

Guide to Resin Infusion

Introduction

Vacuum resin infusion is a sophisticated technique for manufacturing high performance, void free composites even on large or complicated moulds. The process is ideally suited to the manufacture of carbon fibre composites and is widely used by professional manufacturers for the production of carbon fibre body panels such as bonnets and by marine manufacturers for the production of boat hulls.

In resin infusion, reinforcement is laid into the mould 'dry', i.e. without any resin, and then enclosed in a specially configured stack of bagging materials (such as peel ply, infusion mesh and bagging film) before being subjected to vacuum pressure using a composites vacuum pump. Once all the air has been removed from the bag and the reinforcement has been fully compressed under this pressure, liquid epoxy resin (mixed with hardener) is introduced to the reinforcement through a pipe which then infuses through the reinforcement under the vacuum pressure. Once the resin has fully infused through the reinforcement, the supply of resin is cut off (using a pipe clamp) and the resin is left to cure, still under vacuum pressure.

Advantages of resin infusion

Resin infusion, when done correctly, can produce parts of incredible strength and quality of appearance. The combination of vacuum pressure along with carefully placed vacuum consumables (such as peel-ply and infusion mesh) mean that the finished composite will have absorbed resin at the optimum resin-to-reinforcement ratio, avoiding resin-rich composites or variations in performance inevitable with traditional wet-lay manufacture.

The resin infusion process also eliminates some of the problems that can blight wet-lay composites, such as air voids (caused where the reinforcement has bridged around tight corners) and tiny air bubbles caused by air trapped within the laminate.

The quality of epoxy 'infusion resins' means that resin infused parts can be made with strength to weight ratios that can rival parts made using pre-impregnated (pre-preg) reinforcement systems.

The Starter Kit – Contents



Components/material	Purpose
Composites vacuum pump	Electric powered vacuum pump capable of very high vacuum pressure (99.98% vacuum). This pump creates the vacuum pressure that draws all of the air out of the vacuum bag and maintains this vacuum pressure throughout the cure cycle of the composite.
Resin catch pot & liners	The catch pot sits between the composite and the vacuum pump and prevents any excess resin from the composite being drawn down the vacuum tube and into the pump. The catch pot can be lined with removable liners so that any resin caught by the pot can be easily discarded after the process is complete.
Vacuum gauge	The vacuum gauge shows the level of vacuum in the system and is invaluable in identifying when there are tiny leaks in the vacuum bag. Infusion should never be started until the whole system is maintaining full vacuum (at least 99.9 on the vacuum gauge).
¼ Turn valve	The ¼ turn valve is used to hold back the vacuum pressure whilst preparing the bag. The valve can be opened and closed to remove more and more air as the bag is shaped to fit properly around the bagged composite.
Tube clamp	The tube clamp is used to close off the flow or resin from the feeder pot into the bagged composite. The tube is usually clamped just before the resin flowing into the composite reaches the end of the reinforcement (to allow for some lag in the system).
Silicone bag connectors	The connectors form the join between the vacuum hoses and the vacuum bag and also between the resin feed pot and the bag. Silicone connectors are used (instead of metal through-bag connectors) because they will become coated in resin during the infusion process. By being silicone, resin can easily be cracked off them after the process is complete and used again.
Vacuum hose	The vacuum hose connects the vacuum pump, catch pot and resin feed pot to the bagged composite.
Vacuum bagging film	This film is used to create the outer vacuum bag from which the air is evacuated by the pump. The film is tear resistant and sticks extremely well to the bag sealing tape.
Peel-ply	This thin woven fabric is the first removable layer between the composite and

