Vacuum Forming Guide for the Classroom


Table of Content

Introduction

Thermoforming has been around for a very long time, and has transformed the world that we live in. It is a process that has helped to make items from the simplest of food packaging trays, to car interior parts, sets and costumes in Hollywood blockbuster movies, life saving medical equipment, and even components for space exploration. The possibilities of this production method are endless, with applications seen in almost every industry you can think of. Despite seeing and using thermoformed plastics every day, not everyone has even heard about thermoforming before, let alone had the chance to use it to design and manufacture something fresh out of their own imagination.

‘Thermoforming’ is used to describe any process in which heat is used to shape and mould plastic, although in this guide we will be talking specifically about ‘vacuum forming’, which can certainly be considered part of the thermoforming family, only with some very important extras.

The simplest description of the vacuum forming process is that of a sheet of plastic having heat applied to it until it softens, before being draped over a mould. A strong suction of air, or ‘vacuum’, is applied from below, attracting the soft plastic over the mould to adopt its shape. Once cooled, the mould can be removed, leaving just a perfectly formed plastic component. A very simple process, but one which is hugely popular, effective, fast, and easy. The early 1900s saw the development of the first thermoforming machines. They were big, and took up a huge amount of space. We’re glad to say that things have changed a bit since then, and thermoforming equipment today can be so small it might fit on a school desk.

In this guide we will be exploring the potential of the Formech vacuum forming machine that you have available, covering all aspects of how to use it, what to use it for, how to produce your moulds to form over, and all the tricks of the trade that go along with it. This document will be your one stop guide which you can refer back to at any point during a project that involves vacuum forming, to find all the answers, hints and tips you might be looking for. Once you’ve got to grips with the contents of this guide, there will be just one question left unanswered; what are you going to make?

Applications of Vacuum Forming

Aeronautical Manufacturers
> Interior Trim Panels, Covers and Cowlings
  Internal sections for NASA Space Shuttle

Agricultural Suppliers
> Seed Trays, Flower Tubs, Animal Containers, Clear Growing Domes
> Calf Milking Receptacles, Machines Parts
> Lawnmower Enclosures and Covers

Architectural Model Makers
> Production of Miniature Parts for Architectural Models
> Prototypes

Automotive and Vehicular Industry
> Wheel Hub Covers, Ski-Boxes and Storage Racks, Wind Tunnel Models, Parts for All Terrain Vehicles Truck Cab Door Interiors, Wind and Rain Deflectors
> Scooter Shrouds, Mudguards, Bumpers and Protective Panels
> Battery and Electronic Housings, Prototype and Development work
> Utility Shelves, Liners, Seat Backs, Door Inner liners and Dash Surrounds
> Windshields, Motorcycle Windshields, Golf Cart Shrouds, Seats and Trays
> Tractor Shrouds & Door Fascia, Camper Hardtops and Interior Components

Building and Construction Industry
> Drainpipe Anti Drip fittings
> Roof Lights, Internal Door Liners, PVC Door Panels, Producing Moulds for Concrete Paving Stones and Special Bricks
> Moulded Features for Ceilings, Fireplaces and Porches

Boat Building industry
> Boat Hulls, Covers and Hatches Electrical Enclosures, Dashboards

Chocolate industry
> Manufacture of Chocolate Moulds for Specialised Chocolates
> Easter Eggs etc. and Packaging

Computer Industry
> Manufacture of Screen Surrounds
> Soft Transparent Keyboard Covers Enclosures and Ancillary Equipment

Design Industry
> Production of prototypes and Pre-Production Runs
> Prototype Concepts for other Plastic Processes

Film and Media Industry
> Manufacture of Costumes and Sets
> Animation Models and Mock Ups for Computer Simulation

Furniture Manufacturing Industry
> Chair and Seat Backs
> Cutlery tray inserts
> Kitchen Unit Panels and Storage Modules

Hospitals and Medical Applications
> Radiotherapy Masks for Treatment of Cancer Patients
> Pressure Masks for Burn Victims
> Prosthesis Parts
> Dental Castings
> Parts for Wheelchairs and Medical Devices for the Disabled

Machinery Manufacturers
> Fabricating machine guards and electrical enclosures

Model Car and Aircraft Industry
> Production of bodies fuselages and other parts for models

Museums
> Variety of applications within Science and Natural History Museums

Packaging and related Industries
> Point of Purchase
> Trays and Plates
> Cosmetic Cases and Packages
> Electronics and Cassette Holders
> Blister Pack Products, Skin Pack Products Food Trays, Cups and Fast Food Containers

Plastic Sheet Extrusion
> Testing and Sampling of Extruded Sheet

Signage Industry
> Exterior Signs Point of Sale Displays

Education
> Training Aids for Students Studying Polymers and Plastic Processing

Electronics Industry
> Manufacturing Enclosures for Specialist Electronic Equipment
> Anti-Static Component Trays

Sanitary Industry
> Bathroom Fittings
> Bathtubs, Jacuzzis and Whirlpools
> Shower Surrounds, Shower Trays and Retrofit Shower Components

