

Unit 1 Section A Product Design and Practice

Learning Outcomes

By the end of this section you should have developed a knowledge and understanding of:

- off, batch and high-volume production systems
- Modular/cell production systems
- Just-in-time manufacture
- Bought-in parts and components, standardised parts

Introduction

The main categories of manufacturing systems involve production processes that are one-off, batch and high volume. Factors that determine the selection of a manufacturing system are:

- The type of product
- Demand for the product
- Capital
- Premises
- Tooling
- Labour skills

One-off, batch and high volume production systems

One-off production

One-off production refers to the manufacture of a single component or product. It is often referred to as jobbing production. One product is fully completed before the next is started.

Examples include:

- Large-scale products such as ships, bridges and specialist stadium constructions
- Smaller-scale products such as jewellery, specialist furniture and bespoke clothing (suits and wedding dresses for example)

Key Points

One-off production

- Usually produced to a specific client specification
- Small level of demand
- Requires very high skill levels and high labour costs, resulting in high unit costs
- Generally low capital costs
- Worker satisfaction generally very high; often involved in every production stage from start to completion.

Batch production

Batch production involves the production of batches of similar products. It refers to the scale of production - a few items to several thousand - and to the type of production, where components are processed together in a planned sequence. Cars used to be mass produced with only one model manufactured.

Modern car manufacturers produce batches with differing specifications, the quantities of each batch decided by customer demand. Examples include:

- Small batches can be in low numbers, such as a batch of ten aeroplanes

- Large batches can be in high numbers, such as several thousand pairs of training shoes

Key Points

Batch production

- Flexible system, a wide range of products can be produced
- Can react to demand, stop or increase production run
- Workforce usually less skilled than one-off, will operate one or two processes
- Medium investment needed for a range of machinery that can be set up for different operations
- Workers sometimes have opportunity to work on more than one process

High-volume production

High-volume production is often referred to as mass production. High-volume production systems usually operate 24/7 and are used to manufacture high-demand items. Examples include:

- Continuous-flow production systems take in the raw material at one end of the factory, and the finished product comes out the other end.
- These factories seem like a complex, continuous, fully automated machine. Glass, steel and paper are produced in this way
- In-line production systems require the product to be moved from one process to another, usually using a conveyor system. Cars and domestic products such as televisions and kettles are produced in this way
- Pens, clothes hangers, buttons and paper clips are produced in high volume using fully automated specialist machinery

Key Points

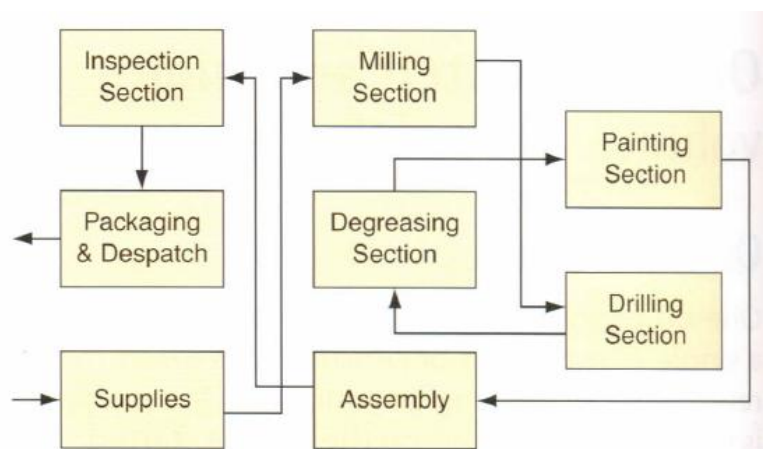
High-volume production

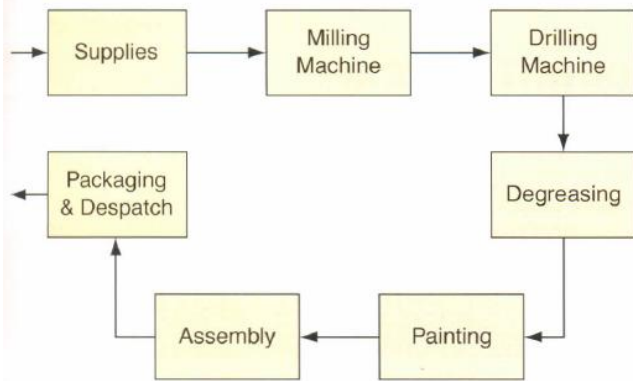
- Minimal, if any, variation in product
- Regular, high demand for product needed
- Usually very high capital investment, low unit cost
- Relatively low skilled workforce - repetitive task, mostly fully automatic production systems
- Control/maintenance team required, stoppages costly
- Often low job satisfaction; workforce usually only involved in small part of production cycle

Modular or cell production systems

These systems use a number of production cells or modules that are grouped together to manufacture a component or sub-assembly of a larger product. The cells or modules usually consist of production machines and include inspection and assembly units. Very often the cells are operated by a small multi-skilled workforce but can be fully automated. Some large manufacturing systems process large batches in sequence through several dedicated process or manufacturing sections. This is often referred to as batch and queue production. Sections usually have large, expensive machines designed to minimise unit costs by mass producing single identical components with minimal tool changes.

This system largely requires advance orders and long production runs. It can be very wasteful as production can be held up if one section does not function correctly. Storage space is required for batches between processes.





In modular or cell manufacturing the workstations are arranged in a logical manner to produce one complete item at a time, in a smooth and quick flow through the production process. The rate of production is decided by consumer demand. Production planning for the cells/modules must be accurately scheduled to ensure that the correct number of components/sub-assemblies is produced in time for the final assembly of the product. A hold up in one module is not as catastrophic as a hold up in an in-line production system. Modular/cell production systems require careful positioning of

workstations to enable minimal and quick movement of parts from one operation to another. The workforce is often multi-skilled to offer maximum flexibility and enable rapid change of production. The machines are often fitted with multiple tools and generally operate a rapid tool changing system. Powered clamping systems offering quick and easy location of the work-piece speed up production times. A standard size of manual locking method, usually in the form of a chuck key or spanner, is used to avoid operators wasting time searching for the correct tool.

Modular or cell production systems

- Functional layout of modules/cells
- Flexible system offering rapid change in production reacting to consumer demand
- High level of job satisfaction; operators work in flexible teams carrying out different tasks, opportunities for training
- All workforce responsible for quality control

Just-in-time manufacture

Many modern manufacturing companies such as Toyota, Dell and Rolls Royce operate a **JIT** system.

The philosophy of **JIT** manufacturing is to meet consumer orders with a quality product with minimal delay and effective use of resources. The **JIT** system is sometimes referred to as 'lean manufacturing' as it focuses on giving customers value for money by reducing wastage.

The storage of materials and components needed to manufacture products requires space and, where appropriate, special conditions such as heating and ventilation. This adds to the overall manufacturing cost.

Lean manufacturing time line

1850 Eli Whitney used interchangeable parts when contracted by the US Army to manufacture 10,000 muskets. Engineering drawing conventions, tolerances and introduction of modern production machines.

1910 Henry Ford production line systems.

1950 Shigeo Shingo, Taiichi Oh no set up Toyota, just-in-time (JIT) production system.

1986 Toyota **JIT** system also referred to as 'stockless production' and 'world class manufacturing' (WCM)

2008 Many of the world's leading companies operate **JIT** systems: Dell's I product cycle is four hours, supplies are delivered 90 minutes after an order is placed.

Companies set up detailed arrangements with reliable suppliers and distributors to ensure that advance orders are taken and regular deliveries of materials and components are made when required for manufacture. The products are distributed as soon as they are completed, removing the need for further storage.

Computerised stock control systems ensure that production is continuous.

Wastage is reduced in terms of:

- Storage space for materials, components and completed products
- Defective products - all of the workforce have a responsibility for quality
- Money invested in materials and components that will not be used and completed products that will not be sold
- Movement of the product through the factory is kept to a minimum

- Inefficient use of equipment - the system makes maximum use of production machinery and no waiting time between processing operations
- Labour misuse - appropriately skilled workers are used
- Product effectiveness - simplicity is a key feature of the system with the removal of product functions that are not necessary
- Downtime with new product run up - detailed plans are made to ensure seamless flow from completed product to new product

JIT manufacture

- The partnerships between the manufacturer, suppliers and distributors is critical - if deliveries are late production stops
- Workforce relationships are also very important - staff absence or strike action can halt or delay production
- Workforce must be multi-skilled, flexible, have job satisfaction and be consulted in decision making
- A spirit of cooperation is vital; proposals for improvement are welcomed by management
- JIT is a very flexible manufacturing system and can react very quickly to changes in consumer demands
- The product is electronically tracked through the system to carefully monitor progress and ensure that the manufacturing schedule is efficient

Drawbacks of the system include:

- Delivery failure - Toyota production was halted as a result of a major fire that prevented supplies arriving
- Unsatisfactory workforce relationships may result in strikes or absenteeism, which holds up production
- Some environmental concerns over frequent road transport of supplies and despatched items
- Requires major suppliers and customers to be relatively close to the manufacturing plant

Bought-in parts and components and standardised parts

Many products make use of similar parts or components. Different makes of computers often have the same make of hard drive or other internal components. Car manufacturers may set up subcontractor arrangements for the supply of components such as headlamps and engine parts.

Key Points

Bought-in parts and components

- No need for production space for the components
- Speeds up overall production
- Quality assured by the component manufacturer, specified tolerances
- Specialist companies provide components, cost benefits through economy of scale
- Choice of suppliers if there are service/quality difficulties, cost benefits through price negotiations and loyalty contracts
- Reduces storage costs, components available when required

Standardised parts

Standardised parts are the common items that are required in the manufacture of a wide range of products such as screws, nuts and electronic components (batteries, resistors, capacitors etc.).

They are usually small, simple items that are manufactured to guaranteed specifications and are of consistent quality. Other examples include:

- In the construction industry standardised components include doors, windows, sinks and other kitchen units
- Zips, buttons and other fastening devices are standard components used in the textiles industry

In the manufacture of cars, a chassis may be used as a standard component and used in the production and development of several models

Key Points

Standardised parts

- The key points relating to bought-in components are relevant to standardised components
- Minimal interface and tolerance problems; standards usually generated by independent body, for example BSI

Ease of maintenance; replacement parts for consumers

- 1 Discuss how manufacturers meet consumer needs in rapidly changing product markets.
- 2 Discuss the workforce issues to be considered when selecting an appropriate production system.
- 3 Discuss the importance of using standardised parts and components in the manufacture of either:
 - Domestic electronic products
 - Textile products
 - Cars
- 4 Discuss how tooling, assembly and labour skills can affect the scale of production of a product.

Learning outcomes

By the end of this section you should have developed a knowledge and understanding of:

- CAD/CAM as used in industry/commerce
- Testing, modelling and rapid prototyping
- Stock control, monitoring and purchasing logistics in industry
- High-volume production and automation
- The implications of the use of digital technology

Introduction

Product designers throughout the years have adapted and embraced the developing technologies and changing methods of communication and processing in their designing

Computer aided design (CAD) and computer aided manufacture (CAM)

Global communication systems have greatly increased the flow of digital information in text, visual or audio format. Large, detailed documents can be transferred instantly between and making activities. The last 40 years have seen a dramatic increase in the availability and use of digital systems in design and technology sites, regardless of distance. The internet has enabled on line research opportunities and companies can make up-to-date checks on the competition and assess market trends.

Marketing, advertising and sales opportunities have increased greatly with this worldwide phenomenon.

CAD system could include	CAM systems could include
Computer Graphics tablet Scanner (flat and 3D) Internet access 2D/3D software	CNC lathe, miller, router Computerised embroidery Laser cutter 3D printer Plotter/cutter, vinyl cutter

CAD (basic 2D systems, although parametric systems where changing one minor element or dimension would



automatically change the whole design were available in schools in the early 1980s) was introduced and initially used as a final output tool, to generate an accurate, detailed and dimensioned drawing of a proposal or solution. The vector-based systems describe geometries that are able to be converted into machine code



and define tool paths for manufacture. The development and increase in sophistication and processing power of computers and the development of an increasing range of computer numerically controlled (CNC) machines signalled the single most significant contribution to the increase in manufacturing productivity.

