# Vacuum Casting in the Loughborough Design School

## A Guide for Final Year Students

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# Selecting Vacuum Casting for Student Projects

Vacuum casting can be an excellent way of creating complex and detailed prototype parts for student projects. It can provide multiple parts that closely mimic injection mouldings in a variety of colours and material properties. However, it should not be seen as an easy option when prototyping. It can be expensive, time consuming and requires skill to get good results. Therefore, careful consideration needs to be given to whether it is appropriate and whether the time and costs incurred are reasonable. Due to the time and cost required, you should discuss your prototyping requirements with the technical staff and only proceed when you have the agreement of your project tutor.

***Shape and Size***

Vacuum casting is not appropriate for the production of simple forms that may well be better bought in, machined, turned, fabricated or formed. Vacuum casting should not be used for cylinders, blocks, gears, axles, pulleys, bushes, fasteners and other simple components that can easily be bought in. Vacuum casting costs are directly proportional to the volume of the part. In addition, a maximum size can be accommodated in the vacuum chamber. Therefore, vacuum casting should not be used for large, bulky, thick sectioned or heavy parts. Remember, vacuum castings require an expensive mould as well as the resin for each moulding.

***Cost***

Vacuum casting can be expensive for students and it should be used sparingly and only where its benefits outweigh those of alternative methods. Due to the cost and time required, the design should be developed and refined as much as possible before embarking on vacuum casting. Cost for the resin is calculated by volume (i.e. per cubic centimetre). You can predict the cost by getting the volume from the CAD model but remember to add about 30% extra for the runners and sprues. You can estimate the size of the mould required by estimating a bounding box around the part plus at least 5 cm in each direction. The volume of silicone required will be approximately the volume of this bounding box. Remember there are also the cost of the original pattern to consider, as well as the cost of mixing jugs, nozzles and piping for use within the vacuum chamber, which can only be used once (these items can be purchased from stores as required).

***Physical Properties***

Vacuum casting utilises Polyurethane (PU) resins that can mimic the physical properties of many engineering thermoplastics. However, they will not exhibit exactly the same properties, especially where stiffness or creep is concerned. Take advice on which resin will best meet the needs of the prototype before proceeding. It may be necessary to outsource a supplier for resins with different properties, such as Alchemie or MTT. Also, bear in mind that some resins have a short shelf life once they have been opened.

***Availability***

The Design School is fortunate to have its own vacuum casting equipment. However, bear in mind that it has to be shared amongst a very large number of students and staff who all deserve equal access. Students must plan well in advance and recognise that access to the equipment and more importantly technical support will be on a ‘first come first served’ basis and you will have to wait your turn. Also, remember that in the final year, you will all be prototyping at the same time and therefore access will be increasingly congested. External suppliers can be used for vacuum casting but full commercial rates will be very expensive. External suppliers should only be used with the agreement of your project tutor.

***Health and Safety***
Some resins can aggravate the skin, so be aware of the safety instructions that should be supplied with the resin. Gloves and eye protection are required.

***If in doubt about whether Vacuum Casting is appropriate contact Richard Bibb, r.j.bibb@lboro.ac.uk***

# Introduction to Vacuum Casting

Vacuum casting refers to the moulding (or casting) of two-part PU resins into silicone rubber moulds. The wide variety of PU resins and the flexibility of the rubber mould mean that complex mouldings can be made economically in very small numbers. It is, in principle, very similar to Resin Injection Moulding or Reaction Injection Moulding (RIM), except that rather than being injected under pressure, the rubber mould is held in a vacuum chamber to ensure it fills fully.

# The Basics

Vacuum casting relies on the production of a precise silicone rubber mould. These are made by pouring liquid silicone rubber over a master pattern. The rubber then solidifies and it is cut into two (or more) parts to release the master pattern to leave an impression of the pattern in the mould parts. Therefore, in order to utilise vacuum casting a high quality master pattern is required. The master pattern can be made in any manner appropriate but as the mould will replicate it extremely faithfully the surface finish and accuracy of the master pattern must be exactly what is required from the moulding. Master patterns for complex parts are often made using Rapid Prototyping (RP) but they can be made by any process (refer to separate guidance on RP).

The mould parts are reassembled and typically held together with tape. The mould is then put into a vacuum chamber; this removes air from the resin and mould to help ensure that it fully fills. In the upper part of the vacuum chamber, the two parts of the PU resin are mixed under vacuum. This helps to remove all the air bubbles from the resin. After a preset mixing time, the resin is poured into the mould. The vacuum is released and the air pressure forces the resin into the mould. The resin is allowed to harden in the mould and is usually heated in an oven for around 45 minutes to cure the resin fully. The mould can then be opened and the moulding removed. Each moulding will therefore take about 2 hours to produce.

