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Technology in School: Alternative Approaches III

In pursuing the notion of alternative technology in school, this final paper of the three will examine several more unusual metal-forming techniques and conclude with a look at one or two ideas for inexpensive woodworking equipment. The ideas themselves are diverse, but the theme throughout remains the same: existing resources are used as far as possible, preparation time is reduced to a bare minimum, and the cost is low.

Hydraulic Forming of Metals

Hydraulic forming is a well established commercial technique which involves deformation by fluid pumped under high pressure. In the manufacture of specialised exhaust systems, for example, a length of steel tubing can be sealed at both ends and 'pumped up' with hydraulic fluid; simple restraining collars and/or dies placed along its length are used to control expansion locally – thus producing a profiled tube which might be difficult, if not impossible, to manufacture in one piece by other means.

Another interesting application is to be found in musical instrument making where brass tubing which is to be formed into a very tight bend is first pressed flat, formed into the required curve in that condition, and then pumped up again in a suitable die. The principal can, of course, be extended to forming flat sheet material providing that the sheet can be suitably constrained (and sealed down) to allow fluid to be pressurized under one side. If a suitable die is held over the free side of the sheet metal, the sheet will be forced into it as pumping proceeds.

This is clearly a fascinating and useful technique, but one which demands special and often expensive equipment. Very good seals are normally required to contain fluid under these relatively high pressures, and although one can envisage a simple form of pump, it could be very time-consuming to make (or convert) one.

For small scale work, both of these problems can be avoided by using 'Plasticine' as the hydraulic fluid in a simple piston and cylinder arrangement. Fig. 1 illustrates such a system in which the sheet to be deformed is trapped at its edge between the cylinder flange and a die (both of which might be bolted together or clamped externally). When the piston is forced down, the 'Plasticine' will obviously begin pushing the sheet into the die and this process continues, ideally, until the cavity is full. In practice – depending on the size of the whole device – the piston can be forced down using a 'G' cramp, fly press or large bench vice. If a clamping ring is substituted for the die, the sheet will simply dish out until a combination of thinning and strain hardening causes it to rupture. To increase the fluid pressure obtainable, the diameter of the cylinder

