ENGINEERING IN MINIATURE

WHAT YOU WILL LEARN

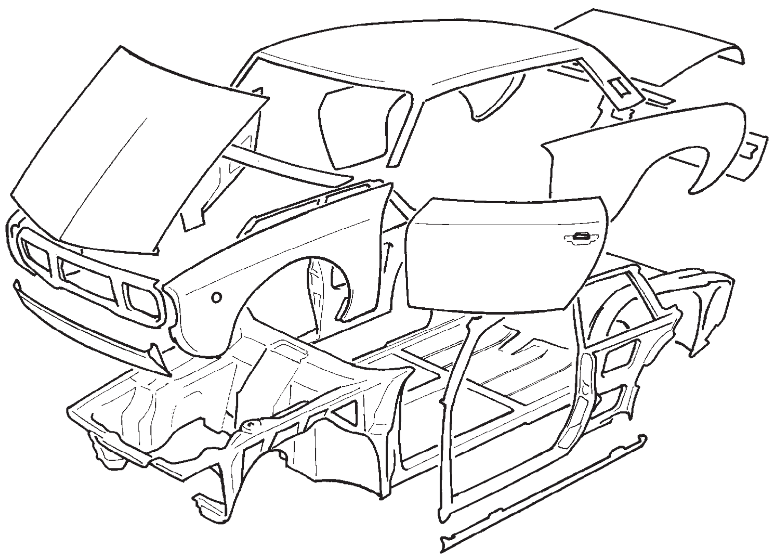
After completing this project, you should understand:

- The importance of metal press work as a means of making things.
- How to mark out (and cut out) simple sheet metal developments.
- How a two-part press tool works.
- How to calculate the size of pulleys or gears needed for a motorised drive.
- The importance of bearings.

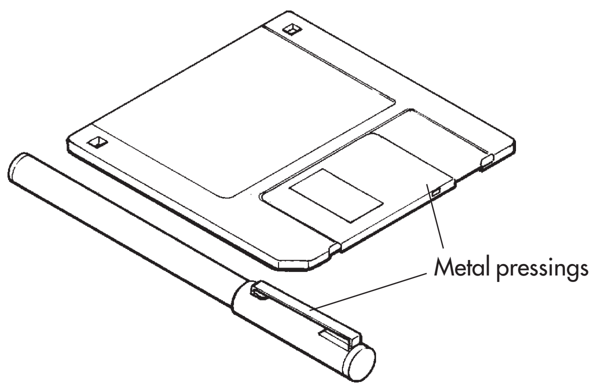
After completing this project, you should be able to:

- Work to a design brief and write a specification.
- Recognise design constraints when designing.
- Design and make pressed metal shapes.
- Make something that requires the assembly of several parts.

Pressing sheet metal into shape (forming) is one of the most important methods of making products - or parts for them. The modern car is a good example of how sheet metal is formed into complex shapes to make both the body panels and a strong framework. Part of this framework forms a 'safety cage' designed to resist crushing if there is an accident. It is made entirely from thin sheet steel pressed into shape.



The parts of many 'hi-tech' products are also made from steel sheet that is cut and pressed into shape. Examples include the cover plate on a floppy disk, pen clips, and many components in computer disc drives, Walkmen, etc.



NOTE

Opportunity for product analysis and disassembly.

Sheet metal is produced by rolling down thicker sections. It can be obtained in a variety of materials, thicknesses and conditions of hardness. Examples of sheet metals include:

Copper,	*lead,*
brass,	*aluminium,*
steel,	*tin-plated steel ('tinplate'),*
silver,	*pre-coated aluminium.*

NOTE

0.5mm aluminium with a polymer coating is now available from TEP. Pre-coated material is now used widely in manufacturing white goods to avoid the need for painting after manufacturing. A sample is enclosed with this book.

Aluminium and tinplate are found commonly in schools. They are relatively cheap and easily cut. Aluminium is available in large sheets (e.g., 2' × 4') and in different gauges such as: 0.2 mm, 0.5 mm, 0.75 mm, 1.0 mm. Each gauge can be obtained in one of three conditions: 'soft' 'half-hard' 'hard'.

The soft condition means the aluminium can be folded and bent very easily; in its hard condition, it is much more resistant to bending and is quite 'springy'. Sheet in the half-hard condition is the one normally used.