Souvenir Industry
> Making parts for and moulds to cast craft souvenirs

Sports Industry
> Helmets, Guards and Gum Shields

Theatre
> Manufacture of Props, Sets and Costumes

Toy Industry
> Games, Action Figures, Packaging, Dolls, and Prototyping

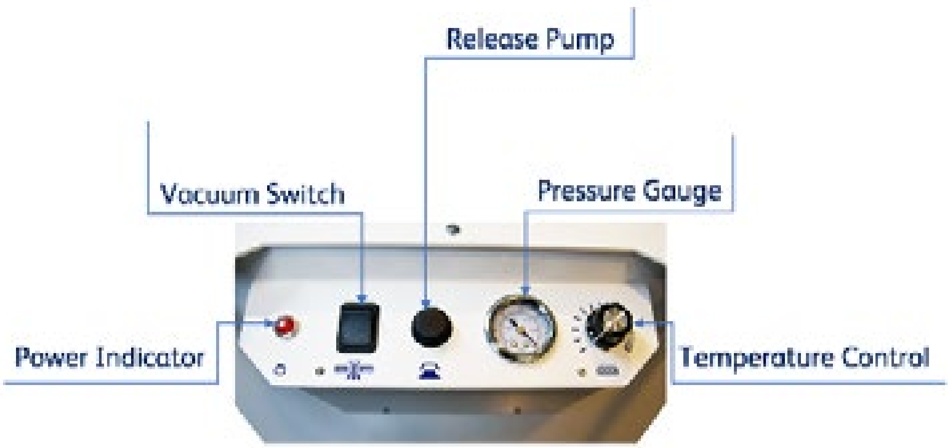
The Vacuum Forming Process: Step-by-Step

Vacuum forming machines are simple in their function, although this has come over decades of development and advances within both engineering and plastics knowledge. The vacuum forming machine needs the presence of just 3 things to produce high quality and consistent plastic products; a mould, sheet plastic material, and an operator who understands its basic operation (that operator is you!). It is here where we will walk through the basics of the machine, and how to carry out a successful vacuum form.

The Formech machine will need to be switched on 15 minutes before it is to be used, with the heater in its back position. This is to allow the heaters to heat up and deliver a consistent and even temperature.

The table can be raised by simply pulling the lever towards you until it clicks. The mould to be vacuum formed over can be placed on the table and positioned centrally, and the table then slowly lowered, seeing the mould now go inside the vacuum forming machine.

A sheet of plastic material can be placed over the aperture plate, as if putting a lid on the space containing the mould. The clamp frame can be lowered and secured in place. The tight clamp will create an airtight seal between the aperture window and the plastic sheet, creating perfect conditions for the vacuum forming process.



The heater can now be pulled forward to cover the clamped plastic, and be given the appropriate length of time to heat the material depending upon both its thickness, and the type of plastic material used. The heater can be moved back and forth to check on the material as needed.

Having had ample time to heat the plastic, the heater can be pushed back all the way. The sheet material should have a visible slight sag, indicating that it is ready to be vacuum formed.

The table can then be raised completely using the lever, at which point the mould will be seen pushing into the heated plastic sheet from below. The vacuum pump can be switched on, which will draw air out from under the mould, attracting the soft plastic over it. The vacuum pump might be applied for 15 seconds or more, to ensure a high definition form, and to allow some time for the plastic to cool.

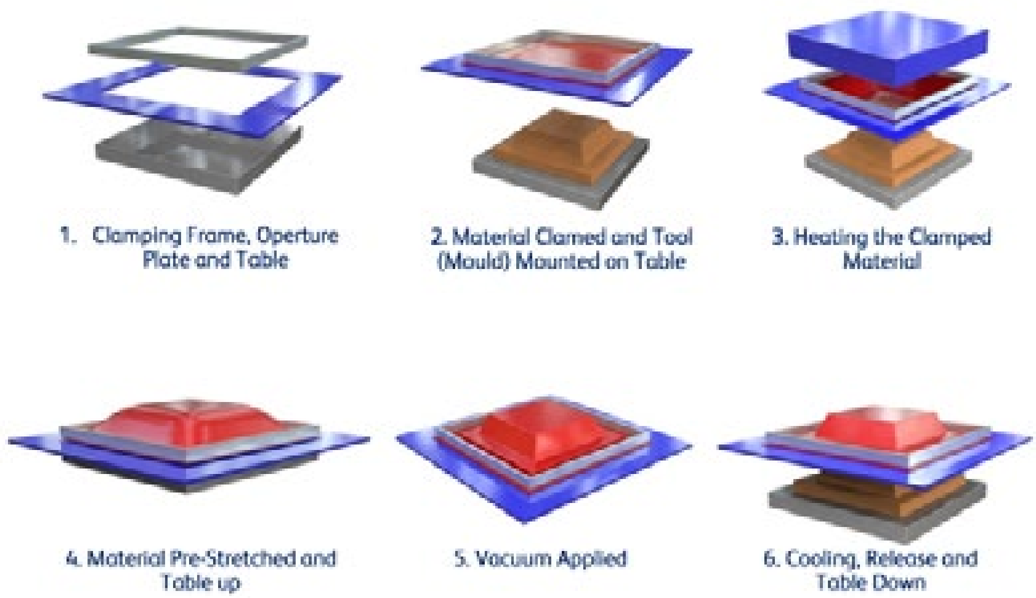
The vacuum pump can now be switched off, and then the exhaust/release pump is pulsed once or twice. Rather than removing air like the vacuum pump, the exhaust/release pump does just the opposite, pushing air in from below. This pushes the plastic material up very slightly and encourages mould release.

The table lever can be lowered slightly, lowering the table just a short distance lower than the aperture window. By then tapping gently on the plastic material, the mould will be released from the formed shape, and sit back on the table. The table can now be slowly lowered completely.

The clamps can now be unclipped, and the clamp frame raised. The user will now have their completed vacuum formed product, ready to have excess plastic material trimmed off.

Once one forming cycle has been completed you will have a good idea of how long heat needs to be applied to the plastic material for it to be vacuum formed. You can now begin using the integrated timer which is available on most Formech machines, or use an external timer to aid the vacuum forming process, removing the need to check on the plastic during the heating cycle.

