RE-INVENTING THE PAPERCLIP

WHAT YOU WILL LEARN

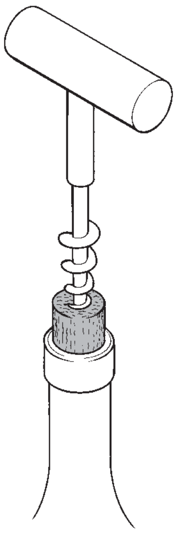
After completing this project, you should understand:

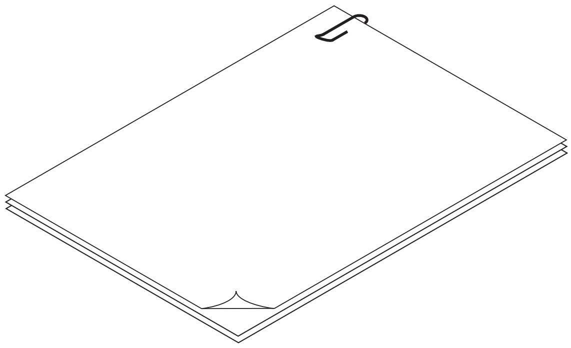
- The importance of production tools in batch manufacturing.
- How to calculate the quantity of materials needed for a product.
- How the behaviour of a material has be taken account of in manufacturing.
- The need for close tolerances in a production tool.
- Some of the problems associated with batch production.

After completing this project, you should be able to:

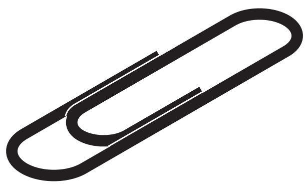
- Work to a design brief and write a specification.
- Recognise design constraints when designing.
- Design and make folded wire products for batch production.
- Design small production tooling.

There are many problems that designers and inventors return to time and time again. Getting corks out of bottles is one example; holding pieces of paper together is another. Almost as soon as a new paperclip comes on the market, someone comes up with what they think is a better idea.





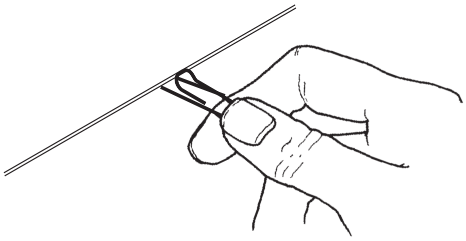
Many patents for “improved” paperclips are still taken out each year, and some make fortunes for their designers. Many of these look very similar to the oldest and most familiar type - the GEM. This was first made about 100 years ago and billions are still sold every year.



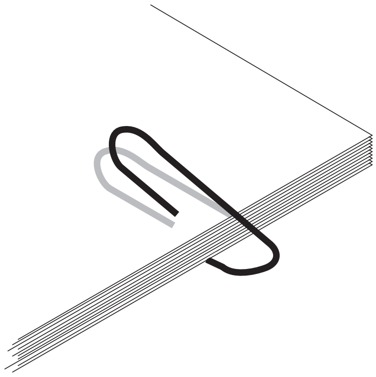
If a paperclip is such a simple thing, why do so many people re-design it every year ? The design of the GEM is a good example of a design that combines simplicity with economy. It answers a need - holding pieces of paper together - with a minimum of material and is relatively simple to make.

However, it does have limits. For example:

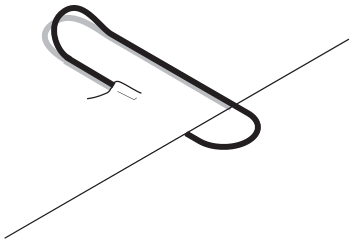
- the original GEM is flat and needs to be opened before it is slipped over the papers. Although you might not think it this requires a little skill and takes time. Newer versions of the GEM have a small turn-up in the inner "loop" so that it slips over more easily.



- even a larger GEM can only hold so many pieces of paper; after that it can become distorted.



- the sharp ends can dig in and damaged documents and in time they may go rusty and discolour them.



- a major drawback is the lack of grip. GEM paperclips are not as secure, for example, as staples, and sheets of paper can slip out.

No wonder people think they can improve on the GEM despite its success record to date.