Ideas could be shared and worked on in real time in different parts of the world, and could be sent to manufacturing units within the same facility or anywhere in the world. The development of 3D CAD tools enabled designers to quickly generate and explore ideas, not just create life-like presentation representations.

Three-dimensional ideas can be realised using rapid prototyping technologies.

Other acronyms relating to the use of computers in designing and making include:

- CADD - computer aided design and drafting

- CAA - computer aided analysis
- CAAD - computer aided architectural design
- CAE - computer aided engineering
- CAPP - computer aided process planning
- CIM - computer integrated manufacturing

Testing, modelling and rapid prototyping

Computers can be used to test the feasibility of design ideas using a range of software. Various software including Finite Element Analysis programs can be used to predict the effects of loading and identify weaknesses and stress points. Simulations of functional aspects of components and assemblies can be used to ensure designs are feasible.

CAA software can be used to analyse the effect of external factors such as vibration, extreme temperature changes and variable loading on design proposals. The software will predict likely outcomes and give opportunities for improvements and modifications to proposals before production.

Fluid Dynamic software is used in the design of vehicles, analysing and measuring the effects of air flow, and in architectural design where the effectiveness of air conditioning and heating systems can be tested.

Computers are used extensively in 2D and 3D modelling of ideas. Images can be rotated, zoomed in and shown in an infinite variety of colours and textures. Modifications are carried out speedily and with relative ease.

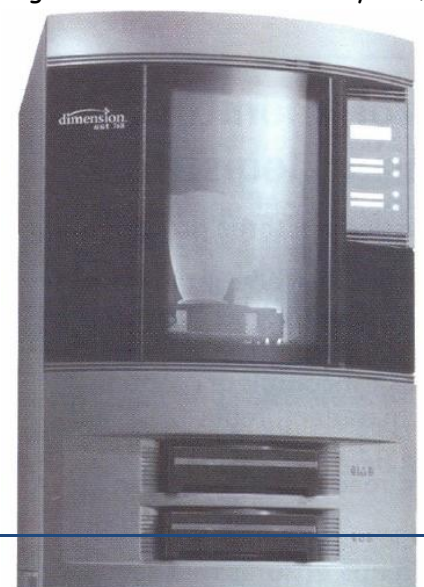
Computer simulations are particularly useful when a real-life process is too dangerous for humans to carry out, takes a disproportionate amount of time to complete and is too expensive.

Machine processes are simulated to test tool selection and settings: incorrect settings could result in *very* expensive damage to machinery and possibly lengthy delays in production.

Rapid prototyping

Several systems are available that translate 3D designs into solid, physical forms. Software is used to 'slice up' the 3D design into a series of adjacent horizontal layers which are then sent in sequence to a rapid prototyping system. They are then built up layer by layer in a number of different ways:

- Laminated object manufacturing - one of the earliest systems available, building up layers of adhesive-coated sheet material. This can be time



consuming and the final object has a rough texture and may need additional finishing Fig 5.6 3D printed object: tape winding case

- Stereo lithography - a laser traces the shape of a layer onto a bath of liquid resin. This cures the resin. The platform is lowered and another layer is traced until the whole object is created. Typical layer thickness is 0.1 mm
- Laser sintering - works in a similar way to stereo lithography. The laser traces the shape onto fine heat-fusible powder (plastic, metal or ceramic). The powder becomes solid; another layer of powder is laid on top of the fused layer and the process is repeated until the object is completed
- 3D printing - this system 'prints' a thermoplastic material (ABS) in successive layers on top of previous layers to build up a 3D shape. Complex shapes often require an additional support material to be printed to support the object while it sets. Objects can be painted or electroplated for a high-quality finish

Stock control monitoring and purchasing logistics

Stock is usually classified in three groups:

- Materials/components - bought in from suppliers to be used in the manufacture of products
- Work in progress - incomplete products currently being manufactured
- Finished products - assembled products of desired standard ready for distribution

Stock control enables production to flow without costly hold ups, ensures that sufficient raw materials and components of acceptable quality are purchased and customer demand is met.

Stock control systems used to rely on careful checks, regular stock takes and ordering, all carried out by individual employees. The system was time consuming and errors occurred.

Computerised systems, including the use of bar codes and other digital recognition processes to monitor stock, have speeded up the process considerably.

Links are easily made with the purchasing, marketing and sales departments. Accurate forecasts of predicted sales will ensure that sufficient orders are placed to meet demand.

The purchasing and logistics departments will make decisions on the suppliers who are reliable, competitively priced and are able to provide the materials and components of the required standard.

The system will include 'buffer' stock to cope with unforeseen problems or emergencies in the supply chain, or if there is a sudden and unexplained rise in demand.

Electronic Data Interchange

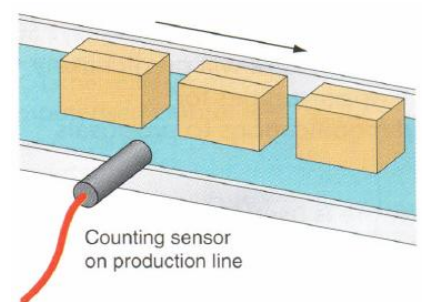
Electronic Data Interchange (EDI) is a way in which information can be exchanged between computers within a company or between companies. It is used extensively in stock control systems, enabling the speedy exchange of orders and invoices.

EDI is an automatic process, using an agreed standard for product codes, prices and location.

It is an accurate and efficient system as it does not require extra human intervention, reducing the possibility of errors through re-keying of data and costs are reduced.

Benefits of using EDI are:

- Eliminating error
- Eliminating paper
- Reducing lead time through effective stock control



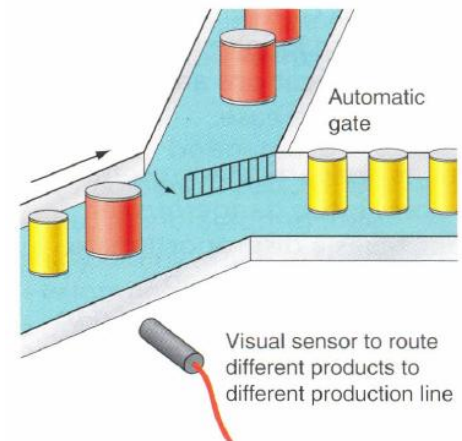
- Confidence of trading relationships through overall increased efficiency and accuracy of system.

Benefits of computerised stock control	Drawbacks of computerised stock control
Lower Costs	Initial cost of set up and training
Improve Efficiency	Sometimes only one person can operate system, so Cater for fluctuating levels of demand problems occur if absent or leaves firm
Cater for fluctuating levels of demand	Possibility of manual input error
Efficiencies can lead to price reductions Possibility of manual input error improving competitive edge	Software failure, virus attack
Very quick system	Computer breakdown can be costly; backup No manual checks required systems essential
No manual checks required	Digital data may be accessed without security system
Detailed, accurate, well-presented data available Digital data may be accessed without security for print out or distribution in electronic format	
Data can be selective for presentation to different groups	
Data easily stored	

High-volume production and automation

By the end of this section you should have developed a knowledge and understanding of:

- Trade description and sale of goods
- BSI standards applied to products/systems
- Labelling
- The implications of intellectual property - design rights and patents, registered designs, registered trade marks and copyright
- Regulations



Trade description and sale of goods

There are a number of Acts of Parliament that are designed to protect consumer rights. The Sale of Goods Act 1979 and the Supply of Goods and Services Act 1982 are concerned primarily with the sale of goods and services. The Trades Description Act 1968 and the Consumer Protection Act 1987 are concerned with product liability, products incorrectly described or defective products. The Consumer Credit Act 1974 is concerned with the purchase of products.

Key features of the Sale of Goods Act

- The goods must conform to the description given, for example a waterproof watch must not let in water
- Goods must be of satisfactory quality, based on what a reasonable person would accept as satisfactory considering factors such as age and price
- The goods must be of acceptable quality, fit for purpose and free from defects
- It is the seller, not the manufacturer, who is responsible if the goods do not meet acceptable standards
- Purchasers have the right to request their money back if the goods do not conform to contract. The claim must be made within a reasonable time period
- The purchaser, in some circumstances, can request a repair or replacement
- If repair or replacement are not possible or too costly, the consumer can request a partial refund, if they have had some benefit from the product, or a full refund if they have enjoyed no benefit from the product

Trade Descriptions Act 1968

The Trade Descriptions Act makes it an offence for a trader to apply, by any means, false or misleading statements, or to knowingly make such statements about services or goods.

Key features of the Trade Descriptions Act

- An offence is committed if the description given is false or misleading and has a significant impact on the purchaser's ability to use the goods or service as reasonably expected. A court would decide upon what constitutes a significant Impact
- The description may be given verbally, in writing (for example in a brochure or advertising leaflet) or by illustration (advert or on the product packaging)
- It is an offence to supply goods to which a misleading or false description is applied. A trader may commit an offence without intending to do so. In such cases the trader must prove that he/she took all reasonable precautions and Exercise due diligence
- The maximum penalty on conviction at Magistrates Court is £5000 per offence.
- The maximum penalty on conviction at Crown Court is an unlimited fine and/or two years imprisonment
- Traders may lose their consumer credit licence on conviction of an offence



Examples of Health and Safety assurance labelling

CE is not an abbreviation. The CE marking is a declaration by the manufacturer that the product meets all the appropriate provisions of the relevant legislation. The CE mark refers to safety, not quality. It is mandatory and indicates conformity with European safety requirements. It is the responsibility of the person placing the product on the market, to ensure that the product is correctly CE-marked.

Without the CE marking the product may not be placed in the market in the fifteen member states of the European Union and Norway, Iceland and Liechtenstein.

BSI British Standards

BSI British Standards is one of three divisions of the BSI group. The other divisions are BSI Management Systems and BSI Product Services.

BSI British Standards is the National Standards Body (NSB) for the UK and was the world's first NSB. It works with governments, industry, businesses and consumers to produce British, European and international standards. Fig 5.15 A safety label found on electrical products such as light fittings, fires and cookers, indicating that they have been double insulated (protected) throughout

- BSI British Standards has 27,000 current standards - one for every 59 businesses in the UK
- The price of a standard reflects its complexity; the price range for BSI standards is £5 to £1150
- The most popular standard in the world -ISO 9001 Quality management systems (Requirements) - is used by over 670,000 organisations in 154 countries

A standard is an agreed, repeatable way of doing something. It is a published document that contains a technical specification or other precise information designed to be used consistently as a rule, guideline or definition.

There are five types of British Standard: specifications, methods, guides, vocabularies and codes of practice.

Standards help a company to:

- Attract and assure customers that products are safe and fit for purpose
- Demonstrate market leadership, creating a competitive advantage
 - Continue to develop and maintain best practice

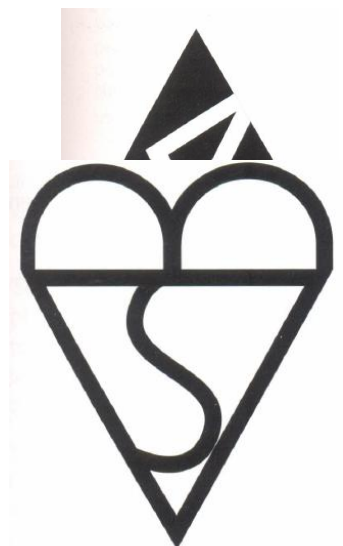
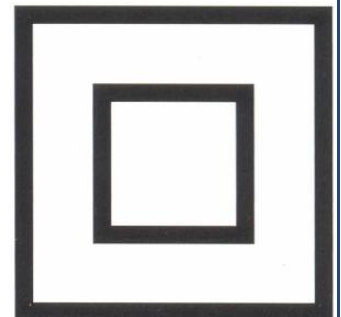
As consumers become increasingly informed about their choices, conformity to recognised standards becomes a key purchasing decision issue.

Some examples of British Standards include:

- BS EN 71-1 :2005 + A4:2007 Safety of toys. Mechanical and physical properties .
- BS EN 71-2:2006 + A 1:2007 Safety of toys. Flammability.

These standards would be essential for any individual or manufacturer involved in the design and manufacture of toys.

