Considering Resin Transfer Molding?

Here is what you need to know...

By
Bob Lacovara

When considering closed molding options for composites production, there are several possibilities. In the case of high volume production, the compression molding process produces low cost parts, but requires a high capital investment in presses, infrastructure and tooling. At the other end of the spectrum, vacuum infusion molding, requires very low capital investment, but produces cycle times similar or slower than traditional open molding. Resin Transfer Molding stands in the gap - able to produce mid-range volumes of parts at a moderate capital investment.

With styrene emissions a major issue, quality at the top of everyone’s list, and good help hard to find, why don't we see more resin transfer molding (RTM) taking place in the composites industry? To provide focus on this question we will explore several areas of the RTM process, including process capability, cost, and the technical skills RTM requires.

To define *Resin Transfer Molding* the process is described: Fiber reinforcement is placed in a mold set; The mold is closed and clamped; The resin is injected into the mold cavity *under pressure.* The motive force in RTM is pressure. Therefore, the pressure in the mold cavity will be higher than atmospheric pressure. In contrast, vacuum infusion methods use vacuum as the motive force, and the pressure in the mold cavity is lower than atmospheric pressure.

Closed molding is no stranger to the composites industry. The precursor to RTM was vacuum infusion molding. One historically notable project was vacuum infusion molding of 40' Coast Guard patrol boat hulls in the late 1940's. The process, then known as the Marco method, involved a male mold in the inverted position with a trough around the bottom flange. The fiberglass reinforcement was draped over the mold, then the female mold half positioned with the lower edge in the resin trough. Catalyzed resin was poured in the trough and was pulled upward to the keel line by vacuum. Although this process never gained wide spread acceptance, at least six hulls were produced and were in Coast Guard service through the early 1970's.

In Europe, a few boat hulls in the 30-50' range have been closed molded, with limited success. However, very large parts have not enjoyed serial production in closed molding for some obvious reasons. At the top of the list is tooling cost and the high-risk experimental nature of developing such a project. However, small parts, ranging from 2 sq.ft. to 50 sq.ft. in size have been far more successful overall.

In the mid-1970's RTM *mania* swept the fiberglass industry. Several materials suppliers were promoting RTM as the greatest thing since polyester resin. It was common to hear statements claiming "In 10 years open molding will be obsolete." The sales pitch was that minimum wage operators would be popping high tech parts out of low cost molds. Best of all, it was promoted, you could easily adapt your existing open molds to RTM by building a second half and adding few c-clamps. As many as two hundred FRP fabricators jumped on the RTM wagon and were suddenly in the closed molding business.

Unfortunately, in most cases the process did not work on a sustained basis. Initial efforts at prototypes brought success and enthusiasm from many companies, at least in low volume development settings. These prototype projects spawned many RTM "experts", who rode the success of molding a few parts in non-production environments. However, almost as quickly, as these companies tried to reach economical production volumes, the process fell apart. Disillusioned by lack of success and unfulfilled promises in production, only a handful of operations continued with the process into the mid-1980's. RTM almost died from mis-application.

However, the last five years has brought a renewed interest in RTM and success rates are much improved. With a few notable high volume applications on the map, and a number of general molding projects, which have gone well, the potential for RTM is better than anytime in the past. What has made the difference?

One answer is that RTM has captured the attention of high volume press molders. In turn, these molders, who deal primarily with matched metal tooling, have brought more advanced tooling and process technology to the table. Rather than attempting to adapt low tech open molds upward, they have taken expensive matched metal tooling technology and backed it down to fit the RTM process. In reality, what has been accomplished is the application of proper design and engineering concepts to the RTM process for the first time. The result is, a renewed interest in RTM, and a host of viable tooling options that fit a wide range of situations.

Let's be careful not attach the previously mentioned hype to current RTM technology. RTM is neither simple, cheap or a cure-all for composites production. It will not single handedly save the industry from a fate worse than the EPA, nor will it cut your labor force in half and make you rich. Nevertheless, it might do a little of each of these things if you are ready to commit to doing it right.

Resin Transfer Molding *is* a strikingly effective method of fiberglass production *in the proper context*. This context includes: molding parts that are adaptable to RTM design parameters; production volumes which support the process; and the design expertise to develop tooling and process.