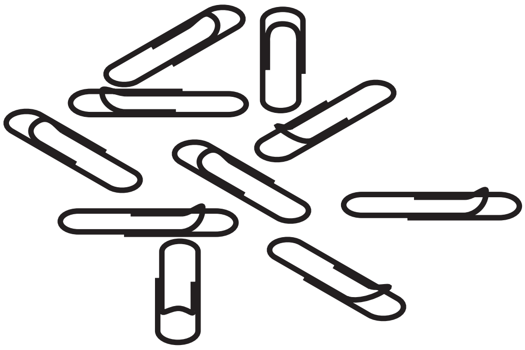
RE-INVENTING THE PAPERCLIP

Although it may seem very easy, re-inventing the clip is not a simple matter. Clip designers are faced with some very interesting engineering problems, but the good news is that you, too, can have a go and possibly make a fortune !

YOUR TASK

◀ DESIGN BRIEF

Design and make a small batch of paperclips to fasten loose sheets of paper together. As well as designing the clip, you must design and make a tool that will enable you to manufacture at least 100 identical clips for evaluation by commercial manufacturing companies.



DESCRIBING YOUR TASK

◀ DESIGN SPECIFICATION

First, you need to describe in detail what the product will be like, what it will do and who will use it. This is called a design specification and will guide your design work and help you judge how well the outcome works.

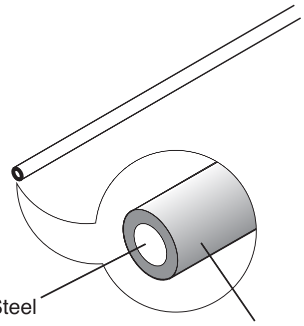
You are really being asked to design two things: the clip <u>and a manufacturing tool</u>. Here are some questions to help you first with your design specification for the clip:

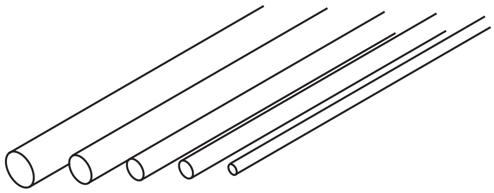
- *Who will use the clip ?*
- *What size should it be ?*
- *What should it cost ?*
- *What materials can it be made from ?*

MATERIALS AND COMPONENTS PROVIDED

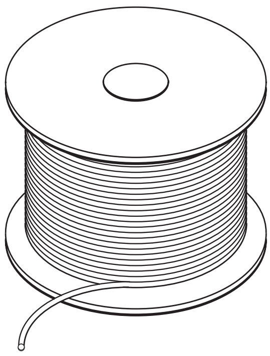
DESIGN CONSTRAINTS

Before you get on with your design work, you need to know what materials and components are available. Your teacher will provide you with some of the items shown. Make a note of what is available and what you think you can supply.

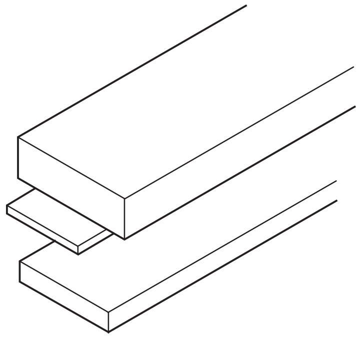




Steel or brass rods
for forming pins



Aluminium
welding wire



Lengths of aluminium,
brass, steel, etc

WORKING OUT YOUR DESIGN

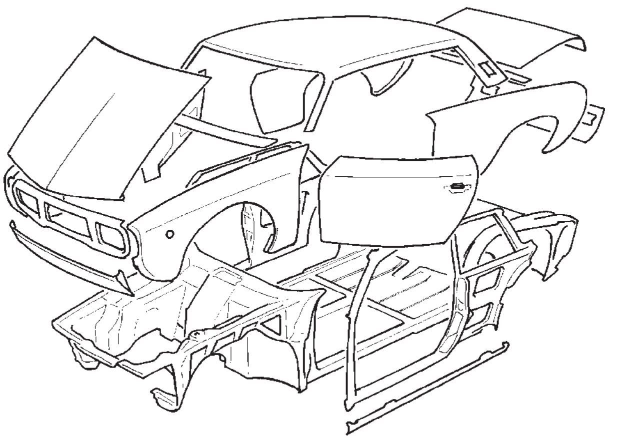
When you know what materials and components are available for the clip and manufacturing tool, you need to think in more detail about the design:

- *Set your ideas down on paper.*
- *Experiment with your ideas.*
- *Check your ideas against your specification.*
- *Decide which is the best design.*
- *Do a detailed drawing of the design.*
- *You need to end up with a working drawing which you or somebody else can use to mark out, make and assemble the parts. It will be a good idea to draw full size the parts for your final design.*

The following notes will give you some ideas about how the clip could be designed and made. They do not give you an answer, though ! You must make the important decisions. Remember, too, that part of the brief asks you to design and make a tool to manufacture at least 100 clips. When you are designing the clip, you must think about the tool at the same time and not produce a clip that is impossible to make. (Read the section below on tool design before you design any clips.)

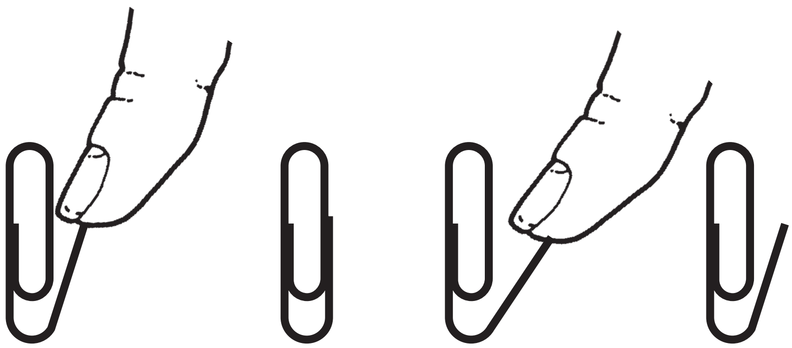
THE CLIP

Your clip will probably use steel wire of about 1mm diameter. It is important to know something about the properties of steel or any other wire before you start. Two simple experiments with a GEM clip will introduce you to some of the main problems that engineers face when using steel and other metals in larger structures such as cars.

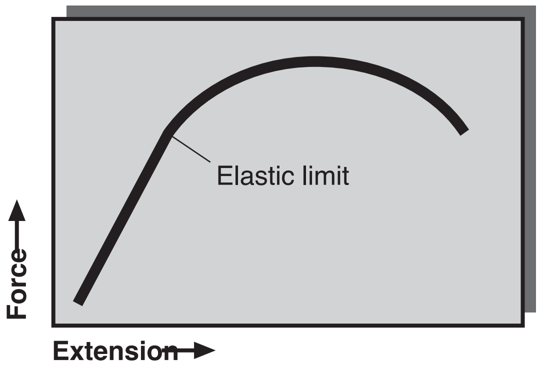


EXPERIMENT 1

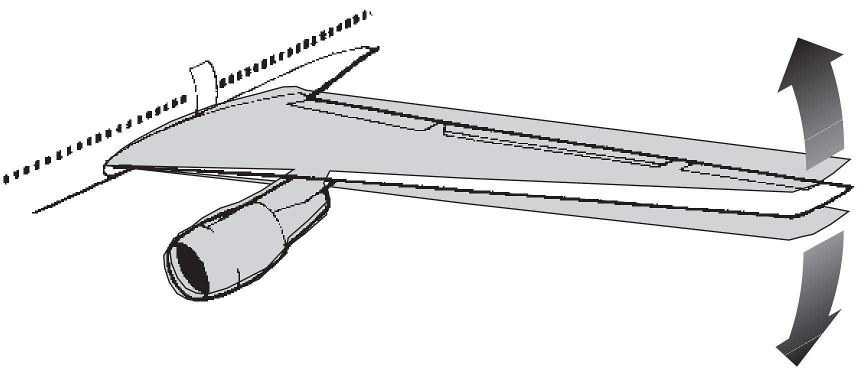
Take a clip and bend one end outwards. Up to a certain point, the clip will spring back into shape. If you bend it a bit more, it will spring back but not to the original shape.



