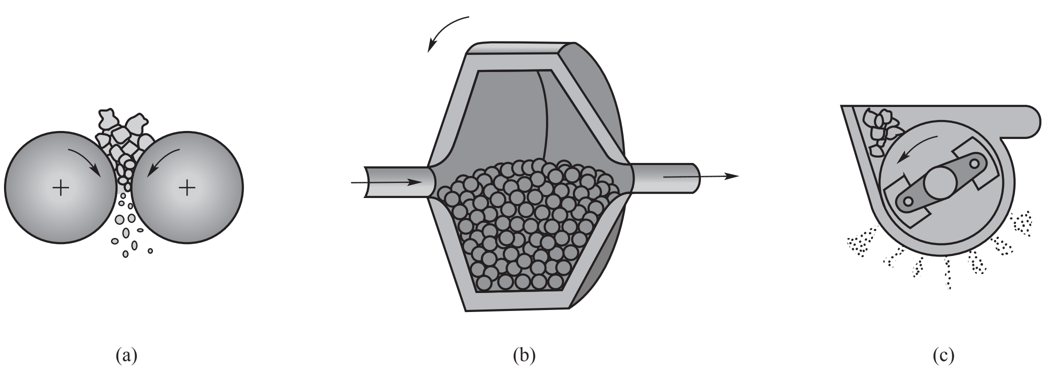


An illustration of powder rolling 粉末滚压成形



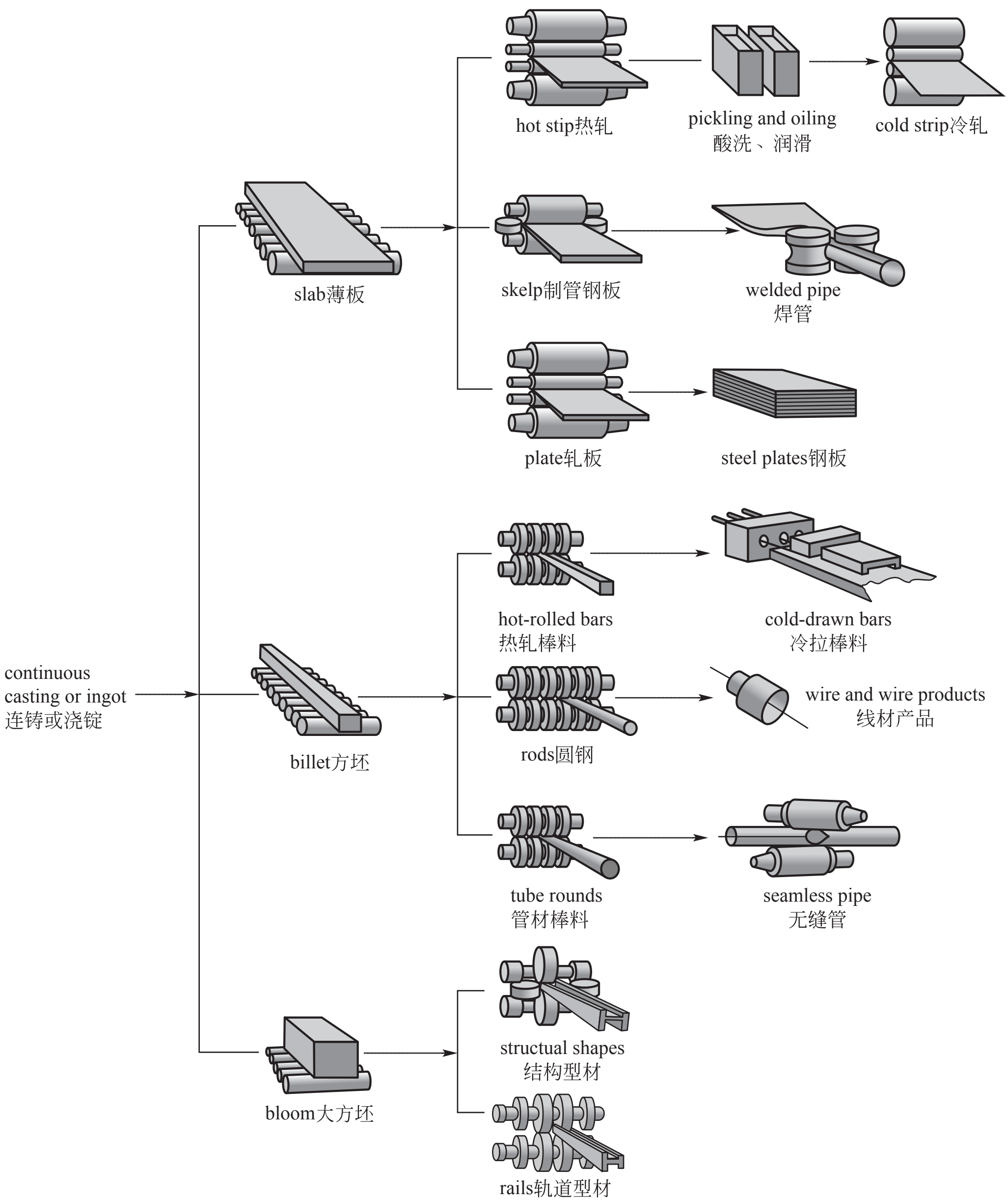
Methods of metal powder production by atomization 雾化制粉技术方法

（a）gas atomization 气体雾化 （b）water atomization 水雾化
（c）centrifugal atomization with a spinning disc or cup 转盘离心雾化
（d）atomization with a rotating consumable electrode 回转耗损电极雾化



Methods of mechanical comminution to obtain fine particle 机械粉碎制粉方法

（a）roll crushing 滚筒压碎 （b）ball mill 球体粉碎 （c）hammer milling 锤打粉碎



Schematic outline of various flat-rolling and shaped-rolling 板材和型材轧制工艺示意图

Reading Materials

Passage 1: **Die Casting**

The die casting process, developed in the early 1900s, is a further example of permanent-mold casting. Typical parts made by die casting are motor housings, engine blocks, business-machine and appliance components, hand tools, and toys. The weight of most castings ranges from less than 90g to about 25kg. Equipment costs, particularly the cost of dies, are somewhat high, but labor costs are generally low, because the process is now semi-or fully automated. Die casting is economical for large production runs.

In this process, the molten metal is forced into the die cavity at pressures ranging from 0.7 to 700MPa. The European term pressure-die casting (or simply die casting), which is described in this section, is not to be confused with the term pressure casting. There are two basic types of die-casting machines: hot-chamber and cold-chamber.

The hot-chamber process involves the use of a piston, which traps a certain volume of molten metal and forces it into the die cavity through a gooseneck and nozzle. Pressures range up to 35MPa with an average of about 15MPa. The metal is held under pressure until it solidifies in the die. To improve die life and to aid in rapid metal cooling (thereby reducing cycle time) dies usually are cooled by circulating water or oil through various passageways in the die block. Low-melting-point alloys (such as zinc, magnesium, tin, and lead) commonly are cast using this process. Cycle times usually range from 200 to 300 shots (individual injections) per hour for zinc, although very small components such as zipper teeth can be cast at rates of 18000 shots per hour.