What are the advantages of Resin Transfer Molding? The stock list of advantages assumes that the RTM process is properly designed and efficient. If these criteria are met, the possibilities include:

Higher Productivity

An open mold usually produces one part per day in the average molding shop. This can be pushed to two or three parts per day at the maximum. A well thought out RTM system can produce 4 to 16 complex parts per day and as many as 12 to 30 simple parts in an eight-hour shift.

Repeatability

If quality is engineered into the tooling and production system, the result will be a high level of repeatability. If a quality-molded part is being repeated, the advantage is obvious.

Reduced Labor

As the molding volume of RTM goes up, the labor per part comes down. In contrast to open molding, if it takes 1 man/hour to laminate a part, it takes 8 man/hours to make 8 parts. In RTM, an operator may have the capability to produce 8 parts in a basic set-up. By enhancing the molding "support" process, that same operator may be able to produce 16 parts from the same mold.

Two-sided finish

Both sides of a part can be molded with gel coat, with no increase in cycle time over gel coating one side. If gel coat is not required, the laminate side of the part still has a "molded" finish. This produces a much more professional look then, for example, a finished part with raw laminate on the backside

Better Dimensional Tolerance

The dimensional tolerance of an RTM part is a function of the mold design to a large degree and to a lesser degree resin shrinkage. In contrast, open molded part thickness is very operator dependent. In RTM the tolerances are determined by engineering rather than by the operator.

Reduced Styrene Emissions

In theory, the largest amount of styrene emissions from the RTM process will occur when the mold is opened to remove the part. It is possible to transfer resin from the drum, through the injection unit, and into the mold with almost no styrene evaporation. Only when the cured part is removed from the mold will there be a small residual styrene release. There is one catch in the emissions advantage - the gel coat process. RTM parts are gel coated in conventional fashion, therefore typical gel coat styrene emission levels are expected.

Greater Tooling Design and Construction Skills Required

An accomplished open mold tool builder could be lost in the development of an RTM mold. This does not put RTM tool building in the "rocket science" category, but there are many more things to think about with RTM molds as compared to open molds. An RTM mold requires design engineering expertise that is associated more closely with compression molding then open molding. If you start at ground zero on the RTM experience index, the learning curve is quite steep. History has shown that open mold builders generally have a poor success rate in developing workable RTM molds.

Higher Tool Cost

The RTM process must be able to support a production volume that realistically amortizes the tool cost. If you have to go to an outside vendor to purchase turnkey RTM tooling the cost is even higher yet. It may be necessary to develop in-house skills to keep tooling cost reasonable.

Reinforcement Loading May Be Difficult With Complex Parts

In certain instances, loading the glass becomes the bottleneck in the process. Some parts with complex geometry may require a glass preform for efficient loading. Making preforms requires a separate glass forming operation. In some cases, preforms can be purchased from an outside preform fabricator.

Trimming is Normally Required

Wet trimming of the laminate is obviously not possible in the RTM process. With soft tooling (includes everything but steel) it is very difficult to design the mold and load the glass to result in a "net" part, or a finished edge. So far molding net finished parts in normal RTM has been an elusive goal. The basic problem is positioning the glass reinforcement to the finished edge of the part. If the glass stops short of the edge, even by a 1/16", a resin rich edge will result and be prone to cracking. If the glass projects through the pinch land (the edge of the mold) the tool won't close properly. In prohibitively expensive steel molds, the glass can be sheared at the edge, under great pressure. Molding the "finished edge" part, in the type tooling the RTM process supports, has not been accomplished on a production basis at this time.

RTM Disadvantages

In balance, there are also some disadvantages to resin transfer molding. You will notice in the following discussion many of these disadvantages involve finding the right "fit" for the process. The most successful RTM projects have been products that were designed from the ground up for RTM processing. In some cases, adapting resin transfer molding to a part previously molded in another process is difficult. If RTM is not the right process in a given situation, these disadvantages are magnified. Conversely, where the fit is right, the advantages far outweigh these drawbacks.

Volume Requirements

The magic volume vs. cost number for the RTM process has a wide range. If a part is being molded in RTM for technical reasons, for example a two-sided finish, the economical volume might be as little as 50 parts per year using lower cost RTM tooling. In order to take advantage of the labor savings RTM has to offer, the production volume revolves around the output of a single operator or a two person molding team. For an operator to be efficient, they must work full time at the molding process. In the case of a lower volume set-up processing 8 parts per day, the overall yearly production yields 2000 parts per year. Of course, if there are six different RTM parts in production, the same molding team can produce about 300 of each (or 2000 total) to reach efficient molding levels.

