Tools and techniques

Whether the product is being designed and made by you in school or by an international company, the first step in processing a resistant material is to measure and mark it up accurately.

There are a number of processes for shaping resistant materials, including wasting, deforming, fabricating and reforming.

1. Measuring and marking out
2. Shaping by wasting
3. Shaping by deforming: woods and metals
4. Shaping by deforming: plastics
5. Shaping by fabrication
6. Shaping by reforming
7. Information and communication technology (ICT)

Measuring and marking out

Whether you are measuring wood, metal or plastics, you will always use the same measuring tools:

- a steel rule for measuring lengths
- outside calipers for measuring round rods
- inside calipers for measuring holes

Always measure from a baseline or datum surface.

- A datum surface is flat and straight. A lot of tasks require two datum surfaces at right angles to each other. Smoothing off will turn a rough, newly-sawn edge into a datum surface.
- To create a datum surface on wood, use a plane.
- To create a datum surface on metal and plastics, use a flat file or hand file.
- Use a steel rule or straight edge to check that a surface is flat. Then check that a surface is at right angles to another surface with a try square.

Marking out

'Marking out' means the transfer of shapes and lines onto the material, as guides for cutting, bending or shaping them. Accurate marking out is essential if the different parts of the product are to fit together properly.

The following table gives the right marking-out tools for different materials

<table>
<thead>
<tr>
<th>Process</th>
<th>Wood</th>
<th>Metal</th>
<th>Plastics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lines</td>
<td>Pencil</td>
<td>Scriber</td>
<td>Felt-tip pen</td>
</tr>
</tbody>
</table>

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61 **Shaping**: is any process which defines or moulds or changes the shape of an object.
62 **Wasting**: achieving the shape you want by removing the bits you don’t want
63 **Deforming**: changing an object’s shape without losing any material.
64 **Fabricating**: putting together from separate components.
65 **Reforming**: is changing and object’s shape by means of changing its state – usually from solid to liquid, then back to the solid.
66 **Baseline**: horizontal line marking a point of origin from which all vertical measures are made.
67 **Datum surface**: common horizontal surface from which all vertical measures are taken.
Whenever you are cutting and shaping resistant materials, undertake the following tasks in order:

- Mark out where the material should be cut.
- Cut the material, leaving some spare material for finishing to a smooth surface.
- Smooth the material to the lines marked out.
- Cut any joints.
- Final smooth off.
- Apply a suitable finish.

### Shaping by wasting

Shaping by wasting simply means cutting away material to leave the desired shape. It gets its name because the material which is removed, such as shavings or sawdust, is usually thrown away. Shaping by wasting can be done on any type of material.

The table below illustrates the methods of shaping by wasting which can be done by hand:

<table>
<thead>
<tr>
<th>Process</th>
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<tbody>
<tr>
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<td>Tenon saw (dovetail saw for fine work)</td>
<td>Hacksaw (junior hacksaw for small work)</td>
<td>Hacksaw (junior hacksaw for small work)</td>
</tr>
<tr>
<td>Cutting curved lines</td>
<td>Coping saw (fret saw for fine work)</td>
<td>Abra saw (piercing saw for fine work). Tin snips can be used on thin sheet metal</td>
<td>Abra saw (piercing saw for fine work). A coping saw can also be used</td>
</tr>
<tr>
<td>Trimming cut edges to a straight line</td>
<td>Jack plane or smoothing plane</td>
<td>Flat or hand file</td>
<td>Flat or hand file</td>
</tr>
<tr>
<td>Trimming cut edges to a curved line</td>
<td>Spokeshave or rasp</td>
<td>Round or half round file</td>
<td>Round or half round file</td>
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<tr>
<td>Cutting grooves and slots</td>
<td>Tenon saw to cut sides, then wood chisel or coping saw</td>
<td>Drill holes at ends, then use abra saw</td>
<td>Drill holes at ends, then use abra saw or piercing saw</td>
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### Machine wasting

Almost any wasting technique can be mechanized. The table lists the common machines used for shaping by wasting. For health and safety reasons, some of these processes should only be done by a teacher.

