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PLASTIC INJECTIO THE AMATEUR

1. Moulding machine – mark 2

Background

Virtually every where you look we are surrounded by injection moulded components, the tops of containers, aerosols, hi-fi equipment, even our models. Injection moulding has revolutionised our everyday lives yet we feel it is something which can only be done in a well equipped factory. I too felt like this but the need arose for a means of making small injection moulded components to enable the rapid construction of a radio controlled 35g helicopter made predominantly from carbon fibre rods. Up to this point the method of construction was too labour intensive to enable more than a few to be made. In addition I have always wondered whether it was possible to make such a machine with limited facilities. To put these in perspective I have a Myford Super 7, a Dore Westbury milling machine and a MIG welder. The welder is not really necessary but it does speed up the construction a bit.

At its simplest an injection moulding machine is merely a means of heating plastic above its melting point and forcing the molten plastic into a mould from which the final product can be extracted. In practice commercial machines are much more complicated in that they use a hardened rotating screw to transfer the plastic from a hopper via a heated nozzle to the mould. Much use is made of hydraulics for both injecting the plastic, clamping the mould and releasing it. All of the component parts are made from hardened special steels which are outside the capabilities of most amateur workshops. In addition, industry uses very large pressures for rapid and economic production.

Chris Fouweather demonstrates that useful moulded components are achievable with rudimentary equipment.

Initial efforts and frustration

On searching the internet and my stock of Model Engineers I could only find very limited information but did come across the book by Vince Gingery. Being mean I borrowed it and started cutting metal. After about a week of hard work I reproduced the Gingery machine and made a simple mould consisting of a drilled 10mm hole and loaded up the heated block with scrap plastic.

As I pulled down the lever I thought to myself this is easier than I imagined. I removed the mould and discovered that there was no plastic in sight. To my horror I discovered that the ½in. precision ground steel injection rod was bent **Photo 2**. This alone gives some idea of the forces involved. On looking at the lever system with hindsight it was clear that these bending forces were almost inevitable (Gingery even hints at it in the book), so it was back to the drawing board. I have come to the conclusion that the Gingery design may be improved by reducing the volume of plastic to be injected to an amount more suitable for a manually operated design.

Mark 2 injector and heated block

My final version **Photos 1 and 3** uses a ⅜in. dia. stainless injector with a slightly shorter block but a much improved lever system **figure 1**, which ensures that the minimum amount of sideways thrust is applied to the injector. If I had my time over again, I am sure that the arrangement could be refined considerably. That said, it has made all the mouldings shown in this article.

The heated block was made from bright mild steel bar and the first injector was from precision ground mild steel. I have

2. Bent injection rod.

N MOULDING FOR
R WORKSHOP

made one from silver steel but the final version was from precision ground stainless steel of unknown parentage. There is some advantage in using stainless steel as with nylon you are working at temperatures close to 300deg.C. which causes bluing (oxidation). Clearly it might be desirable to make the block from stainless bar but I was unable to source anything suitable. In any event machining a ⅜in. dia. bore 3-4inches long in stainless steel is not my idea of fun. To date the mild steel block has proved entirely satisfactory. After all in amateur hands we are unlikely to produce thousands of components. In respect of the fit of the injector in the bore I used a ⅜in. reamer and lapped the bore lightly. Clearly we are looking for a reasonably close fit but I am fairly certain you could get away with a drilled hole and some lapping combined with some bright mild steel bar for the injector (alternatively use silver steel). In my case the injector would fall though the bore under its own weight. Molten plastic has significant viscosity and I have not experienced any "blow by"- if that is the correct expression. I would not recommend aluminium or brass for the heated block as scoring could be a problem.

The most important thing to ensure when setting up the machine is that the injector is in line with the bore of the heated block. I used a few pieces of steel shim. You will notice a discrepancy between the photographs of the machine and the diagram of the heated block. As I had two 150 watt cartridge heaters to hand I used them. Anyone starting from scratch would be advised to purchase a 250 watt heater from Farnell. The 250 watt heater noted in the references is priced at £16.02+VAT.