1. Discuss the role of the BSI in the design and making of products.



2. Discuss the importance to manufacturers of ensuring that their products are safe for the public to use.

By the end of this section you should have developed a knowledge and understanding of:

- The regulatory and legislative framework related to materials and equipment using Health and Safety at Work (HASAW)
- Control of Substances Hazardous to Health (COSHH) legislation
- Protection of the worker/operator
- Protection of the user/customer
- Protection of the environment
- Risk assessment

Health and Safety at Work Act

The Health and Safety at Work Act 1974 (HASAW) forms the basis of British health and safety law. It states that employers have a duty to ensure, so far as is reasonably practicable, that employees and other visitors are protected at work. Other visitors may include the self employed, subcontractors and the general public.

'So far as is reasonably practicable' is a key phrase: employers do not have to take measures to avoid or reduce the risk if it is technically impossible, or the time, effort and cost is grossly disproportionate to the risk.

The Management of Health and Safety at Work Regulations 1999 give detailed guidance on what is expected of employers. Employers are also required to keep everyone involved informed of health and safety issues.

There are two organisations whose job it is to enforce existing health and safety law, and to act as a source of advice and information on health and safety matters:

Health & Safety Commission (HSC), which considers and develops health and safety policy on behalf of the government

• **Health & Safety Executive (HSE)**, which advises the HSC on the shaping of policy and is responsible for its implementation

Key Points

Key features of the Health and Safety at Work Act 1974

Employers duties include:

- Make sure the workplace is safe and without risks to health by assessing risks
- Ensure plant and machinery are safe and that safe procedures of work are set and followed
- Ensure articles and substances are moved, stored and used safely by providing correct equipment and training
- Provide adequate welfare facilities including first aid arrangements
- Provide the information, instruction, training and supervision necessary for personal health and safety
- Make sure that work equipment is suitable for intended use, and that it is properly maintained and used
- Ensure that appropriate safety signs are provided and maintained

Employees duties include:

- Taking reasonable care for their own health and safety and that of others who may be affected by their actions
- Correctly using work items provided by their employer, including personal protective equipment (PPE).in accordance with training or instructions

- Using anything provided for health, safety or welfare correctly



Control of Substances Hazardous to Health Regulations 2002 (COSHH)

Using chemicals or other hazardous substances at work can put people's health at risk. Employers have a duty to control the exposure to hazardous substances and to protect both employees and others who may be exposed.

Failure to control exposure to hazardous materials can result in harm, from mild eye irritation, skin complaints and fainting as a result of fumes, to chronic lung disease or, on rare occasions, death. Consequences for the individuals harmed are obvious. For the employer they could be lost productivity and liability for legal action, including prosecution under the COSHH Regulations and civil claims.

Implementing the requirements of COSHH regulations can lead to:

- Improved productivity, using more effective controls (for example less use of a raw material or change of material or process)
- Improved morale, with a better employee understanding and compliance with health and safety requirements

Hazardous substances include:

- Substances that are used during work, for example adhesives, paints, cleaning materials and developing materials
- Substances that are created as a result of work activities, for example fumes from soldering
- Air-borne particles, for example dust Asbestos, radioactive substances and lead are not included under this legislation as there is specific legislation relating to these materials.

Aesthetics and function, shape, form, colour and taste

By the end of this section you should have developed a knowledge and understanding of aesthetics and be able to:

- Develop a critical awareness of designed objects/products in terms such as colour, form, shape, taste, texture and surface finish
- Consider the way aesthetic aspects influence appearance, contrast, composition, harmony/disharmony

The introduction of new and innovative products is essential to any economy. Products have to be designed to suit the users' needs.

They must be affordable, ecologically sound, work well and be aesthetically pleasing. Very often, customers are drawn to products because of their visual impact.

Aesthetics, in its widest interpretation, is involved with our senses - vision, hearing, taste, touch, smell- and our emotional responses to objects and things.

The Bauhaus, a design school founded by Walter Gropius in 1919, was very influential in shaping an understanding of design and taste. Design was considered crucial and integral to the production process rather than merely a visual 'add on:'

'Form follows function' was a phrase often used to counteract the historically prevalent view that beauty was achieved by including additional features, not necessarily useful features.

Architects and industrial designers in the 20th century were beginning to show that the form or shape of an object should be based on its intended purpose or function.

There are many examples of products that demonstrate a sensitive consideration of both aesthetics and function, some examples of which are shown in Figures 5.54 to 5.57.

Fig 5.45 Apple Pod, Jonathon Ive (2001)



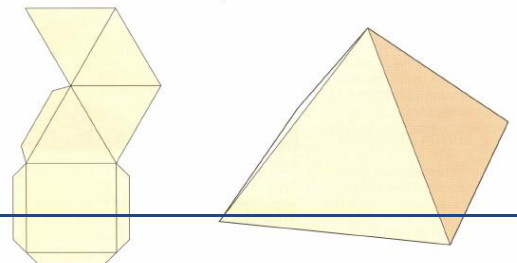
Key Points

Aesthetic failure

In *Design for the Real World* Victor Papanek describes how automotive designers in Detroit, looking at making car dashboards more symmetrical and aesthetically pleasing by relocating ash trays, controls and switches, could have resulted in 20,000 fatalities and 80,000 serious injuries over a five-year period. This happened as a result of drivers having to over-reach for controls, diverting attention from driving for split seconds longer.

Shape

Shapes are formed as a result of closed lines. Shapes can be visible without lines when a designer establishes a colour area. They may be composed from parts of different objects in an arrangement; they can be gaps, or negative shapes between the objects. Basic shapes include circles, squares, triangles and polygons, all of which appear in nature in some form or another.



Form

Form refers to the three-dimensional quality of an object. When light from a single direction hits an object, part of the object is in shadow. Light and dark areas within an image provide contrast that can suggest volume.

Colour

Colour is very important in product design. It creates responses by stimulating emotions and can excite, impress, entertain and persuade.

Colour can also create negative association Research suggests that 73 per cent of consumer purchasing decisions are made in-store. Catching the consumer's attention and conveying information effectively are critical to successful sales.

A designer must be aware of how people respond to colour and colour combinations.

Apple broke with tradition by introducing iMac computers in a wide range of colours. They realised that home computers did not need to look like the usual office machine and that customers wanted a more visually interesting and appealing design.

The success of the iMac rescued a brand that had suffered \$1.8 billion of losses in two years.

Define the following aesthetic features. Give examples of where they apply to products.

Visual	Hearing	Taste	Touch	Smell
Pattern Balance/ composition Rhythm Harmony/contrast	Loudness Pitch Melody	Sweetness Sourness Texture	Texture Comfort Temperature	Strength Pleasant/unpleasant

Red	Aggressive, passion, strong and heavy, danger, socialism, heat
Blue	Comfort, loyalty and security, for boys, sea, sky, peace and tranquillity, cold
Yellow	Caution, spring and brightness, joy, cowardice, sunlight
Green	Money, health, jealousy, greed, food and nature, inexperience
Brown	Nature, aged and eccentric, rustic, soil and earth, heaviness
Orange	Warmth, excitement and energy, religion, fire, gaudiness
Pink	Soft, healthy, childlike and feminine, gratitude, sympathy
Purple	Royalty, sophistication and religion, creativity, wisdom
Black	Dramatic, classy and serious, modern, evil, mourning
Grey	Business, cold and distinctive, humility, neutrality
White	Clean, pure and simple, innocence, elegance

Taste

Taste depends upon the individual. In product design we often refer to 'good taste' or 'bad taste':

There are accepted standards, often legally defined, but we all have our own views and preferences regarding what is 'aesthetically pleasing; and what combinations of shapes, colours and aromas work. Taste is often linked to aesthetics and the personal appreciation of beauty. Product designers will research thoroughly to ensure that their creations will appeal to targeted groups and will acknowledge that taste changes quickly, depending on factors such as peer pressure and celebrity endorsement.

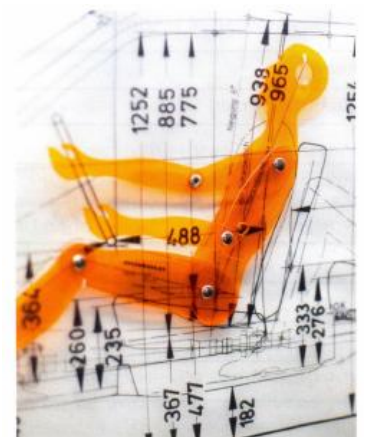
Ergonomics and anthropometries

By the end of this section you should have developed a knowledge and understanding to be able to:

- Demonstrate an understanding of ergonomics when designing products
- Interpret and apply anthropometric data when designing

Key Term

'If an object, an environment or a system is intended for human use, then its design should take into account the characteristics of human users' Stephen Pheasant



Consider which percentile you would need to use for the following:

- The height of a doorway
- The size of a handle for an upright vacuum cleaner
- Ventilation slots in the casing of an electric motor on a lawn mower
- The diameter of a screw-top water bottle

EXAMINER'S TIPS

Students commonly mix up ergonomics and anthropometrics. Ergonomics is the study of how we use and interact with an object/tool, etc. Anthropometrics is the study of the sizes of the human body. Anthro in Greek means man; metric should help you remember measurement.

Using human factors in designing

Hand tools are anything that can be manipulated by the hand. Bad design may cause result in slower work and more error, and possibly injury or accidents. The grip and the level of muscle exertion needed must be considered. The wrist angle is also important.

Slight contouring of the grip or flared handles can increase comfort and reduce slippage in sweaty hands. Handles should be at least 100-125 mm long for power grip. Longer handles distribute forces on fingers. Smooth handles for tools requiring wrist rotation should be avoided because of the increased risk of slippage and rotational wrist damage. Padding handles reduces the force needed to grip the tool. The effect of tool weight is also a factor. Use of rests, supports, two hand grips, etc. can all help to decrease the effort required to use heavy tools.

When designing, try to design tools and handheld items for operation with both hands. When only right-handed users are considered, lefthanders may be at an increased risk of injury. A simple experiment can demonstrate how the wrong angle can affect strength and grip in your hand.

Quality control and quality assurance

By the end of this section you should have developed a knowledge and understanding of:

- Quality control
- Quality assurance
- Total quality management

Quality Counts

Every product is designed and manufactured with a particular customer in mind. It is vital that the end product fulfils the requirements and expectations of the customer. These may include appearance, performance, availability, delivery, reliability, safety, maintainability, value for money and price. It is important that an organisation knows and understands their customer's needs and expectations, and then puts in place the procedures and systems to ensure it meets them.

Failure to meet the customer's specification will result in a product that does not sell as well as expected and such a response will result in wasted materials, wasted resources during the manufacturing process, and damage to the reputation of the manufacturing company. This could have a drastic effect on the future success of the company.

Total quality management

An important consideration for the organisation of the company is how can they guarantee the manufacture of a quality product. It is because of a company's desire to gain customer satisfaction that TQM procedures are set up. Companies who implement TQM are constantly seeking improvement, trying to continually improve the performance of its organisation and its products and services. TQM emphasises the importance of the whole manufacturing process, reviewing and monitoring every stage of management and manufacture. Checks are made at every stage from the delivery of resources through to the final delivery of the product to the customer. In order to be effective TQM relies upon every *employee* within the workplace to be responsible for their quality standards. If any faults are found then these need to be corrected immediately; by doing so this allows repairs to be carried out or changes to the production methods made. By applying such procedures faults are identified at an early stage and the amount of rejected items can be reduced.

Quality assurance

Quality assurance is carried out by the company to see that the product meets the quality standards set. A series of planned actions and procedures are set up to check the product before, during and after manufacturing operations have taken place. The aim of the process is to prevent failure and to make sure that quality of the product is right first time and

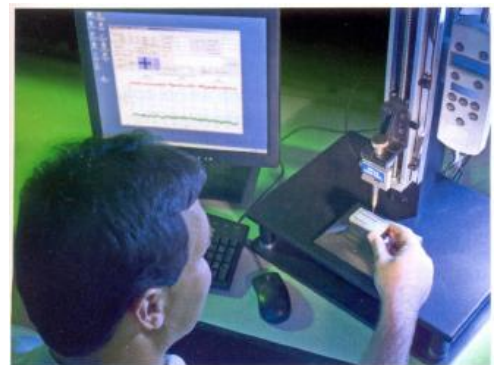


Fig 5.73 Testing being carried out as part of the quality control process

every time. Quality assurance is the responsibility of everyone and it should be built in to the process from the beginning of day one until the end of the production process.

