Relevant Knowledge

I Material Processing Technology

1. Material Removal

Material cutting is a process of removing the excess portions of a material. Examples of this kind of process include cutting objects to specific dimensions, drilling holes and cutting slots. Materials can be cut simply by hand tools; machinery can also be used to enhance the cutting effectiveness.

(a) Hand cutting

Some hand tools for cutting

There are many kinds of hand tools that can be used for cutting materials including hammers, hand saws, files, hand drills and planes. Some small portable machinery, such as electric hand drills, are also commonly used for cutting materials quickly. The following are the usages and examples of some commonly used hand tools for cutting.

Hand tools for cutting	Usage	Examples of tools	Examples of cutting materials
Hammer, chisel	Cutting a material with the edges neatly trimmed	Mallet, woodwork chisel	Timber
Saw	Separating a material into two parts	Woodwork saw, metalwork saw, coping saw, portable jigsaw	Timber, metals, plastics
File	Thin cutting and smoothing of the surface of a material	Flat file, half-round file, square file, round file, triangular file	Timber, metals, plastics
Drill	Drilling holes on the surface of a material	Hand drill, electric hand drill	Timber, metals, plastics

Plane	Thick cutting on the surface of a material	Plane, lace planning machine	Timber
Tap	Cutting internal threads inside a hole of a metal. Used in conjunction with a tap wrench.	Taper tap, second tap, bottoming tap	Metals
Die	Cutting external threads on a metal cylindrical rod. Used in conjunction with a die holder.	Round split die, combination die	Metals

Relevant Knowledge

(b) Machine cutting

Cutting machines can cut materials quickly and effectively. There are many types of cutting machines, including lathes, drilling machines, sawing machines, milling machines and grinding machines. Each type of them has its own characteristics.

(i) Drilling Machines

The main function of drilling machines is to drill holes of different diameters on workpieces with drill bits. There are two kinds of drilling machines, bench type and floor type.

(a) The various parts of a bench type drilling machine

(b) A floor type drilling machine

Drill bits, which are usually made of high speed steel, are the cutting tool of drilling machines. A drill bit can be divided into two major sections, head and shank. The cutting tip of a drill bit head cuts the workpiece and guides the drill bit into the workpiece; the cutting edge cuts the workpiece. The helical flute on the drill bit can lift the cutting chips out of the hole, also allowing coolant to flow into the hole.

Metal drill bits

Wood drill bits

Special-purpose dill bits

The cutting part

(ii) Metalwork Lathes

The main function of metalwork lathes is to cut cylindrical metal workpieces using lathe tools. Lathes can be categorised into woodwork lathes and metalwork lathes. They are used for cutting timber and metals respectively.

Finished products cut by lathes

A metalwork lathe

Lathe tool angles

A metalwork lathe

Lathe tools are usually made of high speed steel. To cut materials effectively, they are grinded to different shapes and angles by an abrasive wheel before using. The shapes of lathe tools are designed according to the purposes of the tools. Lathes can perform a number of cutting operations. Some commonly used cutting methods of lathes are shown below.

(a) Facing

(b) Parallel turning

(c) Knurling

(d) Parting off

(e) Boring

(f) Taper turning

The following table lists the functions of the cutting methods of lathes.

Cutting method	Function of the cutting method
(a) Facing	The lathe tool moves against the end surface of the workpiece, flattening the surface by removing the uneven parts.
(b) Parallel turning	The lathe tool moves in a direction parallel to the workpiece, cutting along it.
(c) Knurling	A knurling tool is used to cut a serrated pattern onto the circular surface of the workpiece, creating a part for use as a hand grip.
(d) Parting off	The lathe tool moves back and forth in a direction parallel to the workpiece and gradually moves into the centre part.
(e) Boring	The boring tool moves inside the hole of a workpiece in a direction parallel to the workpiece, enlarging the diameter of the hole.
(f) Taper turning	Using the blade angle of the lathe tool, a short distance of bevel is cut at the end of the workpiece.

(iii) Woodwork Lathes

When using a woodwork lathe, the turning tools are held by hands. The operation is thus more flexible. A woodwork lathe is only suitable for turning timber, which can be used to make lampposts, wooden bowls, wooden plates, etc.

A small-sized woodwork lathe

Products made by woodwork lathes

(iv) Sawing Machines

The main function of sawing machines is to cut workpieces using saw blades. Sawing machines can be categorised into jigsaws, band-saws, hacksawing machines, etc.