3. Detail of heated block and clamp.

I am certain that injection moulding professionals will hold up their hands in horror at this device, but I can assure you that it will produce anything the average modeller could need, subject to the volume of plastic you can load into the heated block. In commercial practice most if not all moulding machines make use of a rotating screw and hydraulics to generate the pressure required. To keep things simple, all we have at our disposal is muscle power. If anyone doubts the pressures obtainable I should point out that I have split apart a mould during injection when secured by a 6in. G clamp.

Additional equipment

Besides the injection moulder we need a number of other items :-

1 A substantial clamp to hold the mould together
2 Some means of preheating the mould
3 A mould into which the molten plastic can be injected.

Multi- size clamp

Rather than make a different clamp for each mould the device shown in **figure 2** and **Photo 4** is suggested. It can be made from any steel in the scrap box but should not be less than ⅜in. thick as the clamping forces are considerable. This has proved adequate for everything attempted so far. You are advised to tighten the 10mm nuts with a ring spanner. In some small commercial machines a toggle clamp is used. **Photo 5** shows the assembled clamp around a two part mould.

Preheating device

I dismantled an old domestic iron and turned it upside down on three legs to provide a flat surface on which to place the mould for heating (**Photo 6**). Preheating is important for the amateur as the pressures available will almost inevitably be less than those in industry and without it you have difficulty filling the mould before the plastic solidifies. I would like to claim that the iron was designed specifically for this job but I already had it to hand as I use it for surface mount soldering.

4. Multi-size clamp.

Mould design

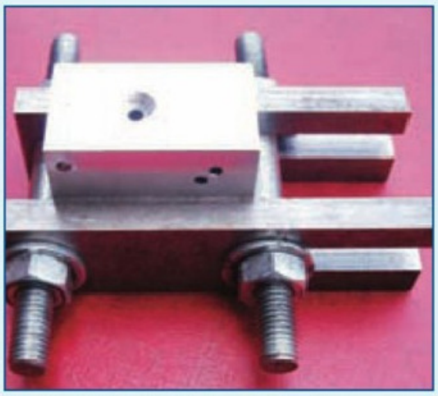
The essential components of an injection mould are two metal blocks held together with register pins, with some provision for injecting the plastic into the mould. In the sizes we are talking about two ⅛in. or 5/32in. silver steel pins in reamed holes will suffice. Try to make sure that the pins are a good sliding fit for registration purposes but it is important that the pins slide out easily to allow the mould to split otherwise you end up looking around the workshop for something to knock them out A diagram of the essential parts of an injection mould are shown in **figure 3**.

The two blocks should be square and true on all faces as this assists with marking out and allows the use of all faces to play a part in mould design which we will see can be important for the amateur and in any event makes machining easier. It is particularly important that the top and bottom faces are true and flat so that the mould sits on the injection table without rocking.

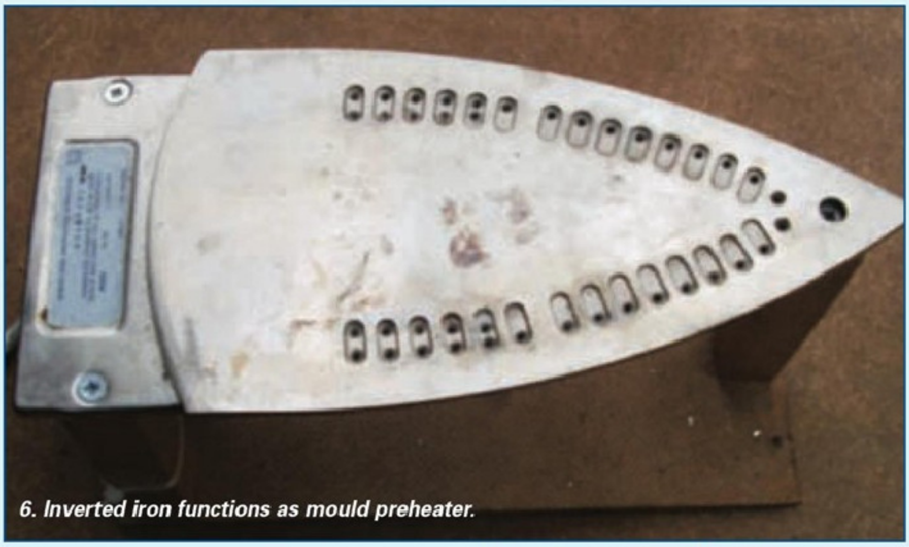
The easiest way to mate the mould with the bottom of the injection unit is a 90deg. countersunk hole feeding a ⅛in. bore which in turn feeds the runners and cold well(s). The cold well is needed to trap any part solidified plastic on the end of the injection nozzle. One important aspect of mould design is to ensure that all parts of the finished product have a similar thickness. This can go some way to avoid distortion and shrinkage.