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<td>---------------------------------</td>
<td>-------------------------------------------</td>
<td>--------------------------------------------</td>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>Cutting curved lines</td>
<td>Jig saw, either fixed or portable, with suitable blade. Band saw (teachers only)</td>
<td>Bench mounted Jig saw (with suitable blade). Band saw (teachers only)</td>
<td>Jig saw, either fixed or portable, with suitable blade. Band saw (teachers only)</td>
</tr>
<tr>
<td>Making holes</td>
<td>Drilling machine and suitable drill bits</td>
<td>Drilling machine and twist drills</td>
<td>Drilling machine and twist drills</td>
</tr>
<tr>
<td>Creating round shapes of different diameters</td>
<td>Wood turning lathe</td>
<td>Metal turning lathe</td>
<td>Metal turning lathe</td>
</tr>
<tr>
<td>Cutting grooves and slots</td>
<td>Hand router or Computer Numerical Control (CNC) milling machine</td>
<td>Vertical milling machine or CNC milling machine</td>
<td>Vertical milling machine or CNC milling machine</td>
</tr>
</tbody>
</table>

Shaping machines may also be controlled by computers - an example of **computer-aided manufacturing**\(^{68}\). Computer control means the work is more accurate and the task can be more frequently and quickly repeated without any deviation from the standard.

**Shaping by deforming: woods and metals**

Deforming is a method of shaping materials by either bending in a straight line or by creating a bowl or dish shape. The key methods for deforming materials in a straight line or in two dimensions are described below:

**Bending**

Metals can be bent in a **vice** or in **folding bars**. Thin metal may be bent whilst cold, while thicker metal may need heating or **annealing**\(^{69}\). Larger pieces of metal may also need to be heated first.

The material is marked where it is to be bent, and clamped to the line in the vice or folding bars. To prevent damaging the material as you hit it with the mallet, place a piece of wood next to it and hit that instead.

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68 **Computer-aided manufacturing**: used of computers to assist in any of the phases of manufacturing a product. CAM for short.

69 **Annealing**: heating a metal to toughen it so it will not break when bent. Some metals like copper will go red with hot. With those that don’t glow like aluminium, put soap on them first, it will be hot enough when the soap goes black.
Laminating
Wood is usually bent by laminating. This is done by cutting thin strips of wood, putting glue on the strips and clamping them into a mould\(^70\).

Three-dimensional deforming

Hollowing
is a way of deforming thin sheet metal to produce a bowl shape. The metal is first annealed\(^71\) then cooled in cold water. Next it is placed on a leather sand bag and shaped using a bossing mallet. Finally it is placed on a hollowed wooden block and shaped it with a blocking hammer.

Press moulding
Press moulding can be used to force sheet metal into 3D shapes. The metal is placed between two moulds which are then squeezed together until the metal takes on the shape of the moulds.

Wood will not deform in three dimensions.

Shaping by deforming: plastics

Bending
Thermoplastics cannot be bent when cold. They are bent using a strip heater or line bender which will heat the plastic in a straight line, so it can be bent by hand, as shown below.

Press or compression moulding
A mould is made in two halves - top and bottom. Sheet plastic is placed between the two halves, which are then heated and pressure applied. The heat from the mould causes a chemical reaction in the plastic which enables it to assume the new shape. Press moulding is used to make electrical fittings, handles, and many other products. It can only be used with thermosetting plastics\(^72\) such as phenol and melamine formaldehyde.

\(^{70}\) Mould: a hollow form into which a softened material is placed. The material hardens and the mould is the removed to produce a product of the desired shape.

\(^{71}\) Annealed: (of metals) heated to make it together.

\(^{72}\) Thermosetting plastics: type of plastic that can only be melted once, and then become very hard.
Blow moulding is used to shape plastics - mainly for making bottles, plastic buckets and similar shapes. A tube of softened plastic called a parison is extruded\(^\text{73}\) into a mould, which then clamps one end closed. Air is then blown under pressure into the interior of the parison, which expands to fill the mould and create the desired shape. PVC, polythene and polypropylene are commonly used in blow-moulding.

**Vacuum forming**

This process uses a wooden mould or form. A sheet of thermoplastic is heated, then shaped by creating a vacuum underneath it. Air pressure then forces the plastic over the mould. Vacuum forming is used to for food and confectionary packaging, trays, shop fittings and baths. Suitable thermoplastics include acrylic, polystyrene and PVC.

**Shaping by fabrication**

Fabrication involves joining separate pieces of material by cutting joints or by using other components, such as screws, nails and adhesives, or by using heat processes such as soldering or welding. Fabrication processes can be either permanent or temporary. Temporary fabrications are designed to be easily taken apart.

The chart below gives an outline of fabrication processes and when they might be used.