Sawing machine	Characteristics	Materials to cut
Jigsaw	The saw teeth must all point downwards; usually used for cutting curves.	Thin plywood, plastic sheet, etc.
Hacksawing machine	The saw blade is made of high speed steel and the power of the motor is higher; can be used to saw large workpieces.	Metal materials such as copper, aluminium and mild steel

(a) A jigsaw

(b) A hacksawing machine

Relevant Knowledge

II. Selection of Appropriate Materials and Processes

Both hand tools and machine tools can achieve the purpose of material processing. However, the properties of materials, safety and quantity of production will all affect the selection of processing methods. The removal, forming, jointing and finishing processes of materials have both similar and different considerations. The first thing we need to know is what kind of processing is to be carried out. We will discuss the removal of materials as an example.

1. Properties of Materials

In Teaching Material 1A, we have introduced some of the properties of materials. Here, we will discuss how to choose an appropriate processing method based on the properties of the materials. For example:

a. We often need different cutting tools to handle different materials. Wood surfaces are usually flattened by planes but surfaces of metal workpieces are usually made smooth by files, milling machines or grinding machines.

b. When choosing a proper cutting method and cutting tool, we need to consider the mechanical and working properties of materials, e.g. hardness, toughness and cutting properties. The hardness of the cutting tools is usually higher than that of the materials being cut.

c. The tools to be used depend on the materials. To drill holes on an aluminium sheet, which has a lower hardness, we can select among a hand drill, an electric hand drill and a drilling machine; to drill holes on a much harder steel sheet, we should consider using a drilling machine.

d. Grains of the materials also have an influence. Will cutting along the grain increase the cutting speed, or will it increase the difficulty of cutting according to plan?

e. Can we make use of the chemical properties of materials, e.g. using heat to melt or using chemicals to dissolve the materials?

f. Can we make use of other physical properties of materials? For example, the linear expansion property of materials has been employed by ancient Egyptians to split stones.

A high speed steel drill bit with higher hardness

A hot wire cutter for cutting foam

An obelisk made by Ancient Egyptians

2. Safety

When cutting a material, the material is separated and the process may somehow cause danger. Therefore we must be aware that

a. cutting often involves striking and flying chips. When performing a cutting action, we should put on goggles and install the protective shield on the machine.
b. machine tools have a higher rotating speed and the chips are projected away quicker. Extra caution must be taken.
c. attention should be paid not to get burned when cutting using heat; when using chemicals, beware of the chemicals from splashing out, as well as the ventilation and discharge of gases to avoid poisoning.
d. some devices have specific safety instructions to follow during use.
e. when choosing a material processing method, we fully realise that it should be used under a safe environment with all necessary safety equipment ready.

3. Quantity of Production

The quantity and required rate of production of workpieces are important factors to consider in choosing the right cutting method and cutting tool. For example, if we are mass producing delicate chess pieces from metal rods, we may use large machinery such as computer numerically controlled lathes or automated machine tool centres. On the contrary, if we are only producing a single piece of metal product, we may use tools such as hand tools, drilling machines, lathes and milling machines.

A chessboard

An automated machine tool centre

As have pointed out at the beginning of this section, we will take the removal of materials as an example for discussion. In fact, the methods for manufacturing products can be categorised into three main groups:

a. Removal
b. Forming
c. Fabrication

When we are producing a large quantity of workpieces, the required cost, time, equipment, manpower, technology, venues, etc. become more important as compared to producing one single product. This is because these requirements will become crucial when we are producing 1,000 pieces of product rather than producing only one.

For production methods such as injection moulding, the equipment used is larger and more expensive, the cost of mould production is high and the technological requirement is more demanding. A combination of these factors leads to the fact that it is less frequently used in producing a single product. However, due to its higher precision, lower average production cost and shorter production time, it is often employed during mass production.

An injection moulding machine

Relevant Knowledge

Materials such as rock cannot be processed using the forming method. Large stones are usually processed by the method of removal and the final products are constructed through fabrication.

Cutting of stones

When choosing a production method, other than the quantity of products needed, we should also take into consideration factors such as those mentioned in previous chapters*, including the properties of materials, properties of tools and methods, cost, time, manpower, technology, venues and safety.

* Students may refer to S1 Teaching Materials about properties of materials, tools and methods, and S2 Teaching Material 1B about ‘selection, operation, maintenance and disposal of technological equipment’ so as to have a more thorough understanding about the selection process.