Basic Principles of Vacuum Forming



Key Things to Consider During the Forming Process

It is important to heat the plastic material appropriately to gain the perfect vacuum form. This comes with the experience of just a few forming cycles, although a good general rule is to apply 20 seconds of heat for every 0.5mm of thickness of the plastic material. For example, 1.5mm thick plastic requires approximately 60 seconds of heat. This varies between type of plastic material used, but these timings can be a good place to start (see page 28).

Do not touch the heated plastic material with your hand or any other object during the heating cycle. This may cause harm or damage the material itself. Rely on the visible slight sag as the indicator for the optimum temperature to perform the vacuum form, or use a temperature gun to aid you.

Do not attempt to raise the table of the vacuum forming machine when the heaters are in the forward position. This may damage the lever mechanism, or the heating elements. Most vacuum forming machines have a safety mechanism which will not allow the table to be raised unless the heaters are in their fully back position, or for the heaters to be pulled forwards if the table is raised.

When lowering the table, be sure to make this a smooth and steady motion rather than dropping it. This will prevent any damage or movement of the mould within the forming area, and reduce stress on the machine.

Always remember, this machine produces heat that reaches very high temperatures. Do not touch or put anything on top of the heating draw of the machine, or put your hand under the heating draw itself.

When plastic cools from its heated state, it will shrink just a small fraction; anything between 0.3 – 0.8mm. With this in mind do not leave the mould inside the vacuum formed product for any longer than it needs to be. This will enable ease of mould release.

If there are any issues or problems with your final vacuum formed product, these are often for simple reasons and will have easy solutions. These will be addressed later in this guide (see page 19).

Mould Materials and Mould Design

Mould design is for most people the most exciting and rewarding part of the vacuum forming process. It is here that you can draw upon everything that is in your imagination as a designer, an artist, or an engineer, and realize it in a real physical object. The mould, sometimes called the ‘tool’, is the object which is placed on the table of the vacuum forming machine over which heated plastic will be formed. This mould is the most important part of the vacuum forming process, as without its considered and purposeful design, there would be limited success in the forming process.

Successful mould design will enable the machine operator to produce high definition, high quality vacuum formed products, to the production amount required before mould degradation (when the mould begins to lose its shape or stability).

There are a few considerations to make when designing your mould, from its shape, to the material used, to airflow, to size, and spacing, but don’t worry; in this section of the guide we will take you through each consideration, and have you making perfect custom moulds which produce perfect vacuum formed products.

Mould Materials

There are a wide variety of mould materials available to choose from, from clay, to wood, to MDF, resin and more, which can be selected based upon a list of requirements for the designer and the final vacuum formed product.

- How many times will the mould need to be vacuum formed?
- How much detailing will the mould involve?
- How are you going to shape or tool the mould?
- How much does the mould need to cost? Is there a budget?
- How much time do you have to produce the mould?

These are all questions that need to be considered before selecting the mould material. Here we will go through each material one by one, covering its benefits and drawbacks, which should help you make the correct choice in your mould material choices.

Wood / Medium Density Fibreboard (MDF)

Wood and MDF are very popular mould materials due to their low cost and ease of tooling. Using a range of simple woodworking tools and techniques, the designer is able to produce a mould with relative ease which is capable of withstanding hundreds of vacuum forming cycles.

If using wood, harder woods are recommended due to their close-knit grain and higher strength, which also makes them more resistant to heat. To increase wooden mould strength even further, finished moulds might be sealed with varnish to increase their production run lifespan, although this is something seen mainly in industry rather than in smaller workshops, and so this is by no means necessary for single or small run production.

MDF is especially easy to work with, with designers often stating that "it cuts like butter", which is very true. MDF is not as strong as wood, but certainly performs well in the vacuum forming process, whilst providing a fast and effective mould making material.

All woods will expand and contract with every heating and cooling cycle, which means that over extended use they will display visible degradation with cracks and deformity. That said, this material is a favoured material in education and small factories due to its cost, time, and ease of tooling benefits. Venting holes will need to be applied to most wood and MDF moulds.

Modelling Clay

Modelling clay is widely used as a mould material due to its incredible ease of shaping and very low cost. For simple mould designs the designer might even use just their hands to shape and mould the material to their desired shape. This makes it an ideal material for producing a one-off item, or to prototype a product quickly.

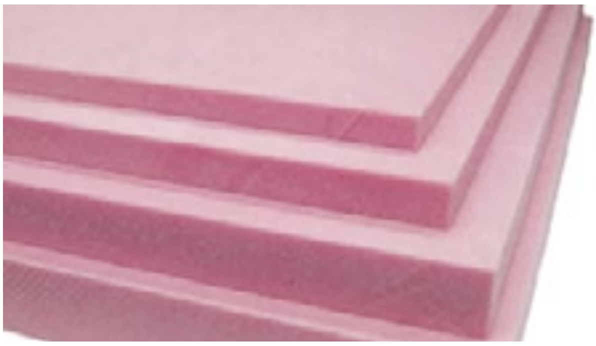
One big disadvantage of clay is its fragility, or lack of strength. It performs well for a limited number of forming cycles before becoming brittle, at which point cracks will begin to appear and shape will be lost. This makes it ideal for only a very short production run.

Clay moulds will need to be dried completely before being vacuum formed to ensure that they hold their shape during the vacuum forming process. The heat and pressure applied during a forming cycle will most likely deform any clay mold that has not been allowed to dry thoroughly. Dried clay moulds will also likely require few or no venting holes applied, as the material is relatively porous and will allow air to flow through it. It should be possible to push a wire through the clay before it has dried to create vacuum holes.

Foam

Foam material can be one of the cheapest, and easiest materials to shape. When we talk about foam, we mean large sheets of building insulation foam that can be cut to the desired shape very quickly, using a machine or hand saw, or a hot wire cutter. Using a variety of both hand and machine tools, detail can be added and some very impressive moulds produced. Due to this ease of working, it is a popular material for prototyping or single run vacuum forms. We recommend that you use a foam with a small bubble structure so that you get a good quality end result, that is less likely to crumble.