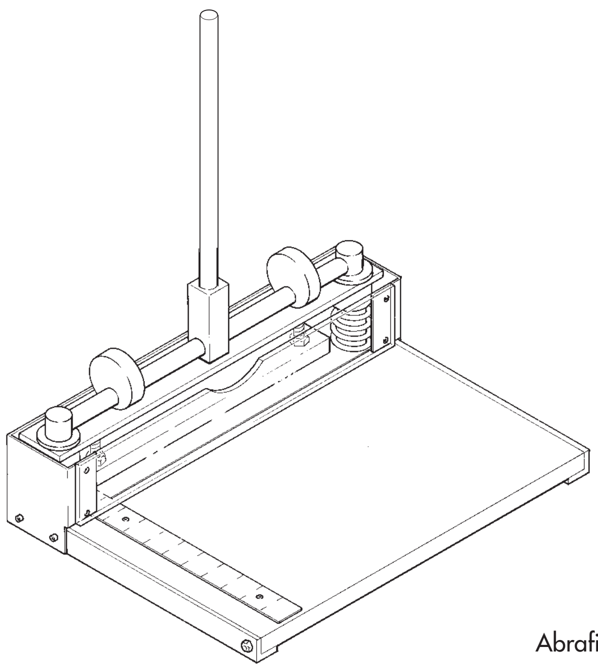
The different conditions are produced by a combination of heat treatment and rolling. The hard condition occurs from rolling which leaves the material strain hardened.

NOTE

See Study File 6 (Processing and forming materials)

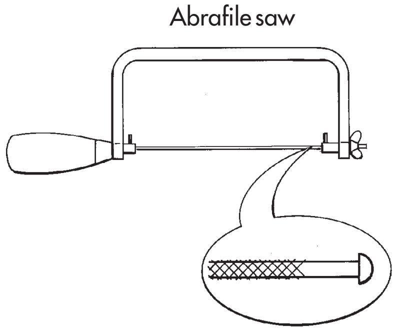
CUTTING, FOLDING AND PRESSING SHEET METAL

Sheet material is normally cut on a guillotine if possible. This produces a good straight edge without distortion.

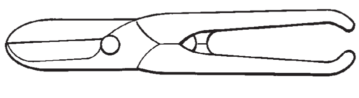


NOTE

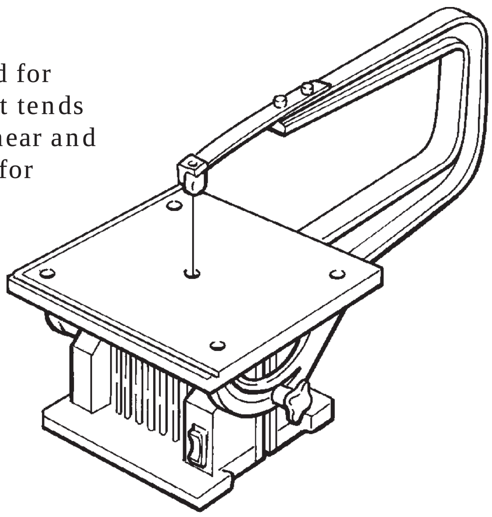
TEP guillotine is capable of cutting up to 1mm guage aluminium sheet or PCB material as well as plastic up to 2mm thick.



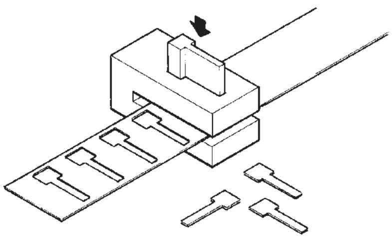
A PCB guillotine, shears or a saw can be used for cutting thin gauge aluminium sheet. Shears tend to distort the edge as they cut, so that after cutting the sheet needs flattening.



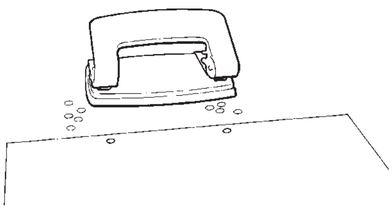
A vibrosaw can be used for cutting sheet metal but tends to be slow. Both the shear and saw methods are used for cutting round curves.



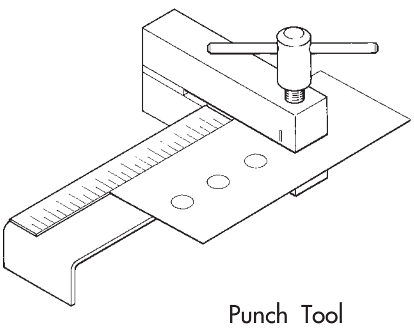
In industry, shapes are stamped out of sheet metal using a two-part stamping tool.



