INTRODUCTION TO THERMOFORMING-

Mould Making

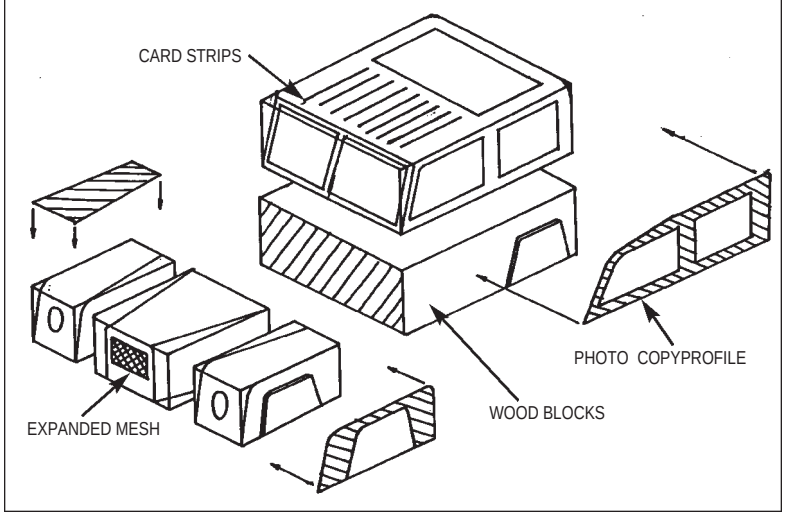
4

MATERIALS

Moulds for vacuum forming are most commonly made from a timber product, aluminium or epoxy resin. Other materials such as steel, copper, brass, paper, card, glass, thermosets like 'Bakelite' (Urea formaldehyde), plaster of paris, dental plaster, clay or plasticine can be used on their own or in combination.

Details can be added by mesh, perforated sheet, wire and even sandpaper (which is used for providing surface texture on vacuum formed braille diagrams).

First stages of mould manufacture



TIMBER BASED MOULDS

One of the best materials to work with is Medium Density Fibre Board (MDF) as it has no grain, is easy to shape, and is relatively stable when heated. It is easy to work into reasonably complex shapes using cutting and abrasive tools such as bandsaws or sanders, and other materials such as card or metal can be fixed to its surface using adhesives. Other fibre boards or regular close grained timber can be used.

Tools needed to produce a prototype mould can be found in most carpentry workshops including:

1 Saws
2 Chisels
3 Gauge
4 Drill bits
5 Sanding block
6 Tilt table disc sander
7 Drill press
8 Small high speed PCB drill such as a 'Dremel'
9 Band saw
10 Sash clamps

The tilt table disc sander is particularly useful for quickly developing blocks with draft angles and radii.

1. Prepare the base blocks

If necessary, assemble a composite block or blocks of MDF or some other timber or timber based board. Glue boards together with PVA wood glue, clamp together with sash clamps and cure overnight.

If you have an oven or a hot box (see 4: Vacuum Forming), you can improve the curing time.

2. Marking out

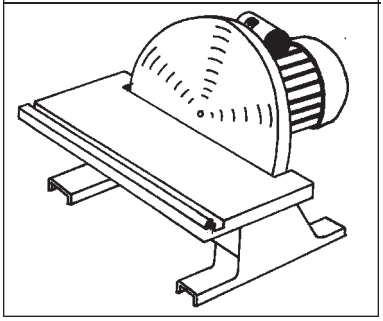
Get an accurate set of scale drawings to work from and if it's a complex shape, break it down into simple components that can be assembled later.

Mark out or paste photocopies of the drawings or drawing sections onto the composite block or blocks (use the same face for each part - usually the base - so that angles are generated from the same datum).

3. Shaping & assembly

Cut roughly to shape using saws and then finish the shapes more accurately with the disk sander. Assemble the mould frequently to check on progress.

Tilt table disc sander



If the mould ends up too long, cut it in half, remove a slice from one of the ends and glue the two halves back together.

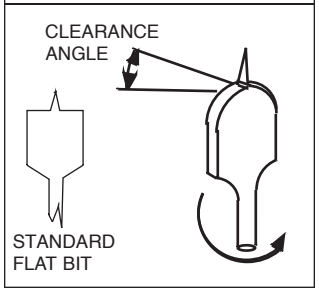
If the mould ends up too short, cut it in half, add a section to one of the ends and glue the two halves back together.