Mould material

In commercial practice moulds for mass production are made in either aluminium alloy or hardened steel. I also understand that some "O" gauge kit parts are



5. Mould halves clamped together.



6. Inverted iron functions as mould preheater.

produced in brass moulds. For our purposes, either mild steel or aluminium alloy would be perfectly adequate. It is reported that anodised aluminium moulds have a longer life. I have used both steel and aluminium alloy but obviously steel is the more difficult to machine and cutter breakage more likely with small cutters (less than 3mm). I have therefore standardised on aluminium alloy. The precise alloy used is of unknown provenance as it has all come from the scrap box. I therefore assume that the precise composition is unlikely to be critical for our purposes.

Runners and gates

The dimensions of the runner should be greater than the hole in the end of the injection nozzle and of sufficient size to enable the plastic to feed the parts of the mould. This becomes more important if you have more than one part in the mould. In addition the shape and size of the runner is important in respect of plastic flow and the size of the component. Some guidance is given in **figures 4 & 5**. The gates can be cut in one half of the mould or both sides but I have found that for small parts one sided gates are satisfactory.

Internal diameters of finished components

Controlling the internal diameter of bores is the one easy thing about moulding as the pins I have used are made from mild steel or piano wire. In the event that the bore is too big the pin can be machined or polished or if too small the pin remade. I have made extensive use of model shop brass tube and piano wire in metric sizes as it is very quick to make up the necessary items. typically 1mm wire slides inside 2mm o.d. brass tube etc.

It is very much easier to design items requiring circular bores than rectangular recesses if only for the reason that you can easily extract the circular pins by twisting from the finished component. Flat /rectangular pins can be fiddly to remove.

Draft

Published data suggests a draft of ½-1 deg. for most parts. To date I have made no attempt to do this as removal of the finished components has not been a problem at the scale I have been working. The polishing process does tend to produce an inherent draft as it is difficult to avoid rounding over the edges of the recesses. Larger components would clearly benefit from draft especially for parts of the mould where the plastic shrinks onto an isolated "island". Conventional wisdom suggests that anything over 0.2in. deep in the mould will need draft.