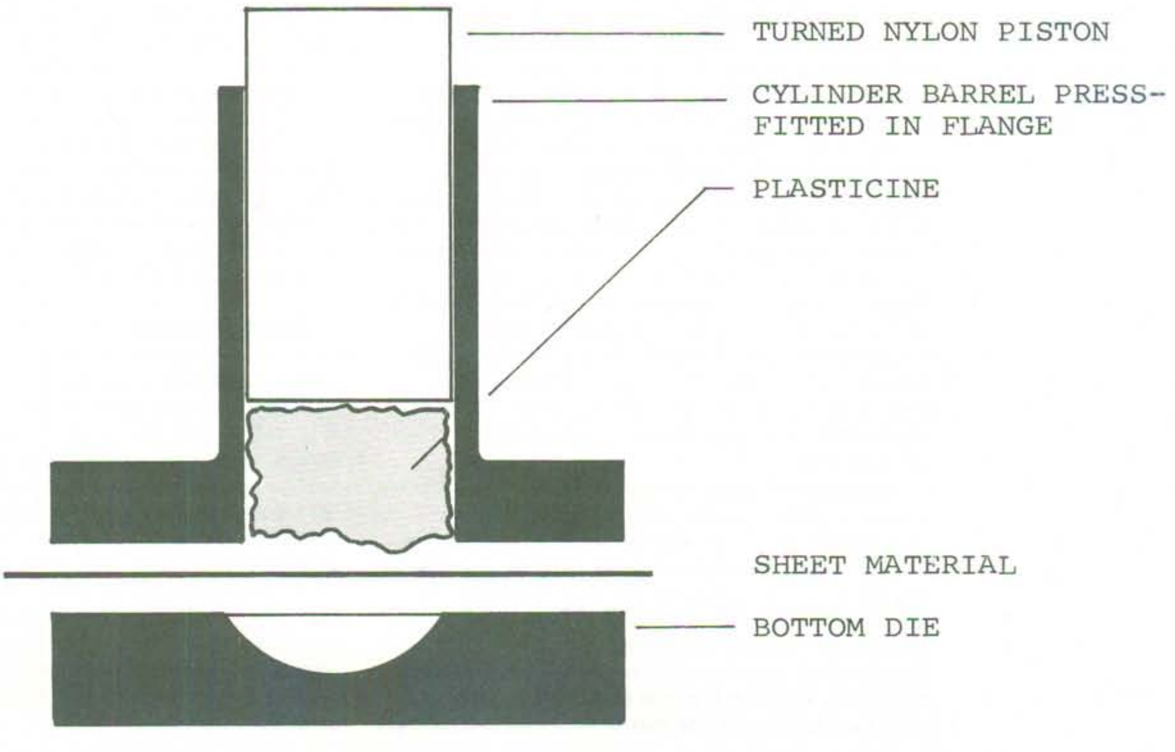

Fig. 1
Diagram showing the working principle of a simple hydraulic former. When the piston is depressed, 'Plasticine' forces a blank of sheet metal into the bottom die.

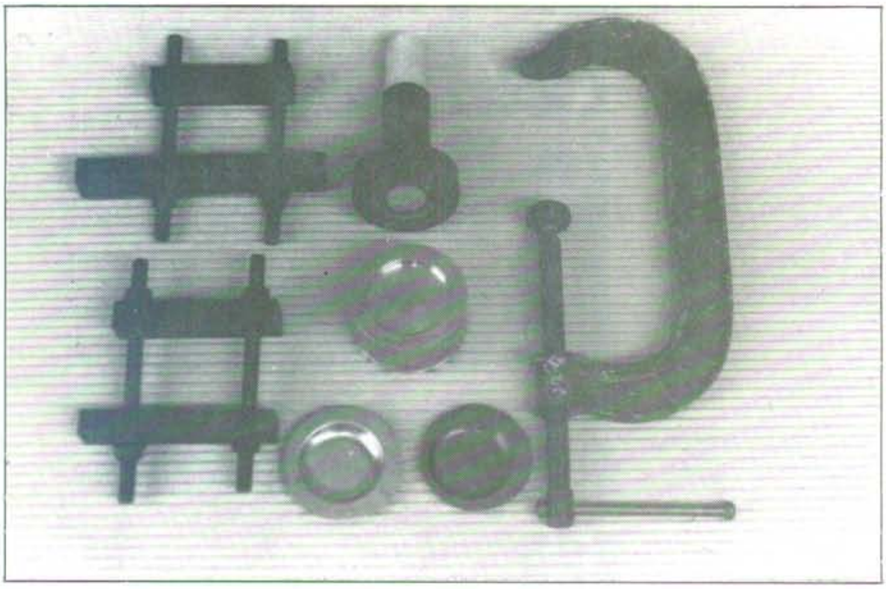

Fig. 2 (above) Components of prototype hydraulic former. The piston/cylinder arrangement is seen in the top centre of the picture and below is the die and two formed blanks. The die is held in place by means of the two simple clamps on the left.

Fig. 4: The component parts of the former shown assembled in Fig. 3 seen here with two of the interchangeable dies.

Fig. 3 A complete hydraulic former in which pressure is applied by means of an inexpensive car jack.

can be reduced but this correspondingly reduces the volume of 'Plasticine' and it may be necessary to complete a forming operation in several cycles topping up each time with more 'Plasticine' and perhaps taking the opportunity to anneal the sheet.

The construction of such a former can be very simple indeed. In the first prototype here, constructed to produce a number of identical dishes (Ø 80mm), a piece of round section aluminium was turned to produce the die and a piece of (seamless) steel tubing was force-fitted into a turned steel flange. The sheet is clamped between flange and die by means of four bolts located in pairs in two simple cross-bar clamps. Fig. 2 illustrates the various parts of this very crudely constructed prototype – a device which works perfectly but which took only approximately two hours to make and assemble.

Although seamless tubing is ideal for the cylinder, a seamed tube – or one with a relatively rough interior surface – can be employed providing that the resistance of the sheet to be deformed is not too great. There will naturally be a tendency for the 'Plasticine' to leak backwards between the piston and cylinder wall if the fit is poor, but the 'Plasticine' is an extremely viscous fluid and tends to effect a seal as it leaks in this way. A penalty is paid, however, since the piston becomes increasingly difficult to withdraw from the cylinder after the forming operation. A reasonably well fitting nylon piston with a turned 'feather' edge against the 'Plasticine' seems to work well under these circumstances. (It is also worth noting that a piece of thin paper placed over the metal sheet prior to forming obviates the problem of 'Plasticine' removal from the surface afterwards).

