

## **Infusion Intrusion: Embracing Change**

### **Abstract**

If you're reading this article, the chances are that you are already successful at building composite parts for a market that you've taken years to understand in order to survive the competition. In the composites industry, this usually means innovating and optimizing shop practices. That's why you're probably saying "why is everyone pushing Resin Infusion Processing on me?" Well, the world doesn't stand still and unless we continue to improve manufacturing processes, our business will be lost to a competitor who can build better parts in a more environmentally-friendly fashion. Indeed, the labor-intensive nature of the composites industry makes it extremely vulnerable to overseas competition. However, overhauling manufacturing processes on the shop floor may require some revision of your corporate culture as well.

### **Background**

The term Resin Infusion Processing broadly encompasses many variations of composites manufacturing where dry reinforcement is stacked in a mold under a vacuum bag that draws resin into the stack. The vacuum bag produces a high-fiber content laminate and limits worker exposure to curing resin systems. Resin Infusion Processing may not be a cost-effective alternative to lightly-loaded parts now made with chopper gun technology. However, structural laminates made with woven or knit reinforcements are good candidates for Resin Infusion, especially if sandwich construction is used. The biggest challenges for the newcomer to Resin Infusion are getting resin to flow through compressed reinforcement and reinforcing to your workforce to go with the flow. For this article, I've relied on experts from various material suppliers, which is something any builder contemplating the switch to Resin Infusion should do. More likely than not, your current material supplier has the in-house expertise to help you make a smooth transition to infusion manufacturing.

### **Corporate Commitment**

The Resin Infusion process utilizes unique skill sets that are not found in a hand lay-up shop. Personnel that have spent their careers becoming proficient at hand lay-up tasks will naturally resist retraining to a new process. A company needs to be committed to change and should seek professional help to smooth the transition. Phil Steggall of the Vectorply Corporation notes "Be prepared to spend time and money to develop the necessary skills. First, find an expert that can retrain everyone from engineers, purchasing, and the shop crew. Infusion employs very different disciplines and mastering these will mean the difference between success and failure."

I found Russ Elkin of Alcan Composites demonstrating infusion of a boat hull at last year's IBEX show. Like most Technical Service Engineers in the composites industry today, he has a lot of first hand experience with shops making the change to infusion. "People that have begun to experiment with and implement infusion processes are not fully taking advantage of the benefits because they are taking the same incremental and trial-and-error approach to manufacturing as they did when they were learning to build fiberglass parts years ago. Back then, we were all learning on the job. It is human nature

to try the same approach to infusion. For example, first they try to build a part with the same materials and lay-up schedule they use for open molding. They see the result is too thin, maybe they add a layer and try again, then another or a 'new' idea and try again and again until they get a 'satisfactory' result. At this point too much time, effort and money have been spent for not enough return."

So we're going to spend a lot of time and money to switch to a process that uses more process consumables; will require re-engineering of laminates; and possibly alienate our workforce. Management must be committed that product and workplace improvement will justify such an investment. Workers should view the change as a chance to improve their job security. Elkin tells us to "Use infusion as an opportunity to take a fresh look at your structure and manufacturing process. This is often overlooked and can be significant in making infusion cost-effective." Better products and a more high-tech labor pool working in a cleaner environment is a win-win situation for everyone.

Belle Gall, Technical Services Representative for DIAB reminds us "Changing your fabrication process is a major undertaking and should be treated as such. Most failures in this endeavor come from half-hearted attempts at changing. If you are going to start any new program it should be given as much attention as needed to make it a success – be committed."

### **Obstacles to Changeover from Hand Lay-Up**

Obstacles to change come in two forms – physical and physiological. Physiological obstacles involve worker retraining touched on above. Gall adds: "Change is difficult for everyone. It creates tension and stress. The best way to make workers accept change is to show it is accepted in management. Let the workers know that they will be brought along in this change and that it is to their benefit as well as the company's. Any worker who is prepared for a change can look forward to it, and will be much more successful at it, compared to a worker who fears he/she will lose their job due to the change."

It's also important to look at laminates from a fresh perspective. Al Horsmon, the Chief Naval Architect at SP Systems North America has been designing sandwich laminates for over two decades. He notices that some builders have a "problem adjusting to the idea that with infusion, their laminates will be thinner, so the bulk from the [extra] resin they had before will be gone." He also sees builders "in a hurry to have a quick infusion with big cuts [in cores] and fast flow. I tell them to minimize the number and volume of cuts in the core." Once management has convinced itself and labor of the benefits that Resin Infusion can bring to their business, several physical changes to the composites manufacturing process need to be considered.