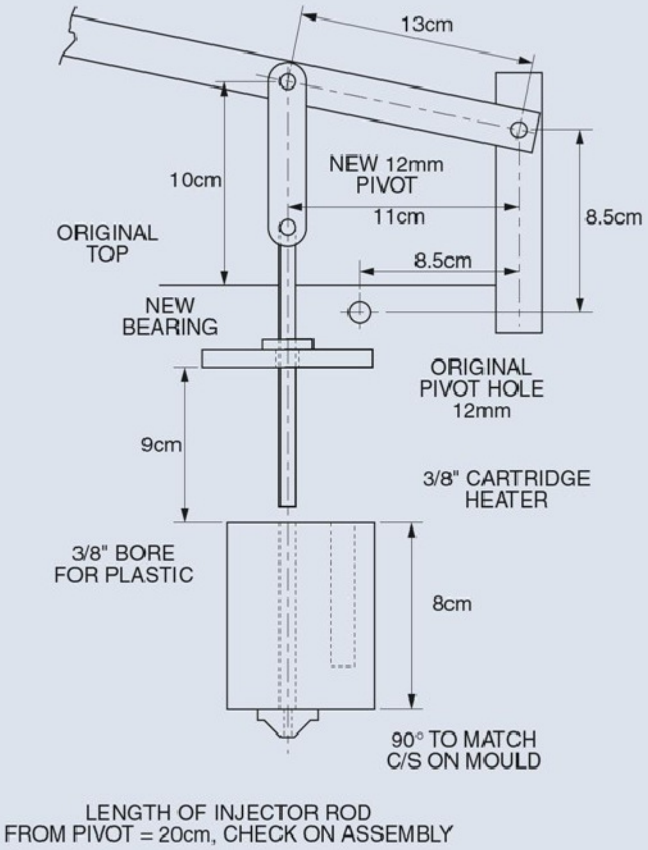


FIG. 1. LAYOUT OF MOULDING MACHINE

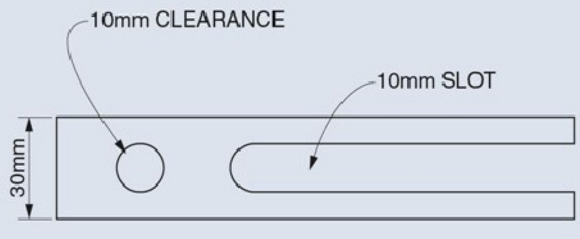


FIG. 2. MULTI-SIZE CLAMP
10mm MILD STEEL, LENGTH TO SUIT MOULDS
MAKE 2

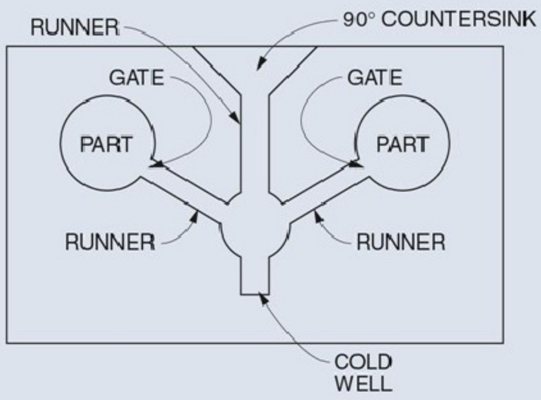
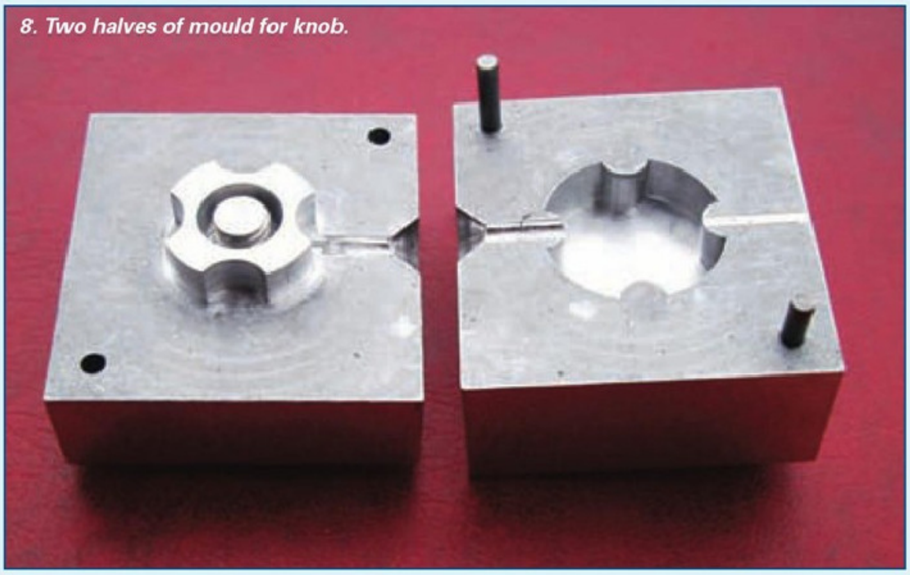


FIG. 3. VIEW ON MATING FACE
OF MOULD HALF

7. *Moulded knob.*



8. Two halves of mould for knob.

Air release

Clearly when you inject plastic into a mould at 1000+p.s.i. the air has to be expelled otherwise the mould will not fill. In practice a slot cut with a 1/16" slotting cutter about 0.002in. deep works well. Even if you increase this to 0.005in. very little plastic finds its way up the slot and you just get a small "nib". In many cases this can help us produce more accurate mouldings with the limited pressure at our disposal.