Quality control

Quality control supports the quality assurance process and is used to set up ways of checking quality against the required customer standards or to see that items have been made within set tolerances. It involves using an inspection team who are looking for items that are not up to the specific standards. Inspections take place at identified stages during manufacturing as well as after the final item has been assembled.

Inspections can be carried out on all, or a sample, of the products, depending upon the number of items being produced.

Inspection checks can be carried out in a variety of ways, including:

- Simple visual checks
- Detailed data comparisons
- Checking accuracy of dimensions
- Flammability tests
- Tasting
- Checking weight
- Electric circuit checks
- Safety checks

It is the ultimate aim of every company to produce products that quality control procedures identify as having zero faults. However, when mass producing certain products it may be impossible for every product to be identical and therefore a tolerance has to be applied. Such procedures allow slight agreed differences to be approved and for the product to be passed as meeting the product specification when inspections are carried out.

Very few products and components need to be manufactured to a zero tolerance. Manufacturing to high levels of accuracy will be costly. The specifying of tolerances enables an adequate level of accuracy to be provided and keeps costs to a minimum.

Key Term

Tolerance

How much variation from a precise standard can be tolerated or allowed. For example, on the drawing of an engineering component a measurement is shown as 100 ± 0.5 , indicating that the minimum permissible size for the component is 99.5 mm, and the maximum is 100.5 mm.

Smart and modern materials

By the end of this section you should have developed a knowledge and understanding of:

- Up-to-date development of materials and their application in product design

Scientists and technologists have been developing and creating new materials with useful properties since the 19th century. Plastics are often regarded as 'modern' materials, yet cellulose nitrate was introduced at the Great International Exhibition in London in 1862. Further technological advances in product design will depend increasingly upon the development of new materials with valuable properties.

Smart Materials respond to changes in temperature or light and adapt in some way.

Some smart materials have a 'memory' and can revert back to their original state. An example of this type would be medical threads, which knot themselves. Temperature and/or light could be used to activate the 'memory material to revert to its original shape.

Smart or modern materials may be high performance materials, such as genetically engineered dragline spider silk, which is used to produce super-strong, super-light military uniforms. The materials that will have the greatest impact are those that sense conditions in their environment and respond to those conditions. These materials function both as sensors and actuators.

Modern Materials are developed to perform particular functions and have specific properties; they are intentionally developed, rather than being naturally occurring changes.

Many smart and modern materials are developed for specialised applications, though some eventually become available for general use. In the last ten years a range of smart materials has been produced for personal, domestic, medical, transportation and telecommunication applications.

Smart goggles are made using a low-cost electrochromic sheet that changes colour and shade using minimal power.

Materials are being developed that repair themselves, for example a bridge could reinforce itself and seal cracks during an earthquake.

Aerospace engineers are developing smart materials, which can automatically seal cracks in airplane wings. Cars are being designed with 'intelligent crumple zones' using smart materials to regain their original shape after an accident.

There are many uses of smart materials in medicine. In order to prevent the collapsing of arteries, small tubes are inserted. The smart material tubes are injected directly into the vein, without the need for a complicated operation, and take on the required form in the affected artery, opening out and improving blood circulation. The changes in the smart material are triggered by body temperature. Smart bandages and plasters can use bacteria sensors to warn of infection using colour changes.

Smart materials allow complex items to be disassembled easily and in a cost-effective manner. Components that may have been difficult to remove and thrown away in the past can now be recycled or reused. Screws can be made from shape polymers that, under heat, return to their original shape, retract their threads and are easily removed from their holes.

Polymorph

Polymorph (polycaprolactone) is often used as a modelling material. It is heated by water or a hairdryer and becomes easily mouldable at 62°C and takes on a solid form, very similar in performance to nylon. It is also available in liquid form: it is liquid at room temperature but solidifies at approximately 2°C.

Shape memory alloys

Early use of nickel-titanium alloys (Nitinol) established that they had a 'memory': When heated they retained their original shape. Gold-cadmium and some alloys of brass all have a memory: Available in wire or sheet form, shape memory alloys are used in robotics (copying muscle function) and are being developed to operate the wing flaps on aeroplanes. They are used in modern buildings in automatic air vents.

Piezoelectric materials

When a piezoelectric material is deformed it gives off a small electrical discharge. Also, when an electrical current is passed through a piezoelectric material, it increases in size by up to a four per cent change in volume. A piezoelectric material is used as the airbag sensor in a car. The material senses the force of an impact on the car and sends an electric charge that sets off the airbag.

Chromic materials

Chromic materials refer to materials that radiate a colour, erase a colour or change it as a result of external stimuli;

- Photochromic materials change colour with changes in light intensity. Usually, they are colourless in the dark; when sunlight or ultraviolet radiation is applied the molecular structure of the material changes and it exhibits colour

- Thermochromic materials change colour reversibly with changes in temperature; they are usually in the form of semiconductor compounds, liquid crystals or metal compounds
- Electrochromic materials change when electricity is the external stimuli
- Piezochromic materials change when pressure is the external stimuli
- Solvatochromic materials change when liquid is the external stimuli

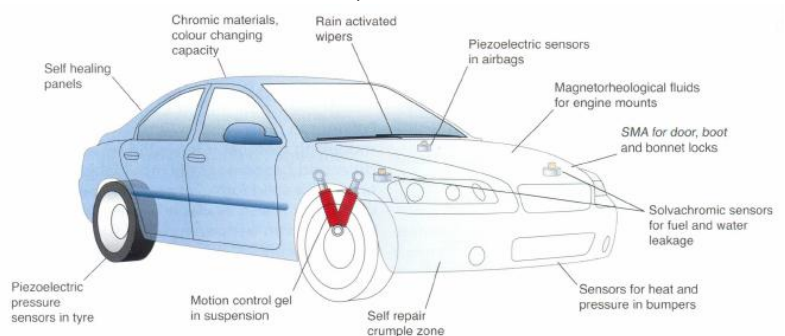


Fig 5.74 Applications of smart materials in automobile design

Processes used to manufacture products from metal - milling, turning, casting, modifying characteristics using heat, pressing and stamping

The following pages are intended to give you a deeper understanding of what is required in order to manufacture a typical metal-based product to a required specification, giving consideration to the future maintenance of the product and its performance throughout its working life.

The manufacture of any given product will often require a great deal of knowledge and understanding of the materials being used, and skill in manipulating those materials to produce the required end result.

Initially it is vitally important to evaluate which process is most suitable for the manufacture of a specific product. These considerations may take several forms and may well depend on the criteria laid out in the product specification, for example:

- Material used
- Quality of the final product
- Costs, both manufacturing and final selling price
- The quantity to be manufactured
- Tolerances (accuracy of the engineering process)

Secondly, the manufacturing team must consider which of the following engineering processes (and associated techniques), are the best to be used and to what extent:

- **Material removal** - includes turning, milling, sawing, shearing and drilling; how much material can safely be removed in one cut?
- **Basic Shaping** - includes forging, bending, moulding, pressing and stamping; can the final product be produced in one piece?
- **Joining and assembly** - includes nuts and bolts, screws rivets, soft soldering, welding, brazing; how are the component parts of the finished product to be connected together, and will it be a permanent connection?
- **Surface finishing** - what will the finished product look like, under what conditions will it be used, and how can consistent quality be maintained throughout the manufacturing process?
- **Heat treatment** - can the basic properties of the material being used be enhanced? Can the hardness and toughness be modified by the application of heat?
- **Chemical treatment** - as for surface finish, will the final product require a special corrosion resistant finish?

Designers and engineers have to consider some or all of the above factors prior to commencing manufacture.

Study the following list of common products. State briefly which of the above processes and associated techniques you think are used to make them. Some may require more than one process/technique:

- An open-ended spanner
- A bicycle frame
- A motor car gearbox casing (excluding the gear train)
- A gear cog
- A 13 amp electric plug (all components)
- A hammer (the head)

Material removal

When manufacturing any sort of metal product it is inevitable that some amount of material will have to be removed from the metal blank in order to produce the required shape. Three of the most common procedures for removing excess material include:

- Turning
- Milling
- Drilling

It can sometimes be quite difficult for engineers to decide which of the three techniques listed above would best be used in the manufacturing process since, often, more than one of the three could be used. In cases such as this, the production team would have to consider a further set of criteria. These would include:

- What is the basic shape of the product?
- What material is being used and what is the (possible) best process for this material?
- What are the required tolerances (the level of accuracy and precision required)?
- What is the size of the batch; how many are to be made?
- Is one of the available processes/techniques quicker than another?
- What are the cost implications of using one process when compared to another?

In order to make an informed choice in the manufacture of a particular product, there is a requirement to be familiar with the basic material removal process as well as the more specific techniques within that process, for example:

- Turning - typically used to produce cylindrical shapes, tapers, holes and screw threads (both male and female)
- Milling - this process is generally used to produce smooth, flat surfaces, slots and sometimes curved surfaces
- Drilling - used typically to produce holes all the way through a material, as well as to produce blind holes, counter-bores and countersinking

Complete the table below to show which of the three processes listed above is used in the manufactured products shown. One has been done for you as an example.

	Centre punch	Brake disc	Bolts	Printed circuit boards	Car engine cylinder head
Turning	✓				
Milling					
Drilling					

Turning

Turning is done on a lathe (see right); the most common type found in engineering workshops and manufacturing industries is called a centre lathe. The main function of the turning process is to produce parallel cylindrical shapes or tapered cylindrical shapes to a very high degree of accuracy.

The basic turning process involves the use of a single point cutting tool in which material is removed from the outside diameter of the workpiece, or a twist drill used to bore a hole into (or through) the centre of the horizontal axis of the work piece.

There are many types of lathe cutting tools that are available to the engineer. Some of those are shown in Figure 7.2.

The removal of material is achieved by clamping the material that is to be worked on (the workpiece) firmly into a work-holding device.

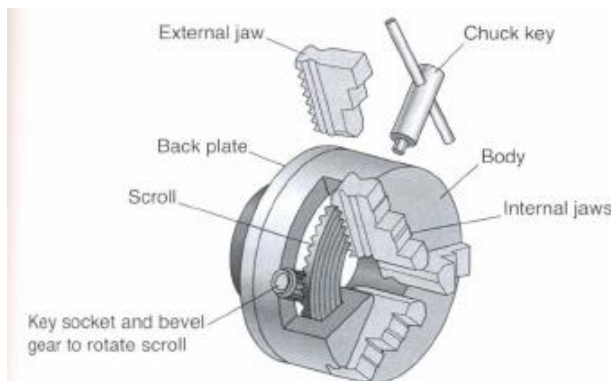


Fig 7.3 Three jaw self-centring chuck

Milling

This process allows for the rapid removal of material using multi-tooth cutting devices. The workpiece is secured to the machine work table and is fed under the cutter. There are two basic types of milling machines:

- Horizontal millers - the tool spindle axis is in the horizontal plane
- Vertical Miller - the tool spindle axis is in the vertical plane

Additionally, there is a third type called a universal miller. It is similar to the horizontal miller but has a table that can be swivelled through a prescribed angle.

All three types of machines are used to machine flat surfaces, slots and steps.

Both types of milling machines have a work table that can be raised or lowered and also moved horizontally in two perpendicular directions. On most milling machines it can also be set to traverse automatically beneath the cutter.