It may be quick and easy to work with, but be warned, foam material has a very low level of heat resistance, and its shape will be affected by the heat produced during a forming cycle. This means that a foam mould may only be suitable for a handful of vacuum forms. To increase its cycle life and to encourage ease of mould release, a foam mould might have a layer of aluminium tape, or simple aluminium kitchen foil applied to any surface which will come into contact with heated plastic material. This will greatly reduce any stress caused by heat. It is also a very light material, and with the vacuum forming process relying on the movement of air, it is advisable to secure the mould to the vacuum forming machine table before with some double sided tape, before beginning the forming process.



Cast Epoxy Resin

Epoxy resin begins life in liquid form, most often two separate liquids which are mixed together; the resin, and a hardener agent. When combined and mixed thoroughly, they can be poured into a prepared mould and allowed to set, creating a very hard and very durable mould to be vacuum formed. These resins are available in many different varieties, and can take anything between 30 minutes and 12 hours to set completely.

Imagine having a large animal shaped jelly mould. This would be the perfect mould to use to create a vacuum forming mould using resin. Having coated the inside of the jelly mould with a silicon release agent spray to encourage the final resin mould to be released, mixed resin can be poured in and allowed to set, following the manufacturers instructions. You could also pour resin into a mould you have made yourself out of wood, or a vacuum formed part made previously.

This is a good example of how a mould might be made quickly, easily and cheaply using clay, and allowed to dry. Once the clay mould has been vacuum formed, the newly formed plastic shape can then be used to cast epoxy resin within, creating an incredibly durable and strong replica of the original clay mould, perfect for repeated forming cycles.

The main benefit of resin as a mould material is its long life and durability. Unlike clay, a well-made resin mould will be fit to withstand hundreds of forming cycles with little or no visible sign of aging, or decrease in quality of the vacuum formed product.

The only real draw backs of casting moulds from resin are the relatively high expense, length of time required, and the need to source or make an original mould within which to pour the resin in its liquid form. Resin is also a non-porous material, which means that no air can pass through it, therefore venting holes will need to be applied for most moulds made from this material.

3D Printing

This is where vacuum forming and computer technology meet in the middle, and we find ourselves with a wonderful tool with which to produce a mould to be vacuum formed. 3D printers have become increasingly cheaper and much more common in recent years, and can be found in most schools and workshops around the country. They allow an object to be designed using Computer Aided Design (CAD), which can then be printed as a 3D physical object using a wide variety of materials. This allows the designer complete control over the size, dimensions, and specifics of the object to be printed, which can be produced sitting in front of a computer rather than in a workshop using traditional tools and materials. Alternatively, 3D printing files can be downloaded from online sources, and scaled up or down as desired. Either way, they can be printed with the single click of a mouse.

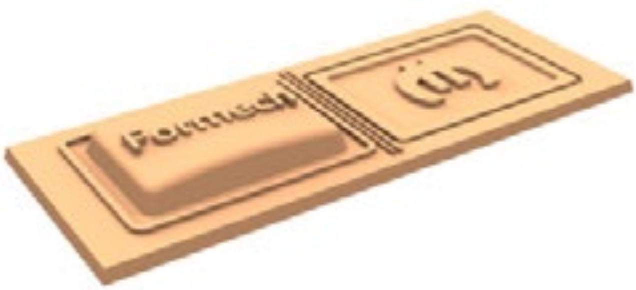
The types of materials and processes used to 3D print objects vary widely in both characteristics and cost, but two processes which are commonly used are FDM and PolyJet. The FDM process produces a high quality and heat resistant mould, which is porous by design with no need for venting holes. The PolyJet process also produces high quality results, whilst being known for producing very smooth finished surfaces, although does not produce a porous mold, and so venting holes will need to be considered at the CAD stage. When 3D printing using either of these processes, it is advisable to use ABS or polycarbonate materials over PLA material. This is simply to ensure that the 3D printed mould will perform well when exposed to heat and pressure during the vacuum forming process. PLA moulds are known to lose their shape much more quickly than ABS and polycarbonate 3D printed moulds.

3D printing a mould to be vacuum formed certainly opens up many new possibilities and challenges for designers and manufacturers during the mould making process. 3D printing a single small object can often take in excess of 12 hours, and so alternative mould materials might well be better suited to school projects or simple designs, but no one can discount 3D printing as a real benefit to designers during the mould design process.

Computer Numerical Control (CNC) Machined Tooling Board

CNC is a method used widely in industry to cut materials to shape, using a rotary cutting tool whose path is controlled by a computer. With the mould material laid stationary on a machine's table, the tool then works its way around above it, changing its height and direction, cutting away material as it goes. This is a method of tooling which is unlikely to be readily available for High School level students, but never the less not impossible. Because it is so widely used in industry, it is important it receives a mention in this guide.

Materials for which CNC is widely used might include MDF, tooling/model board, aluminium or Alwapor porous board. All of these cut relatively easily and produce moulds perfectly suited to vacuum forming, whilst providing a high level of control and detail. Just like 3D printing, all the hard work takes place behind a computer, with the physical shaping of the materials being done by an automated machine. Tooling paths can be produced on a computer using specialist software, or downloaded from various online sources.



Aluminium Cast

Aluminium is a favoured material for moulds used in mass production lines using vacuum forming. It is incredibly strong whilst remaining incredibly light, and allows heat to dissipate quickly following the forming cycle, reducing the need to cool it down between cycles on lengthy production lines where temperatures can get very high. It can be machined by human control or CNC, or can be cast to the desired shape. Just like CNC, it is unlikely to be found in High School workshops, but certainly helps give context to the range of mould materials available to designers and engineers within the mould making process.