Design and machining

This is the hard bit as every machining mark is reproduced in the plastic and any mismatch in the two halves of the mould will produce "flash". Having said that if you can machine all or most of the component in one side of the mould so much the better. One thing you do have to get used to is thinking in reverse. I sometimes get confused and pushing plasticene into some part machined component can sometimes clear the head and avoid the scrap bin. It is worth spending a fair bit of time with a piece of paper before launching in to metal cutting as the production of the registered blocks does take some time. Try drawing the part on paper and filling it in with one colour and the surrounding area in another .The latter is what you have to machine but make sure you can get the finished product out of the mould. (machining a recess from which the plastic cannot be removed is easily done)

For those who have CNC machines or milling machines more accurate than mine the following will seem rather nonsensical but it works. The basic problem with two sided moulds is that the two halves/parts have to line up or the result is unsightly or unusable. To get round this problem, I drill though both parts of the mould and then use the holes as reference . These holes can be seen in a number of the moulds in this article. It is fairly easy to insert a piece of silver steel into the resultant hole and locate its position with a dial gauge. Using this technique you can produce acceptable registration with even the most worn of milling machines. You should also be able to locate two holes with reasonable precision using the micrometer collars, (subject to any shrinkage allowance). The other very easy thing is you can locate and machine at 90deg. using the longitudinal and cross slides of the milling machine. Repeatable stops on both axis can also help. Most of the moulds described are approximately 2" sq by ½" thick (total thickness 1"). Anything much smaller than this could produce rocking at the nozzle.

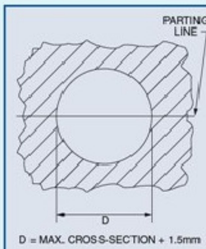


FIG. 4. GATE CUT IN BOTH HALVES OF MOULD

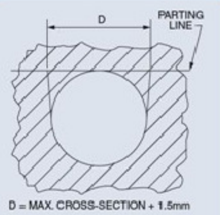
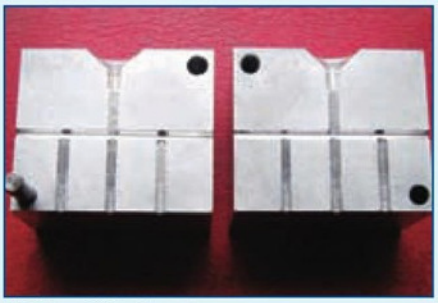


FIG. 5. GATE CUT IN ONE HALF OF MOULD



9. Mould for Tee piece.

10. Tee piece mould with inserts for bores.

Materials /temperature

Some suggested temperatures for materials I have used is shown below

Polythene (low density)	190-240 deg. C
Polythene (high density)	190-240 deg. C
ABS	240-260 deg. C
Nylon 6	260-280 deg. C

Tolerances/shrinkage

I can give little guidance on shrinkage as the only thing I have made where it was critical was a small tail rotor gearbox for a model helicopter. In this case I allowed the maximum gear mesh clearance plus 0.01in. for the shrinkage where the separation between the two gears was 0.276in. Much will depend upon the thickness of the individual parts of the moulding, the molten plastic temperature, and the temperature of the mould at injection. Some experimentation will be required to give optimum results.