All metals behave to an extent like an elastic band - although they are more difficult to stretch like one ! This is called elastic behaviour. If you plot the elastic behaviour of the clip on a graph of force again extension you first get a straight line. This means that the force you apply is directly proportional to extension. (This is called Hookes Law.) However, if you go on bending the clip, it reaches a point called the elastic limit and the line on the graph starts to go “flat”. When this happens the metal behaves a bit like Plasticine. This is called plastic behaviour. If you take the force away the clip springs back a bit but stays permanently deformed.



The difference between elastic and plastic behaviour is crucially important for engineers. When they manufacture a product such as a car body shell or parts for a building the metal is plastically deformed into shape. However, once it is in that shape, it must not be subjected to forces beyond its elastic limit. In flight the wings of an aircraft flex up and down but they do so safely within the elastic limit of the aluminium alloy from which they are made.

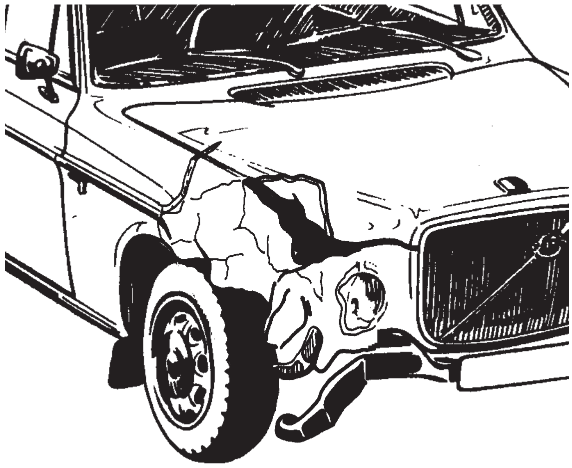


The wire used to make paper clips is deformed plastically into shape but must not be bent in use beyond its elastic limit otherwise it will simply stay bent.

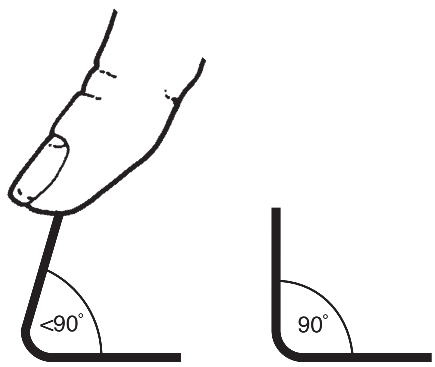
EXPERIMENT 2

If you bend the straight part of a clip beyond its elastic limit and then try to bend it flat again, you will find it almost impossible. This is because during plastic deformation the metal structure changes and it gets harder (this is known as work hardening or strain hardening).

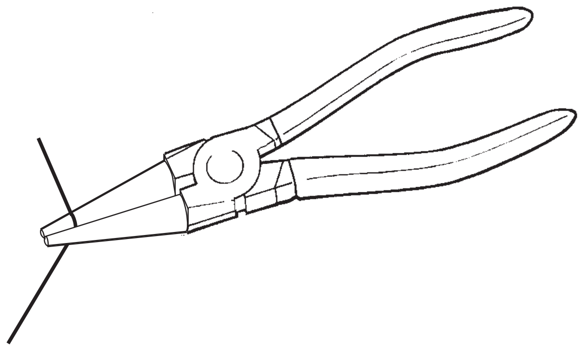
This is a very useful property because formed metal parts become very strong. It can also be a problem is you want to unbend or straighten something like a dent in a car!



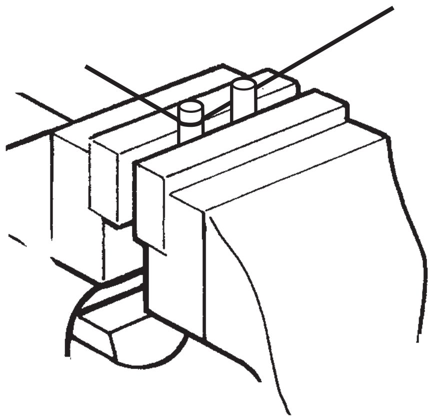
When you are forming the clip, you have to deform it plastically but there will also be some elastic “springback”. If you want a 90° bend, for example, you must “overdo it” slightly. Also, remember that due to work hardening, it will be almost impossible to straighten out a mistake. It is better to start with a new piece of wire.