This is not to say that the RTM process must operate five days a week if requirements do not support that production volume. The goal is to have operators working exclusively on RTM when the process is in operation. The scheme of having an operator jump back and forth between RTM and other jobs, decreases efficiency considerably.

The next issue is amortizing the cost of the tooling. If a tool cost $10,000 and has a life span of 2000 parts, it costs $5 per part to amortize the cost of the molds. In a production run of 2000 parts per year the payback is reasonable. If the same $10,000 tool is used to produce 300 parts per year, the payback is stretched out to 6 1/2 years at $5 per part, which may not be reasonable. The other possibility is to raise the amortization rate to, say $15 per part, which requires over 600 parts in a two-year period to pay for the molds.

Here is a quick summary on RTM volumes: You can mold volumes as low as 50 to 200 parts per year (ppy) if there is a technical requirement for the attributes of RTM produced items. To take advantage of labor savings and production efficiency, 300 to 500 ppy is on the low scale and the process gains efficiency moving toward the 1000 to 2000 ppy range. In certain cases, volumes upward of 8000 ppy have been produced.

Tooling Options

One of the interesting aspects of RTM, compared to other molding methods, is the wide range of mold types which can be adapted to the process. Tooling possibilities range from, quick epoxy/gypsum prototype molds costing mere hundreds of dollars, to machined steel molds in hydraulic presses where six digit costs roll off the tongue easily. For the FRP composites industry reality lies in tooling which costs more than open molds, but not as much as the high end metal tooling. In general, tooling of increasing complexity will have greater production capability. The hierarchy of RTM tooling is as follows:

Mold Type	Cost Index (Open Mold = 1)
Epoxy/Gypsum Prototype Temporary Tools	.2-.3
Low Mass Laminated Tools – Room Temperature Polyester or Epoxy Construction	3-5
Low Mass Laminated Tools (No heat sink) – Heated Only Polyester or Epoxy Construction	4-6
High Mass Laminated Tools (High density heat sink)- Temperature Controlled (Heat & Cool) Polyester or Epoxy Construction	5-8
Mass Cast Tools – Temperature Controlled Acrylic - Low Profile Polyester - Epoxy - Polymer Ceramic Construction	6-10
Net Cast Aluminum Tools	6-10
Electroformed Nickel Shell Tooling	12-15
Machined Steel Tooling	20-50

The key to success in RTM is *tooling*. With well-designed tooling, it is hard to produce bad parts. With under designed tooling, it is impossible to produce good parts. In most cases, the RTM process produces either a very good part or a reject. There is little middle ground in the process. In contrast, open molding has the potential to produce varying degrees of acceptable part quality.

A vast majority of RTM failures can be directly attributed to poorly designed or structurally inadequate molds. In the past, there has been a line of logic from would-be RTM’ers that says "We'll go with a quick and dirty production mold to start, and if it works we'll invest in good tooling". Universally these projects fail. RTM is not as forgiving as open molding, where you can actually get by with a marginal mold to build a few parts. RTM tooling must be engineered to perform in ways an open mold builder never has to consider.

A fallacy of RTM is that it is a low pressure process.

The crux of the matter is that very little is asked of an open mold. All it has to do is to maintain the proper shape of the tooling surface. An RTM tool is part of a dynamic system. RTM tool halves must be able to be aligned with one another, be closed effectively, resist considerable internal pressure without deflection, and contain pressurized liquid resin without leaking. All of these items require good design and engineering practices.

A fallacy of RTM is that it is a low-pressure process. One line of thought says that because the vents are open the mold never develops full static pressure. This is true during the filling process - until the resin flows out to the vents. When the resin flow reaches the vents, a large pressure spike occurs with the final pump strokes. There is also the very real possibility that an operator will add a couple of extra shots of resin to purge residual air out of a given vent. In fact, over-pressuring a mold is a technique that is used to produce better cosmetic surfaces.

Another idea which has been propagated is that vacuum can be used to offset injection pressure and make lighter tools possible. While true in principle, vacuum is of little help in reducing internal injection pressure. A vacuum of 20" Hg is about the maximum that can be pulled before styrene begins to boil on the leading edge of the flowing resin. A vacuum at 20" of mercury is the equivalent of about 10 psi. So the overall mold pressure can be off-set by a small percentage with the addition of vacuum assist. There are good reasons to use vacuum assist, but offsetting internal pressure in not one of them.