4. Adding detail

When you are happy with the mould's basic shape, add detail using wire, mesh, sandpaper or

any other heat resistant material that achieves the desired result (metals can be glued to MDF using Locktite 499).

Modified drill bit for cavities



Dimples and hollows can be drilled into the mould using a custom shaped flat drill bit.

Off the shelf mouldings can be used to make decorative bases and surrounds - mitre at the corners and pin in position.

_ _ _ _ _ _ _ _ _ _5. Mounting on a baseboard

Once the mould is complete it should be mounted on a baseboard. This is necessary for three reasons:

1. To hold down the mould during the blow cycle.
2. To locate the mould (or moulds) on the platen in the best vacuum forming position.
3. To prevent material stretching all the way down to the platen tray causing unnecessary thinning.

The baseboard can be made from a timber based product or metal and should be cut so that it fits neatly inside the platen tray.

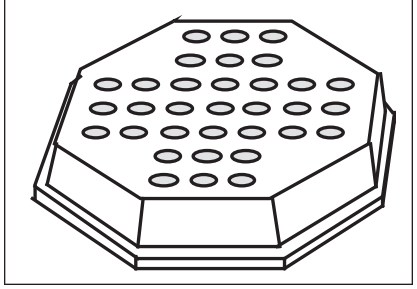
The mould is placed on the baseboard on shimms (double sided sticky pads work well) and screwed into position from underneath. The shimms provide an air track around the bottom edge of the mould.

At least one hole should be drilled in the centre of the base board but, if evacuation is slow, you can drill more.

_ _ _ _ _ _ _ _ _ _ _ _6. Forming & modifying

Place your mould in a vacuum former and attempt a forming. The first forming will usually show up areas of the mould which need modifying. Keep on modifying the mould and testing it until you are satisfied with the result.

Solitaire mould



RESIN CAST MOULDS

A timber based mould is good for most educational or experimental applications and should last for a hundred formings or so - depending on how well it is made. For a more durable, resin cast mould, first make a timber based mould as described previously, then follow these steps:

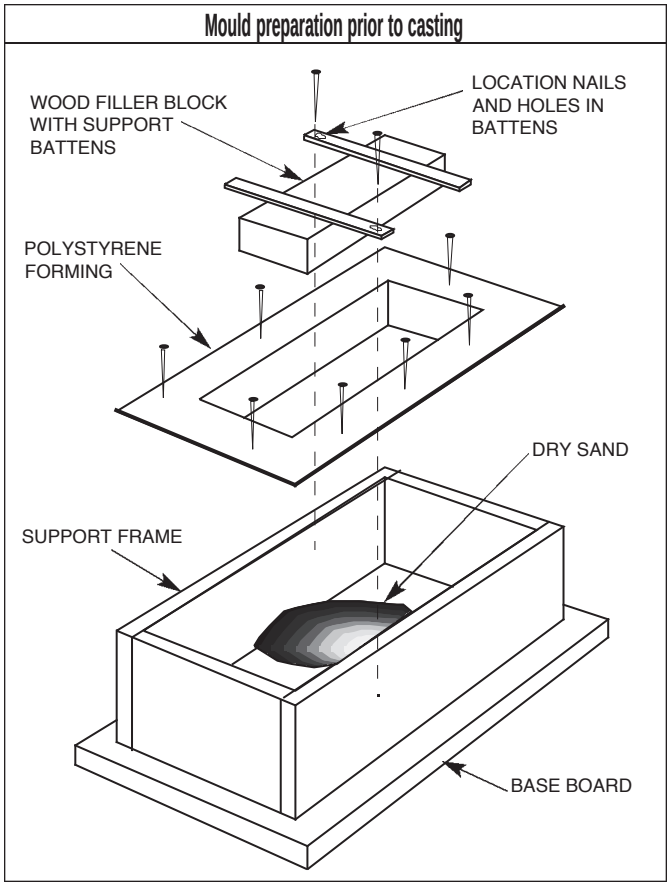
_ _ _ _ _ _ _ _ _1. Vacuum forming a pattern

Take a forming of the timber based mould in 1.5 - 3.0 mm PS, forming at maximum temperature to attain the best definition. The PS sheet has a gloss side and a matt side - remove the film from the gloss side and form with it on the inside.