The life of the mould will vary depending how carefully it is handled and the geometry of the mould surface but typically no more than 20 mouldings would be expected. This is because the PU resins chemically affect the silicone rubber, making it increasingly hard and stiff until ultimately it breaks, cracks or crumbles.

For fine details, such as precise holes, metal mould inserts can be made. With care and practice, it is also possible to over-mould pins, bolts, nuts, etc. However, that would probably prove to be too ambitious for student projects.

# In Practice

The following example illustrates the key steps in vacuum casting.

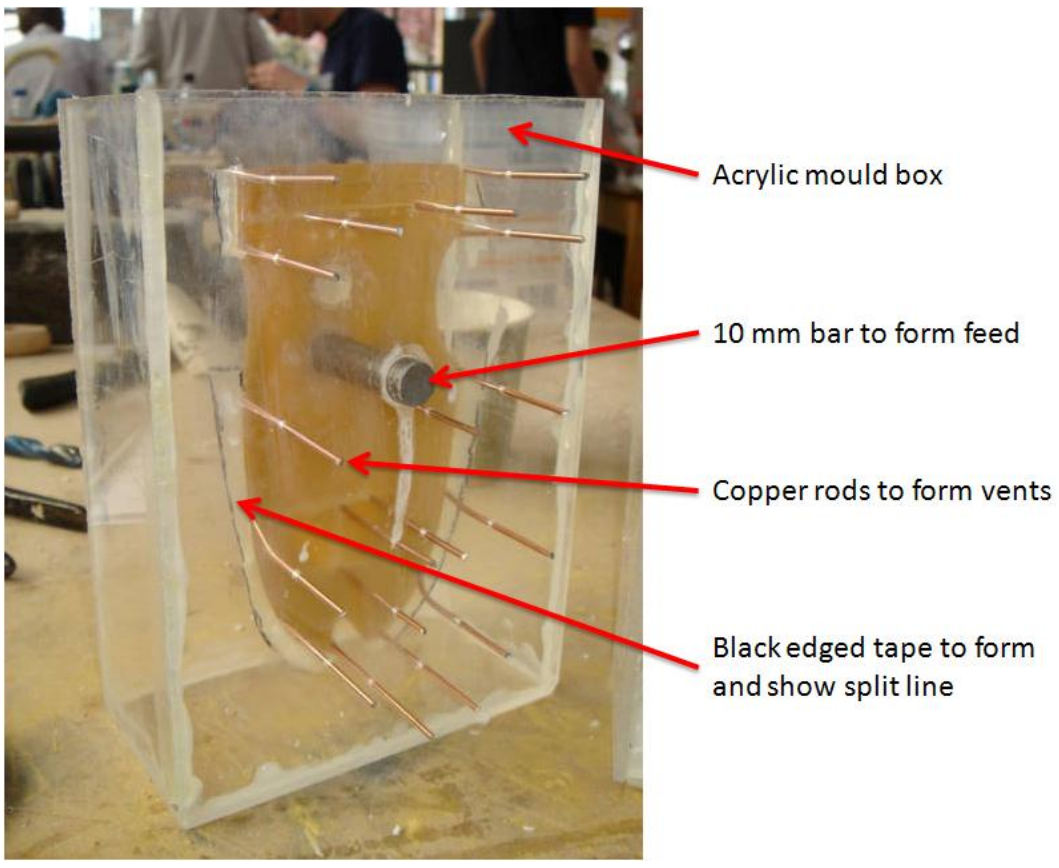
***Step 1***

The original master pattern was made from CAD data using Rapid Prototyping. The visible surfaces are highly finished and the pattern is thoroughly cleaned.

***Step 2***

The master pattern is then assembled into a mould box. Bar and rod is used to make feeds and vents. Tape is placed around the edge of the part to form a split line. The tape is edged in black so that it can be seen through the rubber mould- this is used as a guideline when the silicone mould is being cut to remove the master pattern.