The spindle, which holds the cutting device, can be driven either by a variable speed drive motor or through a gearbox so that



Fig 7.1 A centre lathe

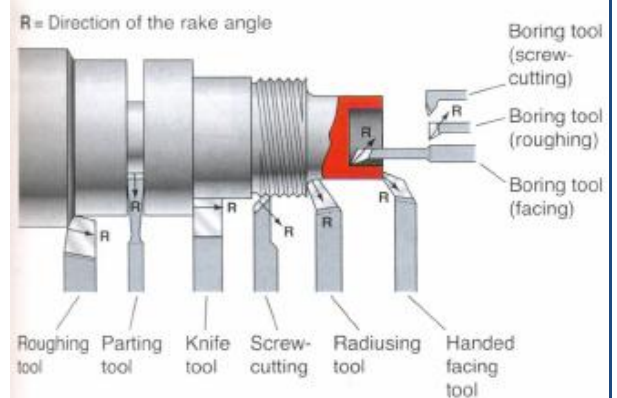


Fig 7.2 Typical turning tools

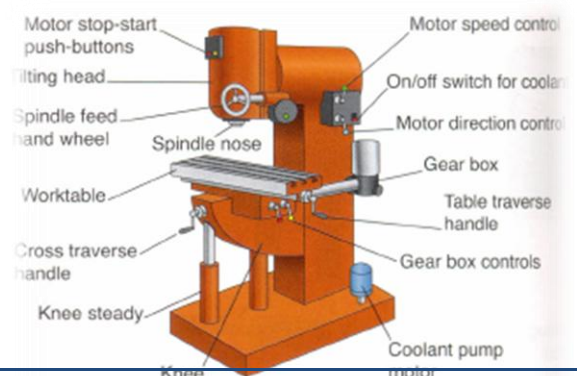


Fig 7.7 Vertical milling machine

the correct cutting speed can be selected depending on the nature of the material being worked . For milling operations, there is a wide variety of cutting tools, all of which comprise of a series of wedge-shaped teeth that have been ground with suitable rake and clearance angles.

Horizontal milling

Four of the most common cutting tools used in horizontal milling operations are:

- Slab cutters - sometimes known as slab mills or roller mills; they are used to produce wide, flat surfaces
- Side and face cutters - these have their cutting teeth around the periphery and the side faces of the tool; they are generally used for light facing operations and for cutting slots and steps in a workpiece
- Slotting cutters - these are somewhat thinner than either of the two above cutters and have cutting teeth on the periphery only; they are used for cutting narrow slots and keyways in shafts

Casting

There may be a need to produce quite complex shapes during the making of an engineered product; this is not always possible using standard material removal techniques so the product is made in one piece, usually by using a casting process. There are several methods by which a component can be produced by casting including:

- Sand casting
- Die casting
- Gravity die casting
- Pressure die casting
- Investment casting



Sand casting

Some form of crude metal casting was practiced by early civilisations over 6000 years ago. Its popularity reached a peak during the industrial revolution in the early part of the 19th century where the casting of base iron ('cast iron') was used extensively.

Although the majority of today's products are now made from steel, cast iron is still used in the manufacture of machine tool beds and some engine blocks due to its inherent compressive strength.

Sand casting is a relatively straightforward process in which an impression is made in damp sand using a pattern of the required product. The pattern is slightly oversized to compensate for the shrinkage of the final product during the cooling stage.

Wood is quite often used to make the pattern as it is a relatively cheap material that can be easily worked into the desired final shape. Sand is used, again, because it is cheap, strong enough to withstand the pressures of the molten metal and permeable enough that it can allow the escape of the hot gasses produced during the casting process. Green sand is generally used as it contains small amounts of clay which help to bind the fine particles of sand together.

Castings can vary in size from small components that would fit in your hand up to very complex products weighing many tonnes. Although the casting method varies according to the product being made, the basic process remains the same.

Depending on the complexity of the final product, the pattern may have to be made in two halves, which are joined together using locating dowels as shown in Figure 7.11. This is called a split pattern.

One half of the pattern is placed face down on a 'turnover board' and the lower half of the two-part steel mould, called a drag, is placed around it. A fine sand called parting powder is then sifted over the pattern until it is completely covered (this is to assist the final removal from the mould) and the whole is then packed tightly with green sand. The drag is then inverted, the turnover board removed and the second half of the pattern located onto the first using the locating dowels.

The top half of the mould, known as the cope, is then placed in position and the process is repeated. The only difference is that two extra items are inserted before packing with sand: these are known as a runner, which allows for the pouring of the molten metal into the cavity of the mould, and the riser (which is always placed in the highest part of the cavity), which allows the gases to escape and also shows when the mould is full. These two pieces also act as reservoirs for the molten metal so that the casting can draw down additional metal as it cools.

To prevent cohesion of the two parts of the mould a parting material such as graphite powder is dusted onto the sand in the drag before the cope is placed in position. Once the mould has been packed, it is carefully separated and the pattern removed to leave a mould cavity. At this stage, if required, ready-formed sand 'cores' can be placed into the mould cavity to produce holes in or through the finished casting. The molten metal is then poured into the assembled mould. During the solidification stage, the metal in the mould contracts slightly, hence the need for a slightly larger pattern at the outset.

This process allows for the manufacture of complex-shaped engineered products from virtually any metal that can be melted. Although the sand can be reused, the moulds cannot and have to be remade each time. This makes it a very time-consuming process.

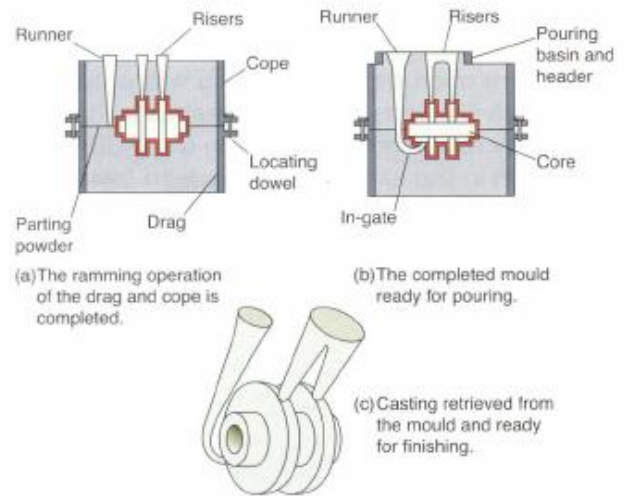


Fig 7.11 The sand casting process

Die casting

The major disadvantages of the basic sand casting process are:

- The mould has to be remade for every component manufactured
- The overall accuracy of the finished product is poor

This is overcome to a great degree by the use of die casting, molten metal is poured into reusable steel moulds called 'dies' and the resultant casting is, in general, left in its finished state with little or no further machining required. This is a much faster process and subsequently leads to a reduction in production costs.

However, there is one drawback of this process in that it can really only be used for casting nonferrous materials, mostly aluminium and zinc, as the higher temperatures needed for casting steel and iron damage the expensive dies and lead to premature loss of accuracy and finish of the product being cast.

Gravity die casting

This process also uses a permanent metal die; it closely resembles the processes of basic sand casting in that the die is filled with molten metal by the natural force of gravity. If cores are needed, they are often made so that they can collapse in order to allow them to be withdrawn from the casting. Where this proves to be a problem then, just like the sand casting method, sand cores are used. This process is not suitable for zinc-based alloys as it tends to promote a fairly coarse grain in the finished product.

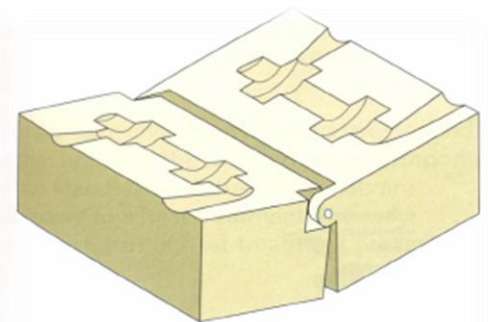


Fig 7.12 Typical steel mould used in die casting

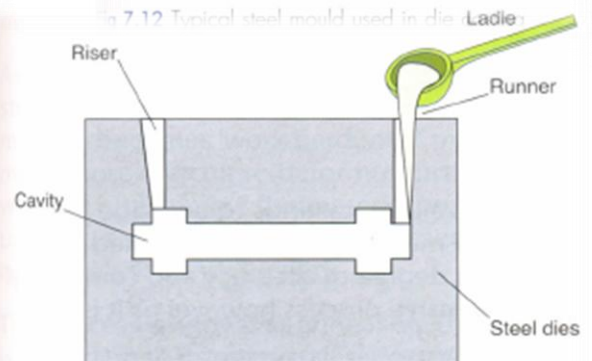


Fig 7.13 Gravity die casting

Pressure die casting

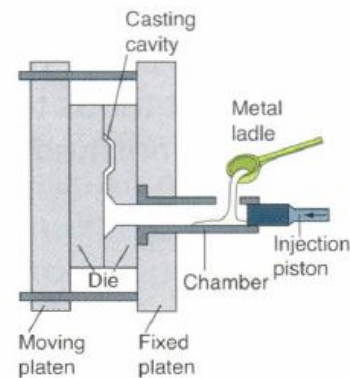
As the title suggests, this process utilises pressure. The pressure is applied to the molten metal as it is fed into the dies (moulds) using a simple plunger. This technique ensures that the molten metal makes good contact with the walls of the casting dies and, by maintaining the pressure throughout the cooling stage, gives a sharp and well-defined casting that requires little or no additional machining.

If the dies are cooled when filled the components will solidify quicker and the casting can be removed while solid but still hot, enabling the process to be repeated again giving a much faster turnaround of components. One disadvantage of this type of process is that the cost of producing the dies is quite high. It only becomes economical if a large number of components are being made.

PROCESS
Permanent mould
 Molten metal is forced into a water-cooled metal mould (die) through a system of sprues and runners. The metal solidifies rapidly and the casting is removed with its sprues and runners.

SHAPE
3D solid
 Used for complex shapes and thin sections. Cores must be simple and retractable.

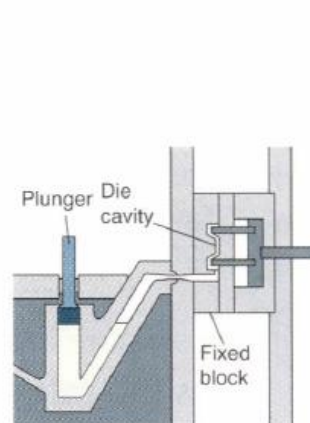
MATERIALS
 Light alloys
 High fluidity requirement means low melting temperature eutectics usually used. Hot chamber method restricted to very low melting temperature alloys (e.g. Mg)



Cold-chamber high pressure die casting. Molten metal is poured into a cold shot chamber. A high pressure plunger forces metal into the single or multi-die cavity.

CYCLE TIME
 Solidification time is typically < 1 s so cycle is controlled by time taken to fill mould and remove casting.

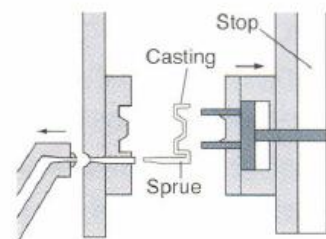
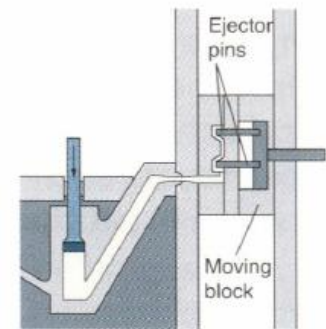
QUALITY
 Good surface texture but turbulent mould filling produces high degree of internal porosity.



Hot-chamber high pressure die casting. A gooseneck hot chamber is submerged in a pot of molten metal. Metal is injected directly from the pot via the gooseneck.

FLEXIBILITY
 Tooling dedicated so limited by machine setting up time.

MATERIALS UTILIZATION
 Near net shape process but some scrap; in sprues, runners and flash which can be directly recycled.



OPERATING COST
 High, since machine and moulds are expensive.

Fig 7.14 Pressure die casting

Investment casting

This process is also known as lost wax casting. It is used where a very complex component that requires a high degree of accuracy is needed, and one that is difficult to machine after casting.

The moulds used in this process are made from fine refractory materials that can withstand very wide heat ranges and which can provide fine dimensional accuracy. The process involves the following procedures:

- A wax pattern is made of the component being manufactured; if there are a large number of these components being made, then a mould would be made to produce the wax pattern
- The wax pattern is then coated with a refractory slurry (either by dipping or spraying); as the slurry dries it forms a hard, brittle shell which now forms the 'die'

PROCESS

Expandable mould and pattern

A ceramic shell (investment) is slip cast around a wax pattern. Wax is melted and molten metal cast into the investment which is broken up to remove the casting.

SHAPE

3D
Best for relatively small, complex 3D components. Re-entrant angles possible.

MATERIALS

Suitable for most metals. Reactive metals can be cast in a vacuum.