_ _ _ _ _ _ _ _ _ _ _ _2. Making a casting box

Construct a timber frame and fix the forming in it using small, large headed nails or tacks. Turn the assembly upside down and fill with dry sand (moisture may permeate and distort the PS). Strike off the sand level with a straight edge and fix a timber board over the box to prevent the sand tipping out.

Mould preparation prior to casting



Turn the assembly back over, and you will have a sturdy hollow mould, that will not distort even under several kilos of resin or with the heat created by curing.

3. Packing out the cavity

Suspend blocks of expanded PS or timber over the main cavity, making sure that there is always a gap of approximately 20 - 25mm (3/4 - 1") between the forming wall and the packing. This will reduce the amount of resin required to make the mould and make drilling evacuation holes easier (see later).

The blocks can be suspended on wooden battens which will need to be weighted down or fixed to prevent them floating when the resin is poured.

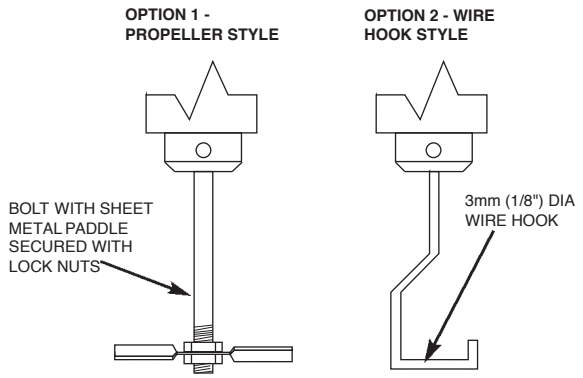
If you are making more than one mould, it might be worth making a vacuum forming of the inner shell which can be suspended over the blocks in the same way.

4. Mixing the resin

Calculate how much resin the mould is likely to need and mix that amount.

The best resin for vacuum forming moulds is aluminium epoxy but, there are others on the market including fast curing types, which can be used. Whichever resin you use it will come as a two part pack and need to be mixed thoroughly before pouring.

Mixing paddles



NB: The twists in the paddle blades will act like a propeller, pushing the drill out of the resin. If they have the opposite effect ie. they suck the resin pot onto the paddle, then you should reverse the direction of the drill or turn the paddles over.

Most resins are too viscous to be mixed by hand so you will need to make some form of paddle mixer, fit it to an electric drill and mix for 3 - 4 minutes, making sure all the resin from the corners of the container is mixed in, to ensure you have a good resin that doesn't have any soft spots when it's cured.

5. Pouring

Brush the forming with resin to prevent any air bubbles spoiling the mould surface (air bubbles will have been formed during mixing and will not be able to escape due to the resin's viscosity - this doesn't cause a problem on the inside).

Once the entire forming surface has been coated, pour resin in until the forming is about half full.

Place the packing blocks in place and pin or weight them down and then pour the rest of the resin. Slight shrinkage may occur during curing so overfill to just above the top of the forming.

6. Curing

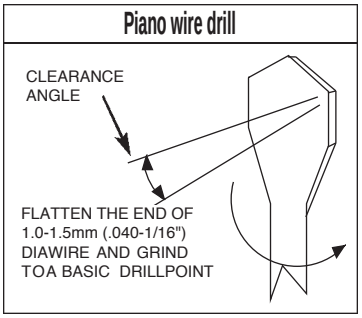
Aluminium epoxy resin needs 24 hours at a minimum 20˚C (68˚F) to cure after which time it can be taken out of the forming box. The packing blocks will probably remain inside the mould and the original forming may be destroyed in the process of removing it. Once it is out of the box, it should be post cure heated at 80˚C (176˚F) for about one hour per kg. Other resins will have different curing requirements and you should refer to the manufacturers' recommendations in each case.