Very elementary calculations will point out that substantial pressures are involved in the process. Let's look at a mold for a typical hatch cover with dimensions of 24" x 36". The mold cavity will cover 864 in^2. If we are using an injection unit with a 4:1 resin pump, about 40 psi input air pressure is minimum operating pressure for the resin pump. For each 1 psi of input air the fluid pump puts out 4 psi of fluid pressure. So the 40 psi input air becomes 160 psi of resin line pressure. Now multiply the mold cavity area by the line pressure, 864 in^2 x 160 psi and you will find the total hydraulic pressure in the mold will be 138,240 pounds. *One hundred thirty eight thousand two hundred forty pounds of hydraulic pressure trying to separate the mold halves!* Armed with the numbers it is understandable why lightweight RTM tooling has a low success rate.

But that's not all. It takes about 5 psi to compress a 30% glass load in the mold and another 2 psi to compress and seal the gasket. Our two foot by three foot hatch cover mold must be designed to handle a minimum of 167 psi and have accommodations for a total of 72 tons of clamping pressure.

Beware of experts in RTM clothing and always ask the question "Did it work in *sustained* long term production?"

Armed with this information we can make rational decisions about the mold structure and clamping methods. *Don't panic over the 72 tons of clamping pressure.* A single screw clamp can generate about 10,000 pounds or 5 tons of force. In this case 14 clamps will do the job - four on each long side and three on the short sides. Another alternative is an air bag press, which squeezes the mold set between two platens. If the platens operate at 80 psi, a platen area of 1804 in^2, or 3 ft. x 4 ft., will produce the required 72 tons of overall pressure.

The next challenge is to transfer the clamping pressure evenly across the mold cavity. When using a press, the tool structure is required to distribute the platen load evenly across the mold cavity and provide a level interface to the press. In the case of perimeter clamping, the tool structure is called on the transfer the clamping resistance at the edges to the interior of the mold. Each of the 5 ton clamps must be attached to enough structure to counter the bending moment at the center of the mold. This calls for steel - real steel, not whimpy 2" box tube.

I cringe when a tool builder describes how he has used lots of steel to build a "heavy" mold and it turns out to be small tubing. Many times, they are thinking 2" or 3" box tubing is ultra heavy, and it is - compared to what they use on an open mold. In some cases novice RTM mold builders have an aversion to beefing up a tool, so it doesn't get too heavy.

Follow this train of thought. If one man can handle a mold by hand, a case for lightness might be made. However, if it takes two men to handle a mold, then one worker can do the job with the addition of a lifting device. A hoist is much less expensive in the end than the second worker. If a lifting device is used than the weight of the mold doesn't matter. Therefore, the weight of an RTM tool is *not* an issue. If a hoist is needed to pick-up a 250 lb. mold, the same hoist could pick-up a 1000 lb. tool. The conclusion: Build the mold to meet structural requirements, not weight requirements.

Structural requirements (if you design by the numbers) call for heavy steel. Steel is cheap. In fact, steel is one of the least expensive materials per pound that will go into an RTM tool. Therefore, when we start talking about a 6" wide flange I-beams or 10" C-channel, don't be alarmed. From a labor standpoint it is not much more time consuming to weld an I-beam joint or a small square tube joint.

Hopefully we've established these facts dealing with mold design philosophy:

- Mold pressures are considerable
- Mold weight is a minor consideration
- Steel structure is relatively inexpensive

With these points in the record, it must be noted that history strongly supports these conclusions. Although lightweight tooling has worked in prototype development, there are few, if any, cases of this style tooling being successful in sustained long term production. "Sustained production" is what separates a viable RTM from developmental experimentation. Beware of experts in RTM clothing and always ask the question "Did it work in sustained long term production?"

All viable RTM production molds must incorporate a number of important elements to function properly. These features include:

- A mold set indexing method to align the mold halves
- An injection port to introduce resin into the mold
- A venting arrangement to allow air out
- A containment seal to keep resin in the tool
- A clamping method to maintain proper mold cavity dimensions.