	the vacuum bag. Peel-ply creates a surface that can absorb excess resin and also, when removed from the composite (after the process is finished) provides a textured surface that is particularly well suited to bonding to.
Resin infusion mesh	Infusion mesh is a plastic mesh pattern designed to promote resin flow during the infusion process.
Resin infusion spiral	This plastic spiral tube is used to provide a very free-flowing channel through which the resin is distributed near the point where the resin is first fed into the composite. Resin flows freely through the centre of the spiral tube, but just as easily out of the spirals in the side, allowing resin to be supplied all the way along an edge of the composite.
Bag sealing tape	This special sticky, gum-like tape is used to create perfect seals between the two faces of a vacuum bag (when envelope bagging) or between the vacuum bag and mould's flange when half-bagging a mould.
Breather	In the infusion process, breather is often simply used to create an absorbent barrier between the composite and the vacuum connector.
Epoxy Infusion Resin (1KG)	The resin infusion process requires special low viscosity resin. Unlike polyester resins (which tend to 'boil' under the vacuum) epoxy infusion resin is the very best resin for the job. Continued developments in the performance of epoxies means that epoxy resin infused parts can now rival the strength and performance of pre-preg parts!

Before You Start

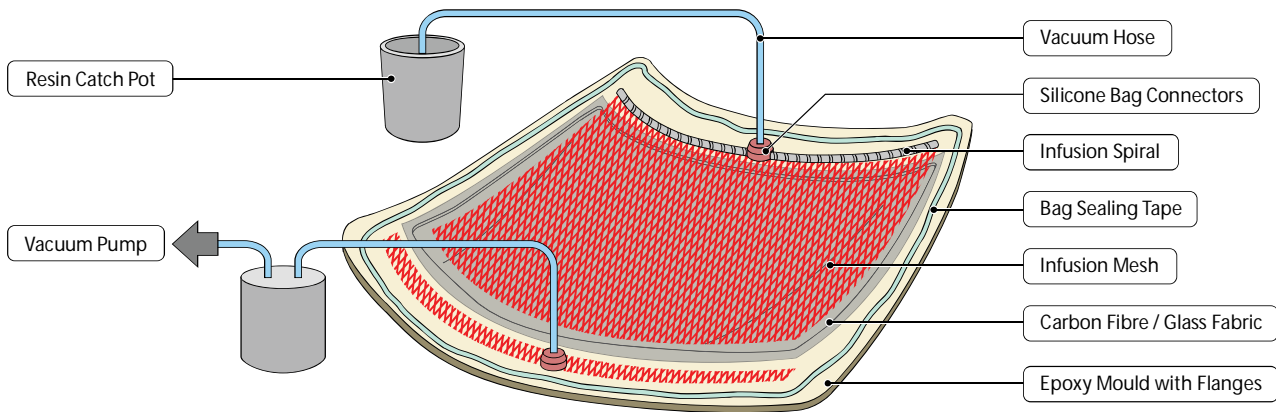
The key to successful vacuum resin infusion is having all the right equipment and preparing everything in advance.

Once the epoxy infusion resin has been mixed with its hardener, if anything goes wrong it is generally too late to do anything about it. Any problems such as running out of resin, losing vacuum or having a leak in the bag will almost certainly result in the part being ruined. This means that for the first few attempts, methodical planning is essential. Having said this, the nature of resin infusion is such that correctly following the procedure should produce perfect parts every time.

Basic Configuration

All the equipment and supplies necessary to undertake vacuum resin infusion are included in this Carbon Mods starter kit.

The parts of the kit are used as follows:



There are many alternative configurations to the above that can be used for resin infusion. The above configuration, however, is quite typical and makes a good starting point.

Suitable Moulds

Before you can start the resin infusion process, the first step is to have a suitable mould.

A mould suitable for resin infusion is much the same as a mould that would be used for conventional wet-lay fibreglass, with a couple of important distinctions:

Mould Surface

The best infusion resins are epoxy (including the infusion resin that comes with this kit), therefore it is important that the surface of the mould that will be used for infusion is also made from epoxy; either an epoxy tooling gel coat, or just epoxy resin used as a surface layer. Mould surfaces made using polyester gel coat or polyester resin as a surface layer are likely to result in parts made from epoxy resin (or with an epoxy gel coat) sticking to the mould, destroying the part and the mould.