The hole punch used for stamping holes in paper for ring binders is an example of a two part tool. It stamps out discs of paper, although its main purpose is to make the holes!

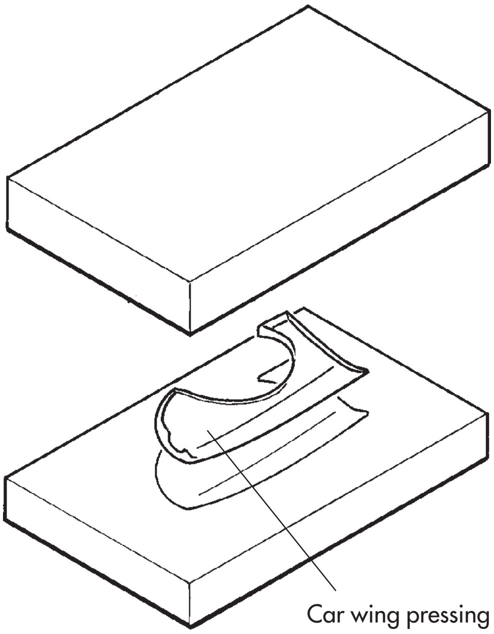


A strong paper punch can punch discs from sheet metal. The TEP punch tool offers an effective and accurate method of punching 4mm holes in sheet metal or plastic.



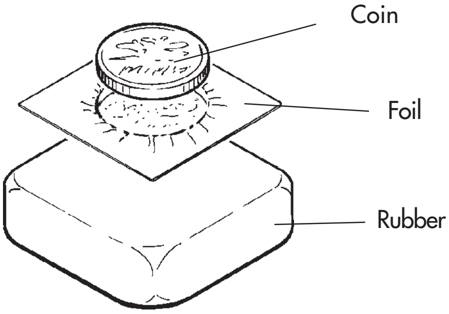
Punch Tool

There are many ways of forming sheet metal. A common way is to use a two-part forming tool one half of which is a mirror image of the other. Car body pressings are made using this type of tool.

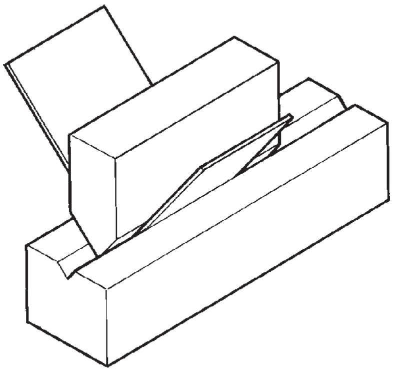


Another method of forming is to use a one-part metal tool like a shallow jelly mould and to press the metal into it using a special rubber block.

You can show this by pressing aluminium foil between a small coin and a pencil rubber.

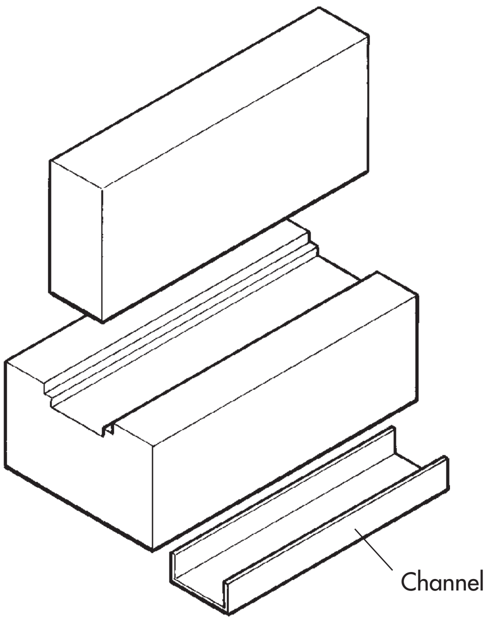


Often, sheet metal needs to be bent or folded along a line. This can be done using sheet metal folding equipment or a press tool. The illustrations show two press tools for folding metal.



In the first example the sheet is trapped between a 'V' section former and a 'V' section groove. (Sometimes the groove is replaced by a special rubber strip.) The angle of the bend given to the sheet depends on how hard the two parts of the tool are forced together. The pressure to make the tool work can be applied either in a flypress or in a metalworking vice.