7. Drilling evacuation holes

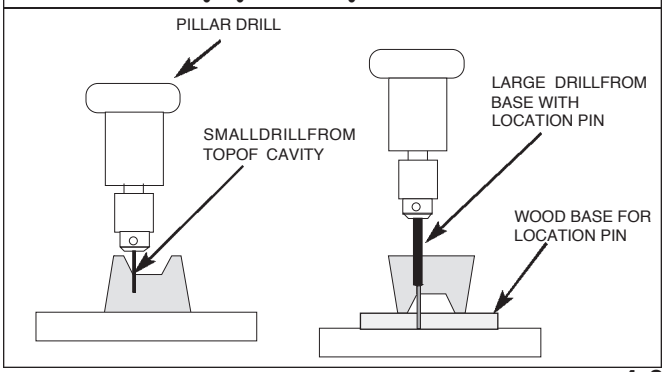
An epoxy mould differs from a wooden mould in that it is not porous and will require evacuation holes for the vacuum to be able to draw material down into all the details.

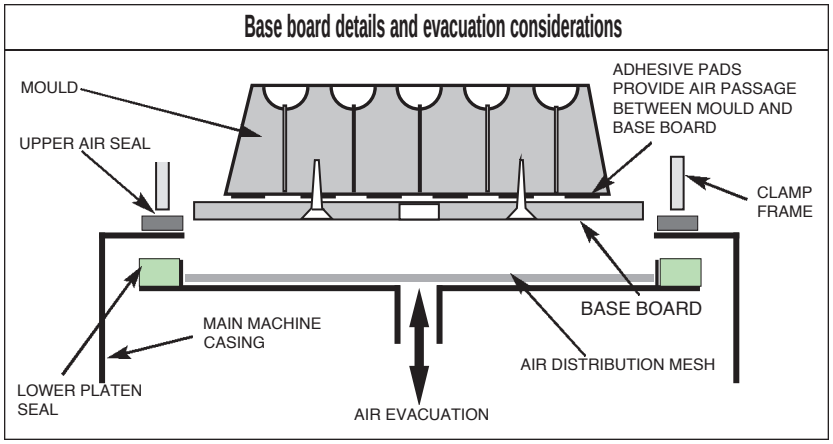
You can easily tell where evacuation holes will be needed initially, by holding the original forming up to the light and seeing where it has thinned the most. These points are exactly the points which need evacuation holes.

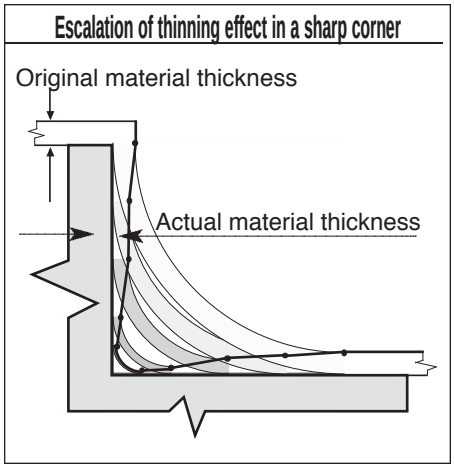
Piano wire drill



Aligning small and large evacuation holes







Drill with a 1.0 - 1.5mm (0.04 - 1/16") diameter drill bit, or a section of flattened and sharpened piano wire or similar, in a high speed PCB drill such as a Dremmel.

As well as the thin spots, hemisperical cativities and large flat or gently domed areas such as model car roofs, may need evacuation holes too.

Sand down or grind the bottom of the mould until it is flat and mount onto a baseboard. Try forming it before drilling too many evacuation holes as you may need less than you think.

8. Finishing

Final finishing, patching up with resin or car body filler, sanding with fine grade wet & dry paper and buffing should leave you with a high quality mould that will last for many thousands of formings.

Note: Large aluminium epoxy resin moulds for high volume production may need to be water cooled.

ALUMINIUM MOULDS

Commercial vacuum formers tend to use aluminium moulds which is a technology becoming increasingly prevalent in schools and colleges as CNC milling equipment becomes more widely available.

CNC milling has the potential to make mould production very simple - all you have to do is draw or 3D scan your model into the computer and then wait while the computer and the mill do all the hard work; mount the finished piece on a baseboard, drill the evacuation holes and you are ready to vacuum form.

Aluminium moulds are very stable when heated and the larger ones have such a high thermal mass that they don't need water cooling.