If you need to use a mould made with a polyester gel coat in your infusion project one solution is to use a P.V.A. mould release agent, rather than mould release wax. P.V.A. will create a sufficient barrier between the polyester mould surface and the epoxy part to endure that the part will release from the mould. The disadvantage of this method is that P.V.A. needs to be cleaned off the mould and re-applied each time it is used and also that the part will need quite a bit of polishing to remove the smear pattern that P.V.A. causes.

Mould Flanges

The resin infusion process requires the mould to have some additional flange area around the edges. This flange area is used to place the vacuum connectors, resin feed connector, infusion mesh and resin flow channels. It is sometimes possible to find enough space on existing moulds to position these infusion specific items but if there isn't room you will need to remake or extend your moulds.

Safety Information

Infusion epoxy resin, once mixed with its hardener is exothermic. If large amounts of mixed resin remain in the feed pot or accumulate in the catch pot, the resin can become very hot indeed. In extreme circumstances, the resin can actually start smoking as it reaches very high temperatures. This will only happen where the resin is accumulated in one place (i.e. never in the part) and only where too much resin has been prepared.

During your first few infusion projects, it is important that you keep an eye out for large amounts of excess resin either remaining in the feed pot or accumulating in the catch pot. Whilst there isn't much that can be done about excessive resin in the catch pot (without breaking the vacuum and spoiling the part), excess resin in the feed pot can be dispensed into smaller containers or otherwise dispersed to reduce the chances of this becoming too hot. This should only ever be done once the infusion process is complete and the resin feed line has been clamped-off.

Step by Step Instructions

1. Before You Start

The mould surface should be prepared using your favoured release agent. PVA, wax and chemical release agents are all suitable although you should ensure that if a chemical release agent is used that it is compatible with or better still, designed for epoxy resin systems.

If a gel coat is required on the part then this should be applied and allowed to cure before proceeding.

2. Lay Laminate into Mould

The key to successful resin infusion is preparation. Before actually starting your project, ensure that you have read through these instructions in advance. Make certain that you have everything you need.

Preparation

1. Prepare the mould surface (see fig.1)

If you will be allowing the infused part to cure at ambient temperature then conventional mould release wax is a suitable release surface for the mould. If you intend to accelerate the cure with elevated temperature (see 'Advanced Techniques') then wax is not suitable and a temperature tolerant chemical release agent should be used instead.

Prepare the mould surface according to the guidance that accompanies your chosen release agent. Remember to cover the entire surface of the mould and flanges with the release agent as you won't be able to control where the resin goes once the infusion starts.

2. Cut and position the reinforcement (see fig.1)

Cut your reinforcement to the appropriate size for your moulding. Where possible, always try to make the part using a single piece of fabric for each layer. A typical carbon fibre product will use anywhere between 2 and 6 layers of carbon fibre. If you're unsure how many layers to use, 3 layers is often right for a small, light part.

Ensure you cut the fabric large enough that it extends beyond the all the edges of where the trimmed part will come to. Position the multiple layers of fabric into the mould (you can position them all at once).

In more complicated moulds; particularly those with steep sides or multiple contours, it is sometimes necessary to use spray-tack to hold the laminate against the mould surface and hold subsequent layers of reinforcement to each other (see 'Advanced Techniques').

3. Add the peel-ply layer (see fig.2)

Peel-ply is the first layer of the infusion 'bagging stack' and is a removable barrier that is peeled off the finished part, leaving a relatively consistent surface that is also ideal for bonding to. The peel-ply included in the starter kit is heavier than budget peel-ply but you'll find that a slightly better peel ply is easier to remove and well worth the difference.

Peel ply is usually applied in one single layer, positioned to completely cover all areas of the reinforcement. The peel-ply does not need to overlap the edges of the reinforcement but it does need to cover it all so it is usually cut to be just fractionally bigger than the reinforcement.