Any suitable existing object

One of the most enjoyable parts of design and engineering is being inspired by the world around you, and using ‘organic’ objects to aid the design process. This can be true of the designs that you draw on paper, and also of the materials you use, and mould materials are no different.

Imagine making a number of plastic plant pots using vacuum forming as your production method. You might need to design and produce six identical plant pot moulds from a suitable material listed above, dedicating time, effort, money, materials, and hard work to the process. Alternatively, you might choose to simply use six existing terracotta plant pots as your moulds. They are both strong and heat resistant, and the correct shape to be vacuum formed over. This alleviates a great deal of time and resources, enabling you to move through your production process much more effectively.

This use of an existing physical object is not exclusive to simple terracotta plant pots, rather it is wide reaching and applies to many objects all around you. So long as the object you choose is both heat resistant and strong, as well as abiding by some very simple mould design basic requirements (see page 15) it may well make the perfect mould for the project you are completing.

Mould Design: Basic Considerations

In addition to mould materials, any designer must also think about mould design requirements when designing their mould. In this section we will explore just a few brief, but absolutely essential requirements for mould design, so listen up, this is important.

Draft Angles

When designing a mould it is important to think about working draft angles into the design. These are very slight tapers which are applied to the outer edges of the mould, and any substantial angles within. They aid both the distribution of plastic material during the vacuum forming process, and mould release. These inward tapers do not need to be dramatic or hugely visible, although the bigger the draft angle, the more successful the vacuum forming process and mould release will be. It is recommended that draft angles should be a minimum of 3° - 5°.

Imagine vacuum forming over a perfect 10cm cube of wood material. The cube would be lifted into the heated plastic material when raising the machine table, and when the vacuum pump is applied the material would be sucked straight down to form over the sides of the cube. This means that the material will be stretched thinner than desired, creating weak spots in the final vacuum formed product. This is called 'thinning'. If we now think about mould release, the uniform cube shape does not lend itself well to this process. The heated plastic will have stretched, formed, and importantly cooled over the cube mould. We know from earlier in this guide that plastic shrinks during the cooling process, which means that in this case it will now be formed very tightly around the cube mould, creating a situation where it will be very difficult to release the mould without damaging the formed plastic.

Now, imagine this same 10cm, only with the 4 outer edges with 5° draft angles applied. The plastic material would not be nearly as stretched during the forming process, nor would the cooled plastic clamp around the wooden mould, making for much easier mould release, and this, is the magic of draft angles.

Venting

We know that vacuum forming relies heavily on airflow to attract heated plastic over a mould. It's quite simple; the greater the amount of airflow, the more successful the vacuum forming process will be. With this in mind, every mould produced should have venting holes considered. These are holes which are made from the top of the mould, right the way through the mould material and out of the base, creating a channel for air to flow completely through. They do not need to be a huge diameter and can in fact be just 1.5mm wide, and can be drilled using a simple pillar or hand drill. These small holes will not be visible on the final vacuum formed product.

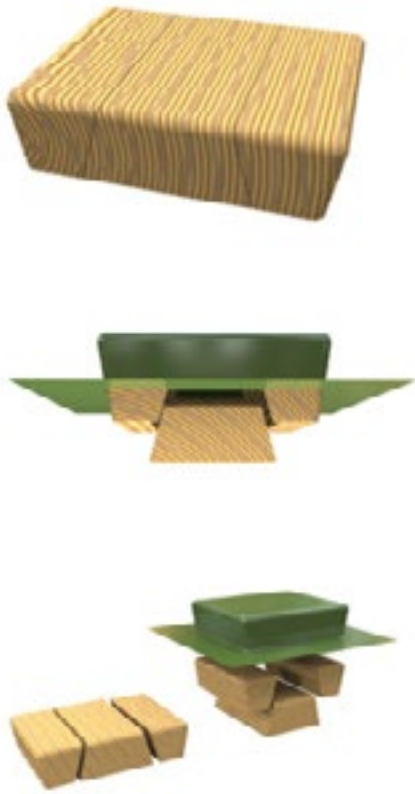
Knowing where to apply them is easy. Any place on a mould where there is a recess or notable groove will need a venting hole or two. This will create an air channel which when the vacuum pump is applied, will attract the heated plastic into that specific area of the mould. Think of any part of a mould where plastic will need to be formed within it rather than over it. These are the key spots where venting holes will be essential.

Undercuts

Undercuts are very rarely seen in any vacuum forming mould. 99 % of moulds will have no undercuts at all, and there is very good reason for this. Imagine vacuum forming over a dining plate, which has a very visible undercut all the way around its outer edge. During the forming cycle plastic material would be formed over, and indeed under the plate itself. This would make it impossible to remove the dining plate from the formed plastic material. This simple consideration should be applied to all mould designs, with every effort made to avoid undercuts at every turn.

If undercuts are an unavoidable element of mould design, then there are some methods which may assist you in a successful form and mould release.