In the cold-chamber process, molten metal is poured into the injection cylinder (shot chamber). The chamber is not heated, hence the term cold chamber. The metal is forced into the die cavity at pressures usually ranging from 20 to 70MPa, although they may be as high as 150MPa.

The machines may be horizontal or vertical, in which case the shot chamber is vertical. High-melting-point alloys of aluminum, magnesium, and copper normally are cast using this method, although other metals (including ferrous metals) also can be cast. Molten-metal temperatures start at about 600℃ for aluminum and some magnesium alloys, and increase considerably for copper-based and iron-based alloys.

Passage 2: Impression-Die and Closed-Die Forging

In impression-die forging, the workpiece takes the shape of the die cavity while being forged between two shaped dies. This process usually is carried out at elevated temperatures for enhanced ductility of the metals and to lower the forces. Note that, during deformation, some of the material flows outward and forms a flash. The flash has an important role in impression-die forging. The high pressure and the resulting high frictional resistance in the flash presents a severe constraint to the material in the die for outward flow. Thus, based on the principle that in plastic deformation the material flows in the direction of least resistance (because it requires less energy), the material begins to flow into the die cavity, ultimately filling it completely.

Instead of being made as one piece, dies may be made of several pieces (segmented), including die inserts and particularly for complex shapes. The inserts can be replaced easily in the case of wear or failure in a particular section of the die and usually are made of stronger and harder materials. Of course, dies should allow the removal of the forged workpiece without difficulty.

The blank to be forged is prepared by such means as (a) cropping from an extruded or drawn bar stock; (b) a preform from operations such as powder metallurgy; (c) casting; or (d) using a preform blank from a prior forging operation. The blank is placed on the lower die, and as the upper die begins to descend, the blank's shape gradually changes.

Preforming operations typically are used to distribute the material properly into various regions of the blank using simple shaped dies of various contours. In fullering, material is distributed away from an area. In edging, it is gathered into a localized area. The part then is formed into the rough shape (say, a connecting rod) by a process called blocking, using blocker dies. The final operation is the finishing of the forging in impression dies that give the forging its final shape.

Passage 3: Shielded Metal-arc Welding

Shielded metal-arc welding (SMAW) is one of the oldest, simplest, and most versatile joining processes. About 50% of all industrial and maintenance welding currently is performed by this process. The electric arc is generated by touching the tip of a coated electrode against the workpiece and withdrawing it quickly to a distance sufficient to maintain the arc. The electrodes are in the shapes of thin, long rods (hence this process also is known as stick welding) that are held manually.

The heat generated melts a portion of the electrode tip, its coating, and the base metal in the immediate arc area. The molten metal consists of a mixture of the base metal (workpiece), the electrode metal, and substances from the coating on the electrode; this mixture forms the weld when it solidifies. The electrode coating deoxidizes the weld area and provides a shielding gas to protect it from oxygen in the environment.

A bare section at the end of the electrode is clamped to one terminal of the power source, while the other terminal is connected to the workpiece being welded. The current, which may be DC or AC, usually ranges between 50 and 300A. For sheet-metal welding, DC is preferred because of the steady arc it produces. Power requirements generally are less than 10kW.

The SMAW process has the advantages of being relatively simple, versatile and requiring a smaller variety of electrodes. The equipment consists of a power supply, cables, and an electrode holder. The SMAW process commonly is used in general construction, shipbuilding, pipelines, and maintenance work. It is useful especially for work in remote areas where a portable fuel-powered generator can be used as the power supply. This process is suited best for workpiece thicknesses of 3 to 19mm, although this range can be extended easily by skilled operators using multiple-pass techniques.

The multiple-pass approach requires that the slag be cleaned after each weld bead. Unless removed completely, the solidified slag can cause severe corrosion of the weld area and lead to failure of the weld, but it also prevents fusion of weld layers and, therefore, compromises the weld strength. Before another weld is applied, the slag should be removed completely, such as by wire brushing or weld chipping. Consequently, both labor costs and material costs are high.

Passage 4: Characteristics of Stamping

Stamping is a kind of plastic forming process in which a part is produced by means of the plastic forming of the material under the action of a die. Stamping is usually carried out under cold state, so it is also called cold stamping. Heat stamping is used only when the blank thickness is greater than 8～100mm. The blank material for stamping is usually in the form of sheet or strip, and therefore it is also called sheet metal forming. Some non-metal sheets (such as plywood, mica sheet, asbestos, leather) can also be formed by stamping. Stamping is widely used in various fields of the metalworking industry, and it plays a crucial role in the industries for manufacturing automobiles, instruments, military parts and household electrical appliances, etc.

The process, equipment and die are the three foundational problems that needed to be studied in stamping.

The characteristics of the sheet metal forming are as follows:

(1) High material utilization.

(2) Capacity to produce thin-walled parts of complex shape.

(3) Good interchangeability between stamping parts due to precision in shape and dimension.

(4) Parts with lightweight, high-strength and fine rigidity can be obtained.

(5) High productivity, easy to operate and to realize mechanization and automatisation

The manufacture of the stamping die is costly, and therefore it only fits to mass production. For the manufacture of products in small batch and rich variety, the simple stamping die and the new equipment such as a stamping machining center, are usually adopted to meet the market demands.

The materials for sheet metal stamping include mild steel, copper, aluminum, magnesium alloy and high-plasticity alloy-steel, etc.

Stamping equipment includes plate shear and punching press. The former shears plate into strips with a definite width, which would be pressed later. The later can be used both in shearing and forming.

Part 4 Terminology for Machine Parts & Mechanism

机械零件和机构专业词汇(汉—英)

A

阿基米德蜗杆 Archimedes worm

安全系数 safety factor；factor of safety

安全载荷 safety load

凹面、凹度 concavity

B

扳手 wrench，spanner，lever

板簧 flat leaf spring

半圆键 woodruff key

变形 deformation

摆杆 oscillating bar

摆动从动件 oscillating follower

摆动从动件凸轮机构 cam with oscillating follower

摆动导杆机构 oscillating guide-bar mechanism

摆线齿轮 cycloidal gear

摆线齿形 cycloidal tooth profile

摆线运动规律 cycloidal motion

摆线针轮 cycloidal-pin wheel

包角 angle of contact

保持架 cage

背对背安装 back-to-back arrangement

背锥 back cone；normal cone

背锥角 back angle

背锥距 back cone distance

比例尺 scale

比热容 specific heat capacity

闭式链 closed kinematic chain

闭链机构 closed chain mechanism

臂部 arm

变频器 frequency converters

变频调速 frequency control of motor speed

变速 speed change

变速齿轮 change gear；change wheel

变位齿轮 modified gear

变位系数 modification coefficient

标准齿轮 standard gear

标准直齿轮 standard spur gear

表面质量系数 superficial mass factor

表面传热系数 surface coefficient of heat transfer

表面粗糙度 surface roughness

并联式组合 combination in parallel

并联机构 parallel mechanism

并联组合机构 parallel combined mechanism

并行工程 concurrent engineering

并行设计 concurred design，CD

不平衡相位 phase angle of unbalance

不平衡 imbalance (or unbalance)