### **Molds**

Unless the switch to Resin Infusion coincides with the start of a new product line, most builders will want to use their existing hand lay-up molds for production. Russ Elkin warns us: "Make sure your molds do not leak. Leaky molds are something that even experts cannot overcome." One of the most difficult aspects of Resin Infusion is maintaining a vacuum on the assembly before resin is introduced. Any leaks will make it

impossible to establish a vacuum to draw resin into the dry fiber stack and also create unwanted voids in the laminate. “We have seen large parts go the way of the dumpster because the tool opened up,” notes Phil Steggall.

Molds used for Resin Infusion also need to have a larger flange area than conventional molds to accommodate sealing of the vacuum bag perimeter. Extending flanges on molds can be more time-consuming than initially estimated, especially considering that airtight integrity is paramount.

### **Laminate Schedule**

Builders must understand that infused laminates will be thinner with higher fiber content than those built using hand lay-up techniques. Thinner skins on sandwich laminates may only be a problem with impact resistance but solid laminates will also bend a lot easier and consideration should be given to restoring thickness with infusion media or print blockers, which are required for successful infusion anyway.

Eliminating cosmetic “print-through” is always a concern of composites manufacturers. The demand for dark surface finishes combined with the fact that Resin Infusion processing “pulls” the laminate stack against the mold with vacuum and may create more exotherm because the entire laminate is curing at the same time all combine to create a “perfect storm” for print-through problems. The current state-of-the-art to control print-through has builders spraying gel coat and skin coats into molds, essentially identical to conventional open molding process - perhaps adding an additional print blocker. Steggall has observed “After working with the clean, no smell of infusion, filling the shop with fumes just for a skin coat seems an unnecessary step. But currently, it’s the hardness of that skin coat that blocks the print.”



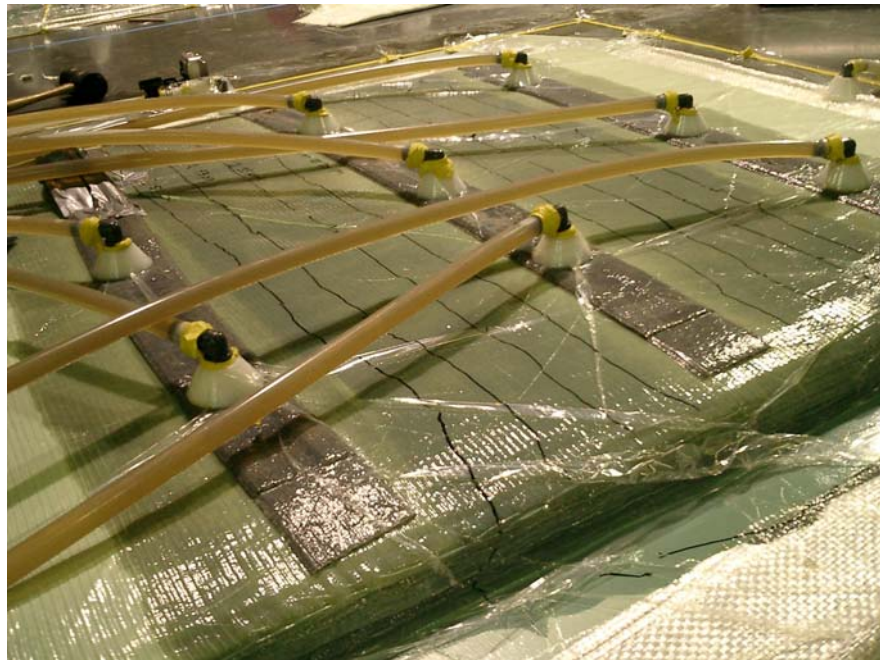
**Figure 1. VectorFusion™ E-3LTi 10800 x 21 layers being prepared for infusion. In this case, the finished part is a thick component at a hydro power site. (photo courtesy of Vectorply Corporation)**

One of the biggest challenges of the Resin Infusion process is proper placement of reinforcement and core material. Remember that this material is all going in dry and must stay in place as vacuum pressure is applied. Figure 1 shows the placement of dry fiber for a very thick laminate. Again, some advice from Phil Steggall: “An important factor to successful infusion is a way to hold the dry fiber and core while the dry stacking is completed and the part is bagged. There are two ways to accomplish this. One is a good spray adhesive. The other way is fiberglass staples. Keep in mind that some spray adhesives can interfere with the resin and inhibit flow if it is applied too thickly. The pitfall of fiberglass staples is that they sometimes can rise up out of the laminate and puncture the bag if they are not covered appropriately. If you use them to install resin plumbing lines inside the bag, cover the staple up with a layer or two of masking tape after they are inserted. Staples are excellent for keeping a core seam together tightly so the risk of print-through is reduced in the finished product. When used appropriately, the staples can be a great time and labor saving step. They are easy to install and don’t interfere with the laminate flow or chemistry. I recommend Raptor brand staples. They will also help you select the appropriate staple size and gun.”