You can design your clip using sketches on paper, but in the end there is no substitute for bending actual pieces of wire and trying them out on paper. The wire can be bent entirely by hand, but if it is stiffer wire round nosed pliers are need. These have a tapering nose so that different diameter bends can be made.



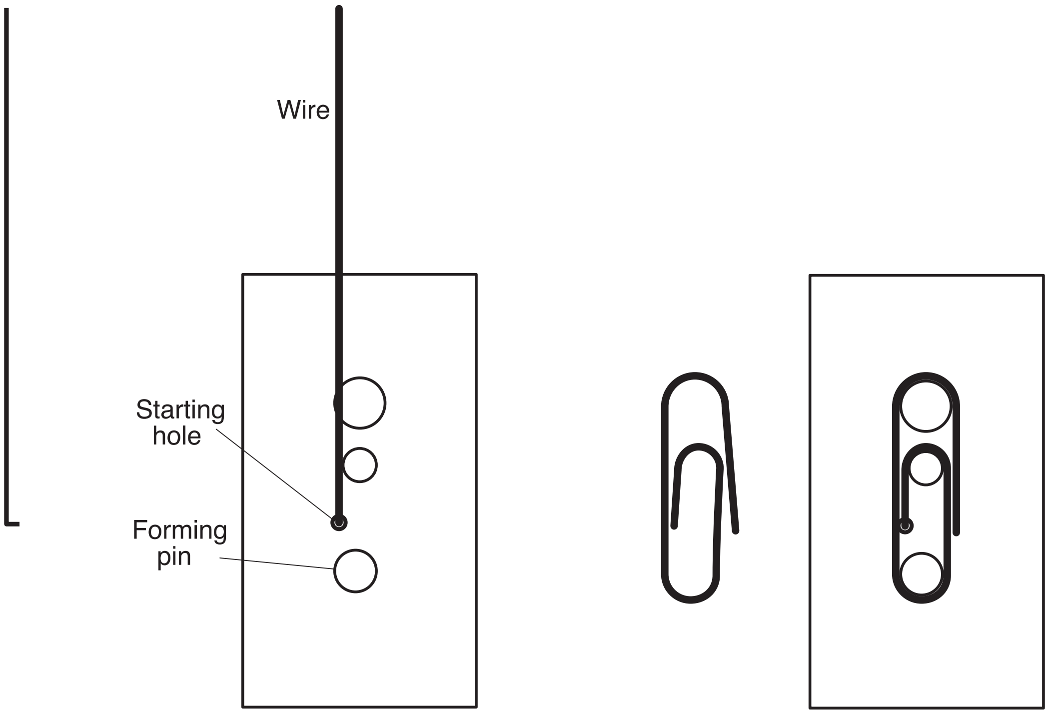
An alternative to pliers is to secure two pegs of metal in a vice and bend around these. An even better method is to drill holes in a metal block and bend the wire around pins fitted into these.



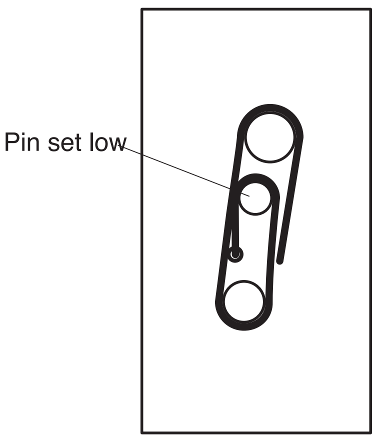
THE MANUFACTURING TOOL

The “pin tool” idea shown above is the easiest way of creating a manufacturing tool for the final clip. However, because of springback and the need to wrap the wire in several loops, there are one or two problems to face !