Temperature control is a major consideration for repeatable production runs and is integral to the mold type and design. Once the mold is designed, the next consideration is loading the reinforcement in the mold cavity and assessing the options for injecting resin in the tool.

When designing a simple open mold, the builder has a few major items to consider - the tooling gel coat surface, the laminate construction and a supporting framework. In contrast, the RTM mold designer has much more to ponder. RTM tooling requires a method to align the mold halves, a way to introduce resin in the mold, vents to let the air out, a seal to keep the resin in the tool and a method of clamping the tool set together. You also have to simulate the finished part to create the mold cavity and the second side of the mold set. In addition, the forces acting on an RTM tool demand a well-designed structure including a substantial supporting framework. The job of the RTM toolmaker is to integrate these factors into a workable production mold.

The first decision is to determine the type of RTM mold is needed for a given situation. There are a number of choices. One of the advantages of RTM is the range of tooling options. The hierarchy of tooling types ranges from quick build temporary, tooling up to very expensive machined steel molds.

Epoxy Faced Gypsum Prototype Tooling

This is a quick low cost method to make *temporary* RTM molds. Temporary is emphasized because these molds are capable of producing only 3 to 6 parts on the average. The mold consists of an epoxy surface coat backed by a fiber filled cast gypsum. The hydrophobic epoxy cures in the presence of water and therefore can be combined with the gypsum backup.

The construction procedure entails brushing a coat of the epoxy surface fill on the plug and allowing to cure. A second coat is then applied and a gypsum slurry is mixed with the wet epoxy surface coat. Following this application the fiber reinforced gypsum is simply cast behind the surface coat. The whole process takes about an hour and the mold can be used that day.

What makes these molds temporary is the surface coat delaminates from the gypsum substrate fairly quickly. Also the molds are rather brittle and must be gently clamped to avoid cracking. This method is normally used for relatively small (<10 ft^2) proof of concept molds to verify fit between several different parts or glass loading and resin flow issues.

Low Mass Laminated Tooling

The lowest common denominator in RTM production tooling is a laminated polyester/polyester tool which is not temperature controlled. A standard polyester tooling gel coat with a polyester laminate forms the mold substrate, which is then backed with the supporting clamping frame. The low mass designation denotes a tool that does not employ a heat sink and thus is comparatively lightweight. Attention must still be given to the structure of the mold, and deflection may be more difficult to control with this type structure. Room temperature tooling can be used for low volume production that does not require high clamping pressure. One of the implied drawbacks of non-temperature controlled tooling is inconsistent molding temperatures, which change as parts exotherm during cure. If the mold cycle time is long enough, this temperature fluctuation can be minimized, however as the molds are turned faster the temperature issue can become a consistency problem.

High Mass Temperature Controlled Tooling

For all practical purposes, temperature controlled molds are where it's at for RTM production. By closely regulating mold temperature, cycle times can be optimized to take advantage of specialized RTM resins. In this case high level of production consistency can be achieved. In order to control mold temperatures it is necessary to incorporate a high-density heat sink behind the mold face. In the case of a traditional laminated tool the heat sink (normally a casting resin highly filled with aluminum pellets) is cast over the back of the laminate. With mass cast type tooling an 85% aluminum filled casting resin is poured directly behind the tooling gel coat, excluding the need for a glass laminate.

In both cases copper or stainless steel tubing is integrated into the heat sink. Temperature adjusted water is then circulated through the tubing, using readily available hardware store components, such as a hot water heater and a circulator pump. The purpose of the heat sink is to maintain a constant temperature by either absorbing heat or by siphoning off excess heat from the mold surface.

Cast Aluminum Tooling

Cast aluminum tooling has been around for years, but has not had much influence in the composites industry. Run-of-the-mill cast aluminum tooling has several problems that have deterred its acceptance in the composites industry. First, it has traditionally had a rather porous surface that is not appropriate for high quality finishes. Second, it required considerable machining to turn the raw casting into a production mold.

These problems have been addressed by new casting and alloy technology. These casting methods have made this tooling medium viable in some circumstances. The new casting methods have made great improvements in surface porosity with in aluminum molds. Although they are not yet achieving a "class A" finish the surfaces are acceptable for slightly less cosmetic applications. The other major advancement in cast aluminum tooling is the advent of "net shape" casting. This is a method, which closely controls shrinkage during the alloy casting process and eliminates the need for most machining to complete the mold. The result is a metal mold that costs slightly mold than a laminated epoxy mold and is capable of producing upward of 50,000 parts.