### **Infusion Media**

Wetting out dry reinforcement during hand lay-up operations has always been challenging. With Resin Infusion, we only have “direct access” to the laminate at the ports where the resin is introduced and we’re trying to wet out the entire laminate stack at once. Oh, let’s not forget that the stack is under a vacuum bag that compresses it making it even harder for resin to flow.

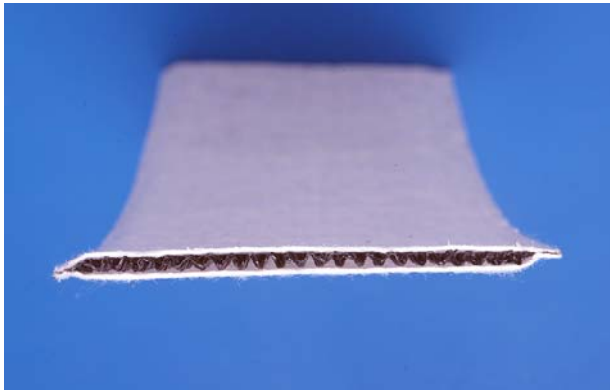
Infusion media are products placed either in or on top of the laminate stack that create channels where the resin can flow throughout the part. Figure 2 shows a Resin Infusion configuration as resin is being introduced into the part.



**Figure 2. Resin feed lines are spaced according to the porosity of the reinforcement and viscosity of the resin. (photo courtesy of Vectorply Corporation)**

Most reinforcement suppliers offer products with flow media integral to the reinforcement. When queried on the subject, Steggall told us “Vectorply has infusion specific reinforcements that are grooved or channeled to let air escape and resin flow at consistent, predictable rates. These fabrics have been very successful (over 1.5 million pounds used in the past 12 months). They provide excellent flow characteristics without the need for additional costly flow mediums or meshes. These fabrics have the unique ability to resist the compression due to vacuum so they build thickness at a rate proportional to the resin viscosity”

Colbond makes an infusion media called EnkaFusion, shown in Figure 3. Figure 4 shows a small hull being molded using EnkaFusion.



**Figure 3. Colbond EnkaFusion Infusion Media (courtesy Colbond)**



**Figure 4. Boat hull infusion (courtesy of Colbond)**

Elkin tells us: “Alcan Baltek offers an interlaminar infusion medium that does not compress under vacuum. This material combines excellent resin flow with high conformability. It can be used in places where a rigid core material like balsa or foam would not be suitable. One form of this product can even provide print blocking capability.”

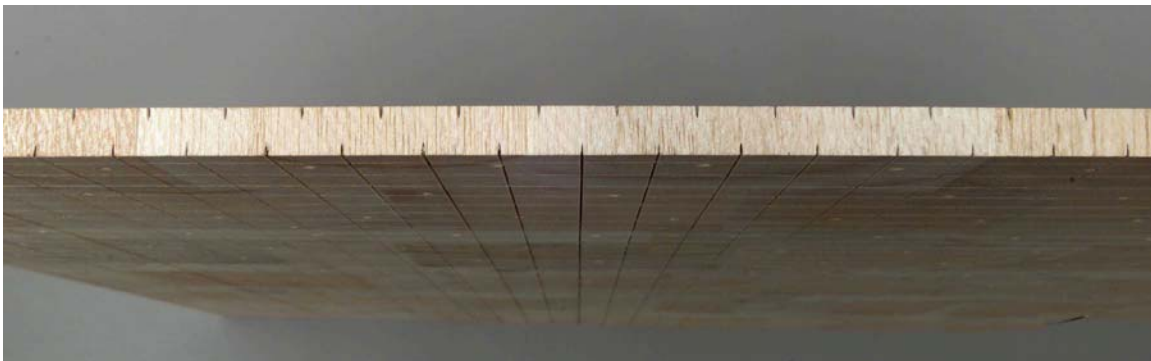
### **Infusion with Structural Cores**

Cored construction offers both new challenges and opportunities for the Resin Infusion process. On one hand, the core is another layer that needs to be properly fitted in place and an obstacle to resin flow between inner and outer skins. On the other hand, cores can be modified with grooves and through-thickness holes to facilitate resin flow.