不平衡量 amount of unbalance

不完全齿轮机构 intermittent gearing
波数 number of waves
波发生器 wave generator
补偿 compensation

C

参数化设计 parameterization design，PD
操纵及控制装置 operation control device
槽轮机构 Geneva mechanism；Maltese cross
槽凸轮 groove cam
差动轮系 differential gear train
差速器 differential
车床 lathe
承载能力 bearing capacity
尺寸系列 dimension series
齿槽宽 spacewidth
齿顶高 addendum
齿根高 dedendum
齿厚 tooth thickness
齿宽 face width
齿廓曲线 tooth curve
齿轮变速箱 speed-changing gear boxes
齿轮插刀 pinion cutter；
pinion-shaped shaper cutter
齿轮机构 gear
齿轮传动系 pinion unit
齿条传动 rack gear
齿数比 gear ratio
齿条插刀
rack cutter；rack-shaped cutter
齿形系数 form factor
插齿机 gear shaper
重合度 contact ratio
传动比 transmission ratio，speed ratio
传动系统 driven system
传动轴 transmission shaft
串联式组合机构 series combined mechanism
创新 innovation；creation
残余应力 residual stress
槽轮 Geneva wheel
槽数 Geneva numerate
侧隙 backlash
差动螺旋机构 differential screw mechanism
常用机构 conventional
mechanism；mechanism in common use
承载量系数 bearing capacity factor
成对安装 paired mounting
齿槽 tooth space
齿侧间隙 backlash
齿顶圆 addendum circle
齿根圆 dedendum circle
齿距 circular pitch
齿廓 tooth profile，flank profile
齿轮 gear
齿轮齿条机构 pinion and rack
齿轮滚刀 hob，hobbing cutter
齿轮轮坯 blank
齿轮联轴器 gear coupling
齿数 tooth number
齿条 rack
齿形链、无声链 silent chain
齿式棘轮机构 tooth ratchet mechanism
重合点 coincident points
冲床 punch
传动装置 gearing；transmission gear
传动角 transmission angle
串联式组合 combination in series
串级调速 cascade speed control
创新设计 creation design
唇形橡胶密封 lip rubber seal

垂直载荷、法向载荷 normal load
磁流体轴承 magnetic fluid bearing
从动件 driven link，follower
从动件停歇 follower dwell
从动轮 driven gear
从动带轮 driven pulley
从动件平底宽度 width of flat-face
从动件运动规律 follower motion
粗线 bold line
粗牙螺纹 coarse thread

D

大齿轮 gear wheel
打包机 packer
带传动 belt driving
带式制动器 band brake
单向推力轴承 single-direction thrust bearing
单位矢量 unit vector
当量齿数 equivalent teeth number；virtual number of teeth
当量载荷 equivalent load
导数 derivative
导热性 conduction of heat
导程角 lead angle
等速运动规律 uniform motion；constant velocity motion
等宽凸轮 constant-breadth cam
等效力 equivalent force
等效量 equivalent
等效转动惯量 equivalent moment of inertia
底座 chassis，base，foundation
点划线 chain dotted line
垫圈 gasket
碟形弹簧 belleville spring
顶隙 bottom clearance
动密封 kinematical seal
动力粘度 dynamic viscosity
动平衡 dynamic balance
动态特性 dynamic characteristics
动压力 dynamic reaction
打滑 slipping
带轮 belt pulley
单列轴承 single row bearing
单万向联轴节 single universal joint
当量齿轮 equivalent spur gear；virtual gear
当量摩擦系数 equivalent coefficient of friction
刀具 cutter
倒角 chamfer
导程 lead
等加等减速运动规律 parabolic motion；constant acceleration and deceleration motion
等径凸轮 conjugate yoke radial cam
等效构件 equivalent link
等效力矩 equivalent moment of force
等效质量 equivalent mass
等效动力学模型 dynamically equivalent model
低副 lower pair
(疲劳)点蚀 pitting
垫片密封 gasket seal
动力学 dynamics
定轴轮系 ordinary gear train；gear train with fixed axes
动能 dynamic energy
动力润滑 dynamic lubrication
动平衡机 dynamic balancing machine
动态分析设计 dynamic analysis design
动载荷 dynamic load

端面 transverse plane
端面齿距 transverse circular pitch
端面重合度 transverse contact ratio
端面压力角 transverse pressure angle
对称循环应力 symmetry circulating stress
对心直动从动件 radial
(or in-line) translating follower
对心曲柄滑块机构 in-line slider-crank (or crank-slider) mechanism
多楔带 poly V-belt
多质量转子 rotor with several masses
端面参数 transverse parameters
端面齿廓 transverse tooth profile
端面模数 transverse module
锻造 forge
对心滚子从动件 radial
(or in-line) roller follower
对心移动从动件
radial reciprocating follower
多列轴承 multi-row bearing
多项式运动规律 polynomial motion
惰轮 idle gear

E

额定寿命 rating life
Ⅱ级杆组 dyad
额定载荷 load rating

F

发生线 generating line
发生面 generating plane
法面参数 normal parameters
法面模数 normal module
法向齿距 normal pitch
法向直廓蜗杆 straight sided normal worm
反馈式组合 feedback combining
反转法 kinematic inversion
范成法 generating cutting
方案设计、概念设计 concept design,CD
飞轮 flywheel
非标准齿轮 nonstandard gear
非周期性速度波动
aperiodic speed fluctuation
粉末合金 powder metallurgy
分度圆 reference circle;standard (cutting) pitch circle
分度圆柱螺旋角
helix angle at reference cylinder
法面 normal plane
法面齿距 normal circular pitch
法面压力角 normal pressure angle
法向齿廓 normal tooth profile
法向力 normal force
反向运动学 inverse (or backward) kinematics
反正切 Arctan
仿形法 form cutting
防振装置 shockproof device
飞轮矩 moment of flywheel
非接触式密封 non-contact seal
非圆齿轮 non-circular gear
分度线 reference line;standard pitch line
分度圆柱导程角
lead angle at reference cylinder
分母 denominator
分度圆锥 reference cone;standard pitch cone
封闭差动轮系 planetary differential
复合式组合 compound combining

分子 numerator
分析法 analytical method
复合铰链 compound hinge
复合轮系 compound (or combined) gear train
复合平带 compound flat belt
复式螺旋机构 compound screw mechanism
复合应力 combined stress
复杂机构 complex mechanism