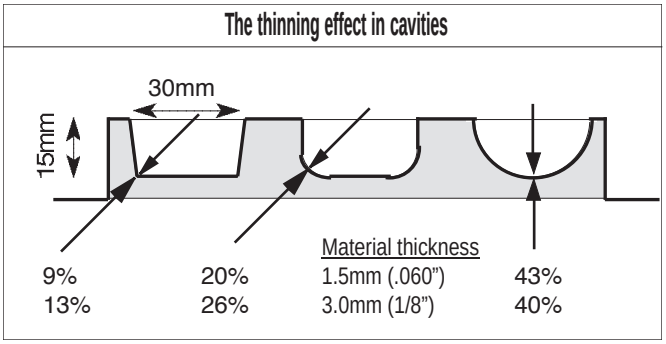
Some complex moulds have moving parts which are easier to engineer in aluminium.

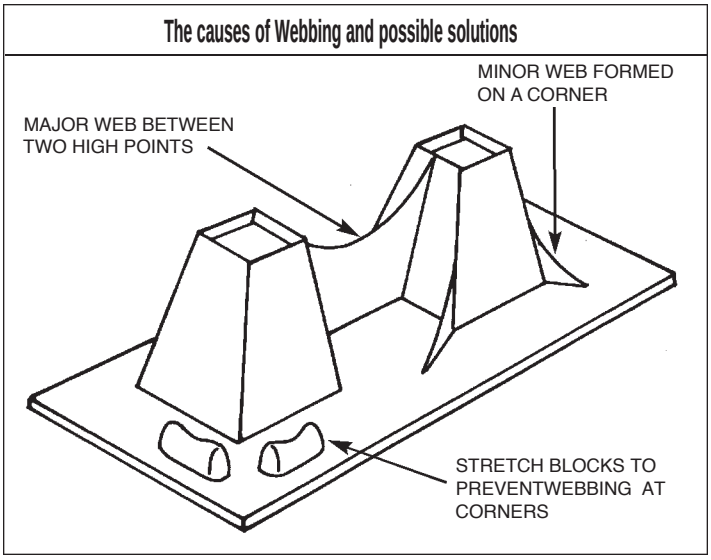
PROBLEMS WITH MOULD DESIGN

THINNING

One of the most common problems in the design of vacuum formed products is thinning. Different mould shapes present different thinning problems too numerous and diverse to discuss here.

The circular cup mould though, is helpful to bear in mind. If a cup mould is straight sided with sharp corners, the maximum depth of cavity will be about half the diameter at the top of the cup. Radiusing the corners at the bottom will improve the depth and rounding the bottom completely will treble it.





If you go beyond these parameters the material at the bottom of the cup becomes paper thin, like a carrier bag, and the cup won't stand on it's base.

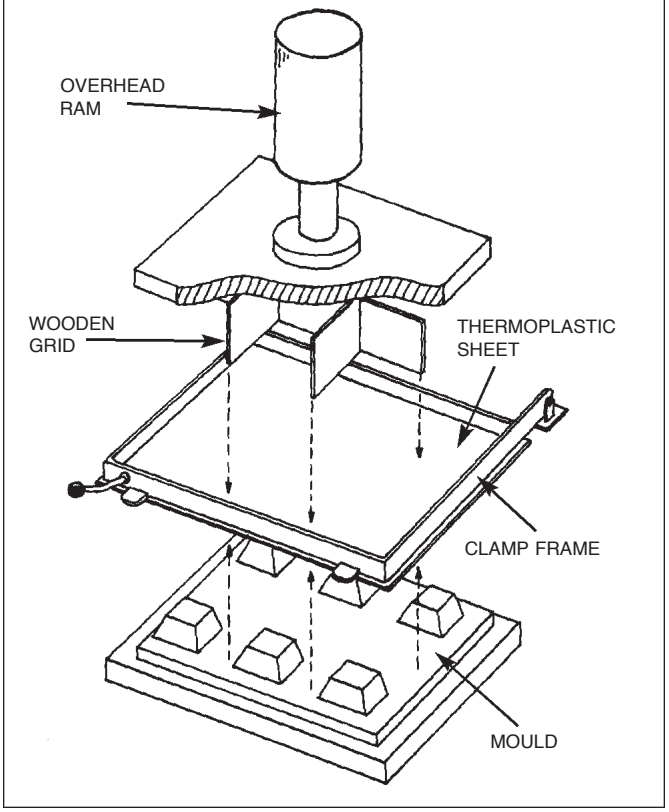
WEBBING

Webs will form between points that are too high and/or too close together. As the material is drawn down it meets itself and forms a fold before it comes into contact with the mould.