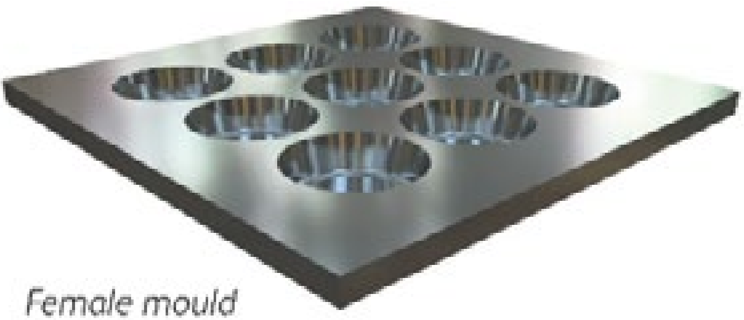
- Use putty or clay to fill in the spaces within the undercut during the forming process
- Complete the vacuum forming process with flexible material, like Polyethylene foam
- Us a tool which is made up of multiple intersecting pieces, which once vacuum formed can be dismantled and removed



Male and Female Moulds

Male and female moulds are the two categories that moulds fall into, sometimes referred to as 'positive and negative' moulds. Put very simply, the difference between the two is whether heated plastic material will be formed over or within the mould. This simple illustration clearly demonstrates what this means.

The female mould illustration also demonstrates nicely a time when venting holes would be an absolutely essential part of mould design, in that it relies on heated plastic material being attracted into the six deep recesses. Each individual recess would likely need several venting holes applied at their base, all the way around their outer edge.


Female mould

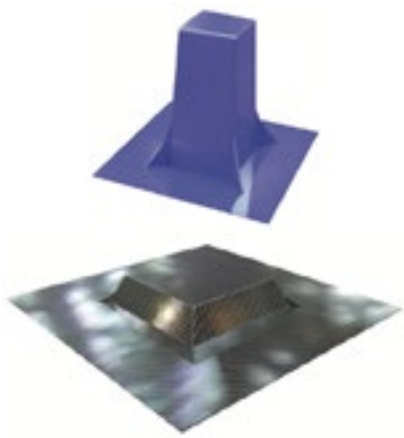

Male mould

Common Problems (and their Simple Solutions)

Webbing

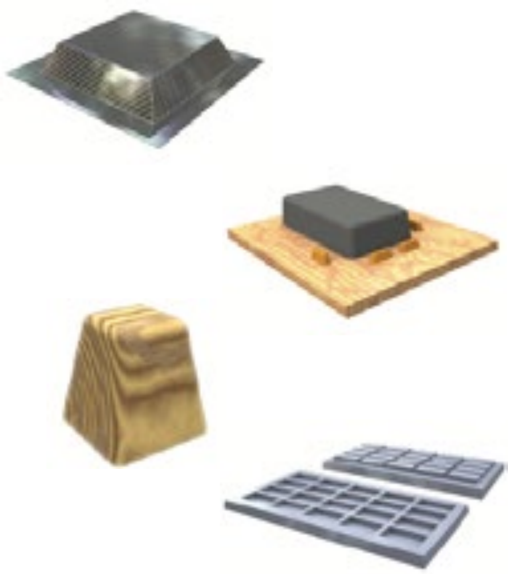
Webbing is used to describe any unwanted folds of plastic that gather around or in between the mould or moulds being vacuum formed. These are most likely as a result of heated plastic material being distributed inappropriately when the mould is raised to make contact with it. When the vacuum pump is applied, the plastic material is pulled down unevenly, rather than forming perfectly over the mould. Some plastic material adheres to itself and creates these unwanted folds around the edges of the formed piece. There are four main causes for this;

- The mould is too tall
- The mould does not have enough draft angles applied
- There is too much heated plastic material for a small mould
- Multiple moulds are too close together



The easy fixes for this are self-explanatory, as all you need to do look at the four causes, and see which one applies to your mould and the forming process.

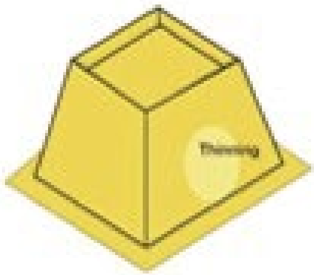
> Use a smaller sheet size so that the mould/tool stretches the material more
> Place angled blocks around the corners to use up the excess material
> Add draft angles and soften corners to allow the material to flow over the mould
> Try using a female mould instead of a male mould



Thinning

When heated plastic material is overly stretched during the forming process, it causes the material to become thin and weak in certain places. Solutions to this are again, very straight forward.

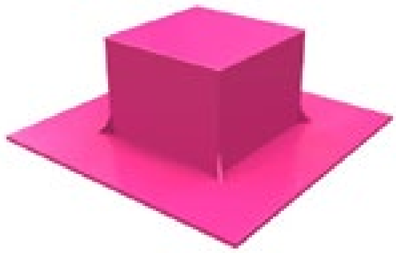
- Increase draft angles around the sides of the mould
- Decrease the height of the mould
- Use thicker material
- Modify the design in certain areas



Difficult Mould Release

Sometimes the mould may become difficult to remove from the formed plastic sheet, which can be very frustrating. Here are some of the possible reasons why your mould and your plastic may not want to part company.

- The mould has become too hot after more one vacuum forming cycle
- The plastic was allowed to cool a little too long over the mould before being removed
- There is an undercut somewhere on the mould
- The reverse pump was not used at the end of the forming cycle



*this graphic displays a sharp cornered rendering with zero draft angles and sharp corners which is difficult to form and also very difficult to release.

Lack of Definition

This is when the formed plastic piece doesn't look quite as impressive as it should do, and without as much detail as the mould should create. It could be caused by any of the following reasons.

- There are not enough venting holes in the mould
- The plastic material was not heated enough
- The seal between the plastic and the aperture window is not airtight and you are losing vacuum – check the vacuum gauge

Finishing and Trimming

Once you have done all of the hard work, made your mould and vacuum formed it perfectly, you are going to want to trim off the excess material, leaving you with just the vacuum formed piece you require. To do so there are a few different techniques that can be used in the classroom or in a small workshop. It is up to you to choose the one that best suits the piece that you are trimming. Whatever method you choose, be sure to approach the process with great care, and only use equipment with the correct training and supervision.