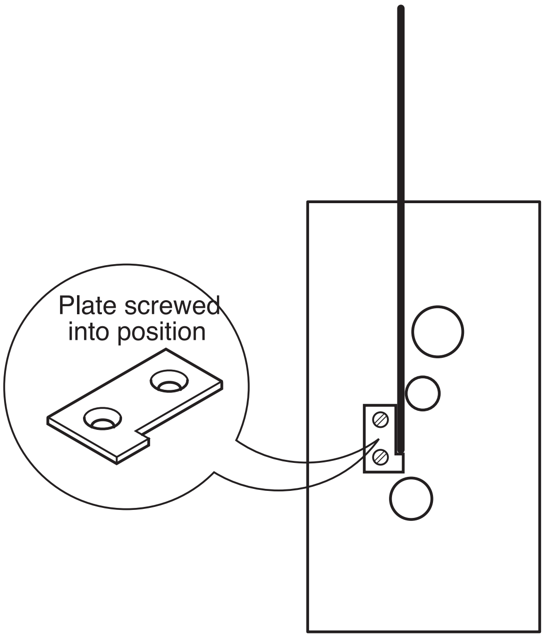
Take the example of making a GEM clip. This can be made by wrapping wire around three pins as shown. To start the clip one end is bent at 90' with a pair of pliers and dropped into a small hole near the first pin. This tool, however, does not take into account springback. The completed clip would open up after folding.



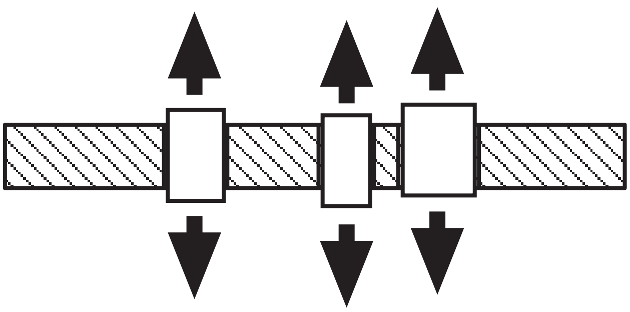
To make the tool work properly , the small starting hole and the pins need to be *offset* so that at each bend the wire is pulled around slightly more than it needs to be for the final bend.



This tool also suffers from the fact that a small bend is put in to start with and then needs to be cut off. An alternative, for example, is to cut out a small piece of steel as shown and bond it onto the surface of the tool. This could be done by soft soldering or using machine screws. A modern adhesive could be used instead.

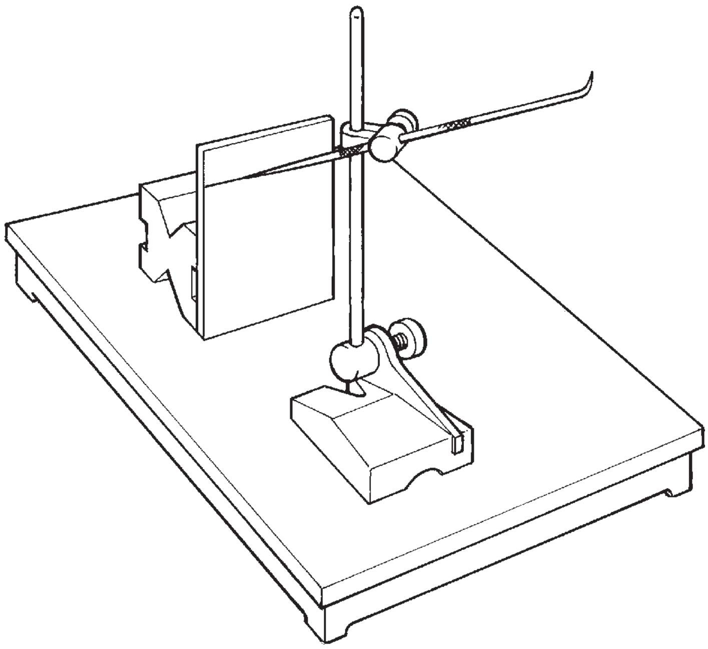


In the second GEM clip-making tool the middle pin has to be lower than the other two because the wire crosses over it. The best way of making a tool with adjustable height pins is to drill right through the tool base and make the pins a **light interference fit** so that they can be tapped to just the right height either from the top or the bottom.