Commercial vacuum formers use a plug assist to push the material down before the vacuum takes effect.

This can be done by hand on a manual machine, using a piece of rounded timber, stiff card or TP offcut.

An overhead grid on the plug assist ram as used on a commercial machine to eliminate webbing



CHILL MARKS

A mark is often left around the top of a forming as a result of the mould cooling or 'chilling' the heated TP sheet as the platen rises (see 3. Vacuum Forming).

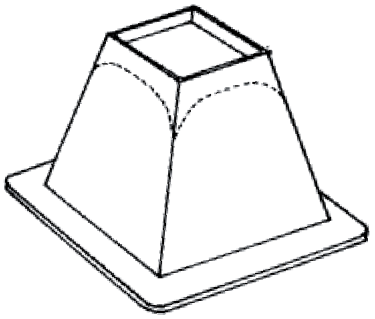
These marks are difficult to eliminate completely but there are two things you can try:

1 Increase the heater output over the high spots.

2 Increase the heat of the mould - this reduces the chill effect and helps material to 'flow' over the mould to give a more even forming.

On some machines it is possibleto blow the material before forming, which can help the chill marks but may aggravate webbing.

Chill marks on a forming

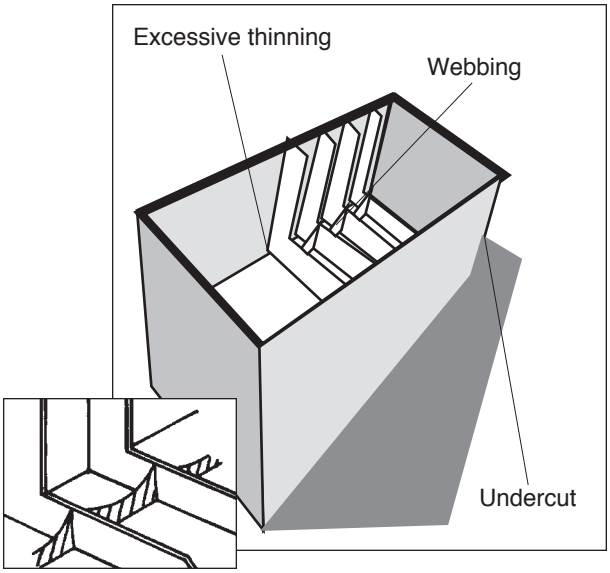


SOLUTIONS

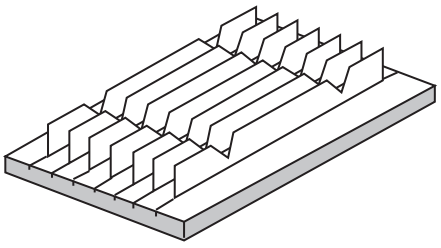
DESIGN

Some products can't be vacuum formed in one piece. But vacuum forming doesn't have to be a one stage solution to any design problem and can produce components for larger products.

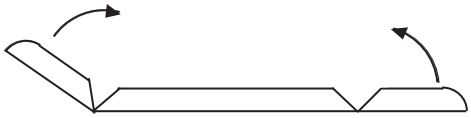
For example, if we tried to vacuum form the CD rack pictured below, we would have problems with thinning, webbing and trapping as illustrated.



Design solution to thinning in a deep mould



FINN'S MADE FROM SHEETMETALUSING A STANDARD SHEETMETALCORNER NOTCHING MACHINE AND INSERTED INTO SAW CUTS IN BASEBOARD



FOLD AFTER VACUUM FORMING. 0.5MM (.020") WILLFOLD COLD. FOR THICKER MATERIALUSE A STRIPHEATER.

But if the rack dividers were vacuum formed flat and folded up afterwards, either cold or on a strip heater, they could be an insert in a casing made from another material.