Fig. 3 shows a more advanced and self-contained version of the former; this is similar in principle, but uses a hydraulic car jack to apply pressure to the former – which is pushed upwards by the jack with the piston remaining stationery against the top plate of the frame. Parts of the former itself are shown in Fig. 4, and it can be seen that the cylinder flange would be bolted to the bottom circular plate, which has a hole to accommodate different dies – two of which appear in the photograph. Die inserts of this sort can be manufactured from a variety of materials including wood and plastics, but precisely what material is used naturally depends on the type and gauge of metal sheet and the fluid pressures involved.

Perhaps the quickest way of making a metal die is to model the form in 'Platstiscine' or wax, build up a thin wall of paper or plastic sheet around it, and pour over a quantity of fusible alloy such as Wood's metal (M.P. 70°C). When the 'Plasticine' is removed from the metal casting, a hard and durable die is the result, and when necessary the expensive alloy can of course be re-melted and used again. (WARNING: Wood's metal is an alloy of tin, lead, cadmium and bismuth and is therefore potentially toxic; ideally, it should be melted in a vessel surrounded by water (i.e., a water-bath) or melted under water to prevent heating above 100°C).

Cryogenic Forming

Of all the techniques so far discussed, cryogenic forming is possibly the most unusual and yet, perhaps, the most straightforward to demonstrate. It is well known that water expands approximately 10% when frozen and that this expansion can cause considerable movement and damage when the water is enclosed as, for example, in domestic plumbing. Michael Farraday, during several of his Royal Institution lectures, gave dramatic demonstrations of the phenomenon by placing water filled cast iron flasks in a freezing mixture of salt and water – with explosive results when the sealed-up contents froze. The expansive forces involved are enormous, and controlling them is the key to very impressive feats of metal forming.

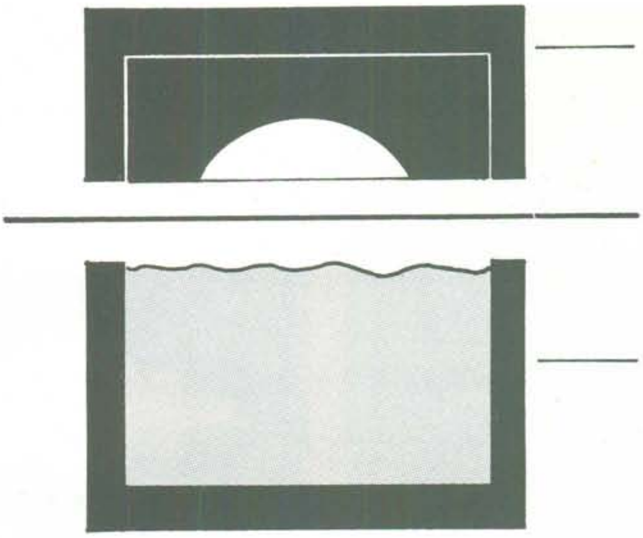

Fig. 5
Diagram showing the working principle of a simple cryogenic former. As water in the bottom half of the cylinder expands, a sheet metal blank is forced into the top die.

Fig. 5 illustrates a very simple arrangement for deforming metal in this way. A disk of metal is placed between two halves of a heavy walled steel cylinder held together by long bolts which pass through steel plates bonded to the cylinder ends. The bottom part of the cylinder is filled with water and a die is placed in the top. Once clamped together – a good metal to metal seal is sufficient between disk and cylinder – the device is simply placed in an ordinary domestic freezer.

In practice, the results are invariably interesting, especially when it is realised that the equipment will take the earliest opportunity to destroy itself. If too much water is used relative to the volume of the die cavity, either the cylinder, the clamping device, or both will also be deformed. It is necessary, therefore, either to continually measure the volume of water or (and/or) build in a safety valve so that excess expansion is harmlessly relieved after deformation of the sheet. (The volume of water can be adjusted by the simple expedient of displacement with, say, ball bearings).