Ball ended cutters

In some cases circular items can be produced by drilling along the parting line of the two mould parts but if of any length you will get run out and it may be difficult to remove the plastic part. For many items

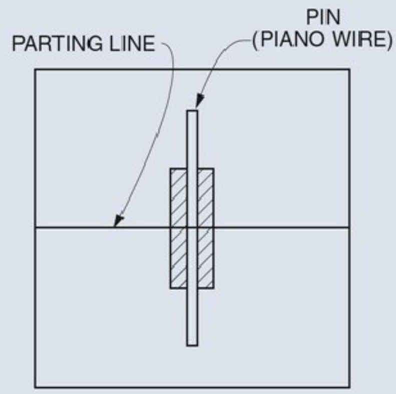
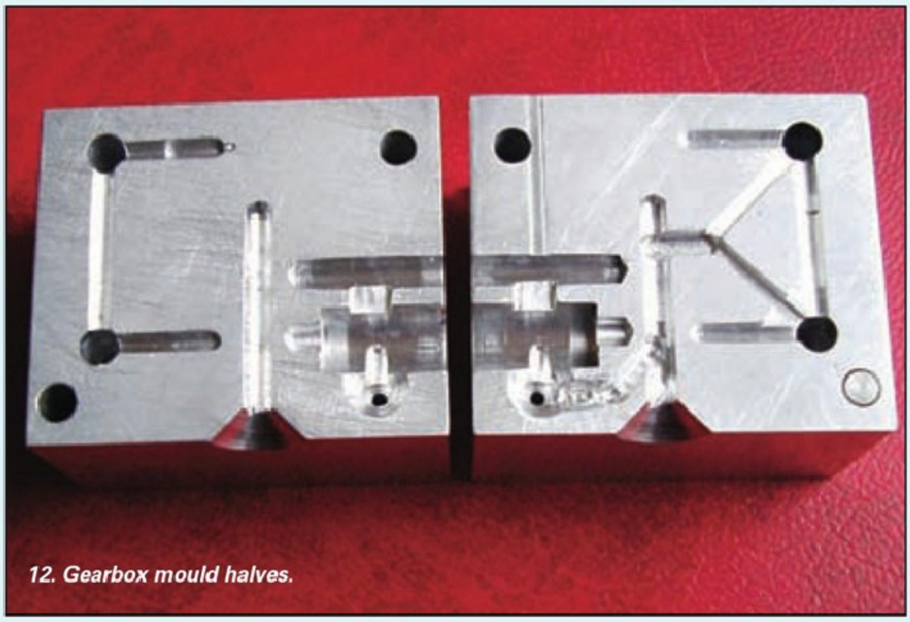


FIG. 6. MAKING COMPONENTS WITH ACCURATE BORES

11. Completed moulding of Tee piece.

you will need ball ended cutters which will form half of the circular item in each mould half. Precise control of the cutter in feed is essential. I have used 2mm and 3mm cutters in a Dore-Westbury miller but the top speed is a little on the low side. Many of the smaller cutters need to be driven at over 10,000rpm.



12. Gearbox mould halves.

Sources of raw material

To date I have used 35mm film containers as a source of HD polythene together with plastic milk bottles for a related material. A trip to the local photo processing shop will produce large quantities of raw material as the film containers are just thrown away. The film containers are ideal and can be injected at the lower end of the temperature range shown above whereas the milk bottles are clearly made from a different material. Both are of course free. Many printer cases are made from ABS and or ABS/polycarbonate and mould well. Nylon can be obtained in the form of rod but I have used nylon tubing. It should be said that nylon is more difficult to mould than polythene. If you look at most plastic items they are marked with identification letters e.g. PE(HD) for high density polythene.

Heating/temperature control

In the original Gingery design he uses a contact thermostat to control the temperature of the heaters. In my hands such an arrangement produced considerable temperature variations so I have reverted to using a thyristor controller (light dimmer). I set the controller on full until the temperature is about 40deg. below that required and then adjust the dimmer switch to produce a slower rise in temperature. It is a fiddly arrangement but once set the temperature of the block is fairly stable.

In my case heating was done with two 3/8" diameter cartridge heaters rated at 150 watts each. Running unregulated the maximum temperature produced was 310 deg. C. If the machine was made smaller with a 5/16in. injector a 200watt heater would suffice for small mouldings in almost any material. Suitable heaters are listed in sources of supply.