Other High Priced Molds

Climbing up the scale of tool sophistication, we find electroformed nickel shell tooling and machined steel tooling. In most cases, the cost of these types of tools is out of reach for typical FRP production rates. Volumes starting at around 5000 parts per year are considered minimal for electroformed nickel molds and about 10,000 parts per year required to even consider entry in the machined steel tool club.

Well-designed RTM tool-ing must meet certain functional criteria to perform properly. These criteria address mold set alignment, resin injection point, the venting arrangement, and the containment seal design. An important perspective is to adapt the design engineering principles used in expensive "high end" molds. These design features are then incorporated into the RTM setting. The urge to simply "beef up" an open mold should be avoided. History has proven this approach is likely to fail.

For example, look at the alignment pins on a steel compression mold, they may be over 1 1/2" in diameter and 10" long. RTM tools do not require hardware this heavy, however the design principle can be scaled down to fit the application. To the other extreme we might find novice designer molding a couple of fiberglass "indexing shapes" into the flange of the mold in conjunction with a 1/4" bolt to align the halves. This method is very inaccurate and leads to production problems.

The Advantage Of Temperature Controlled RTM

In non-temperature controlled tooling internal mold temperature is a result of resin exotherm during curing, and the speed of the molding cycle. This type mold will start the day at room temperature and heat up as the tool is cycled during production. In some cases, the tool will overheat if pushed too fast and part cure times are effected by temperature fluctuations.

Heated (only) tooling has some advantages, but only addresses half of the temperature problem. Heated molds work well in situations where the mold cycle is long enough to dissipate exotherm build-up. However there is no control to prevent overheating.

Temperature controlled tooling usually employs internal tubing to circulate a temperature-adjusted fluid through the mold heat sink. The fluid (usually water) maintains the temperature, sometimes heating and sometimes cooling the mold, while the heat sink acts to moderate the temperature and provide a consistent baseline. Temperature controlled RTM tooling provides a molding consistency that promotes quality along with fast cycle times. The RTM process can be optimized when mold temperature is properly managed.

Mold Set Alignment

A method to align the halves of the mold set is required. All sorts of schemes can be seen to position the two halves during closure. As previously mentioned sometimes a novice mold designer will try matching bumps and hollows are molded in the flange, other times an external pin and socket arrangement is employed to position the molds.

By far the most effective method of alignment is to use standard pattern makers core box pins. These readily available index pins are molded in the male and female halves of the tool set and provide an unchanging positive alignment. It should be noted that it is important to establish a highly accurate mold set alignment during the mold building sequence and not to attempt to provide an "add-on" alignment set-up as an after thought.

Resin Injection Port

An injection port provides for the resin entry into the mold cavity. The best location for the injection port is either, the geographic center of the mold, or in some cases the volumetric center of the cavity. Using the example of a uniform shaped box, the center of the bottom is the best location to inject. In the case of a part with one end much thicker than the other, the port should be positioned toward the larger end, in about the volume center of the mold.

In most cases one injection port is adequate, up to a part of 100 ft^2 for example. As larger areas come into play, several ports can lower injection pressure by limiting the distance from injection point to the vents. Two options for injection ports include a self-sealing port and a manual sealing port. The manual ports are less expensive, but require the operator to place a plug in the opening following resin injection. The self-sealing ports close automatically when resin flow stops and a small resin plug is removed after cure.

Containment Seal

In order to run an efficient RTM process it is necessary to contain resin, under pressure in the mold set. This calls for a containment seal or a gasket around the perimeter of the cavity. The gasket usually is seated in a groove molded into the top half of the mold set. While many styles of gaskets are available, they must be hard enough to crush any stray glass fibers, which might protrude through the mold edge, and yet soft enough to allow for mold closure. A durometer of about 40 on the Shore hardness scale seems to fit the bill.

Venting Arrangement

Since the mold cavity should be completely sealed, provisions must be made for venting the air out of the cavity. There are two basic methods of venting an RTM mold. One is perimeter venting, which spaces vents around the edge of the mold at regular intervals. The other is to use point vents, described as being located at a specific "point" or location in the mold. Perimeter vents can reduce backpressure in a mold, however they may make to difficult to control resin flow through a mold. In addition, perimeter vents are more difficult to effectively seal, thus leading to the potential of increased leakage. Point vents, on the other hand, may easily be opened or closed during the injection cycle, allowing the resin flow to be manipulated during the injection cycle.