<table>
<thead>
<tr>
<th>Process</th>
<th>Wood</th>
<th>Metal</th>
<th>Plastics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joints (permanent)</td>
<td>Wide range of different joints, used in conjunction with suitable adhesives</td>
<td>Usually only simple butt joints used, joined by welding or soldering</td>
<td>Usually only simple butt joints used, joined by glues or heat gun</td>
</tr>
<tr>
<td>Nails, pins (permanent)</td>
<td>Use nails if appearance is not important. Use panel pins for fixing thin plywood and MDF</td>
<td>Not used</td>
<td>Not used</td>
</tr>
<tr>
<td>Threaded fastenings (temporary)</td>
<td>Wood screws of various types used</td>
<td>Machine screws, self-tapping screws and nuts and bolts often used</td>
<td>Machine screws, self-tapping screws and nuts and bolts can be used</td>
</tr>
<tr>
<td>Heat processes</td>
<td>Not used</td>
<td>Soldering, brazing and welding used</td>
<td>Some plastics can be welded using a heat</td>
</tr>
</tbody>
</table>

\(^{73}\) Extruded: shaped by being forced through an opening.
<table>
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<tr>
<th>Process</th>
<th>Wood</th>
<th>Metal</th>
<th>Plastics</th>
</tr>
</thead>
<tbody>
<tr>
<td>(permanent)</td>
<td></td>
<td>on most metals</td>
<td>gun which melts the plastic together</td>
</tr>
<tr>
<td>Rivets</td>
<td>Not used</td>
<td>A useful way of joining: <strong>pop rivets</strong> mainly used</td>
<td>Rivets can be used to join plastics, but not usually used</td>
</tr>
<tr>
<td>(permanent)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adhesives</td>
<td>Usually used with wood joints, but not always</td>
<td>Some limited use, more in industry than in schools</td>
<td>Plastics often joined with adhesives which melt and fuse the material</td>
</tr>
<tr>
<td>(permanent)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Shaping by reforming**

Reforming is a method of shaping materials which changes their overall appearance by first melting or softening them into a paste, then hardening them. Reforming methods include **casting**, **extrusion** and **injection moulding**.

- **Casting**: Most metals can be cast, but in school usually only aluminium is used.  
  Step one: Create the required shape in a soft material - usually wood. This is called a pattern.  
  Step two: Make a mould by placing the pattern in special casting sand inside a moulding box or flask. The sand is made to stick together using water or oil.  
  Step three: The pattern is removed and metal poured into the cavity.

- **Die casting** uses a metal mould which can be very detailed. The mould is made in two parts to allow the casting to be removed. Die casting is a very important industrial process used for many different types of products.

- **Extrusion** is used to produce long, but fairly thin products such as pipes or curtain tracks. Both plastics and metal can be extruded. The material is forced through a die, which contains a hole which is the same shape as the required product.

- **Injection moulding** is a similar process to die casting. A metal mould is used and softened or molten plastic is forced into the mould by pressure from a screw thread or pneumatic plunger. The mould is made in two parts to allow the moulding to be removed. Polythene, polystyrene, polypropylene and nylon are the plastics most often used in injection moulding, which is used extensively in industry.
Information and communication technology (ICT)

ICT can help with designing resistant materials products in many ways:

- Drawings, graphics and diagrams can be produced and edited using graphics or design software.
- Written information about designs can be recorded and edited using word processing software.
- Writing and drawings can be combined using desk-top publishing (DTP) software.
- Pictures of existing products can be scanned and used in graphics, photo-editing or DTP software.
- Database packages can be used to record and analyze survey data.
- Spreadsheet software can be used to make Gantt or other planning charts, to produce graphs and charts, and to help with costing D&T projects.

ICT can help with the making of products in the following ways:

- Shapes printed onto card can be used for templates.
- Text printed out can be glued onto sheet material and cut out.
- Machines for cutting card and self-adhesive vinyl sheet can be used to cut letters or shapes. Complicated shapes can be cut more easily by machine than by hand.
- Computer-controlled lathes can make a number of identical turned parts.
- Computer-controlled milling machines can cut out shapes more easily than by hand, especially recesses in materials. Complicated shapes can be cut more easily than by hand.
- Parts which have fine detail, or need to have accurately fitting parts, can be made more accurately than by hand or manual machine methods.

Industrial design and production

There are four main types of industrial production - one-off, batch, mass and continuous flow production - which have progressively larger scales of operation. ICT is now important in virtually every type of commercial design and production, with different types of computer-control of design and making processes grouped together as CAD\textsuperscript{74} and CAM\textsuperscript{75}.