G

杆组 Assur group
干涉 interference
刚轮 rigid circular spline
刚体导引机构 body guidance mechanism
刚性转子 rigid rotor
刚性联轴器 rigid coupling
高速带 high speed belt
格拉晓夫定理 Grashoff's law
公称直径 nominal diameter
功 work
工艺设计 technological design
工作机构 operation mechanism
工作空间 working space
工作阻力 effective resistance
公法线 common normal line
公制齿轮 metric gears
功能分析设计 function analyses design
共轭凸轮 conjugate cam
鼓风机 blower
固体润滑剂 solid lubricant
惯性力 inertia force
惯性力平衡 balance of shaking force
惯性力部分平衡
partial balance of shaking force
惯性主矢 resultant vector of inertia
广义机构 generation mechanism
轨迹生成 path generation
滚刀 hob
滚动体 rolling element
刚度系数 stiffness coefficient
钢丝软轴 wire soft shaft
刚性冲击 rigid impulse (shock)
刚性轴承 rigid bearing
高度系列 height series
高副 higher pair
根切 undercutting
高度系列 height series
工况系数 application factor
工作循环图 working cycle diagram
工作载荷 external loads
工作应力 working stress
工作阻力矩 effective resistance moment
公共约束 general constraint
功率 power
共轭齿廓 conjugate profiles
构件 link
固定构件 fixed link; frame
关节型操作器 jointed manipulator
惯性力矩 moment of inertia , shaking moment
惯性力完全平衡
full balance of shaking force
惯性主矩 resultant moment of inertia
冠轮 crown gear
广义坐标 generalized coordinate
轨迹发生器 path generator
滚道 raceway
滚动轴承 rolling bearing
滚针 needle roller

滚动轴承代号 rolling bearing identification code
滚针轴承 needle roller bearing
滚子轴承 roller bearing
滚子从动件 roller follower
滚子链联轴器 double roller chain coupling
滚子 roller
滚子半径 radius of roller
滚子链 roller chain
滚珠丝杆 ball screw
滚柱式单向超越离合器 roller overrun clutch
过度切割 undercutting

H

函数发生器 function generator
含油轴承 oil bearing
耗油量系数 oil consumption factor
合成弯矩 resultant bending moment
合力矩 resultant moment of force
横坐标 abscissa
花键 spline
滑动轴承 sliding bearing
滑块 slider
环形弹簧 annular spring
灰铸铁 grey cast iron
回转体平衡 balance of rotors
函数生成 function generation
耗油量 oil consumption
赫兹公式 H. Hertz equation
合力 resultant force
黑箱 black box
互换性齿轮 interchangeable gears
滑键、导键 feather key
滑动率 sliding ratio
环面蜗杆 toroid helicoids worm
缓冲装置 shocks；shock-absorber
回程 return
混合轮系 compound gear train

J

积分 integrate
机构 mechanism
机构平衡 balance of mechanism
机构运动设计 kinematic design of mechanism
机构综合 synthesis of mechanism
机架 frame，fixed link
机器 machine
机器人操作器 manipulator
技术过程 technique process
技术系统 technique system
机械创新设计 mechanical creation design，MCD
机械动力分析 dynamic analysis of machinery
机械动力学 dynamics of machinery
机电一体化系统设计 mechanical-electrical integration system design
机构分析 analysis of mechanism
机构学 mechanism
机构运动简图 kinematic sketch of mechanism
机构组成 constitution of mechanism
机架变换 kinematic inversion
机器人 robot
机器人学 robotics
技术经济评价 technical and economic evaluation
机械 machinery
机械系统设计 mechanical system design，MSD

机械系统 mechanical system
机械平衡 balance of machinery
机械设计 machine design；mechanical design
机械调速 mechanical speed governors
机械原理 theory of machines and mechanisms
机械无级变速 mechanical stepless speed changes
基本额定寿命 basic rating life
基圆 base circle
基圆齿距 base pitch
基圆柱 base cylinder
急回机构 quick-return mechanism
急回系数 advance-to return-time ratio
棘轮 ratchet
棘爪 pawl
极位夹角 crank angle between extreme (or limiting) positions
计算机辅助制造 computer aided manufacturing，CAM
计算机集成制造系统 computer integrated manufacturing system，CIMS
计算力矩 factored moment；calculation moment
加权系数 weighting efficient
加速度分析 acceleration analysis
尖点 pointing；cusp
间隙 backlash
减速比 reduction ratio
减速器 speed reducer
渐开螺旋面 involute helicoids
渐开线齿廓 involute profile
渐开线发生线 generating line of involute
渐开线函数 involute function
渐开线压力角 pressure angle of involute
简谐运动 simple harmonic motion
机械动力设计 dynamic design of machinery
机械的现代设计 modern machine design
机械利益 mechanical advantage
机械手 manipulator
机械特性 mechanical behavior
机械效率 mechanical efficiency
机械运转不均匀系数 coefficient of speed fluctuation
基础机构 fundamental mechanism
基于实例设计 case-based design，CBD
基圆半径 radius of base circle
基圆压力角 pressure angle of base circle
基圆锥 base cone
急回特性 quick-return characteristics
急回运动 quick-return motion
棘轮机构 ratchet mechanism
极限位置 extreme (or limiting) position
计算机辅助设计 computer aided design，CAD
计算弯矩 calculated bending moment
加速度 acceleration
加速度曲线 acceleration diagram
尖底从动件 knife-edge follower
间歇运动机构 intermittent motion mechanism
减速齿轮、减速装置 reduction gear
减摩性 anti-friction quality
渐开线 involute
渐开线齿轮 involute gear
渐开线方程 involute equation
渐开线蜗杆 involute worm
渐开线花键 involute spline
键 key
交变应力 repeated stress
交叉带传动 cross-belt drive
胶合 scoring
角速度 angular velocity

键槽 keyway
交变载荷 repeated fluctuating load
交错轴斜齿轮 crossed helical gears
角加速度 angular acceleration
角速比 angular velocity ratio
角接触推力轴承 angular contact thrust bearing
角接触轴承 angular contact bearing
校正平面 correcting plane
接触式密封 contact seal
结构 structure
截面 section
节距 circular pitch; pitch of teeth
节圆 pitch circle
节圆直径 pitch diameter
节圆锥角 pitch cone angle
紧边 tight-side
径节 diametral pitch
径向当量动载荷 dynamic equivalent radial load
径向基本额定动载荷 basic dynamic radial load rating
径向接触轴承 radial contact bearing
径向游隙 radial internal clearance
径向载荷系数 radial load factor
静力 static force
静载荷 static load
局部自由度 passive degree of freedom
锯齿形螺纹 buttress thread form
均衡装置 load balancing mechanism
角接触球轴承 angular contact ball bearing
角接触向心轴承 angular contact radial bearing
铰链、枢纽 hinge
接触应力 contact stress
阶梯轴 multi-diameter shaft
结构设计 structural design
节点 pitch point
节线 pitch line
节圆齿厚 thickness on pitch circle
节圆锥 pitch cone
解析设计 analytical design
紧固件 fastener
径向 radial direction
径向当量静载荷 static equivalent radial load
径向基本额定静载荷 basic static radial load rating
径向平面 radial plane
径向载荷 radial load
径向间隙 clearance
静平衡 static balance
静密封 static seal
矩形螺纹 square threaded form
矩形牙嵌式离合器 square-jaw positive-contact clutch
绝对尺寸系数 absolute dimensional factor
绝对运动 absolute motion
绝对速度 absolute velocity