4. Add the infusion mesh (see fig.3)

The infusion mesh (also known as 'flow media') is used to ensure that the resin can flow from the resin feed line (and spiral tube) freely through the laminate. The shape of the mesh means that even under total vacuum, there are still gaps through which the resin can flow.

The infusion mesh is also applied in a single layer (although it won't affect anything if multiple pieces are overlapped where necessary). It should be cut to be the same size as the reinforcement/peel-ply apart from at each end where the mesh should extend sufficiently to allow for the vacuum connector at one end, and the resin feed line at the other. By positioning the vacuum connectors directly onto the infusion mesh we ensure good channels for both air and resin will be maintained once the vacuum is drawn.

Alternative Method

An alternative to positioning the vacuum line connector directly above the infusion mesh is to end the infusion mesh short of where the vacuum connector will be positioned. A folded piece of breather fabric is then used to create a pad that can absorb excess resin from the infusion, preventing it from being drawn into the vacuum line and catch pot. In practice, the amount of resin that can be absorbed by the pad is limited and for this method to result in no resin entering the vacuum line or catch pot requires careful timing on the clamping of the resin feed line.

5. Position the resin feed spiral (see fig.3)

The resin feed spiral is spiral wrapped plastic tube that is used to improve the flow of the resin from the feed tube into the laminate. Resin will be disbursed along the full length of the spiral therefore the standard configuration is to position the spiral all the way down one side (the side where the feed tube will be positioned). This means that the resin is quickly distributed along one side of the mould and then advances more evenly towards the other side.

It is essential that the resin feed spiral is positioned directly over the infusion mesh. This ensures that the resin can flow easily from the spiral into the mesh.

In larger or more complicated infusions, multiple resin feed lines and more considered positioning of the resin feed spiral is sometimes required. This is not likely to be necessary for most projects, however, if you find that some areas of your laminate wait an excessively long time for the resin to reach them you can improve resin flow to those areas with some additional feed spiral.

Secure the resin feed spiral in position using a couple of small pieces of the bagging tack-tape.

6. Position the resin feed connector (see fig.3)

The resin feed connector is one of the red silicone connectors. It is slightly different from the vacuum connector in that it has a single channel on the underside running from one side to the other. It is into this channel that the resin feed spiral goes, allowing resin to flow through the feed tube, through the connector and into the spiral.

Position the resin feed connector in the centre of the resin feed spiral. Press the connector down onto the spiral so that the spiral tube runs through the bottom of the connector.

7. Position the vacuum connector (see fig.3)

The vacuum connector is the other red silicone connector; it has a pattern of 3 outlets on the underside and is designed to allow free airflow from the connector into the material underneath (the infusion mesh) even under total vacuum.

Position the vacuum connector on top of the infusion mesh at the opposite side of the mould to the resin feed spiral. The connector should sit on top of infusion mesh in an area beyond where the reinforcement ends.

8. Apply vacuum bagging tape (see fig.4)

Vacuum bagging 'tack-tape' is a type of very sticky gum tape. The tape is used extensively in all vacuum bagging processes where its pliable nature makes it highly effective at providing an air tight seal.

Alternative Method

In resin infusion it is most common to apply the tape to the flange around the edge of the mould, whereby the mould makes one side of the 'vacuum bag', with the bagging film forming the other side (as described above). If this isn't possible then the bag can be wrapped around the entire mould, front and back, in which case the bagging tape would be applied to one half of the bag rather than to the surface of the mould. This may be preferable if the flange is not made from smooth, unbroken gel coat making a good airtight seal to the mould's surface difficult to achieve.

9. Position and tape down the vacuum bag (see fig.4)

It's now time to enclose everything within the vacuum bag.

The vacuum bagging film included in the starter kit is one of the more expensive bagging films available. This superior bagging film is both stronger (making it less likely to puncture) and also more stretchy than cheaper films. In our opinion it is well worth spending a little extra and using one of these high performance bagging films. An inferior or ruined part is far more costly in the long run.