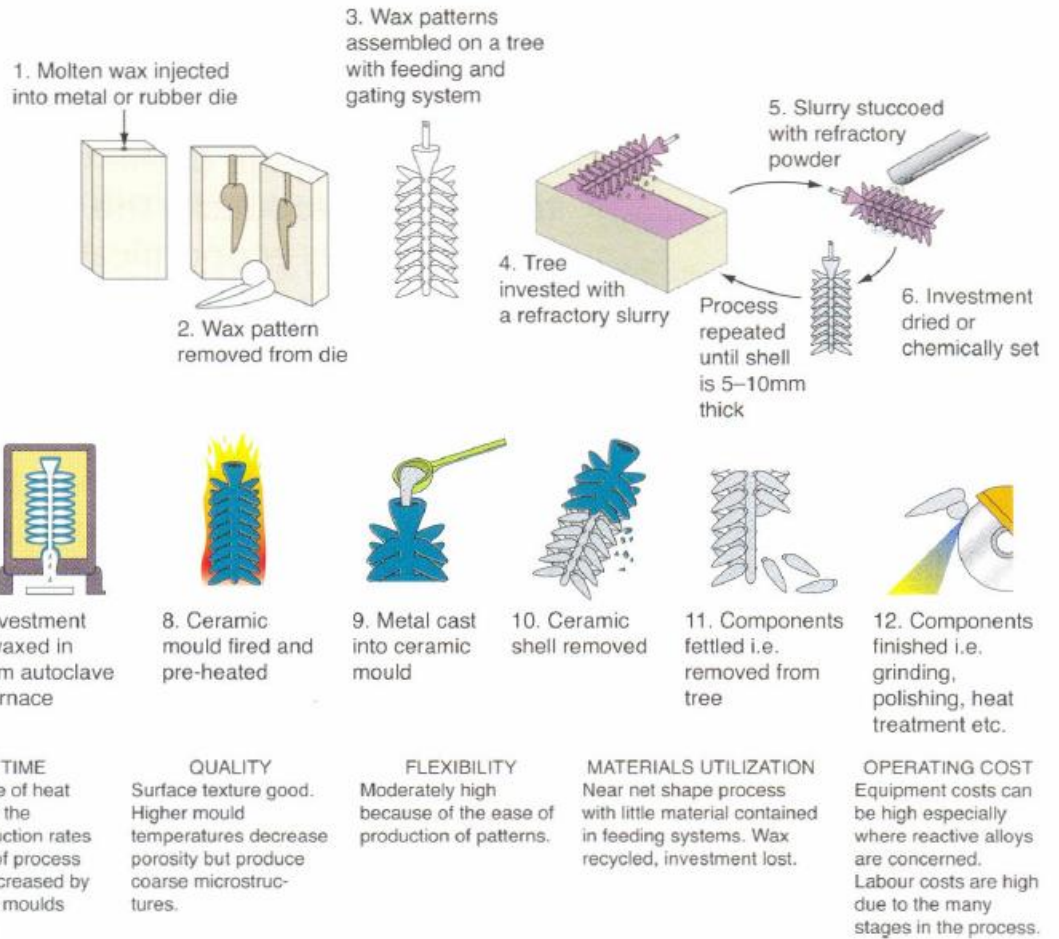


Fig 7.15 Investment casting

For the manufacture of the following components, state which casting process is the most suitable.

- A motor vehicle engine block
- A model toy car
- A turbine blade for a jet engine
- The housing for a small electric motor

• The die is now placed in a preheated furnace or autoclave, and the wax is melted out; this process leaves a

cavity and also assists in the setting of the refractory mould

- Molten material is then poured into the cavity and allowed to solidify; when solid, the refractory lining of the mould is broken off

This process allows castings to be made from virtually any material that can be melted and gives a high degree of accuracy and complexity.

It is an expensive process however as it is very slow.

Pressing

This term describes any press-related operations, which can be categorised as follows:

- **Piercing** - where a suitable punch shears a hole in a piece of metal
- **Blanking** - where the punch shears the required shape from the metal
- **Notching** - where the punch shears an open sided hole in the metal
- **Cropping** - where the punch shears a plain or shaped length from the metal
- **Bending** - where a suitable punch shapes the metal by a folding process
- **Drawing** - a process by which a punch produces a cup or dish shape from a piece of metal
- **Forming** - where the metal is forced into the shape of the surface contours of a die

The above terms cover all of the shaping and manipulative techniques used in sheet metal work and, to a lesser extent, on plate metal.

(Metal up to about 3 mm in thickness is classified as sheet metal and above 3 mm as plate metal).

Virtually all presswork operations are carried out on sheet metal as the vast majority of engineered and manufactured components are made from metal that is less than 2 mm thick.

The main users of these manufacturing techniques are the automobile, aeronautical, heating and ventilation industries, along with canning and container making, and domestic appliance industries. Examples include:

- Car body panels
- Aircraft panels
- Air conditioning units
- Washing machine and tumble dryer carcasses

As a result, more than half of the production of metal products in the western world involves the use of sheet metals. It should be noted though that large presses can be used to fold and form materials up to about 50 mm in thickness, and presses exist that can cater for capacities exceeding 45,000 tonnes (these are generally used in large forging operations however).

The majority of press-related operations are confined to large batch production work due to the high costs and lengthy tool-setting involved.

The tool costs for producing a motor vehicle body part, for example, can exceed several thousands of pounds. Production runs need to be high so as not to add significantly to the retail price of the finished product. Presswork operations on this scale use up vast amounts of sheet steel, so it is usually supplied in large diameter rolls of a pre-determined width to suit the product being made. Operations of this type are virtually all automated now (or, at the very least, semi-automated) with only very small batches of products being suited to manual press operations.

As mentioned above, presses can be manual or power operated to suit the working conditions.

Manually operated presses are obviously limited in the magnitude of the forces that can be applied to the metal, with large fly presses being capable of operating at just a few tonnes at best.

Power Press

There are many types of power presses, all of which are designed for different types of presswork operations, such as blanking or piercing, bending and drawing. In each case the operating energy is derived from an electric drive motor, stored in a large flywheel and delivered to the workpiece by means of a mechanism that changes the rotary motion of the flywheel into linear motion at the tool, in a similar manner to the way in which the screw on the fly press changes the rotary motion of the handle and the fly balls to linear motion at the tool.

In the following example, the open-framed power press, this is generally achieved by means of a connecting rod and a linkage mechanism.

Engineering

The only difference between the fly press and the power press is one of available power: the power transmitted to a fly press is limited by a human operator.

In the case of a power press, the operator only has to press a foot pedal and the motor power is transmitted to the machine. The power press, of course, has a much more rapid action than the manually operated fly or arbor press and, with an automatic feed of work to the tool head, the pedal can be locked down to give continuous operation.

In general fly presses are much cheaper to buy, set up and run, and lend themselves to the use of fairly simple tooling and low volumes of production. Power presses on the other hand are more expensive to buy, set up and run, but are quicker and lend themselves to high rates of production.

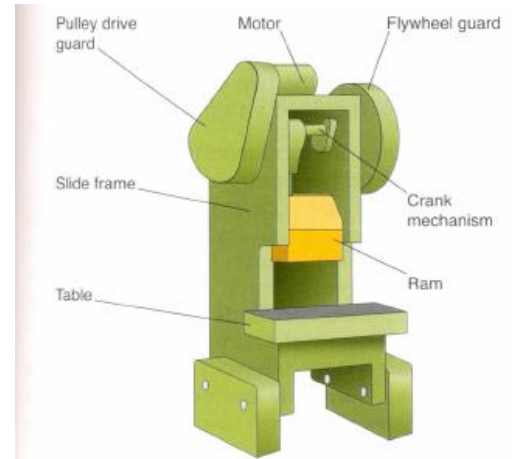


Fig 7.21 Open-framed power press

Stamping (blanking)

Pressing and stamping is often associated with high-volume production. A great deal of time is spent in planning the blanking layout for a particular component: the orientation of the component on the metal strip is important as it affects the economic use of the material. The direction of the grain of the material must also be considered as it may affect the final product, especially if a subsequent bending process is necessary. Some examples of how a saving in the economy of a material can be achieved are shown in Figure 7.22.

From the examples in Figure 7.22 it can be seen that for maximum efficiency of material, it is beneficial to have more than one punch carrying out the stamping operation and that the production rate is increased by the number of punches being used. The increased cost of the punches is more than offset by the increase in the production rate and associated economy of material. The logical conclusion is to arrange for multiple blanking layouts, the limit being governed only by the size of the component being produced and the width of the steel sheet supplied.

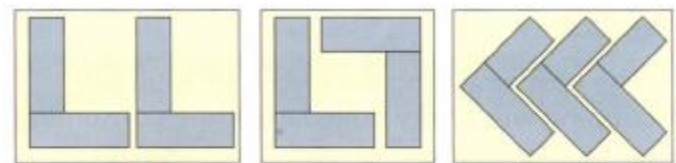


Fig 7.22

Most steel producers today will accurately slit the steel coils to any desired width, so multiple layouts should not present a problem. The only limiting factor is that, when planning for multiple stamping layouts, one has to bear in mind that the minimum 'land' (space) between adjacent components and the outer components; the edge of the strip cannot be less than the thickness of the material being used.

Figure 7.23 shows a typical layout for the stamping of blanks to make coins. Here, six punches are used and the arrangement usually has to be staggered to allow for the outside diameter of the die. The production rates for this arrangement can be in excess of 10,000 per hour per machine.

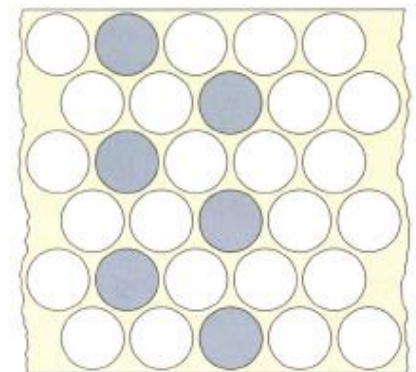


Fig 7.23

In the past arranging the layout for multiple stamping was a very skilled and time-consuming task for the engineer or manufacturer. With today's modern technology of course, a computer program is used to ascertain the maximum usage of the metal strip (referred to as a nesting process).

Processes used to manufacture products from plastic – compression moulding, injection moulding, Vacuum forming, rotational moulding, extrusion and blow moulding

Design of simple jigs, Presses and moulds Jigs and fixtures

The terms jigs and fixtures are closely related and are often interchangeable. The only real difference between the two is in the way in which the tool is guided into the workpiece.

Jigs and fixtures are production tools that are used when a number of duplicate components parts are to be made accurately and the correct alignment between a tool and the workpiece must be maintained. In order to provide this means of repetitive accuracy, a jig or fixture would be designed and made to hold, support and locate each part of a component to ensure that each part is drilled or machined in precisely the same way, within the limits or tolerances of the product specification.

A jig is a special device that holds, supports or is placed onto a part to be machined. It is a production tool that it not only locates and holds the workpiece but also guides the cutting tool as the engineering operation is performed.

They are usually fitted with hardened steel bushings for guiding drills or other such cutting tools (see Figure 7.24a). Small jigs are not necessarily fastened to the drill table: they can be hand held. However, if the holes being drilled are larger than 6 mm then they are generally clamped securely to the drill table.

A fixture on the other hand is a production tool that locates, holds and supports the workpiece securely during a machining operation. Set blocks and feeler gauges are used in conjunction with fixtures to reference the cutter in relation to the workpiece (see Figure 7.24b). Fixtures are always securely fastened to the table of the machine on which the work is being carried out. Although largely used for milling operations, they can be used on a wide variety of machine tools. They vary in design from very simple and inexpensive tools to quite complex, expensive devices.

Manufacturing processes

Learning outcomes

By the end of this section you should have developed a knowledge and understanding of:

- One-off, batch, high-volume production systems
- Modular/cell production systems
- Just-in-time manufacture
- Repetitive flow
- Continual flow
- In-line assembly
- Cell production
- Automated production
- Robotics
- Bought-in parts and components, standardised parts
- The implications of these industrial production processes/procedures
- Appropriate manufacturing methods that take into account the properties of different materials
- The effects of the manufacturing process on the properties and structure of materials



Fig 10.2 Batch production: orange truffles

Processes used in manufacturing are quite diverse depending upon the complexity of the industry studied. Processes *observed* could vary from a manual system where single, one-off items are being produced to the use of fully automated high-volume production systems.