By hand - scissors, tinsnips, or sharp blade

This is a method which will work very well with many items, especially those with straight edges. By placing the vacuum formed plastic flat on a work bench, and placing one hand directly on top of it, the mould can be gently pushed down to prevent it moving around. With the other hand, take a strong sharp blade such as a Stanley knife, and run it along the desired cutting line. It will not cut directly through the material, but after one or two passes it will make the material weak enough that it can be bent along the cutting line and the material will separate nicely. Always break the plastic away from the knife line you have just cut to give you a cleaner break. This works well with HIPS and ABS. The edges may be a little rough, but these can be scraped to remove excess, and sanded with sandpaper to a smooth finish.

For very thin plastic material (less than 1mm thick) a strong pair of scissors might be used to trim off excess material. Again, a light sanding will remove any rough edges created.

Vertical band saw

Trimming using a band saw is quick and easy, although getting very close to the desired cutting line can be difficult if the line is not a straight edge. Curved edges rely greatly on the skill of the operator, and so a little practice may be necessary. This method can produce a rough edge, but this can be neatened up with a small amount of scraping and some light sanding. If you choose a different trimming method, the band saw can still come in handy to trim off the majority of excess plastic material, before trimming neatly by hand for example.

Rotary slitting saw

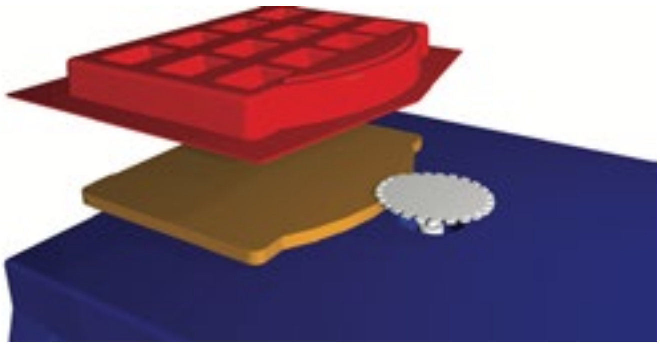
A rotary slitting saw can be fitted into a pillar drill, and the table adjusted to a height where the blade is almost touching it. The vacuum formed part can now be placed flat on the table and moved around so that the rotating blade cuts around the desired line separating the desired piece from the excess material. It is advisable to roughly trim away most of the excess before using this method.

If using this method, please proceed with caution, as the rotary slitting saw is a very effective cutting tool and will certainly cause harm if a hand comes into contact with it. With this in mind, consider turning the slitting saw over on the spindle end so that the rotary slitting saw rotates with the teeth in reverse. This means that the saw will grind plastic material away rather than cut it, and in the event that the saw is mistakenly touched it will not cause serious harm.

Table mounted router (15000 – 25000 RPM)

Not dissimilar to the rotary slitting saw method, a table mounted router also involves a rotating slitting saw, only this one is mounted below the table. A vacuum formed plastic part can be placed over the rotating cutting tool. The formed plastic can be moved around, allowing the cutting tool to trim away excess material from the inside.

Table mounted trimmer (FT10 and FT20 trimmers –1250 RPM approx)



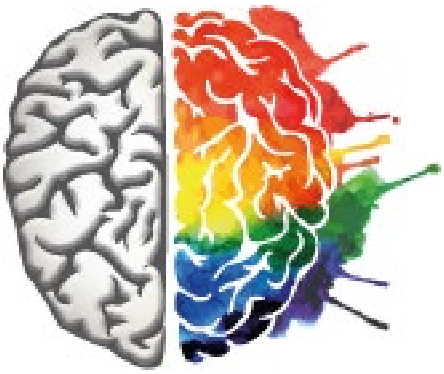
A rotary slitting saw can be used on a table mounted router, although a small sanding disc might also be suitable. This will grind the plastic material rather than cut it and reduce any risk of harm during the trimming process.

Final Thoughts

This brings us to the end of our guide for vacuum forming in the classroom, but certainly not to the end of your learning about the vacuum forming process. These are the very basics to get you started creating some incredible vacuum formed products, drawing upon all of your existing skills in the workshop and applying them to the process. The vacuum forming process will never just be about heating and shaping plastic, rather it is going to draw upon all of your skills as a designer, your problem solving skills, material selection choices, tooling methods selections, and most importantly, your imagination.

This is a technology which can truly change the way you see the world as a designer or artist, and open up new and interesting doors for you as you complete any project you take on.

Be **creative**. Be **innovative**. And most importantly, have **fun**.



For a whole host of complete vacuum forming projects for your class, visit http://formech.com/inspire/. These are step by step projects which will guide your class through every aspect of a number of projects with vacuum forming at their hearts, from mould making, to tooling, and beyond.

Want to share pictures or videos of your Formech project across social media? Use **#formechmade**.

For any additional materials you and your class need, look no further, as you can find an online catalogue of everything you need for vacuum forming in the classroom right here, at **https://formechdirect.com/**.

Follow us on Instagram for regular short videos and photographs from engineers and designers from around the world on **@Formech**.

Formech have a content rich website which is bursting with both video and written materials. We always have new How To and Case Study videos in the making, which showcase vacuum forming being used in the most incredible of ways, so be sure to check them out at http://formech.com/case-studies/.