4. Glossary of Terms

Removal	移除	Drilling machine	鑽床
Forming	成形	Drill	鑽頭
Fabrication	組裝	Lathe	車床
Hammer	鎚	Woodwork lathe	木工車床
Chisel	鑿	Facing	端面車削
Saw	鋸	Parallel turning	平行車削
File	銼	Knurling	滾紋
Drill	鑽	Parting off	切斷
Plane	鉋	Boring	鏜孔
Tap	螺絲攻	Taper turning	錐體車削/推拔車削
Die	絲模/牙板	Power hacksaw/Sawing machine	鋸床

5 . Relevant Information

Website	Content
1. http://www.youtube.com/results?search_query=lathe+turning	Search results of lathe turning
2. http://www.youtube.com/results?search_query=metal+processing	Search results of metal processing
3. http://www.youtube.com/results?search_query=metal+processing	Search results of wood processing
4. http://www.kenplas.com/	Production of plastic products

Exercise

1. The school is preparing to set up a board on the wall at the main entrance for displaying students' works. The dimensions of the board are 2000 mm 1400 mm and its thickness is 30 mm. On the board surface are two layers of certain material for the insertion of pushpins or staples. The two layers should be able to be reused many times and the board should have a smooth frame.

(a) Write down the requirements for selecting the materials used for the above-mentioned display board, including its board located at centre, covering material and frame.

(b) Choose a suitable material for each part of the display board.

(c) Describe the processing methods of the materials if the display board is to be made in the school's workshop. What difficulties do you think will be encountered during production?

(d) Explain briefly the differences in the selection of materials and processing methods if the display board is to be mass-produced.

2. The figure on the right shows a part made of low-carbon steel.
   Suggest an appropriate production method for manufacturing
   (i) one piece;
   (ii) a batch of 500 pieces; and
   (iii) 100,000 pieces in each year.

Project Activity – Material Processing (Smart Assembled Device)

Project Activity Guidelines

1. Objectives

Using a range of commonly used materials to make an assembled device, student will learn to choose and operate different tools and equipment for measuring, cutting and polishing materials.

2. On completion of the design project, students should be able to

a. understand the differences between natural and artificial materials;
b. understand the categories of common materials;
c. understand the differences between metal and non-metal objects; and
d. choose and operate various tools and equipment.

3. Design Brief

a. Design a smart device (two-dimensional or three-dimensional) pieced together from components made of a variety of materials. Its size should not exceed 10 cm × 10 cm and its components should be able to join together.
b. Choose various materials. Carry out processes such as measuring and marking according to the design.
c. Carry out processes such as material cutting and surface finishing.
d. The way to assemble the device should involve elements of thought and fun.

An assembled toy

4. Recommended Time

5 teaching periods × 40 minutes (total 200 minutes)

5. Required Materials

Use various commonly used materials such as mild steel, aluminium, brass, acrylic, wood, foam, cloth, cardboards and corrugated boards to make a smart assembled device.

Basic Design Drawing

Draw your design in the following space on a 1:1 scale and write down the material used for each component (e.g. mild steel, aluminium, brass, acrylic, wood, foam, cloth, cardboards and corrugated boards). You can decorate the components with different colours.

Draw your assembled device in the following space.

Production of Assembled Device

Production procedure

1. According to the design, measure the length and angle of each component. Choosing appropriate materials (e.g. mild steel, aluminium, brass, acrylic, wood, foam, cloth, cardboards and corrugated boards) and using appropriate tools and equipment, perform marking on the materials.
2. Use proper tools and equipment to cut the materials and perform surface finishing.
3. Record information such as the material used, its properties and processing results for each component in the following table.

Component	1	2	3	4	5	6
Material used						
Weight (g)						
Colour of material						
Hardness of material						
Finishing of surface						
Tools and equipment for marking						
Tools and equipment for cutting						
Tools and equipment for polishing						

Properties of the components of the assembled device and the tools and equipment used

Discussion

1. If you are going to make this assembled device again, will you change the materials used? Briefly explain your answers.

2. If you are going to make this assembled device again, will you change the tools and equipment used? Briefly explain your answers.

3. What surface finishing method will you use to protect each of the components of your assembled device? Briefly explain your answers.

Examples of Three-dimensional Assembled Device:

An assembled dinosaur

An assembled helicopter

Wind chimes

Wind chimes decorations in the West Kowloon Waterfront Promenade

Decorations made by assembling screws and nails

Search the Internet with terms such as ‘LuBan lock’ and ‘Kongming lock’.