K

抗压强度 compression strength
开式链 open kinematic chain
可靠度 degree of reliability
可靠性设计 reliability design，RD
开口传动 open-belt drive
开链机构 open chain mechanism
可靠性 reliability
空气弹簧 air spring

空间机构 spatial mechanism
空间连杆机构 spatial linkage
空间凸轮机构 spatial cam
空间运动副 spatial kinematic pair
空间运动链 spatial kinematic chain
框图 block diagram
空转 idle
宽度系列 width series

L

雷诺方程 Reynolds's equation
离心力 centrifugal force
离心应力 centrifugal stress
理论廓线 pitch curve
离合器 clutch
离心密封 centrifugal seal
理论啮合线 theoretical line of action
隶属度 membership
力 force
力封闭型凸轮机构 force-drive (or force-closed) cam mechanism
力多边形 force polygon
力矩 moment
力平衡 equilibrium
力偶 couple
力偶矩 moment of couple
连杆 connecting rod，coupler
连杆机构 linkage
连杆曲线 coupler-curve
连心线 line of centers
链 chain
链传动装置 chain gearing
链轮 sprocket；sprocket-wheel；sprocket gear；chain wheel
联组 V 带 tight-up V belt
两维凸轮 two-dimensional cam
联轴器 coupling；shaft coupling
六杆机构 six-bar linkage
临界转速 critical speed
轮坯 blank
龙门刨床 double Haas planer
螺杆 screw
轮系 gear train
螺母 screw nut
螺距 thread pitch
螺钉 screws
螺旋锥齿轮 helical bevel gear
螺纹导程 lead
螺栓 bolts
螺旋传动 power screw
螺纹效率 screw efficiency
螺纹 thread (of a screw)
螺旋密封 spiral seal
螺旋机构 screw mechanism
螺旋副 helical pair
螺旋线 helix，helical line
螺旋角 helix angle
绿色设计 green design；design for environment

M

马耳他十字 Maltese cross
脉动循环应力 fluctuating circulating stress
脉动无级变速 pulsating stepless speed changes
铆钉 rivet
脉动载荷 fluctuating load
密封 seal
迷宫密封 labyrinth seal
密封胶 seal gum

密封带 seal belt
密封元件 potted component
面对面安装 face-to-face arrangement
名义应力、公称应力 nominal stress
模块式传动系统 modular system
模糊集 fuzzy set
模数 module
摩擦角 friction angle
摩擦学设计 tribology design，TD
摩擦力矩 friction moment
摩擦圆 friction circle
末端执行器 end-effector
密封装置 sealing arrangement
面向产品生命周期设计 design for product's life cycle，DPLC
模块化设计 modular design，MD
模幅箱 morphology box
模糊评价 fuzzy evaluation
摩擦 friction
摩擦力 friction force
摩擦阻力 frictional resistance
摩擦系数 coefficient of friction
磨损 abrasion；wear；scratching
目标函数 objective function

N

耐腐蚀性 corrosion resistance
耐磨性 wear resistance
挠性机构 mechanism with flexible elements
内力 internal force
能量 energy
逆时针 counterclockwise (or anticlockwise)
啮合 engagement，mesh，gearing
啮合角 working pressure angle
啮合线长度 length of line of action
牛头刨床 shaper
扭转应力 torsion stress
内齿轮 internal gear
挠性转子 flexible rotor
内齿圈 ring gear
内圈 inner ring
能量指示图 viscosity
啮出 engaging-out
啮合点 contact points
啮合线 line of action
啮入 engaging-in
凝固点 freezing point；solidifying point
诺模图 Nomogram
扭矩 moment of torque
扭簧 helical torsion spring

O

O 形密封圈密封 O ring seal

P

盘形凸轮 disk cam
盘形转子 disk-like rotor
疲劳极限 fatigue limit
偏置式 offset
抛物线运动 parabolic motion
疲劳强度 fatigue strength
偏(心)距 offset distance
偏心质量 eccentric mass

偏心率 eccentricity ratio
偏距圆 offset circle
偏置滚子从动件 offset roller follower
偏置曲柄滑块机构 offset slider-crank mechanism
评价与决策 evaluation and decision
频率 frequency
平带传动 flat belt driving
平分线 bisector
平均中径 mean screw diameter
平衡 balance
平衡品质 balancing quality
平衡质量 balancing mass
平衡转速 balancing speed
平面机构 planar mechanism
平面连杆机构 planar linkage
平面凸轮机构 planar cam mechanism
偏心盘 eccentric
偏置尖底从动件 offset knife-edge follower
拼接 matching
平底宽度 face width
平带 flat belt
平底从动件 flat-face follower
平均应力 average stress
平均速度 average velocity
平衡机 balancing machine
平衡平面 correcting plane
平衡重 counterweight
平面副 planar pair，flat pair
平面运动副 planar kinematic pair
平面凸轮 planar cam
平面轴斜齿轮 parallel helical gears
普通平键 parallel key

Q

其他常用机构 other mechanism in common use
起动阶段 starting period
气动机构 pneumatic mechanism
起始啮合点 initial contact，beginning of contact
千斤顶 jack
强迫振动 forced vibration
曲柄 crank
曲柄导杆机构 crank shaper (guide-bar) mechanism
曲柄摇杆机构 crank-rocker mechanism
曲率 curvature
曲面从动件 curved-shoe follower
曲线运动 curvilinear motion
驱动力 driving force
全齿高 whole depth
启动力矩 starting torque
奇异位置 singular position
气体轴承 gas bearing
嵌入键 sunk key
切齿深度 depth of cut
曲柄存在条件 Grashoff's law
曲柄滑块机构 slider-crank (or crank-slider) mechanism
曲齿锥齿轮 spiral bevel gear
曲率半径 radius of curvature
曲线拼接 curve matching
曲轴 crank shaft
驱动力矩 driving moment (torque)
权重集 weight sets
球面滚子 convex roller
球面副 spheric pair
球面运动 spherical motion

球 ball
球轴承 ball bearing
球面渐开线 spherical involute
球坐标操作器 polar coordinate manipulator
球销副 sphere-pin pair

R

燃点 spontaneous ignition
人字齿轮 herringbone gear
柔轮 flexspline
柔性制造系统 flexible manufacturing system；FMS
润滑油膜 lubricant film
润滑 lubrication
热平衡 heat balance；thermal equilibrium
冗余自由度 redundant degree of freedom
柔性冲击 flexible impulse；soft shock
柔性自动化 flexible automation
润滑装置 lubrication device
润滑剂 lubricant