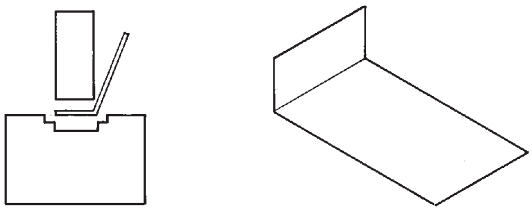
The second press tool is designed for several operations. If a strip of aluminium is placed along its length and the top press bar forced down, the strip folds up at the sides to create a channel.

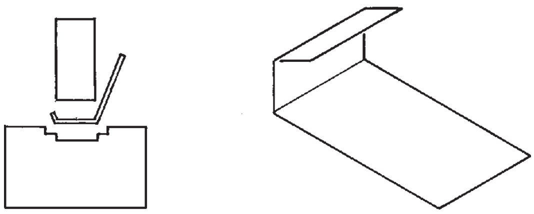


NOTE

The TEP's 'universal' press tool comprises two extruded aluminium sections with locating pins. It will produce channel sections as shown or near 90° bends. It works very effectively with TEPs pre-coated metal.

Because of the strain hardening along the bends and the shape of the channel, the strip of metal is now much stiffer than it was originally. To bend one end of a larger sheet, place that end in the press tool. Depending upon how the sheet is placed, the result is either a plain bend or a bend with a lip (which provides more stiffness).

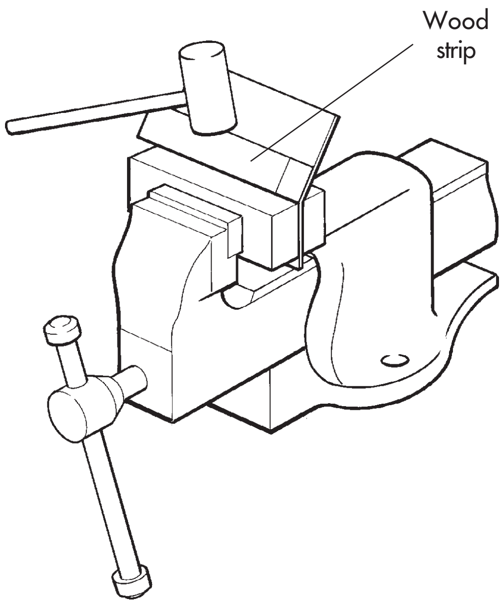




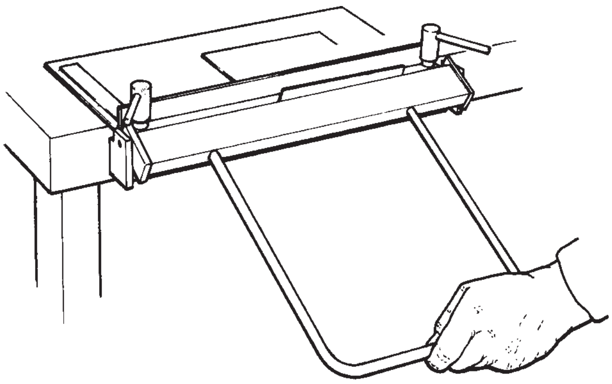
The angle of the bend depends on the clearance between the press bar and the bottom of the tool. The greater the clearance, the less the angle. If the clearance is fixed, the angle of bend depends on the gauge of the material being formed. If an angle of 90° is required and the press tool provides less than this, the bend can be increased by tapping with a mallet as shown.

NOTE

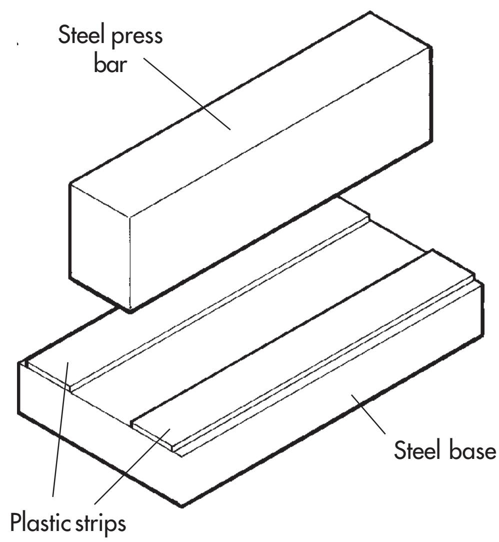
See Study File 6 (Processing and forming materials)



The TEP folding tool provides a more controllable and accurate method of bending sheet metal than folding with wooden strips in a vice.