“In the open mold world, fitting the core comprised of pushing on it with rollers or the occasional sand bags to weigh it down. But with infusion, a poorly fit core will suck up drums of resin as fast as you can say ‘heavy expensive boat.’ Fitting the core is critical to cost and weight control. Basically, resin will fill any area that does not have core or fiber. Laminates can get heavy fast if the core does not fit properly” according to Phil Steggall. Belle Gall of DIAB reminds us “Kits can improve the fit of the core so that gaps between sheets are minimized and reduce labor needed to install the materials.” All major core suppliers offer materials in kit form for their production builders.

When it comes to custom core machining for infusion, it seems the sky’s the limit. “We have 6 standard and 40 or so custom infusion cuts in Corecell and we’ll do mostly what the customer wants,” say Al Horsmon of SP Systems. Belle Gall tells us “DIAB offers core materials that are specifically made for infusion. We offer a core with an infusion cut on one side only for fabricators that are concerned with print-through issues. The groove configuration that DIAB offers for infusion is very robust. A small groove grid with perforations reduces resin intake, and makes the laminate very easy to fill. We also offer higher temperature cores that can withstand the heat generated by newer dark gel coats that so many marine customers want.”

Figure 5 shows a groove pattern in a balsa core material.



**Figure 5. Shallow resin flow channels cut into balsa core (courtesy of Alcan Baltek)**

## **Resin Systems**

Resin Infusion processing forces us to better understand resin chemistry, an area where help from our suppliers is a necessity. Steggall cautions: “Resin systems, reinforcements, and cores all must work together as a system. This is where hired experts can be useful in bringing the right products together.”

“The newer resins that are formulated specifically for infusion are a great improvement from past resins that were modified for infusion by adding styrene. The best new resins have a lower viscosity and make infusion much easier than in the old days.” Says Belle Gall.

Where we were once limited to polyester and vinyl ester resins, manufacturers have now had success infusing with epoxies and phenolic resins. As an example, Horsmon from SP Systems relates: “We have the Prime 20LV epoxy infusion resin with a number of hardeners, which our customers really like.”