When doing the bagging it is absolutely essential to ensure that there is sufficient bagging film to get into all the shapes and contours of the mould. Any 'bridging' of the vacuum bag where it doesn't get right into the corners of the mould will result in resin-rich areas, reducing the strength and quality of the finished part.

Cut a piece of bagging film (the green plastic film) that is plenty large enough to cover an area about 50% larger than your mould area. Starting in one corner, peel the backing paper off some of the bagging tape and press the corner of the bagging film down onto the exposed tape. Move around the edge of the mould, removing backing paper from the tape and sticking down the bagging film as you go. Don't be tempted to remove all the backing paper from the tape; this is likely to result in the bag sticking to the tape before you've aligned it properly.

As you stick the film to the tape, be as careful as possible to do so without having any wrinkles or folds in the bag. Press down very firmly and use your fingers to 'massage' the film and tape together to create an airtight seal. If you end up with leaks in your finished bag (which we'll test for later) then it is likely that wrinkles or folds in the bagging film where it contacts the tape will be the cause.

10. Connect and seal the resin feed hose (see fig.5)

With all the bagging stack and reinforcement sealed within the vacuum bag, you're now ready to 'breach' the bag to connect the resin feed hose. Using a pair of scissors or a knife, make a small incision in the vacuum band directly above the red silicone resin feed connector.

Cut a length of the clear PVC hose long enough to run comfortably from where you will position your resin feed pot to the resin feed connector on the vacuum bag. When you cut the hose, do so at an oblique angle (such as 45°) so that it is impossible for the tube to accidentally be sealed against the bottom of the mould.

Taking the end of the hose with the oblique cut, push the hose through the small hole in the vacuum bag and into the hole in the top of the resin feed connector. Ensure that the tube has gone all the way into the connector.

Seal the tube to the bag by wrapping a ring of the bagging tape around the tube where it meets the bag. Press firmly to ensure the tape has made an airtight seal.

11. Connect and seal the vacuum hose (see fig.5)

Repeat the process from the previous step, this time using another length of PVC tube that will connect the catch-pot to the red silicone vacuum connector at the opposite end of the part to the resin feed connector. Cut the tube at an angle, cut a small hole in the bag, push the tube through and seal the tube to the bag using some more tape.

12. Set-up the resin feed pot (see fig.5)

The resin feed pot should be securely positioned near the mould. It is absolutely vital that the resin feed pot does not fall over during the infusion; if it does, the part will certainly be ruined.

Position the resin feed hose inside the feed pot so that the tube reaches all the way to the bottom of the pot. If necessary, use a bent paperclip or similar to hold the tube in position.

13. Connect the vacuum pump and catch-pot (see fig.5)

Connect the other end of the vacuum hose to one of the push fittings on the resin catch-pot. Push the hose on firmly to ensure an air-tight seal.

Next, cut a length of PVC tube sufficient to run from the vacuum pump to the other push connector on the catch-pot. This tube can be as long as you need and will not be spoiled by the infusion process (meaning it can be re-used indefinitely).

14. Clamp the resin feed line (see fig.6)

Position the line clamp tube near to the start of the resin feed tube and turn the wing-nut to clamp the pipe shut. Ensure that you close the pipe properly to create an airtight seal.

15. Switch on the vacuum pump

With everything in place, we're now ready to test the vacuum.

If you've not already done so, ensure the vacuum pump is set to the correct voltage for your territory (110V or 240V AC), fill it with the appropriate amount of vacuum pump oil and connect it to the mains power supply.

Switch on the vacuum pump.

16. Evacuate the air and adjust the vacuum bag

As the air is removed from the vacuum bag you will see the bag tighten around the mould surface. As this happens you should move the bag around and position it so that you move 'spare' bagging film into the areas of the mould which need it. This process is essential to all vacuum bagging processes (resin infusion, standard vacuum bagging and even pre-pregs) so give this step plenty of attention.