Examples

A plastic knob

I have a friend who makes extensive use of jigs for woodworking. Some of them use considerable numbers of knobs for stops, setting etc. As a result I was persuaded to make a mould to produce 1in. diameter plastic knobs. The beauty of the design is that the thread is moulded in and requires no further work other than the removal of the runner following injection. We had a session one evening and before long we were surrounded by the things (**Photo 7**). This is the largest component I have moulded and it weighs 2g. **Photo 8** shows the two mould halves with the cap screw used to form the internal thread. This screw is easily removed after cooling.

Helicopter components

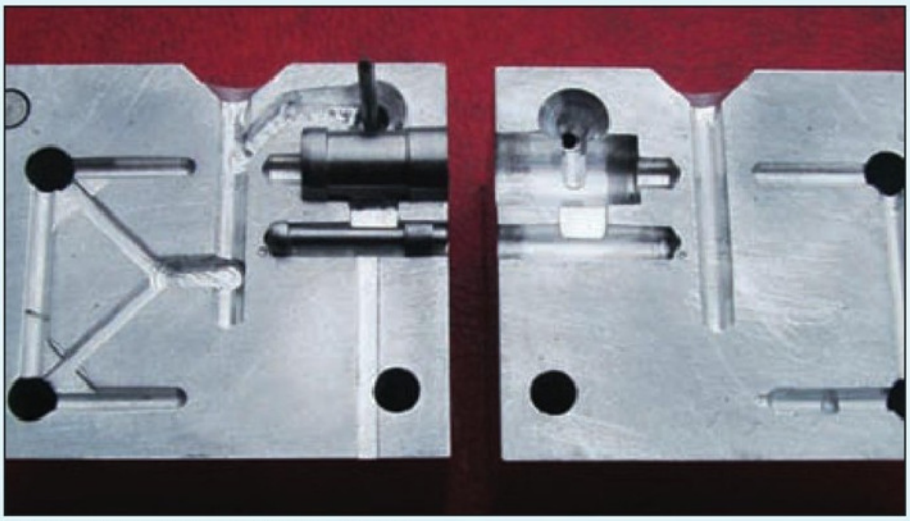
As I said at the start of the article the whole reason for making the machine was to produce small plastic mouldings for a helicopter so I will attempt to describe the finished products and the way in which they were made.

Production of a "T" piece

As stated earlier the easiest way to produce a circular shape with half in each mould part is by drilling. Drill on the parting line of the mould halves and turn the mould through 90deg. and drill again until you break into the hole already drilled. It is important to set the depth stop with care so that the transition between the two bores is neat. Split the mould and you can see the finished "T" shape. All that remains is to make some pins to control the internal diameter of the finished "T". The two halves of the mould are shown in **photo 9** and with the inserted pins to form the internal bore in **photo 10**. The completed moulding is seen in **photo 11**.

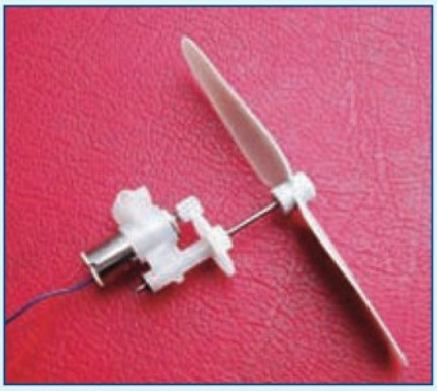
Tail rotor gearbox

Again I made use of the drilling on the centre line technique to generate the circular halves. Using the milling machine line up the parting line with a sticky pin. The George Thomas version which I made many moons ago is superb. Drill a hole for the first bore and using the micrometer collars advance the table to the other bore and drill again. In this way you can locate the gear separation distance to within 0.001in. I used the theoretical gear spacing with an allowance for both the gear tolerance and shrinkage of the plastic. Some thought needs to be given to the drilling depths and I used the micrometer collar on the vertical travel to control the depth.