Clamping

Clamping is a major design consideration for an RTM mold builder. The entire structure of the tool set is designed to accommodate the clamping mechanism. Two clamping methods include perimeter clamping and press clamping. If a press is used, the mold structure can be generally lighter than a perimeter clamped tool. In this case the press platen supplements the structure of the mold and evenly distributes the clamping pressure over the plan area of the tool.

In the case of perimeter, clamping the clamping resistance must be transferred from the outer edge of the mold set to the interior. The steel structure of the tool should be designed in conjunction with the clamps to provide adequate resistance to the hydraulic pressure generated in the mold cavity. As detailed earlier, the pressures generated during the RTM process are considerable, and these loads should be calculated to determine the proper number and location of clamps.

RTM Economics

The most important consideration in making RTM work is the economic viability of the process. The attached spreadsheet compares open molding to RTM. The example will be the production of a hatch cover that is 24" x 36" with a 1/2" core and finished on both sides. We'll look at three different scenarios; open molding, low mass room temperature RTM tooling and temperature controlled high mass tooling. Each of these options will be examined with total production runs of 100, 500, 1000 and 2000 pieces. In addition, we'll examine open molding both a single sided finish and two-sided finish for cost comparison.

The first open molding sequence will produce a one side molded finish on a hand laid-up hatch cover which is then gel coated on the "raw laminate" side to add some cosmetic value to the underside.

The second open molding procedure consists of gel coating and laminating two separate parts, a top and a bottom, then bonding the halves together to complete the hatch cover with a two side molded finish. The top half is molded with the core insert while the bottom panel is fabricated in a separate mold. These two pieces are then mated in a bonding fixture and the edge is finished to complete the part.

In the RTM scenario, both halves of the mold set are gel coated followed by loading the dry glass reinforcement and core in the mold. The mold is clamped, resin injected and cured. Following removal form the mold the part is trimmed to complete.

The numbers reveal the cost of the open mold produced hatches remain relatively constant whether building 100 or 2000 pieces. On the other hand the RTM cost is about 10-15% lower than the two sided open mold hatch at the low volume of 100 units produced. As the overall production volume increases the cost of the RTM molded hatches goes down to about 38% less than open molding at the high volume of 2000 molded parts.

Several points are worth noting in this analysis. One is that labor cost is the same for open molding at high and low volumes. Labor cost decreases slightly as the RTM volume goes up, however the biggest factor is the difference in overhead cost. If heating, ventilation and the possibility of required respirator usage are factored, RTM enjoys a considerable advantage.

Summary

So the question please..."Is RTM ready for prime time?" The answer is a qualified yes. The process has matured to the point of being a capable option for composites production. However, it is not a "do all-end all" process, but has distinct advantages in the hands of a good student of the molding process. There are many profitable opportunities for the average plant to use RTM successfully.

The more important question is "Are composites fabricators ready for RTM?" This answer is more difficult. Tooling can either make or break the RTM process. RTM tooling is a different animal compared to simple open molds, and the new skills must be developed. Anyone who can engineer a quality product can develop the skill to design and build RTM tooling, but experience is the deciding factor in initial success.

In open molding, we routinely expect the first part out of a mold to be exactly what we expected. RTM does not always work that way. One might have to build as many as 10 or even 15 parts to work all the bugs out of the system prior to production. The learning curve, compared to open molding, is much steeper. For example, the first 10 RTM production parts may cost three times more than the target cost. The next 10 may improve to two times target cost and it could take another 10 to 20 parts to achieve the cost objective. About 30 parts to “learn” a new RTM system is a good track record. In the end, once the bugs are out, a refined RTM production system will offer real dollar advantages over open molding.

The best of conventional wisdom is this: Start an RTM program with small non-critical components; Develop your skill and expertise, and then move to larger more complex parts. When in doubt over-build tooling. No one has ever gone wrong with molds that were too strong. RTM works for those who pay their dues - so do your homework before embarking on a closed mold adventure.

Bob Lacovara
Director of Technical Services
Composites Fabricators Association
1655 N. Ft. Myer Dr., Suite 510
Arlington, VA 22209
703-525-0511