The second type of press tool described can be purchased quite cheaply or a version of it can be made from scrap materials. The illustration shows how a simple press tool for aluminium is made from an off cut of a steel bar and strips of plastic bonded with double-side sellotape. (Note, clean all surfaces with a solvent to ensure good bonding.)



DESIGNING AND MAKING A MOTOR-POWERED PIPELINE 'PIG'

YOUR TASK:

A firm which lays electrical cables through buried plastic pipes requires a small battery operated trolley to carry a lightweight cord through pipes up to 50 m long. Once through the pipe, this cord is used to pull lengths of cable through. Devices that run in pipes to clean, repair or pull cables through are called pipeline pigs. At any one time in a large town or city there are hundreds of different pipeline pigs running under ground!

The piping is 150 mm in diameter and lies straight in the ground between inspection chambers. In some pipes there may be an incline of 10% over this length. Tests show that the 'drag' of 50 metres of cord equals a maximum force of 0.5 N retarding the trolley's movement. (1 N is roughly the weight of an apple.)

You are asked to design and make a trolley to act as a 'pig.' As a bonus, the firm would like to give 'pigs' away to clients to advertise their services. The product should therefore be cheap to manufacture and look attractive. The pig is to be manufactured from metal pressings.

NOTE

The term 'pipeline pig' concerns a wide range of self-propelled devices for inspecting and maintaining buried pipes. The Patent Office has a major category of inventions relating to these devices.

DESIGN BRIEF

DESCRIBING YOUR TASK

DESIGN SPECIFICATION

First, you need to draw up a specification for your 'pig'. A specification is a more detailed description of what a product will be like, what it will do and who will use it.

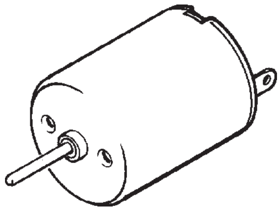
Here are some questions to help you produce your 'pig' specification:

- *What size should the pig be?*
- *What will power the pig?*
- *What does the pig have to carry?*
- *How fast does the pig have to travel?*
- *Is the pig likely to be handled roughly?*
- *Will the inner surface of the pipe always be dry?*
- *What should the pig cost?*
- *If the pig is given away to advertise the firm, how will this affect its design?*

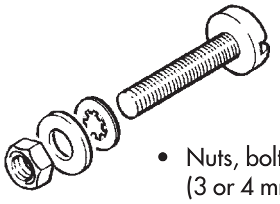
MATERIALS AND COMPONENTS PROVIDED

Before you start work on your design, you need to know what materials and other parts are available. You also need to know something about their properties and characteristics.

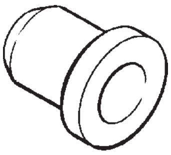
Parts List
The following list contains items that can be bought in for the 'pig'. With the exception of the electric motor, all of the things listed can be made if you have the right materials and equipment.



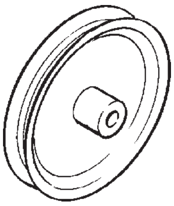
- Electric motor (e.g. type MM28).



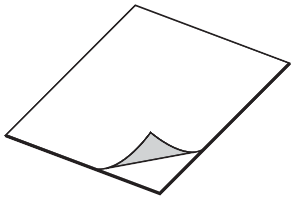
- Nuts, bolts and washers (3 or 4 mm diameter).



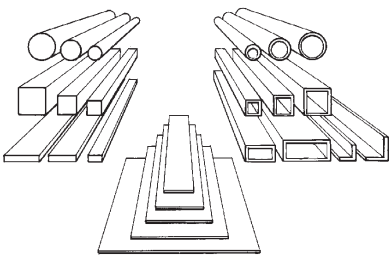
- Nylon 'bushes'.



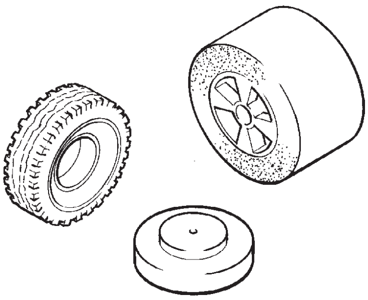
- Pulleys (30 mm diameter).



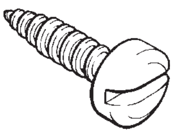
- Polymer pre-coated metal



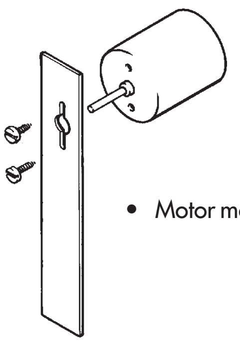
- Aluminium rod or steel rod (3 mm diameter), aluminium plate and other sections.