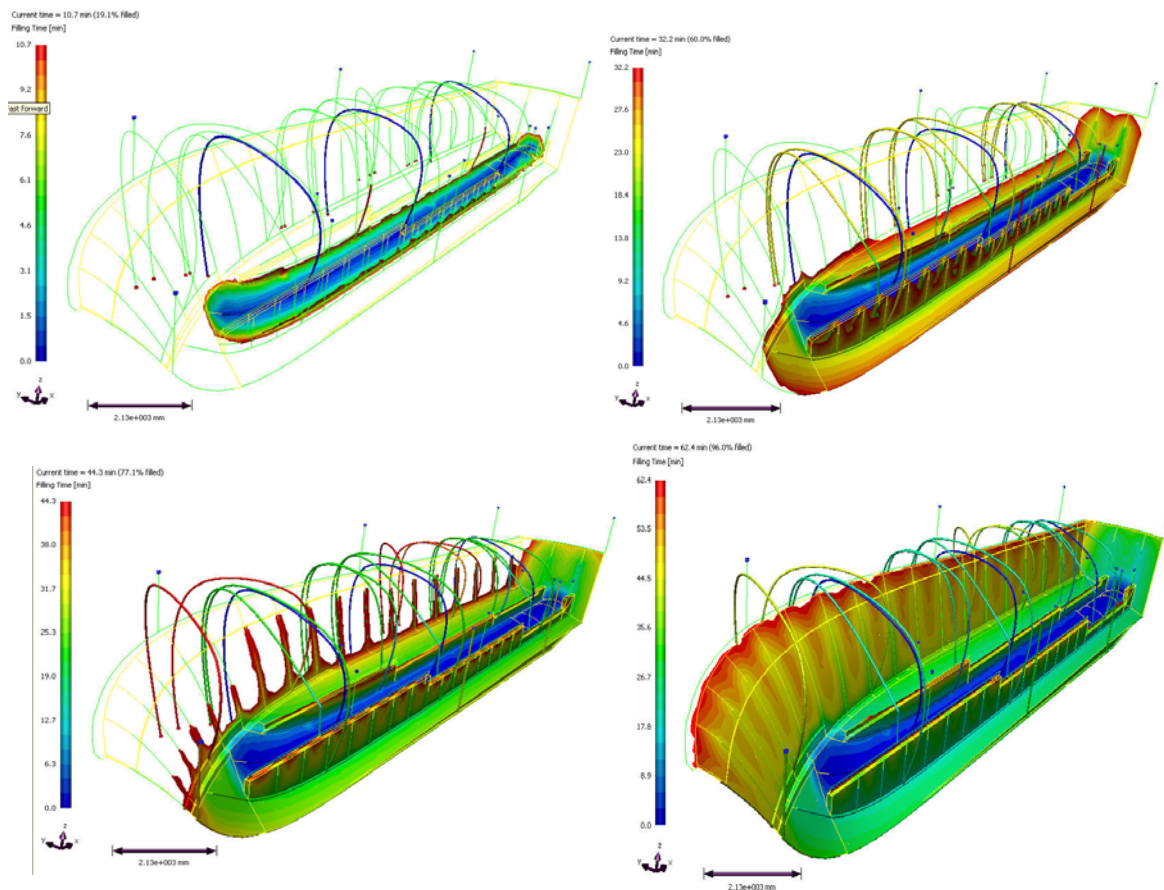
## **Process Consumables**

Process consumables unique to the Resin Infusion include the vacuum bag, its sealing tape and resin feed lines. Assuming a proper resin trap is used, the vacuum pump should not become a ‘process consumable.’ Russ Elkin of Alcan Baltek notes: “The cost of consumables is an easy thing to point to by people who do not want to adopt the process. I think the latest infusion methods demonstrate many different ways to reduce the volume (and cost) of material that is thrown in the garbage. Last fall at IBEX 2005 we demonstrated an infused hull with no disposable feed lines. Everything was routed into the core materials. The most time consuming part of infusion is often sealing the bag. A pre-kitted bag can help, but improvements to bagging materials are needed. I am very interested in the [emerging] spray-on bag technology.”

## **Process Modeling**

Several suppliers indicated to me that they offer flow modeling services to their customers. These programs predict how resin will flow through the part once the valve to the resin supply is opened. It helps the builder position ports and predicts which areas of the part may be harder to fill. I first witnessed flow modeling technology about 15 years ago at the National Institute for Standards and Technology (NIST) where it was being developed for industries with extremely rapid part turnaround times, i.e. automotive. Advances in personal computer technology and more importantly a knowledge base for feedback on modeling accuracy has made flow modeling much more accessible.

“Polyworx™ software uses state of the art interface and FEM technology to minimize part risk. The software is adapted from RTMworx™, and is very reliable. Using this software you can accurately predict the flow of resin through a laminate under vacuum. The infusion can be run over and over in the computer until the desired results are achieved. The use of a computer simulation of the flow can greatly reduce the risks on large parts. This simulation can also build in a comfort level to many first time infusers. Flow modeling may not be necessary for simple or small parts, but for large or complex parts, and companies new to infusion, it can bridge the gap from the familiar to the



**Figure 6. Simulation of a boat hull infusion using Polyworx™ software clockwise from top left at 10, 32, 44 and 62 minutes (courtesy of DIAB Corporation)**

unknown world of infusion. It can also be used to optimize the infusion process, reducing fill time and feed lines” according to Gall of DIAB. Figure 6 is an example of a Polyworx™ simulation for a boat hull.

The switch to closed molding is being dictated by increasingly stringent emissions standards and the quest for improved part quality. Issues of core debonding are practically nonexistent when Resin Infusion manufacturing is used. Belle Gall of DIAB summarized where we are best: “Like the composite industry itself, the infusion process is constantly changing and improving. The infusion process has been around quite a while if you go back to the patents in the 1950s. Since then, improvements in fabrics, resins and refinements in core grooving have improved the process to the point of being user friendly. Yet, the process is still in its infancy. We still need changes to improve cosmetics of infused parts. This is being looked at by all the material suppliers, from gel coat makers to fabric, resin and core manufacturers.”



## **Conclusion**

The good news is that material suppliers are on our side, constantly refining their products and willing to offer engineering and on-site consulting services to ensure that their products are used correctly. They are the experts and I'd like to thank the following for their help with this article: Russell Elkin, Technical Service Engineer, Alcan (Baltek) Composites, [Russ.elkin@alcan.com](mailto:Russ.elkin@alcan.com); Al Horsmon, Chief Naval Architect, SP Systems North America, [Al.horsmon@spnorthamerica.com](mailto:Al.horsmon@spnorthamerica.com); Phil Steggall, VP Technical Development, Vectorply Corporation, [psteggall@vectorply.com](mailto:psteggall@vectorply.com); and Belle Gall, Technical Services Representative, DIAB, Inc, [Belle.Gall@us.diabgroup.com](mailto:Belle.Gall@us.diabgroup.com). Please contact your material supplier for the latest products developed for Resin Infusion processing and technical support to get started.