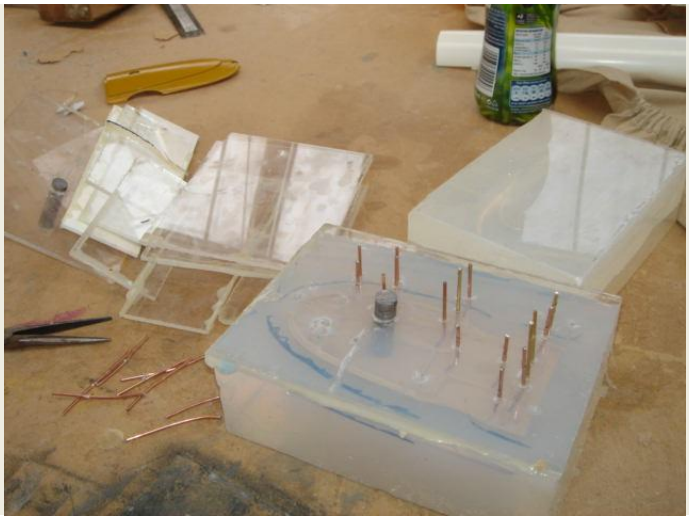
Make sure the mould box is watertight before proceeding to step 2, otherwise the leaking box will waste valuable silicone, and will cause irregularities in the mould whilst it is setting.



***Step 3***

The silicone must be de-gassed in the vacuum chamber before pouring into the mould box. The rubber has been poured into the mould box and allowed to cure for 24 hours.

The mould box can be disassembled and the feed bar and vent rods removed. The mould is then cut with a knife to form a split line, aiming for the black edge of the tape.



***Step 4***

The mould halves are cut open and the master pattern removed. Note the irregular pattern used for the split line. This helps locate and fix the mould halves when they are reassembled.

The mould is reassembled and held together with tape. It is then ready for casting.

***Step 5***

The resin is cast under vacuum in the machine. The filled mould is then cured in an oven for approximately 45 minutes.

Note the fill tube is full of resin and resin has come out of the vents to ensure that the mould is filled.

***Different resins require different operating temperatures for the resin and the mould. You must refer to the material data sheet for the chosen resin to ensure the correct operating temperatures, mixing ratios and venting times are used.***

***Step 6***

The mould is carefully opened and the casting is removed. The feed, vents and any flash around the split line are trimmed with pliers or a knife.

# Getting Parts

Reasons for choosing vacuum casting include a requirement for several exact copies of plastic parts, flexible or rubber parts or transparent parts. Before selecting vacuum casting other avenues should be explored and discussed with your tutor. Develop your CAD model and produce an RP or fabricate your master pattern. Remember the pattern will have to be very well finished. If vacuum casting is the best option, then see Les and ask for advice. Calculate all of the costs before you order anything. Also, plan how long it will take and be conservative in your estimates. Remember to allow for a certain amount of waste in both time and cost.

If you need multiple copies of the same part, consider making a multiple impression mould. It may be more cost effective and quicker to cast multiple small parts in one casting, rather than repeating the whole process for each one.

When you are convinced that your plan and costs are reasonable, order what you need through the stores and agree a specific time to undertake the casting with Les.

It is possible to buy in commercial vacuum casting services. The advantage is that their expertise means that you should receive the correct number of perfect castings. However, the costs may be prohibitive. Obtain quotations and discuss them with your tutor before ordering. There are an increasing number of overseas suppliers that can offer vacuum casting services at lower prices. However, be warned that costs are still considerable, communications sometimes get confused and the shipping time and cost will need to be taken into consideration.

# Vacuum Casting Advice from Lloyd Stoker, PDR

- Use at least 30% extra material (mass of part + sprues + 30%) to form a head of material in the feed pipe and in the hopper, this should reduce the probability of short filling
- Add a tape fence around the top of the mould to catch extra material that over flows from the vents
- Ensure the feed enters at the lowest point of the mould at a non-cosmetic surface preferably into a thick wall section
- After mixing, turn off the vacuum pump
- As you pour, just as the material leaves the cup do a fast leak of pressure - about 25%, this kills the bubbles
- Pour in the material and wait for the material to rise through the vents then release the remaining vacuum
- Also, beware of moisture issues with SG95 resin, high humidity causes problems leading to excessive foaming
- Spray dry nitrogen into containers and secure the lids to remove moisture from the container

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| **Advantages** | Strong, durable plastic parts<br>Excellent accuracy (depending on master pattern)<br>Wide variety of colours<br>Wide variety of physical properties (from soft rubber to rigid plastic)<br>Can produce translucent and transparent parts<br>Can produce multiple identical parts (maximum about 20) |
| **Disadvantages** | Time consuming (days)<br>Materials are expensive<br>Practice and skill required<br>Small features difficult<br>Parts can warp if not cured properly<br>Bubbles can affect surface quality<br>Adding colourant to certain resins can be difficult to achieve opacity |
| **Location** | LDS225 via 225 |
| **Contact** | Les Pickstock |
| **Links** | http://www.youtube.com/watch?v=gcrgXa0yYrw<br>http://www.mtt-group.com/vacuum-casting.html<br>http://www.mtt-group.com/vacuum-casting_04.html<br>http://www.alchemie.com/vacuum_casting_polyurethane_systems.htm |