Plastic Materials and Their Characteristics

Acrylonitrile Butadiene Styrene – (ABS)

Formability	Good - Forms to a High Definition
Strength	Good - High Impact
Shrinkage Rates	0.3 - 0.8 %
Finishing / Machining	Machines well with Circular Saws, Routers and Band Saws Takes all Spray Paints
Clear	Not Available
Colours	All Colours and also available in a Flocked Finish ideal for Presentation Trays and Inserts
Applications	Luggage, Caravan Parts, Vehicular Parts, Sanitary Parts, Electrical Enclosures
Price	Medium

Polystyrene – High Impact Polystyrene (HIPS)

Formability	Very Good - Forms to a High Definition
Strength	Medium to Good Impact Strength
Shrinkage Rates	0.3 - 0.5 %
Finishing / Machining	Needs Special Etch Primer before spraying Good Machining with all methods
Clear	Yes - Styrolux (Clarity not to quality of PETG/ PC/ PMMA)
Colours	All Colours and also available in a Flocked Finish ideal for Presentation Trays and Inserts
Applications	Low Cost and Disposable Items, Toys and Models, Packaging and Presentation, Displays
Price	Low - Medium

Polycarbonate – (P.C. / LEXAN/ MAKROLON)

Formability	Good
Strength	Very Good Impact Strength
Shrinkage Rates	0.6-0.8 %
Finishing / Machining	Good for Screen and Digital Printing Good Machine Qualities Can be Ultrasonically Welded, Drilled and Tapped Takes Spray-Paint easily
Clear	Yes
Colours	Translucent and Solid colours. Opal and Diffuser patterns. Available in a variety of Embossed textures
Applications	Light Diffusers, Signs, Machine Guards, Aircraft Trim, Skylights, Riot Shields, Guards and Visors
Price	High

Polyethylene – (PE, HDPE, LDPE, PE FOAM)

Formability	PE – Difficult PE Foam – Good, but Form at Lower Temperatures to prevent Surface Scorching
Strength	Very Good Impact Strength
Shrinkage Rates	LDPE - 1.6 - 3.0 % HDPE - 3.0 - 3.5 %
Finishing / Machining	Does not take Spray Takes some Specialist Inks
Clear	Translucent - goes Clear when in its Plastic State - occurs within Temperature Band of approx. 10˚C and provides excellent Indicator to Forming Temperature
Colours	Black, White and Colours available
Applications	Caravan Parts, Vehicular Parts, Enclosures and Housings
Price	Low

Co-Polyester – (PETG / VIVAK)

Formability	Very Good - Forms to a High Definition Forming range 80 -120˚C / 176-248˚F
Strength	Good High Impact
Finishing / Machining	Can be Guillotined, Saw Cut or Routered Die Cutting and Punching also possible up to 3mm Paints and Inks for Polyester can be used for Printing on PETG
Clear	Yes
Colours	Limited
Applications	Point of Sale and Displays, Medical Applications
Price	High (Competitive with other Clear Materials e.g. PMMA, PC)

Acrylic - PMMA – (Perspex, Oroglas, Plexiglas)

Formability	Tends to be Brittle and is Temperature Sensitive
Strength	Medium to High
Shrinkage Rates	0.3 - 0.8 %
Finishing / Machining	Prone to Shatter Takes Cellulose and Enamel Spray. Good for Hand Working
Clear	Yes
Colours	Solid Colours
Applications	Signs, Roof Lights and Domes, Baths and Sanitary Ware, Light Diffusers
Price	High

Polypropylene – (PP)

Formability	Difficult - Translucent material goes Clear when in its Plastic State - occurs within Temperature Band of approx. 10˚C / 50˚F and provides excellent Indicator to Forming Temperature. Good Temperature Control required in conjunction with a Sheet Level Facility
Strength	Very Good Impact Strength
Shrinkage Rates	1.5 - 2.2 %
Finishing / Machining	Doesn’t take Spray
Clear	Translucent
Colours	Black, White and Colours available
Applications	Luggage, Food Containers, Toys, Enclosures, Medical Applications, Chemical Tanks
Price	Low

Polyvinylchloride – (PVC)

Formability	Forms well but it has a tendency to Web
Strength	Good
Finishing / Machining	Doesn’t take Spray Take some Specialist Inks
Clear	Yes - Different Web Widths available with Thickness from 150 Microns - 750 Microns
Colours	Black, White and Colours available
Applications	Packaging, Machine Guards and Car Trims
Price	Low

Plastics and Approximate Heating Times

Plastic	Thickness	Approx. Heating Time (seconds)
ABS	1mm / 0.04”	40
	1.5mm / 0.06”	60
	2mm / 0.08”	80
	3mm / 0.12”	120
	4mm / 0.14”	140
HIPS	1mm / 0.04”	30
	1.5mm / 0.06”	45
	2mm / 0.08”	60
	3mm / 0.12”	90
	4mm / 0.14”	120
PC	1mm / 0.04”	60
	1.5mm / 0.06”	90
	2mm / 0.08”	120
	3mm / 0.12”	180
	4mm / 0.14”	240
PE	1mm / 0.04”	50
	1.5mm / 0.06”	75
	2mm / 0.08”	100
	3mm / 0.12”	150
	4mm / 0.14”	200
PETG	1mm / 0.04”	30
	1.5mm / 0.06”	45
	2mm / 0.08”	60
	3mm / 0.12”	90
	4mm / 0.14”	120
PMMA	1mm / 0.04”	40
	1.5mm / 0.06”	60
	2mm / 0.08”	80
	3mm / 0.12”	120
	4mm / 0.14”	160
PP	1mm / 0.04”	50
	1.5mm / 0.06”	75
	2mm / 0.08”	100
	3mm / 0.12”	150
	4mm / 0.14”	200

Plastic	Thickness	Approx. Heating Time (seconds)
PS	1mm / 0.04”	30
	1.5mm / 0.06”	45
	2mm / 0.08”	60
	3mm / 0.12”	90
	4mm / 0.14”	120
PVC	1mm / 0.04”	30
	1.5mm / 0.06”	45
	2mm / 0.08”	60
	3mm / 0.12”	90
	4mm / 0.14”	120