As the bag begins to become reasonably tight (certainly not full evacuated but not slack either) temporarily switch off the vacuum pump. This will allow you all the time you need to reposition the bag, working wrinkles towards where they're needed and ensuring that no-where on the mould is the vacuum bag 'bridging' a gap.

During your first few infusion projects, it is possible that you will underestimate the amount of bagging film necessary for your mould. If this happens you will find out at this stage because the bag will be 'bridging' across certain points of the mould and there will be no amount of re-positioning that can fix it. In the unfortunate event that this happens, you should stop, remove the bag (and tape) and do the bag again. If you proceed with a bag that is too small, your finished part will suffer greatly.

17. Test the vacuum

Switch the pump back on and finish evacuating the bag. You should see the needle on the vacuum gauge begin to rise. Leave the pump on and wait as the needle approaches full vacuum. Keep adjusting the bag if necessary to ensure there are no 'bridges'.

After a few minutes the vacuum gauge should read somewhere very near to 100%. Because of variations in atmospheric pressure and calibration of the gauges the needle might not point precisely to 100% vacuum even when full vacuum is being drawn. The most practical way to know when you have a perfect seal (100% vacuum) is to look at the vacuum pump and see whether any oil vapour is being emitted by the pump. When the seal is total, the pump's sound will change slightly and oil vapour will stop being emitted by the pump.

If the seal isn't total, work your way around the bag, pressing the bag hard against the gum tape until it is.

The Infusion

Only once your vacuum bag is perfectly sealed (with the gauge reading approximately 100% and the pump is not emitting any oil vapour) should you embark on the infusion itself.

1. Gauge the correct amount of resin

The amount of resin that your project will need will vary upon its size and the amount of reinforcement you have used; more layers of reinforcement will be able to support more resin.

Use the table below to calculate approximately how much resin your finished part will use (see the PART column), and how much you should mix (see the MIX column) to ensure you have enough project will require:

Total weight of reinforcement in grams per square metre

Size of part	1 layer/200gsm		2 Layers/400gsm		3 Layers/600gsm		4 Layers/800gsm		5 Layers/1000gsm	
	PART	MIX	PART	MIX	PART	MIX	PART	MIX	PART	MIX
0.25sqm	20	84	40	108	60	132	80	156	100	180
0.5sqm	40	108	80	156	120	204	160	252	200	300
1sqm	80	156	160	252	240	348	320	444	400	540
1.5sqm	120	204	240	348	360	492	480	636	600	780
2sqm	160	252	320	444	480	636	640	828	800	1020

2. Mix the infusion resin and add to the feed pot

Once you have worked out approximately how much resin you will need you next need to calculate the right ratio of resin to hardener and mix the resin.

The epoxy infusion resin supplied with the kit (and recommended for future projects) needs to be mixed at a ratio of XXX parts resin to XXX parts hardener. As with all resins, it is important that the correct ratio is accurately measured and thoroughly mixed.

Use a set of digital scales to mix the correct ratio of resin to hardener. Mix the resin in a container *other than the resin feed pot* and then pour the mixed resin into the resin feed pot. This will greatly reduce the risk of any unmixed resin (usually clinging to the sides of the mixing pot) from being drawn into the infusion.

3. Unclamp the resin feed line

With the vacuum pump still running, gently start to unscrew the wingnut on the resin feed line clamp. As you loosen the screw you will immediately see resin start to be drawn down the feed line and into the infusion. Unscrew the clamp all the way to ensure there is no restriction to the flow of resin into the infusion.

4. Monitor the infusion and clamp the resin feed line 2/3 of the way through

Depending on the size and shape of the part, the layout of the feed spiral and the amount of reinforcement used, the resin will take somewhere between a few minutes and an hour to infuse fully through the part.