13. Gearbox mould now fitted with pins.

14. Completed gearbox moulding.



15. Gearbox assembled with motor, gears, and rotor.

16. Typical mould for two parts.

The mould can then be split and the two bores joined by milling. I added a little strengthening rib by milling a 2mm round slot using a slotting cutter. It was then necessary to locate a third bore at right angles to the first two by drilling a 1.5mm hole close to the larger bore. Insert a piece of sharpened 1.5mm piano wire into the bore and assemble the two halves such that the pointed piano wire marks the surface of the other mould half. Disassemble and pick up the mark with the sticky pin and drill 1.5mm. Open both holes up to 3mm but leave enough of the 1.5mm holes to allow location of a piece of 1.5mm piano wire see **figure 6**. A similar technique can be used where bores are machined half in each mould section. The pins would sit along the parting line. The photographs should make this clearer

It is now necessary to make the pins which control the internal diameter of the gearbox, one for the 6mm motor and one for the rotor bearing (2mm). The completed mould halves and pins can be seen in **photos 12 and 13** ,the finished moulding **photo 14** and the complete gearbox **photo 15.**

With all the moulds the final step when all machining has taken place is to lap the two halves of the mould together. I have found the "Timesaver non-embedding" lapping compounds to be ideal. They do not embed in the soft aluminium, and produce a matt even finish as the particles slowly break up during the lapping process. I only wish I had come across this product earlier. The last step is to remove all traces of oil and debris using washing up liquid followed by drying. Surprisingly you do not need to worry too much about cleanliness as all the extraneous rubbish comes out of the mould with the first injection. An assortment of other moulds and components can be seen in **photos 16 and 17**.

Health and safety

It hardly needs saying but wiring in close proximity to electrical heaters requires some thought. Where the wires from the cartridge heater pass through the metal frame they were sleeved with glass fibre insulation and a ceramic block connector was used to connect the heaters to the mains wiring. High temperature cable was used for the mains wiring. PVC insulation might melt and is considered too dangerous. All metal parts should be electrically bonded together and the use of an RCCD (breaker) is essential.

Improvements

A much more satisfactory machine could be made with the aid of a 4in. dia. air cylinder driving the injector. Someone with whom I correspond has made such a machine driving a ½in. dia. injector from a 4in. air cylinder at 100 psi and produces very professional gearbox mouldings for sale in high density polythene /ABS/and high impact polystyrene.

If very small mouldings are required then a 5/16in. injector would significantly increase the injection pressure. If I were to remake my machine I would certainly use a smaller injector as the loss of plastic capacity would be of little significance for small mouldings. The most time consuming aspect of small scale moulding is splitting the mould and removing the pins etc. from the plastic. The time taken to melt the plastic is not that significant as the heating block has a large thermal capacity. I am of the view that a machine constructed from a 30mm sq steel frame with a 5/16in. or 3/8in. injector would be ideal for amateur production. My machine is shown in **photos 1 and 3**. A friend described it as Heath Robinson which is fair but it is essentially to the Gingery design with the lever system modified. However as it works I am unlikely to build another. The unmodified Gingery machine is reported to be capable of moulding 14g of plastic with a ½in. injector whereas mine can cope with about 5g.

It is important to point out that I have no professional experience in the injection moulding field but I have managed to produce mouldings which are more than fit for their intended purpose and I have been amazed by the results from such crude equipment. I hope these notes are found useful and if I can be of assistance to other readers, contact me on jfouweather@aol.com

Sources of supply

Ball ended slot cutters (carbide)
HB tools
www.hbtools.co.uk tel 01704 897722

Cartridge heaters 3.25in.x3/8in. 250 watt part no 711-2476
Farnell 0870-1200 200
www.farnell.com

Piano wire and brass tube –any model shop.

Secrets of Building a Plastic Injection Molding Machine (Vince Gingery)
–**Camden Miniature Steam Services**, Barrow Farm, Rode, Nr Frome, Somerset BA11 6PS tel 01373 830151

"Timesaver" lapping compounds
GA Watt Engineering Supplies, 375 Huntspond Rd, Titchfield Common, Hants, PO14 4PB. Tel 01329 843022

17. Small assembly using several mouldings.