S

三角形花键 serration spline
三维凸轮 three-dimensional cam
砂轮越程槽 grinding wheel groove
少齿差行星传动 planetary drive with small teeth difference
设计变量 design variable
深沟球轴承 deep groove ball bearing
升程 rise
实际廓线 cam profile
矢量 vector
输出构件 output link
输出力矩 output torque
输入构件 input link
实际啮合线 actual line of action
双曲柄机构 double crank mechanism
双头螺柱 studs
双摇杆机构 double rocker mechanism
双列轴承 double row bearing
松边 slack-side
瞬心 instantaneous center
四杆机构 four-bar linkage
速度不均匀(波动)系数
三角形螺纹 V thread screw
三心定理 Kennedy's theorem
砂漏 hour-glass
设计方法学 design methodology
设计约束 design constraints
生产阻力 productive resistance
升距 lift
十字滑块联轴器 double slider coupling；Oldham's coupling
输出功 output work
输出机构 output mechanism
输出轴 output shaft
数学模型 mathematic model
双滑块机构 double-slider mechanism，ellipsograph
双曲面齿轮 hyperboloid gear
双万向联轴节 constant-velocity (or double) universal joint
双转块机构 Oldham coupling
双向推力轴承 double-direction thrust bearing
顺时针 clockwise
死点 dead point

coefficient of speed fluctuation

速度曲线 velocity diagram

速度瞬心 instantaneous center of velocity

速度 velocity

速度波动 speed fluctuation

T

塔轮 step pulley

台钳、虎钳 vice

弹性滑动 elasticity sliding motion

弹性套柱销联轴器 rubber-cushioned sleeve bearing coupling

梯形螺纹 acme thread form

特性 characteristics

调节 modulation，regulation

调心球轴承 self-aligning ball bearing

调速 speed governing

调速系统 speed control system

调速器 regulator，governor

停车阶段 stopping phase

同步带 synchronous belt

凸的，凸面体 convex

凸轮倒置机构 inverse cam mechanism

凸轮廓线 cam profile

凸轮理论廓线 pitch curve

图册、图谱 atlas

推程 rise

推力轴承 thrust bearing

退火 anneal

踏板 pedal

太阳轮 sun gear

弹性联轴器 elastic coupling；flexible coupling

套筒 sleeve

特殊运动链 special kinematic chain

替代机构 equivalent mechanism

调心滚子轴承 self-aligning roller bearing

调心轴承 self-aligning bearing

调速电动机 adjustable speed motors

调压调速 variable voltage control

铁磁流体密封 ferrofluid seal

停歇 dwell

同步带传动 synchronous belt drive

凸轮 cam

凸轮机构 cam ，cam mechanism

凸轮廓线绘制 layout of cam profile

凸缘联轴器 flange coupling

图解法 graphical method

推力球轴承 thrust ball bearing

退刀槽 tool withdrawal groove

陀螺仪 gyroscope

V

V 带(三角带)V belt

W

外力 external force

外圈 outer ring

万向联轴器 Hooks coupling；universal coupling

外形尺寸 boundary dimension

外齿轮 external gear

弯矩 bending moment

往复移动 reciprocating motion

弯曲应力 beading stress
腕部 wrist
往复式密封 reciprocating seal
微动螺旋机构 differential screw mechanism
位移曲线 displacement diagram
稳定运转阶段 steady motion period
蜗杆 worm
蜗杆头数 number of threads
蜗杆蜗轮机构 worm and worm gear
蜗杆旋向 hands of worm
涡圈形盘簧 power spring
网上设计 on-net design，OND
位移 displacement
位姿 pose，position and orientation
稳健设计 robust design
蜗杆传动机构 worm gearing
蜗杆直径系数 diametral quotient
蜗杆形凸轮步进机构 worm cam interval mechanism
蜗轮 worm gear
无级变速装置 stepless speed changes devices
无穷大 infinite

X

系杆 crank arm，planet carrier
现场平衡 field balancing
向心力 centrifugal force
相对运动 relative motion
象限 quadrant
细牙螺纹 fine threads
消耗 consumption
小径 minor diameter
修正梯形加速度运动规律 modified trapezoidal acceleration motion
修正正弦加速度运动规律 modified sine acceleration motion
斜齿圆柱齿轮 helical gear
泄漏 leakage
谐波传动 harmonic driving
斜齿轮的当量直齿轮 equivalent spur gear of the helical gear
心轴 spindle
行程速比系数 advance-to-return time ratio
行星轮 planet gear
行星轮系 planetary gear train
虚拟现实 virtual reality
虚拟现实设计 virtual reality design，VRD
向心轴承 radial bearing
相对速度 relative velocity
相对间隙 relative gap
橡皮泥 plasticine
销 pin
小齿轮 pinion
橡胶弹簧 balata spring
斜键、钩头楔键 taper key
谐波齿轮 harmonic gear
谐波发生器 harmonic generator
行程速度变化系数 coefficient of travel speed variation
行星齿轮装置 planetary transmission
行星轮变速装置 planetary speed changing devices
形封闭凸轮机构 positive-drive（or form-closed）cam mechanism
虚拟现实技术 virtual reality technology，VRT
虚约束 redundant（or passive）constraint
许用应力 allowable stress；permissible stress
悬臂梁 cantilever beam
旋转力矩 running torque
旋转运动 rotary motion

许用不平衡量 allowable amount of unbalance
许用压力角 allowable pressure angle
悬臂结构 cantilever structure
旋转式密封 rotating seal
循环功率流 circulating power load
选型 type selection

Y

压力 pressure
压力中心 center of pressure
压应力 compressive stress
牙嵌式联轴器 jaw（teeth）positive-contact coupling
雅可比矩阵 Jacobi matrix
液力传动 hydrodynamic drive
液体弹簧 liquid spring
液压机构 hydraulic mechanism
移动从动件 reciprocating follower
移动关节 prismatic joint
盈亏功 increment or decrement work
应力集中 stress concentration
应力图 stress diagram
优化设计 optimal design
油壶 oil can
有害阻力 useless resistance
有效拉力 effective tension
有害阻力 detrimental resistance
余弦加速度运动 cosine acceleration（or simple harmonic）motion
预紧力 preload
圆带 round belt
圆弧齿厚 circular thickness
圆角半径 fillet radius
圆盘制动器 disc brake
原始机构 original mechanism
圆柱滚子 cylindrical roller
圆柱副 cylindric pair
圆柱螺旋拉伸弹簧 cylindroid helical-coil extension spring
压缩机 compressor
压力角 pressure angle
摇杆 rocker
液力耦合器 hydraulic couplers
液压无级变速 hydraulic stepless speed changes
一般化运动链 generalized kinematic chain
移动副 prismatic pair，sliding pair
移动凸轮 wedge cam
应力幅 stress amplitude
应力集中系数 factor of stress concentration
应力—应变图 stress-strain diagram
油杯 oil bottle
油沟密封 oily ditch seal
有益阻力 useful resistance
有效圆周力 effective circle force
原动机 primer mover
圆带传动 round belt drive
圆弧圆柱蜗杆 hollow flank worm
圆盘摩擦离合器 disc friction clutch
原动机 prime mover
圆形齿轮 circular gear
圆柱滚子轴承 cylindrical roller bearing
圆柱式凸轮步进运动机构 barrel（cylindric）cam
圆柱蜗杆 cylindrical worm
圆锥滚子轴承 tapered roller bearing
圆锥角 cone angle
约束 constraint
约束反力 constraining force
跃度曲线 jerk diagram