INVESTIGATION

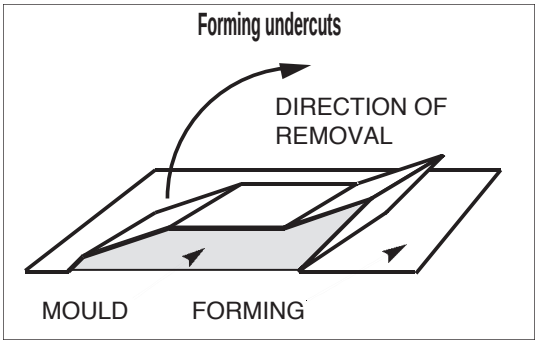
By drawing a grid on a TP sheet before vacuum forming as commercial vacuum formers do when setting up large machines (see 3. Vacuum Forming) you can show where the areas of thinning are originally heated and reduce the heat over those parts.

OTHER THINGS TO TRY

NEGATIVE DRAFT ANGLES OR UNDERCUTS

Normally, a negative draft angle will prevent a forming from being released from a mould.

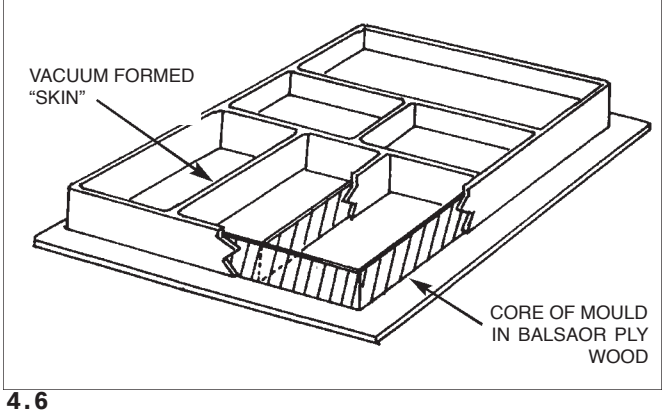
But if a negative draft at one end of a mould, is complemented by a generous positive draft at the other end, it can be possible to get a forming off by releasing the front end first and pulling the forming up and back.



ENCAPSULATION

Skin packaging is carried out using very thin PVC film - less than 0.5mm - and vacuum forming it onto a cardboard base, specially prepared with perforations (for the air track) and heat sensitive adhesive. Products are placed on the board and vacuum formed, with the film.

A "one-off" tool tray using encapsulated Balsa or Ply wood as the core



Using thicker material creates a permanent skin for a product that gives it strength, colour and durability.

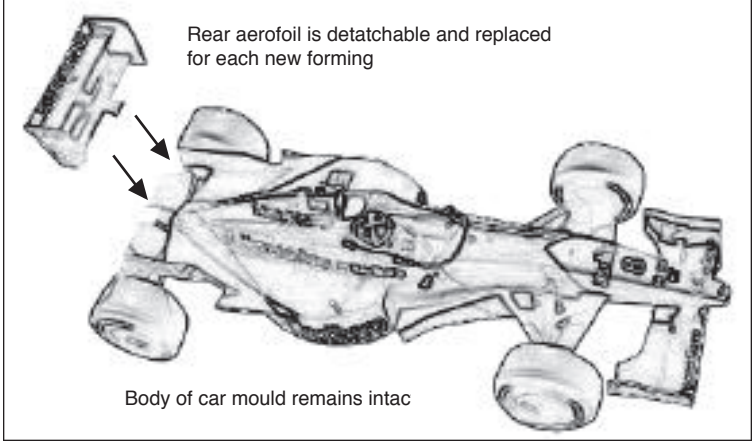
If the mould is going to remain inside the forming, there is no need to worry about draft angles and you can use simple materials, like rectangular sections of balsa wood.

Coins or other artefacts can be simply mounted by encapsulating them in clear PVC, PETG or PS on a decorative base.

PART ENCAPSULATION

You may find yourself faced with the prospect of a complicated mould who's formings are getting stuck on just one part. If you make that part detachable, then you can leave it in the forming and you only have to make another one of those parts and attach it to the main mould with blu-tack or dowel pegs to make another forming.

Formula One car mould concept with encapsulated aerofoil



VACUUM FORMING EXPANDED POLYSTYRENE

Expanded polystyrene, which is easily cut on a Hot Wire Cutter, is an interesting material to use as a mould. The heat of the sheet as it forms over the expanded polystyrene, heats it up to the point of collapse, creating an interesting surface texture. Different density foams collapse to different degrees, creating different surface textures.