Modern industrial methods are moving towards fully automated systems, *however* there are many examples of combinations of manual and automated production systems to produce items as a single product and in volume. This section explores a variety of manufacturing processes that you may see in an industrial situation.

One-off, Batch, high-volume production systems

One-off (also known as job, or custom) production is where a single item may be needed. This method is suitable for producing individual items (often to a particular customer's requirements) but at a high cost. In such cases the designer, who could also be the manufacturer, would work closely with the customer to produce an item that meets an agreed specification. A high level of skill is required. Examples of products produced using

This method includes single items of furniture, a wedding cake or a ball gown. Larger quantities of items are produced using batch production. This method involves the same item being made repeatedly over a period of time, such as 1000 loaves of bread made in a few hours daily in a bakery.

The manufacturing system used can include elements of line and one-off production. Batches produced can be increased or decreased according to demand. As this method produces a lot of items, the individual unit cost starts to reduce when compared to one-off items.

Evidence of batch production can be seen in smaller industries where continuous production may prove to be costly or when the firm does not know what the demand for a particular product will be. The use of computer-controlled machinery and equipment is common, and this enables quick changes of computer programs

Manufacturing

between batches of different products or components.

Fig 10.2 Batch production orange truffles

The continuous production of standardised items over a long period of time is known as mass production or high-volume production.

This method makes use of dedicated machines with trained workers carrying out specific tasks as the manufactured item moves along an assembly line.

The use of such a system was first credited to Henry Ford at the beginning of the 20th century when production of his Model T Ford began. This method of production was quickly adapted and modified by other companies. It has evolved over the years but the appeal to factory owners remains the same: the manufacture of large quantities of a product at a lower cost.

To enable this lower unit cost, investment in machinery and automated production equipment is necessary, and these initial costs can be very high. Only if the sale of large

numbers of the item can be guaranteed can this be justified. Economies of scale are possible, including bulk buying of materials. Although a relatively low skill level is required to operate machinery, highly skilled labour is crucial for the design, programming, and management of the production lines and equipment.

Just-in-time manufacture

Just-in-time manufacture (JIT) is a method used by a lot of firms. The philosophy behind it is that the right part will be available in the right place on the production line at the right time. The implementation of such a system makes the manufacture of the product more efficient; however, in order for it to be effective, detailed production planning is necessary. The success of JIT production depends upon many carefully controlled systems including JIT delivery of parts to the factory.

The car manufacturer Nissan relies "on JIT systems and therefore the location of their site in the north east of England had to be carefully considered so that the delivery of parts from suppliers would not be delayed.

The late arrival of supplies would prevent the items arriving to the appropriate point of the production line at the set time and this would have a heavy financial effect on the company as the production line would have to be slowed down or, at worst, stopped.

Through the use of JIT delivery the manufacturing company becomes more financially smart as parts are no longer stockpiled onsite due to items arriving as they are needed, and therefore a quicker financial return is made on their investment as delivered parts are used immediately.

Processing

In the industrial situation the basic aim of the company is to turn raw materials into a product that a customer would like to buy. Raw materials are delivered to the factory and, after a specified number of processes have been carried out, a final product is manufactured that can then be packaged and delivered to a retail outlet. How the product is manufactured will depend upon the complexity of the item and the environment in which it is to be produced.



Fig 10.1 A one-off dress



Fig 10.3 Mass production

In-line production

In-line production is used where the products move continuously along the assembly line with processes being carried out or parts added in sequence. Such a system is used mainly for the mass production of items such as cars, dishwashers and televisions.

The items are progressively assembled as they flow along a production line. The process is repeated constantly during the working day with the assembly line only stopping in the event of a breakdown. Work carried out during the identified manufacturing stages could be done using a trained workforce, automation, or a combination of the two.

In-line production plants are very expensive to set up; however, as they are mainly used to produce huge quantities of items, the individual product cost is reduced a great deal compared to batch and one-off methods.



Fig 10.4 A production line used in cheese manufacturing

Automated production

Automated production is carried out using machines that have been pre-programmed to work within set parameters. The role of the operator in these instances is an observer who will check that the machine is performing as required.

Samples will be taken at identified intervals and tested. If any discrepancies are found the machine will be stopped, the fault will be corrected and then production continued.

In car assembly plants the car body shell arrives at a welding station on the assembly line. At that point a series of sensors detect the specific body type and robots then place and weld into position the appropriate body panels.



Fig 10.5 An assembly line

Continual flow production

Continual flow production is used to manufacture products that are going to be produced over a long period of time. Such methods are used when refining oil or in other chemical industries. Continual flow production plants usually make use of automated monitoring and control systems as part of the quality assurance process.

Repetitive Manufacturing

In repetitive manufacturing products remain unchanged over a long period of time and are not manufactured in individually defined lots.

Instead, a total quantity is produced over a certain time at a certain rate. This type of production will be used to produce food items such as chocolate bars or high demand drink products.

Cell production

A group of machines or a group of workers and machines that carry out tasks together in order to produce components or a complete product are known as production cells. People who work in this arrangement will be required to work as a team and may carry out several tasks in producing the final item. In the mass production of electrical goods, such as washing machines, Fig 10.6 Robots in action robot cells may be used to weld, assemble and spray particular parts.

Robotics

Computer-controlled devices known as robots are used in industry to carry out material lifting, handling and placing components. They are also used to carry out repetitive tasks that workers may find tedious or



Fig 10.6 Robots in action

operations that could be classed as hazardous such as working with corrosive liquids or processes that may cause fumes that may have an effect on workers health.

Continual flow production

Continual flow production is used to manufacture products that are going to be produced over a long period of time. Such methods are used when refining oil or in other chemical industries.

Industrial robots are built to copy human movements; they are expensive to produce but these costs reduce after continued, prolonged use. Robots offer many advantages to the workplace including repetition of tasks, greater accuracy in carrying out tasks avoiding the possibility of human error, reduction in labour costs, and they can work continuously. Robots are adaptable as they can be reprogrammed to carry out new tasks once an operation is completed.

The introduction of robots into the workplace may have had an effect on the number of workers employed but some human input is still necessary in order to carry out routine maintenance, quality control checks of work and for programming.



Fig 10.7 A robot used in industry

Bought-in parts and standardised parts

Production of complex items such as electrical goods and cars are not entirely carried out in one location.

Several industries may contribute to the production of a variety of parts and then these items are brought together as the final item is assembled. Parts such as motors, seals, glass doors and wheels that are needed in the production of a washing machine may be manufactured, to order, by another supplier.

Standard components and parts are used extensively. These are usually manufactured to comply with international standards for size and specification to ensure interchangeability and to enable repair and maintenance of products as required during their life. They are readily available from suppliers and include bolts and screws, electronic and electrical connectors, batteries, buttons and pop-fasteners, paper and ring binder mechanisms, cardboard, roof tiles and building blocks.

By using bought-in components and standard parts, the manufacturer can reduce the amount of processes that are needed on the production line and this will reduce the number of employees and the range of skills or expertise required from the workforce. It will be the responsibility of the suppliers to meet deadlines and to guarantee the quality of the part produced.

The effects of manufacturing on the properties of materials

Materials used during the manufacturing process must be carefully selected as certain materials will react differently in a variety of situations. Material properties must be considered when a product is at the planning stage. Materials may appear to be appropriate and, from an aesthetics point of view, fit the purpose. However, when in use they may prove to be brittle or wear out quickly. Similarly, during the manufacturing stages processes such as pressing or stamping may affect the structure of the material, and procedures such as annealing may be needed to return work-hardened materials back to their original state in order to avoid stress fractures during use.

Manufacturing, production and planning

Learning outcomes

By the end of this section you should have developed a knowledge and understanding of:

- Preparation and processing of materials
- Assembly stages during production
- Sequencing and timings of manufacturing stages
- Production planning
- Costing

Manufacturing in any company uses various resources including raw materials, people and processing equipment. There are relationships between resources, for example the most suitable process may depend upon the materials used, or the availability of a skilled workforce. For this reason manufacturing resources must be

Materials must be sourced to appropriate quality standards, in the right quantity and at the right time for production needs. Many materials and components can be bought pre-prepared, from electronic components ready bandoliered for use in automated printed circuit board population, to chopped fresh onions used in manufacturing ready meals.

Fig10.8 Custom bandoliered electronic components Using pre-prepared components can lead to savings in storage, handling, processing and other costs (for example, in the case of the considered in the design of manufactured products to optimise production efficiency. Resources of the appropriate quality and quantity must be available and at the appropriate time.

Time itself may be considered a resource when comparing alternative processes or sequences of manufacturing stages. onions, in hygiene measures and waste disposal).

It is important that manufacturers consider all potential savings when deciding whether to carry out material preparation in-house.

Whole processing steps may be eliminated by selecting specific materials, such as pre-coated sheet materials, or by processing materials prior to manufacture.



Fig 10.9 Component preparation: spraying chair parts



Fig 10.8 Custom bandoliered electronic components

Assembly stages during production

Manufacturing production stages typically include preparation, processing, assembly and packaging. The number of assembly stages required varies with the product and scale of production. Assembly may be simply mixing components. In the case of complex products, there may be many sub-assembly stages before the final product takes shape. An example is a car, where the engines are assembled in one factory and then transported.

The availability of computers has had a considerable effect on manufacturing production.

The development of PLCs and robotics, microchip technology and computer-controlled handling devices has increased the accuracy and flexibility

Monitoring, testing and tracking during production

Production systems must be monitored to ensure they are working as required and to avoid wasted production or breakdowns. Simple mechanical systems are physically checked regularly, but modern computer-controlled systems frequently have sensors and in-built checking systems.

CIM, PLCs, Robotics, automation and embedded systems in industrial appliances

CIM is the integration of the product development and manufacturing engineering functions through the use of IT, which has had a significant impact on manufacturing management in general.

Most of the manufacturing automation systems implemented today make use of computer technology. Although automation preceded computer technology, it is computer power that made automation flexible and more effective in applications other than mass production.

PLCs are computers designed specifically for of the manufacturing process. Computer integrated manufacturing systems have developed from these technologies, making manufacturing more efficient industrial use in process automation. They are built to operate in extreme temperatures, and to resist vibration, impact and electrical noise. PLCs allow multiple inputs and outputs through sensors and actuators of various types and were initially developed



Fig 10.13 A CNC woodworking machine with conveyor and monitor



Fig 10.14 A bottling plant

to allow rapid and economical modification of automated manufacturing systems, for example when a new model of car was introduced.

Since robotic systems were first introduced in the mid-twentieth century, their applications and versatility have increased dramatically. Most robots have many degrees of freedom. In manufacturing applications, they can be used for assembly work, processes such as painting and welding, and for material handling. More recent robots are equipped with sensory feedback.

Through vision and tactile sensing, they can check production quality and self-reset as necessary.

A key advantage of robots is that they can be used for repetitive, monotonous, mundane tasks that need precision. They can also be used in hazardous environments not suitable for human operators.

Many modern industrial appliances designed to carry out specific tasks are controlled by embedded systems in the form of pre-programmed microchips. These include control systems on freezing tunnels, and bottling lines. Their output functions may depend on inputs from operators or sensors, but they are limited.

Manufacturing methods

Learning outcomes

By the end of this section you should have developed a knowledge and understanding of:

- Common processes for working with materials - drilling, sawing, shaping, abrading
- Processes used to manufacture products from wood - laminating, bending, routing/profiling, turning
- Processes used to manufacture products from metal - milling, turning, casting, modifying characteristics using heat, pressing and stamping
- Processes used to manufacture products from plastic - compression moulding, injection moulding, vacuum forming, rotational moulding, extrusion and blow moulding
- Processes, materials and components used to manufacture products from differing materials
- Processes used in assembling and joining similar and dissimilar materials
- The design of simple jigs, presses and moulds - see Chapter 7 Engineering
- Joining methods using fittings, adhesives, heat and common joints

Common processes for working with materials

Drilling

Drilling can be carried out by machine or manually and is generally the best method of producing through or blind holes in a workpiece.