Assuming that it might not always be easy to gauge the volume of water precisely, one solution to the problem is to place a block of a relatively crushable material such as wood beind the die, or a tube which would progressively collapse. Had such a sacrificial object been employed in the prototype shown in Fig. 6, the top plate might not have deformed.

Elastomeric Forming

In some respects elastomeric forming is similar to hydraulic forming if one thinks of an elastic rubber block acting on the workpiece instead of fluid. In a typical elastomeric sheet metal forming operation the sheet – for example, a plate of aluminium which is to be lightly ribbed – is sandwiched between a steel die and a rubber block backed onto a platen. When pressure is applied, the plate will be deformed as the block temporarily takes up the form of the die. Different types of rubber can be used in a wide variety of ways for forming metals and, of course, the technique avoids the necessity for expensive intermatching die sets. Indeed, in some operations this principle is often the only economical answer to a forming problem. A pre-formed cylindrical container, for example, which requires expanding into a bowl can be dished out by compressing a cylinder of rubber inside it.

Elastomeric forming is a technique which can be demonstrated in school in several ways without making up special equipment. For example, a Wood's metal die (as previously described) can be put together with a cast 'Vinamould' block using no more than a standard bench vice to apply pressure.

Fig 6: A prototype cryogenic former operating on the principle illustrated in Fig 5. The top plate, which is relatively far too thin, has buckled in use.

A 'tabletop' demonstration is clearly possible using just two plywood plates, a 'G' cramp, a dense foam block, aluminium foil and possibly a few coins for dies.

Pneumatic Presses

The discussion has so far centred on metalworking techniques, but there are obviously no limits in applying this kind of 'alternative technology' thinking elsewhere. This has already happened in many schools in connection with the problem of a suitable press for veneering or laminating operations, but little headway ssems to have been made.

Some schools are fortunate in having access to commercial bag press equipment, but this is still rare and efforts are made to improvise with a bag constructed from polythene sheet and a vacuum cleaner to exhaust it. Anyone who has tried this will know the problems; at best the vacuum obtainable is low, and the vacuum cleaners get hot. Almost all machines rely on a throughput of air for cooling the motor, and when this is restricted for any length of time – even accepting that air can be bled in without reducing the vacuum entirely – the motor can burn out within minutes.

Fig. 7 (right)
Two commercial filter pumps (See Suppliers).

Fig. 8 (below)
The complete bag press assembly. The base board in the bag has a partially drilled hole in one corner to accommodate the underside of the exhaust tube assembly avoid crumpling the bag at this point.

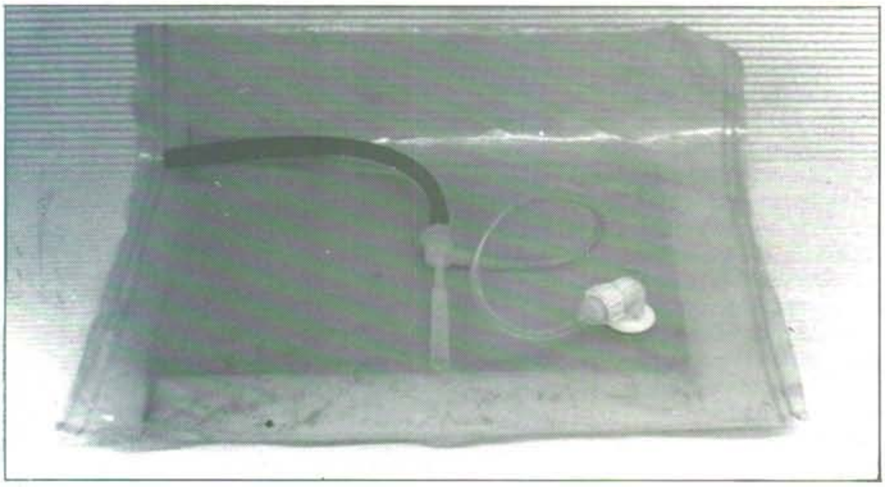

Fig. 9. The plumbing fitting which makes possible an excellent connection between the exhaust tube and bag. The wide flanges of the fitting and nut (with rubber washers) trap a large area of bag material. The only part of the entire bag which involves any manufacturing time is a small turned reduction plug which enables the PVC tubing to be attached to the fitting.