圆柱螺旋扭转弹簧 cylindroid helical-coil torsion spring
圆柱螺旋压缩弹簧 cylindroid helical-coil compression spring
圆柱凸轮 cylindrical cam
圆柱坐标操作器 cylindrical coordinate manipulator
圆锥螺旋扭转弹簧 conoid helical-coil of velocity fluctuation compression spring
圆锥滚子 tapered roller
圆锥齿轮机构 bevel gears
原动件 driving link
约束条件 constraint condition
跃度 jerk
运动方案设计 kinematic precept design
运动副 kinematic pair
运动简图 kinematic sketch
运动失真 undercutting
运动周期 cycle of motion
运转不均匀系数 coefficient
运动倒置 kinematic inversion
运动分析 kinematic analysis
运动构件 moving link
运动链 kinematic chain
运动设计 kinematic design
运动综合 kinematic synthesis
运动粘度 kinematic viscosity

Z

载荷 load
载荷—变形曲线 load-deformation curve
载荷—变形图 load-deformation diagram
窄 V 带 narrow V belt
展成法 generating
张紧轮 tension pulley
振动力矩 shaking couple
振幅 amplitude of vibration
正向运动学 direct (forward) kinematics
织布机 loom
制动器 brake
直齿锥齿轮 straight bevel gear
直角坐标操作器
Cartesian coordinate manipulator
直径系列 diameter series
直线运动 linear motion
质量 mass
执行构件 executive link；working link
智能化设计 intelligent design，ID
中心距 center distance
中心轮 central gear
毡圈密封 felt ring seal
张紧力 tension
振动 vibration
振动频率 frequency of vibration
正切机构 tangent mechanism
正弦机构 sine generator，scotch yoke
正应力、法向应力 normal stress
直齿圆柱齿轮 spur gear
直角三角形 right triangle
直径系数 diametral quotient
直廓环面蜗杆 hindley worm
直轴 straight shaft
质心 center of mass
质径积 mass-radius product
中间平面 mid-plane
中心距变动 center distance change
中径 mean diameter
周节 pitch
周转轮系 epicyclic gear train
轴 shaft
轴承合金 bearing alloy

终止啮合点 final contact，end of contact
周期性速度波动 periodic speed fluctuation
肘形机构 toggle mechanism
轴承盖 bearing cup
轴承座 bearing block
轴承宽度 bearing width
轴承寿命 bearing life
轴承外径 bearing outside diameter
轴瓦、轴承衬 bearing bush
轴环 shaft collar
轴角 shaft angle
轴向齿廓 axial tooth profile
轴向当量静载荷 static equivalent axial load
轴向基本额定动载荷 basic dynamic axial load rating
轴向基本额定静载荷 basic static axial load rating
轴向接触轴承 axial contact bearing
轴向游隙 axial internal clearance
轴向载荷系数 axial load factor
主动件 driving link
主动带轮 driving pulley
转动副 revolute (turning) pair
转动关节 revolute joint
转子 rotor
装配条件 assembly condition
锥顶 common apex of cone
锥轮 bevel pulley；bevel wheel
锥面包络圆柱蜗杆 milled helicoids worm
子程序 subroutine
自动化 automation
自锁条件 condition of self-locking
总重合度 total contact ratio
总效率 combined efficiency，overall efficiency
组合齿形 composite tooth form
组合机构 combined mechanism
轴承高度 bearing height
轴承内径 bearing bore diameter
轴承套圈 bearing ring
轴颈 journal
轴端挡圈 shaft end ring
轴肩 shaft shoulder
轴向 axial direction
轴向当量动载荷 dynamic equivalent axial load
轴向平面 axial plane
轴向载荷 axial load
轴向分力 axial thrust load
主动齿轮 driving gear
转动导杆机构 whitworth mechanism
转速 swiveling speed；rotating speed
转轴 revolving shaft
转子平衡 balance of rotor
锥齿轮 bevel gear
锥距 cone distance
锥齿轮的当量直齿轮 equivalent spur gear of the bevel gear
准双曲面齿轮 hypoid gear
子机构 sub-mechanism
自锁 self-locking
自由度 degree of freedom，mobility
总反力 resultant force
组成原理 theory of constitution
组合安装 stack mounting
阻抗力 resistance
纵坐标 ordinate
最少齿数 minimum teeth number
作用力 applied force
最大盈亏功 maximum difference work between plus and minus work
纵向重合度 overlap contact ratio
组合机构 combined mechanism
最小向径 minimum radius
坐标系 coordinate

附录 A　机械工程常用缩略语

abbr.　略语
AC 交流电
add 住址
app. 附录
AWJ 磨料水射流
bldg.　建筑物，大楼
CAD 计算机辅助设计
Cal.　卡路里
CAM 计算机辅助制造
CAPP 计算机辅助工艺规划(设计)
C 摄氏
cf 对照，比较
ch(ap)章
CHM 化学铣削
CHP 化学抛光
CIMS 集成制造
Co.　公司
Corp.　有限责任公司
db 分贝
DC 直流电
deg 度
Dept 系，部，研究室
DIN 德国工业标准
EBM 电子束加工
ECM 电化学加工
EDM 电火花加工
eg/e. g.　例如
FDM 熔丝堆积成形
EGM (EGC)电解(电化学)磨削
EFM 电铸
EPM 涂镀，刷镀
enc(l)附上，附件
eng.　工程师
ENG 发动机
esp.　尤指
etc.　等等
F 华氏
fig. 图表
FMS 柔性制造系统
HB 布氏硬度
H. P./hp 马力
hr 小时
HRC 洛氏硬度
Hs 肖氏硬度
HSS 高速钢
IBM 粒子束加工
ID 识别，身份
i. e.　那就是，即
I/O 输入/输出装置
ISO，I.S.O. 国际标准化组织
JIS 日本工业标准
JIT 及时制造
lab 实验室
Lb，lb.　磅
LBM 激光加工
LBT 激光处理，表面改性
LOM 叠层制造
Ltd.　有限(的)
M 模数
max.　最大量的
min.　最小量的
mo.　月份
mph/m. p. h 英里/小时
CNC 计算机数控
No. N 号码
P 停车处，功率
PAM 等离子弧(体)加工
PCM 光刻
Pl.　复数(的)
Pg 页.