When manual operations are used a hand-powered drill is used to provide the action.

Portable cordless power drills are a popular tool today, with rechargeable batteries, and consequently few operations are now truly carried out using hand power.

The drill is probably one of the most widely used machining processes and most workshops contain at least one pillar drill or bench-mounted machine drill to provide power and accuracy.

Multi-head and multi-function drilling machines can be found in manufacturing industries.

Bench drills or pillar drills are found in most workshops. The work table can be moved up and down the vertical column and is clamped at the selected height.

The drill is normally located in a three-jaw chuck, which is rotated by the drive system. The chuck is moved up and down by a feed handle that drives the rotating spindle via a rack and pinion mechanism.

When drilling holes in a material a number of factors should be considered, including:

- Material being drilled
- Hole size
- Hole quality
- Rotation speed/feed speed required
- Depth of hole
- Through or blind hole
- Need for coolant
- Capacity of drilling machine



Fig 10.15 Typical bench-mounted drill

- Method of work holding: hand held, vice, clamped
- Orientation of drill (horizontal, vertical drilling, angled)
- Swarf control

Drill Ream Counterbore Countersink Holes can be drilled, but also reamed - a sizing process by which an already drilled hole is slightly enlarged to a desired size. They may also be counterbored or countersunk, which both involve the enlarging of one end of a hole to accommodate a bolt head or screw head so that it will be below or flush with the work surface.

For accuracy and safety, the drilling speed is important; for example, aluminium can be drilled at a faster speed than mild steel. Tables giving the correct drilling speeds can be found in many engineering reference books.

Twist drills are probably the most common drilling tools. They can be used on timber, metal, plastics and similar materials, although HSS (high speed steel) twist bits should be used for drilling metals. Twist drills are normally available in sizes 0.8 to 25 mm. They are designed for drilling relatively small holes.

Spur Point bits are also known as wood or dowel bits. The bit leaves a clean-sided hole. Spur point bits should only be used for drilling wood and are for relatively small sized holes.

Fig 10.19 Spur point bit

Flat wood bits are for power drill use only. The centre point locates the bit and the flat steel on either side cuts away the wood. These bits can be used to drill fairly large holes. Sizes range between 8 and 32 mm.

Hole saws have interchangeable toothed cutting rings and can be used to cut small or large holes in thin sheet metals as well as wood or plastic. They are best used in a power drill at low speed as the blade saws its way through the material.

Forstner bits are used to form holes with a flat bottom, such as for kitchen cupboard hinges.

These are best used in a pillar drill. If used freehand, the positioning is difficult to control as there is only a very small central point.

Wood auger bits are ideal when drilling deep holes in wood or thick man made boards.

Generally, auger bits should only be used in a hand brace but versions are available for portable power drills. The bit will cut a clean and deep hole.

Safety procedures when drilling

Drilling takes place in many different practical situations. In some, such as using a battery powered hand drill to cut a hole in a car body panel, the work is large enough and has enough mass to stay still while being worked on. When a smaller workpiece is to be drilled however, it must be held securely - both to assure accurate placement of the hole, and to prevent it binding to the drill bit and spinning around with the rotation of the drill. This can obviously be a safety hazard, especially if the work is a piece of sheet metal with sharp edges.

There are several methods of work holding available, from clamping the work in a vice to be drilled with a hand drill, to fixing it in a machine vice attached to the table of a pillar drill, or clamping it to the bed or a work bench with G-cramps if the work is larger. As with any process of this nature, appropriate guarding and PPE (personal protective equipment) should be used.



Fig 10.26 Frame saws



Fig 10.18 Twist drill



Fig 10.19 Spur point bit



Fig 10.20 Flat wood bit



Fig 10.21 Hole saw



Fig 10.22 Forstner bit



Fig 10.23 Wood auger bit

Sawing

A wide range of saws are available, all varying in size and with different sized teeth that are set according to the material to be cut. Saws tend to be divided into groups known as back saws, frame saws and hand saws.

- Back saws - tenon saws are used for general cutting out in wood; dovetail saws are a smaller version of the tenon saw used for finer, more accurate work. The back of the saw limits the depth of the cut
- Frame saws - coping saws are used for cutting curves in thin sectioned wood; hacksaw are used for cutting out metal; junior hacksaws are used to cut thin sections of metal and tubes; piercing saws make use of a fine blade and are used for delicate work including cutting out sections by silversmiths or jewellers
- Hand saws - cross cut saws are used on large sections of wood when cutting across the grain; panel saws are used for cutting out panels in large sheets of wood; rip saws are used to cut or rip down the grain on large sections of wood



Fig 10.25 Tenon saw (top), dovetail saw (bottom)



Fig 10.27

The width of the cut that the saw makes is known as the 'kerf' and this must be wider than the blade itself to avoid it sticking when the operation is carried out. To create the necessary gap the teeth are 'set' by turning them to the left or right. Smaller saw blades tend to be set in a waveform.

A general rule to ensure successful cutting of a material, avoiding jumping or sticking, is that at least three teeth should be in contact with the material at any one time. The number of teeth per inch has to be taken into consideration when selecting a saw: finer toothed saws tend to be used for metals. With a magnifying glass, look closely at the shape and 'set' of the teeth of a range of saw blades. Look at both hand-held saws and machine saws. Can you see a difference between those designed to cut metals and those designed to cut wood.

Machine saws

Scroll Saws are fixed saws that are useful for cutting intricate shapes on thin sheet materials.

Jig saws are portable power tools that can be used to cut around curved shapes in sheet material. The blade reciprocates and cuts through the wood.

Power Hacksaws are also available for cutting through bars of metal and plastics.

Bandsaws are used to cut curves and other shapes in wood, metal and plastics. Intricate shapes can be cut with narrow blades.



Fig 10.29 Jig



Fig 10.31 Circular saw

Circular Saws are used for cutting large sheets and straight edges.

It is unlikely that you will use a bandsaw or circular saw in the school workshop. They are however used by trained teachers and technicians to cut and prepare wood, and are widely used in the manufacturing industry. As with any machine, training, appropriate guarding, extraction and PPE should be used.

Snips and shears can be used to cut thin metal sheet and soft plastics. These may be hand held or bench mounted. When bench mounted the lever greatly increases the force that can be applied.

Fig 10.32 Tin snips



Fig 10.30 Bandsaw

Shaping

Shaping of materials can be carried out with tools such as files, rasps and surforms.

Files are available in a variety of shapes, length and grade of cut. The shape of file - flat, round, half round, three square and knife - can be selected according to the profile of material being cut. A swiss or needle file is a smaller version of the engineering file and is used for more delicate work. The selection of cut will depend upon the amount of material to be removed or the surface finish required. Rough cut and bastard cut are used to remove material quickly. The use of these files is followed by a second cut file and finally smooth or dead smooth cut files could be used to produce a surface ready for finishing with emery cloth.

Double cut

Filing is normally carried out by pushing the length of the work, which is called cross filing; surface finishing is done by draw filing.

Rasps are similar to files but they have coarser teeth and are more suitable for use on wood.

Surform tools are available in a range of shapes and sizes with replaceable blades. Due to surforms having a range of blades all with different cutting edges they can be used on a several material groups including hardwoods, softwoods, soft metals, nylon, acrylic and plastic laminates.

Manufacturing

Abrading

Material can be removed from woods, metals and plastics by the use of abrasives. Disc and belt sanders are commonly used. Abrasion is the action of wearing away a surface by friction, and can be a means of shaping a solid form.

An abrasive is any substance that wears down a surface by rubbing against it. Abrasives are available in many forms, including powders, compounds, papers, wheels or disks, brushes, belts, and more.

Grinding of metals can be carried out using a disc or angle grinder, surface grinder or off-hand grinder. All the grinders make use of discs that have been made from abrasive grit that has been bonded together. The size of the abrasive grit used determines the grade or coarseness of the discs.

Glasspaper is an abrasive sheet that can be used manually to smooth wooden surfaces. Emery cloth can be used on metals; silicon carbide paper can be used on plastics. Aluminium oxide is another grit commonly used in abrasive sheets.

Disc sanding machines use abrasive sheets mounted on a backing disc.

Polishing or buffing machines use abrasive compounds such as tripoli applied to cloth mops.



Fig 10.33 Bench shears/guillotine/notcher



Fig 10.32 Tin snips

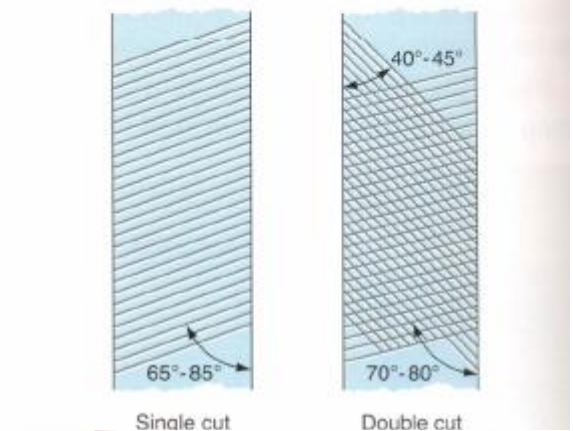
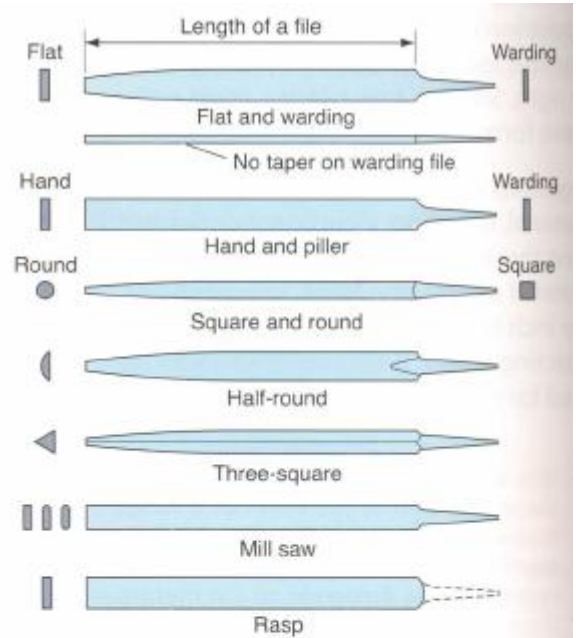


Fig 10.34



Fig 10.36 Surforms



Fig 10.37 A bench mounted grinding machine



Fig 10.38 A disc sander

NEW AND SMART MATERIALS

There is a growing group of new materials which do not fit comfortably into the normal categories as they perform differently to their close relatives. Here are just a few of the new and smart materials available.

SMART WIRE

A shape memory alloy (SMA) which is made in wire form is readily available to schools. By passing a small electric current through the wire it will shrink in length. When the current stops it will return to its original size. One application of this is the ability to operate lightweight mechanisms. Smart springs are also available.

LENTICULAR POLYPROPYLENE SHEET

An unusual characteristic of this sheet is that it appears much thicker than it is and objects placed on top appear to sink under the surface.

NICHROME WIRE

A resistance wire which heats up when electric current is passed through it. Can be used for cutting expanded polystyrene or used with thermocolour sheet.

THERMOCOLOUR SHEET

A self-adhesive sheet material which has been printed with liquid crystal 'ink'. Colour changes occur above 2.7 degrees. When used with nichrome wire, dramatic effects are possible on the 'screen'. Plenty of scope when designing childrens toys and games, additions to jewellery, temperature indicators on products which heat up etc.

SMART COLOURS

A range of pigments which react to changes in temperature or glow in the dark. Simply mixed with acrylic paint they can make your designs really exciting.



dark.

POLYMORPH



A tough polymer (plastic) which softens and becomes easy to mould at just 62 degrees. This means that it can be softened with hot water or a hairdryer and moulded into shape by hand. It hardens to a very stiff plastic. It can be used, for example, for tool handles.

SMART GREASE

A very sticky and viscous gel which can be used to control the movement of mechanisms. For example, on a rubber band-driven toy it can regulate the speed at which the potential energy is released.

CONDUCTIVE POLYMERS (PLASTICS)

Imagine the design possibilities if you can use plastic products which can conduct electricity. These new materials are available to engineers who are starting to see the potential for their uses.