An alternative method of exhausting the bag does exist in the form of a pump having no moving parts. Several versions exist and all are normally described in suppliers' catalogues as filter pumps since they are commonly used to speed up chemical filtering operations. Although the precise design and operating principle of these pumps varies, they all depend on a reasonably high pressure supply of water which, passing through the 'pump' body, causes air to be drawn in through a third port and expelled with the exhaust water. If the mains water pressure is sufficiently high, the more efficient pumps are capable of achieving vacuums of 80%+ (Fig. 7).

One of these pumps drawing air from a well constructed bag gives excellent results. It is not necessary to seal the bag perfectly (which is virtually impossible anyway) providing that the water can be left running throughout the gluing operation – and this is not excessively wasteful since the pumps pass relatively little water. The main disadvantage of the system is the problem of initially exhausting a large bag because the rate of air removal is poor; the only solution seems to be pressing the bag as flat as possible around its contents before connecting up the pump (Fig. 8).

(A bag can be constructed using heavy gauge polythene sheet sealed on three sides with adhesive tape. The fourth side can be sealed when the contents are in place by folding over several times and clamping between two stout strips of wood. The more difficult problem of effecting a good seal between the bag and air exhaust tubes is easily solved by employing cheap commercial plumbing components. See Fig. 9).

A further problem naturally arises if the mains water pressure is insufficient to achieve a good vacuum in this way. In this case, yet another type of pump can be assembled at low cost; the main requirement is a tall workshop.

The pump exploits the simple fact that atmospheric pressure will support a vertical column of fluid in a closed tube only to a certain height, depending on the density of the fluid. For water, the height is about 33 ft., and if water is released from the bottom of such a tube 34 ft. in height the result will be a vacuum at the top. If a tube is introduced into the top of the vertical pipe and this is connected to a container to be evacuated of air, then air will be drawn into the top of the pipe and the column of water will fall until an equilibrium is reached and a partial vacuum exists in the container and top of the pipe. (This is the principle of the so called Sprengel pump which was used by Edison during the latter part of the 19th century to evacuate incandescent lamps. To minimize size, the Sprengel pump used mercury but its use simply involved the repeated production of a Torricellian vacuum).

In practice, using water, a water column approaching 33 ft. is both impractical and unnecessary; if one accepts that the maximum possible vacuum will be 30%, a pipe 10 ft. in length will suffice. However, the resulting vacuum depends on the amount of air initially in the system, and this requires that our bag press, before connection to the pipe, should be purged of air as far as possible by pressing it flat around its contents.

A prototype pump set up at the Polytechnic consists entirely of domestic plumbing components costing about £5 – including a 9 ft. length of Ø100mm PVC downpipe. The pipe is fastened to a wall (adjacent to the sink) using standard clips and is enclosed at both ends with W.C. sealing rubbers which accommodate connectors for the water and air tubes.

In use, the pipe is filled with water through a length of hosepipe connected through the bottom seal. When it is full, a length of thin PVC tubing passing through the top seal of the pipe is attached to the bag press. The pipe filler hose is then quickly disconnected from the tap and plunged into a basin of water so that water can escape from the pipe but no air can enter it from the bottom. A partial vacuum is rapidly established, although its retention obviously depends on how leaky the whole system is. A good idea is to use only a small bag and to seal all joints with something like 'Vaseline'.

Conclusion

The central theme of these three papers on 'alternative approaches' is hardly a new one. Schools have always improvised in designing and making their own equipment, and the ever increasing demands of CDT have certainly encouraged it. But there is clearly still plenty of room for innovation whether the problem is demonstrating an 'exotic' production process or perhaps adapting a scheme of work to increase the emphasis on technology. I hope that it will be possible to examine these and other problems in future issues of this journal, and I imagine that similar contributions would be welcome.

In order to continue our own work in this direction, Middlesex Polytechnic has made funds available to establish a CDT research centre. The work of the centre will be published in the form of occasional papers, the first two of which are advertised on this page with details for obtaining them free of charge.

Acknowledgements

I would like to thank John Heasman and Ken Dunlop for their work on hydraulic and cryogenic forming and John Lomas-Clarke for fruitful discussions on vacuum presses.

Suppliers

The filter pump referred to above may be obtained from: Downswood Products Limited, Park Lane, Knebworth, Herts., SG3 6PJ.