- Wheels (40 mm diameter).



- Self-tapping screws.



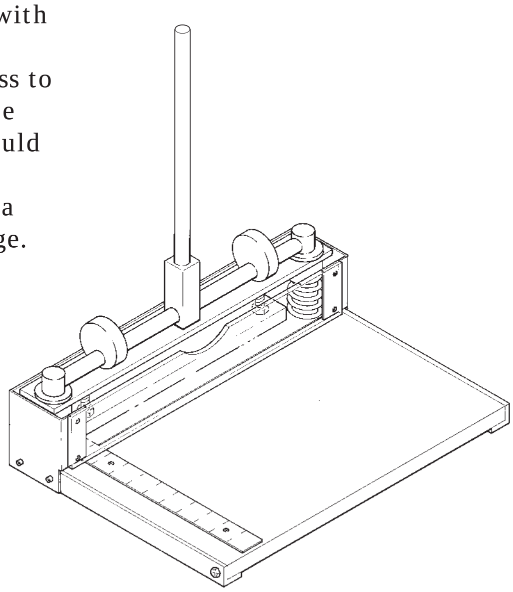
- Motor mounting plate.

DESIGN CONSTRAINTS

NOTE

A sample of the polymer pre-coated metal is provided with this book.

You will also be supplied with aluminium sheet for the project and will have access to a press tool for forming the metal. If possible, you should use a guillotine to cut the aluminium plate so it has a straight distortion-free edge.



What can you make?
What do you need to use ready made?

To answer these questions you have to ask yourself several others - for example:

How do the two options affect the design, cost and speed of making?
Is buying quicker than making?
How easy would it be to make the parts?
Is the equipment and material available to make parts?

WORKING OUT YOUR DESIGN

Once you have researched what is available to make the pig, you need to think about ideas for the design.

- Set your ideas down on paper.
- Play around with your ideas to develop them.
- Check them against your specification.
- Decide which is the best design.
- Do a detailed drawing of it.
- You need to end up with a working drawing from which you or someone else can work to make the parts for the 'pig'. It is a good idea to develop your ideas for the 'pig' as full size orthographic views. This will allow you to try out on paper the positions of the motor, wheels, pulleys (if used) etc.

NOTE

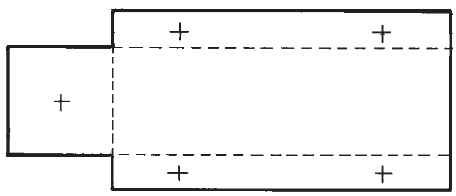
See Technology Study Files 3 and 4.

HOW WILL THE PIPELINE PIG BE CONSTRUCTED?

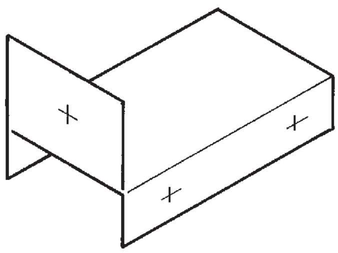
It is likely that your 'pig' will consist of a chassis plus a motor, wheels etc. A chassis is a platform or framework around which the other components are built. If you decide to design and make a chassis by folding a piece of metal, you need to draw a full-size net or development of the shape before marking it out on the aluminium sheet.

It is advisable to draw the development on card so it can be folded up as a model. The model may highlight problems with the idea - these can then be sorted out before any metal is cut and formed.

Any holes for axles in the chassis or other parts should be marked out accurately and drilled before metal is folded.

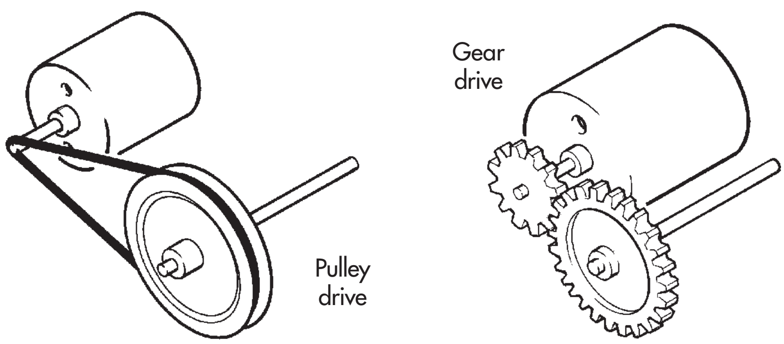


MATHS OPPORTUNITY



OPTIONS FOR DRIVING THE WHEELS

There are two simple and reliable methods for driving wheels from a miniature motor:



Both illustrations show a speed-reduction drive to the wheels. The driven gear or pulley rotates more slowly than the driver. A small motor of the type you will be using rotates at a very high speed when running freely but has relatively little torque ('turning power'). The pulley or gear reduction drives enable the motor to turn rapidly but provide high torque to the axle on which the wheels are fixed.

It is possible to work out the theoretical speed of the driven pulley and the overall speed of the 'pig' if you know:

MATHS/SCIENCE OPPORTUNITY

- motor speed;
- pulley diameters (or number of teeth on gears);
- diameter of wheels.

The following example is based on a motor speed of 2000 rpm (revolutions per minute), pulley diameters of 10 mm (driver), 30 mm (driven), and wheel diameter of 40 mm.

(If calculating for gears, substitute the number of teeth on the gears for the pulley diameters.)

Speed of driven pulley =

$$\frac{\text{driver pulley diameter} \times \text{motor speed}}{\text{driven pulley diameter}}$$

Speed of driven pulley =

$$\frac{10 \text{ mm} \times 2000 \text{ rpm}}{30 \text{ mm}} = \frac{20{,}000}{30} = 666 \text{ rpm}$$

A 40 mm diameter driving wheel has a circumference of 125 mm (circumference = diameter x π). If it rotates at 666 rpm, in one minute it travels:

666 rpm × circumference of wheel

= 666 × 125 mm

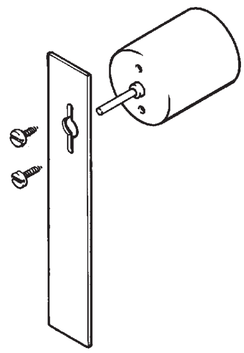
= 83,250 mm/minute

This is roughly 83 metres per minute

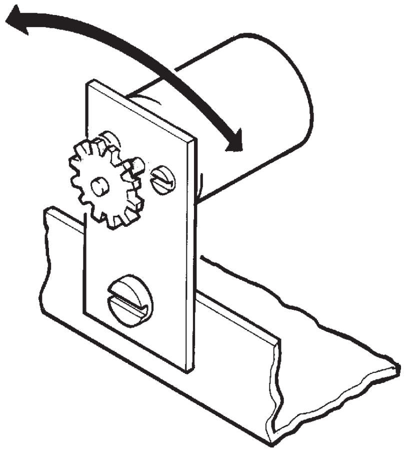
In practice, the speed is lower than this because the motor slows down as it does work in overcoming friction in the system and moving the 'pig'.

MOUNTING THE MOTOR

The motor you will use has two small holes at the front which will accept short self-tapping screws. These holes provide a very convenient fixing method for the motor. A fixing plate with holes already drilled may be available or alternatively they should be drilled as shown. The fixing plate supplied can be cut to length and folded as appropriate to your design.

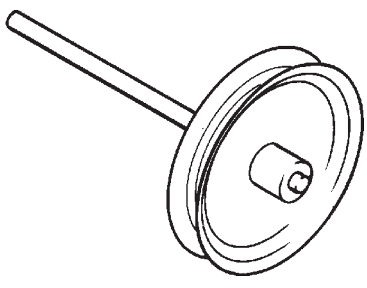


If a gear drive is used, it is a good idea to mount the motor on a swinging arm as shown. This will enable you to adjust the distance between the gear teeth (called depthing) before tightening the screw. If the teeth mesh too tightly, the gears bind; if they mesh together very loosely, they jump over one another.

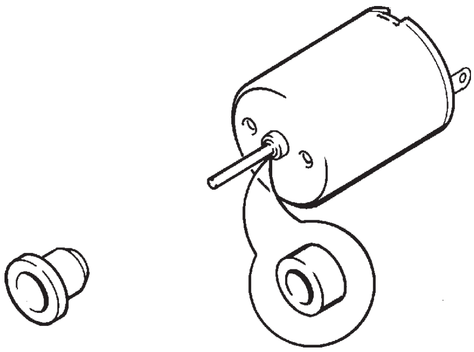


AXLES, WHEELS AND BEARINGS

Plastic wheels can be easily fitted onto a rotating shaft by drilling them out to slightly less than the diameter of the shaft - e.g. 2.8 mm diameter hole to fit a 3 mm diameter shaft. This is called an interference fit. (Plastic gears can be fitted to shafts in the same way.)