Because the resin feed pot is at atmospheric pressure, only the viscosity of the resin itself prevents the part of the mould around where the resin feed hose enters the infusion from being at normal atmospheric pressure. This means that around this area the vacuum bag will no longer feel tight and that excess resin will be accumulating. For this reason, it is normal to clamp the resin feed line closed again well before the resin has fully infused through the part. This gives chance for the excess resin at the atmospheric pressure side of the mould chance to carry on infusing through the part. As it does, the bag will tighten again at this end of the mould.

Experience (and experimentation with different moulds) will show you at which point in the infusion the resin feed line should be clamped but a rule of thumb is to do this when the resin is about 2/3 of the way through the part. Excess resin in the infusion will normally be sufficient to complete the infusion.

Clamping the line too soon will mean that the resin never fully infuses the part. Clamping it too late will result in lots of resin being sucked up into the vacuum tube and into the catch-pot (that's what the catch pot is for). If you are too soon or too late clamping the line it's not a big problem; either unclamp the line again briefly to allow more resin into the infusion or, in the case of clamping the line too late, just watch the catch-pot do its job.

Note: If lots of excess resin is drawn into the catch pot the resin may start to exotherm significantly and could start to smoke. If this happens, there is nothing you can do. Keep an eye of the catch-pot and wait for the exotherm to die down. This is the main reason you should try not to be too late clamping the resin feed line.

5. Continue to monitor the infusion

With the resin feed line clamped and the part fully infused there is nothing more to do other than wait for the resin to cure. The vacuum pump should stay on for the duration of the cure cycle. Don't be tempted to turn it off until the part is fully cured.

Because excessive amounts of mixed resin in one place can exotherm dramatically, you should dispose of any resin in the feed pot and continue to keep an eye on the resin in the catch-pot if there is a lot in there.

The epoxy infusion resin supplied with the kit responds very well to elevated temperature cure (curing in a composites oven or other warm environment). Although certainly not a requirement, curing at an elevated temperature can dramatically shorten the curing time (to only a couple of hours) and improve the temperature tolerance and strength of the finished part.

Use the table below to see how cure temperature affects cure time:

Temperature	20°C	40°C	60°C	80°C	100°C	120°C
Cure Time	24	11hrs	6hrs	4hrs	2hrs	1.5hrs

If you intend to cure the part at elevated temperature whilst still in the mould, ensure that your mould material is able to withstand the elevated temperature and that your release agent is (mould release wax, for example, will melt and the part might stick to the mould).

As an alternative to curing at elevated temperature *in the mould*, you can allow the part to cure fully at room temperature, remove it from the mould and then cure the part in an oven or warm environment. This process is known as post-curing.

De-Moulding

The vacuum pump should stay on until the part is fully cured. When the part is fully cured the pump can be turned off and the vacuum bag cut away from the mould. In some cases you may choose to keep and re-use sections of the vacuum bag although the gum tape and infusion mesh are always thrown away.

De-moulding steps:

- Cut the bagging film around the edge and remove.
- Remove the bagging tape from the edge of the mould (quick, sharp tugs are most effective)
- Remove the silicone connectors and crack any cured resin off them. They are re-used indefinitely.
- Remove and discard the infusion mesh
- Pull the peel-ply off the back of the part. This will take a little bit of force.
- Remove the part from the mould. Be careful not to damage the part or the mould, especially when force is required to remove the part.

Your part is now ready to be trimmed and finished. Carbon Mods recommends Perma-Grit Tungsten Carbide tools for the cutting and shaping of carbon fibre parts.

This Guide to Resin Infusion was produced by Carbon Mods and accompany our Resin Infusion Complete Starter Kit product. The kit is available to buy from the Carbon Mods website at www.carbonmods.co.uk.

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About Carbon Mods

Carbon Mods is a small specialist carbon fibre products company operating from premises in Staffordshire, England. All our products are designed, tooled and manufactured on site using high quality carbon, resins and other materials. We design and manufacture niche performance products for motor sports, aerospace and marine applications as well as a range of best-selling kits to introduce people to the world of carbon fibre.