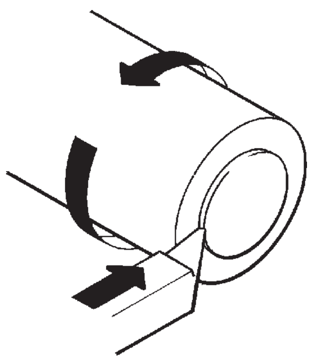


The base of the tool could be made from steel, aluminium or a tough engineering plastic. The advantage of using steel is that it is strong, cheap and can be soldered if necessary. Most toolmaking is done in steel.

The tool calls for very accurate marking out and drilling. When you have produced a final drawing of the layout and decided on the pin diameters, if possible use a surface plate and surface gauge to mark out the hole positions - each of which will be shown with a small cross. These are then centre punched and drilled.

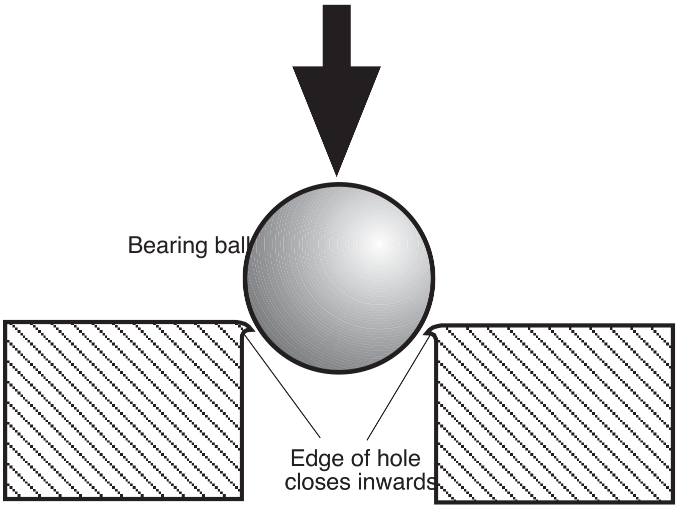


The pins - e.g. aluminium, brass or steel - can be turned down to diameter on a lathe. Remember, though, a drill will make a slightly larger diameter hole than its stated size. For simplicity, you might use available stock size metal for the pins which simply has to be cleaned up.



'Cleaning up' pins using lathe

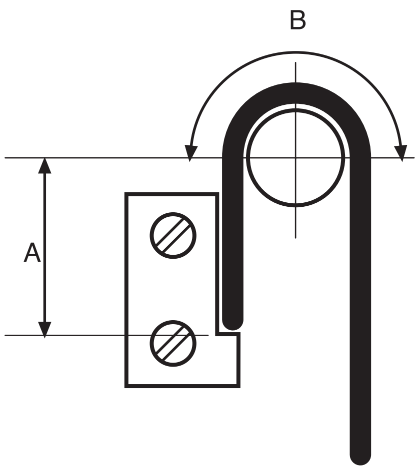
When they are making prototypes, toolmakers use a number of "tricks" to correct errors. If you make a pin slightly too loose, it can be tightened up by "upsetting" the opening of the hole using a bearing ball shown. An alternative is to squeeze the pin in a vice to give it a slight oval cross section - or to indent its surface using a centre punch. This is a last resort !



PUTTING IT ALL TOGETHER

If the tool consists entirely of pins, it can be assembled very rapidly and the pins adjusted for height. If there are other components such as the small plate shown in the suggested GEM tool, these must be secured by the best means at your disposal. Toolmakers would normally favour screws, pinning or soldering a plate like the one shown. For screwing or pinning, it could be secured with adhesive (e.g. araldite) and then drilled so the holes for either pins or screws line up with each other. If soft soldered, the base and plate should be thoroughly cleaned and coated with a solder paste (combined flux and solder), clamped and then gently heated.

(Note: Centre punch "dots" on the underside of the plate would keep it a small distance from the base allowing a gap for the solder and preventing the plate from slipping against the base during soldering.)



EVALUATING YOUR CLIP AND MANUFACTURING TOOL

To evaluate the success of the tool and clip, you must ask whether it meets your specification. You need to ask several questions:

- Does the clip actually work as specified ?
- Does the manufacturing tool allow you to make a clip rapidly? (How long does each clip take ?)
- How much material is used for each clip ?
- Are the clips identical or does the tool rely on an element of skill to make them the same ?
- Can the clip and/or tool be improved ? How ?