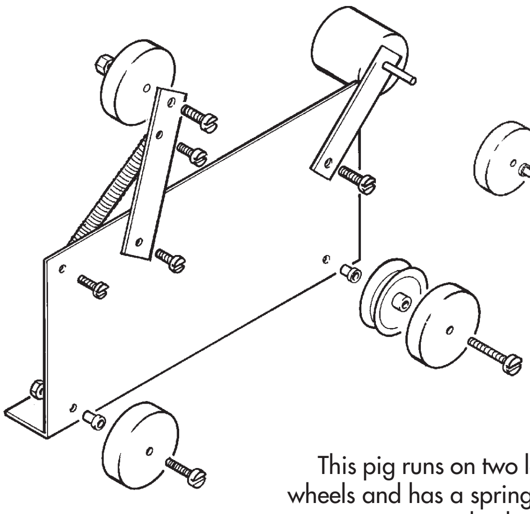


Shafts can rotate in a drilled hole but it is normal practice for them to rest in a bearing. A plain bearing is a small tube of metal or plastic which fixes tightly in a drilled hole but which allows the shaft to rotate freely within it. Many plain bearings - both metal and plastic - are self-lubricating. The bearing in the parts list on page 9 is made from nylon and needs lubricating with oil. Like many bearings, it has a small shoulder so that it is easier to fit.

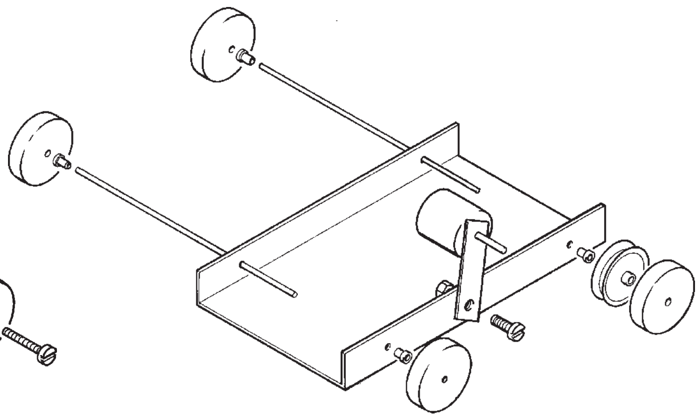


PUTTING IT ALL TOGETHER

If the parts of the pig have been marked out, cut and formed accurately, it should be possible to assemble them with few problems. The most difficult part will probably be adjusting the drive from the motor to one of the wheels or shafts. You may have to experiment with different drive bands if pulleys are used or make careful adjustments to the motor position if there are two meshing gears.



This pig runs on two lower wheels and has a spring loaded upper wheel



This pig runs on four wheels

MANUFACTURING IN QUANTITY

If you wish to make more than one pig - e.g., as part of a mini-enterprise project - you need to think about the production process. If it takes you 5 hours to make one pig, it should be possible to make 10 identical ones in far less than 50 hours. This is because the parts can be made up in batches or groups. For example, once the sheet is cut into the required number of pieces and the press tool is set up for folding, the pressing takes little time.

Production lines used for manufacturing industry use jigs and fixtures to speed up operations such as cutting and forming. (Jigs and fixtures are things that assist making.) You could use a very simple jig to speed up the operation of drilling bearing holes in the pig chassis prior to folding. This might consist of a plywood base with guide blocks clamped to the drill table. Each time the sheet was turned round to drill the four holes required, each hole would be in exactly the same position in the four corners.

QUALITY CHECKING

Checking for quality is important when products are mass produced because a manufacturing fault could be repeated many times. When making several motor mounts, for example, you need to ensure that the motor mounting screw holes are always the same distance from the hole(s) used to attach the mount to the chassis. A simple template gauge with holes in the correct positions could be used for this purpose.

EVALUATING YOUR 'PIG'

1. Test your 'pig'. You may not be able to set up the conditions specified in the brief but you can probably set up a length of pipe and attach a 'drag' load to your prototype.

2. Does the pig meet the requirements of the brief and your specification? Consider all the points you originally listed.

3. Costs. What did the 'pig' cost to make? How much could you sell it for?

NOTE

See Technology Study File 12 (How to evaluate a product).