pref. 前缀
Rd 路
ref 参见
RP 快速成形技术、增材制造
RPM 每分钟转速(数)
sci. 科学
SL 液相固化快速成形
SLS 粉末烧结成形
surf 后缀
temp. 温度
USM 超声加工
vol，额，部，卷，体积
VS. Vs. vs 对，…与…比较
Yd. 码
W 瓦特
WEDM 线切割加工
WJ 水射流

附录 B　常用度量衡单位表

Ⅰ. British(英制)

Linear measure　长度单位

1inch(英寸)	=2.54cm(公分/厘米)
1foot(英尺)=12inches(英尺)	=0.3048m(公尺/米)
1yard(码)=3feet(英尺)	=0.9144m(公尺/米)
1mile(哩)=1.760yard(码)	=1.609km(公里/千米)

Square measure　面积单位

1square inch(平方英寸)	=645.16mm^2(平方毫米)	
1square foot(平方英尺)	=144in^2(平方英寸)	=0.0929m^2(平方米)
1square yard(平方码)	=9ft^2(平方英尺)	=0.836m^2(平方米)
1acre(亩)	=4.840yd^2(平方码)	=4047m^2(平方米)
1square mile(平方哩)	=640acres(亩)	=259ha(公顷)

Cubic measure　体积单位

1cubic inch(立方英寸)	=16.39cm^3(立方厘米)	
1cubic foot(立方英尺)	=1728in^3(立方英寸)	=0.02832m^3(立方米)
1cubic yard(立方码)	=27ft^3(立方英尺)	=0.765m^3(立方米)

Capacity measure　容量单位

1pint(品脱)	=20fluidoz(盎司)	=0.568litres(公升)
1quart(夸脱)	=2pints(品脱)	=1.136litres(公升)
1gallon(U. K.)(英加仑)	=4quart(夸脱)	=4.546litres(公升)
1gallon(U. S.)(美加仑)	=4quart(夸脱)	=3.785litres(公升)

Avoirdupois weight　常衡

1ounce(盎司)	=28.35(克)	
1pound(磅)	=16ounces(盎司)	=0.4536kg(公斤)
1stone(石)	=14pounds(磅)	=6.350kg(公斤)

Temperature　温度

Fahrenheit(华氏)	=(9/5°C)+32
Centigrade(摄氏)	=(5/9°F)−32

Ⅱ. Metric(公制、米制)

Linear measure　长度单位

1millimeter(毫米)	=0.039in(英寸)
1centimeter(厘米)	=10mm(毫米)
1millimeter(毫米)	=1000micron μm(微米)

1micron μm(微米)	=1000nano(纳米)	
1meter(公尺、米)	=39.37in(英寸)	
1kilometer(公里)	=1000m(公尺、米)	=0.6214mile(英里)
Mass　常衡		
1milligram(毫克)	=0.015grain(喱)	
lgram(克)=1000mg(毫克)	=15.43grain(喱)	=0.035oz(盎司)
1kilogram(公斤)	=1000g(克)	=2.205pound(磅)
1tonne(metric ton)(公吨)	=1000kg(千克)	=2204.62(磅)
Square measure　面积单位		
1squarec entimeter(平方厘米)	=0.155in^2(平方英寸)	
1square meter(平方米)	=1.196sqyards(平方码)	
1square kilometre(平方公里)	=0.386sqmile(平方英里)	
1acre(公亩)	=100sqmetres	=119.6sqyards(平方码)
Cubic measure　体积单位		
1cubic centimeter(立方厘米)	=0.061in^3(立方英寸)	
1cubic metre(立方米)	=1.308yd3(立方码)	
Capacity measure　容量单位		
1litre(升)	=1.76pint(品脱)	

附录 C　英文字母象形结构对应中文翻译

A-frame	A 形框架	T-head bolt	T 形螺栓
C-clamp	C 形夹	T-iron	T 形铁
C-form standard	C 形机架	T-joint	三通接头
C-snaped column	C 形柱	T-pipe	T 形管
C-snaped frame	C 形框架	T-rest	T 形刀架
C-spring	C 形发条	T-shape	T 形钢
C-washer	C 形垫圈	T-slot	T 形槽
D-ring	D 形密封环	T-slot bolt	T 形槽螺栓
H-beam	H 字木梁	T-slot cutter	T 形槽铣刀
H-frame	龙门框	T-socket	T 形套管
H-post	H 钢条	T-square	丁字尺
I-bar	工字钢材	T-steel	丁字钢
I-beam	工字木梁	T-wrench	丁字扳手
I-gauge	工字形卡规	U-boat	潜艇
I-girder	大工字钢	U-bolt	U 形螺栓
L-bar	角形钢材	U-clamp	U 形夹头
L-beam	角木梁	U-clevis	U 形夹头
M-tooth	M 形齿(锯条)	U-gauge	U 形压力计
N-girder	N 形大木梁	U-girder	U 形横梁
O-ring	O 形密封圈	U-iron	槽铁
S-hook	S 形钩	U-Lag	U 形槽
S-lead	塞套引出线	U-nut	U 形螺母
S-link	S 形连接	U-packing ring	U 形密封环
S-wrench	S 形扳手	U-shaped	马蹄形的
S-twist	S 形扭转索	U-steel	槽钢
T-bar	T 形钢材	U-trap	虹吸管
T-beam	T 字角梁	U-tube	U 形管
T-bolt	T 形螺栓	U-tube manometer	U 形管压力计
T-engine	T 字头引擎	U-turn	180°转弯
T-fixture	T 形夹具	V-belt	三角皮带
T-handle	T 形手柄	V-belt drive	三角皮带传动
T-handle key	T 字头手柄键	V-belt pulley	三角皮带轮
T-handle taper reamer	T 字柄锥形铰刀	V-block	V 形铁、元宝铁
T-head	T 字头	V-block clamp	V 形铁夹头

V-clamp	V 形夹	X-ray examination	X 射线检
V-cylinder	V 形汽缸	Y-axis	Y 轴
V-gear	V 形齿轮	Y-bend	Y 形接合
V-groove pulley	V 形槽带带轮	Y-connection	星形接法
V-guide way	V 形导轨	Y-curve	Y 形曲线
V-joint	V 形接合	Y-joint	Y 形接头
V-rope	V 形钢索	Y-level	Y 形水平仪
V-shaped anvil	V 形砧	Y-line	Y 轴线
V-shaped antenna	V 形天线	Y-pipe	叉形管
V-slot	V 形槽	Y-section	三通管接头
V-thread	三角螺纹	Y-Δ starter	星-三角形启动
V-type step pulley	V 形塔轮	Z-axis	Z 轴
W-engine	W 形发动机	Z-bar	Z 形铁
X-alloy	X(铝轴承)合金	Z-beam	Z 形木梁
X-axle	X 轴	Z-bit	Z 形钻
X-component	X 轴向分量	Z-crank	Z 形曲柄
X-direction	X 轴向	Z-iron	Z 字铁
X-line	X 轴线	Z-section	Z 形剖面
X-moment	X 轴的力矩	Z-steel	Z 形钢
X-ray	X 射线		

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