The different production methods may have different design requirements, but most commercial designers have three roles: a functional\textsuperscript{76} role, an aesthetic\textsuperscript{77} role and an

\textsuperscript{74} CAD: stands for Computer-aided design – The use of computers to assist in any of the phases of product design.

\textsuperscript{75} CAM: stands for Computer-aided manufacturing - The use of computers to assist in any of the phases of manufacturing a product.

\textsuperscript{76} Functional: relating to the performance of a product – its ‘fitness for purpose’
organizational role. Designers need to be aware of the standards and conventions which regulate industrial design practices.

1. **Industrial production methods**
2. **ICT in industry**
3. **Industrial design**
4. **Laws and standards**

### Industrial production methods

There are four main types of industrial production methods:

- **One-off production** is when only one product is made at a time. As every product is different, one-off production is labour intensive. Products may be made by hand or a combination of hand and machine methods.

- **Batch production** is when a small quantity of identical products are made - from two up to about 100. Batch production may also use a lot of labour, but jigs and templates are used to aid production. Batches of the product can be made as often as required. Often the machines can be easily changed to produce a batch of a different product.

- **Mass or repetitive flow** production is when hundreds of identical products are made, usually on a production line. Mass production often involves the assembly of a number of sub-assemblies of individual components. Some parts may be bought from other companies. There is usually some automation of tasks (eg by using **Computer Numerical Control** machines) and this enables a smaller number of workers to output more products.

- **Continuous flow** production is when many thousands of copies of identical products are made. The difference between this and mass production is that the production line is kept running 24 hours a day, seven days a week to maximise production and eliminate the extra costs of starting and stopping the production process. The process is highly automated and few workers are required.

### ICT in industry

Computer-aided design and making are nowadays commonplace in industry. ICT is most often used in mass production, as computer control makes it possible to produce many identical items very quickly. But ICT is also useful in small batch and even one-off work, as computer control also enables complicated shapes to be produced more accurately than by hand.

The box summarises the many roles of ICT in industry:

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77 **Aesthetic**: related to shape, style, colour, pattern and other aspects of a product’s visual appeal.

78 **Computer Numerical Control (CNC)**: the use of computers to control cutting and shaping machines.
• Data can be stored electronically and retrieved easily.
• Designs can be modelled on-screen and viewed from any angle.
• Reaction to outside forces, such as wind flow and pressure can be modelled.
• Designs can be quickly altered.
• "Zoom" facilities can allow for the whole product or one detail to be easily seen.
• Libraries of standard components can be stored electronically and integrated into new designs.
• Control sequences can be simulated before working on the actual material.
• CNC (Computer Numerical Control) manufacturing is usually more accurate.

You need to know and understand a number of terms used to describe aspects of ICT in design and production. They are:

- **CAD** - Computer-aided design
- **CAM** - Computer-aided manufacturing
- **CIM** - Computer-integrated manufacturing
- **FMS** - Flexible manufacturing systems
- **CNC** - Computer numerical control
- **PDM** - Product data management
- **CADMAT** - Computer-aided design, manufacturing and testing

### Advantages and disadvantages of using CAD:

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
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<tbody>
<tr>
<td>- can be more accurate than hand-drawn designs –</td>
<td>- the software itself is expensive so initial costs are high</td>
</tr>
<tr>
<td>- It reduces human error.</td>
<td>- staff need to be trained how to use the software, which also adds to costs</td>
</tr>
<tr>
<td>- You can save and edit ideas, which makes it easier and cheaper to modify your design as you go along</td>
<td>- requires a PC</td>
</tr>
<tr>
<td>- you can modify existing ideas, which saves time</td>
<td></td>
</tr>
</tbody>
</table>

### Two examples of CAM

- A design machined by a computer numeric control (CNC) miller, which removes all the unwanted copper from the board.
- A design layout printed on to acetate and transferred to a copper-clad board using the photo transfer method. The unwanted copper is removed using acid.

### Advantages and disadvantages of using CAM:

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<td>- in large-scale production, the results are consistent (always the same)</td>
<td>- the software itself is expensive so initial costs are high</td>
</tr>
<tr>
<td>- enables very high accuracy levels in large-scale production</td>
<td>- can be slower than traditional methods for one-off or low-volume production</td>
</tr>
<tr>
<td>- usually speeds up production of low-volume products</td>
<td>- staff need to be trained how to use the software and machinery, which adds to costs</td>
</tr>
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<td></td>
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