

Vacuum Resin Infusion – A Brief History
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While the resin infusion process is one of the most popular processing methods at the moment, there is still some reluctance in adopting it over open mould processes. It is seen by some to be a “black art”, surrounded in mystery, and only understood by a few. However there is a substantial amount of information available on this process, and in this article I wish to look at the history and some of the mechanics involved.

The term Resin Infusion is used to describe the method by which resin passes through the reinforcement using a combination of natural physics (capillary action) and a driving force, i.e. pressure. This process is used in RTM, VARI, VARTM and other well known process acronyms where the pressure is above atmospheric and rigid tooling is used. However herein we shall be concentrating on the process using flexible tooling where the driving pressure is vacuum, i.e. no greater than atmospheric pressure.

The earliest patent on resin infusion was in 1950 by Marco; his initial process was subsequently amended and patented over the following decades, until Seeman Composites Resin Infusion Moulding Process (SCRIMP) was patented in the US in 1990. Outside of the US, notably in Europe, no patent was enforceable due to prior knowledge. Seeman’s infusion of yacht hulls was widely reported although little detail of the process or the mechanics involved was fully understood until some time later. However By the mid 1990’s parts of up to 30m were being routinely infused in a single shot.

My personal involvement in the infusion process was in the mid to late 1990’s using the Seeman type of process for structural rehabilitation in the UK offshore oil and gas market. We had renamed our system after the UK University of Plymouth’s acronym RIFT (Resin Infusion under Flexible Tooling). The Seeman process used a diffusion medium which covered the majority of the surface of the part. This method allowed the resin to flow predominantly through the thickness of the reinforcement making the process very fast as the resin only flowed through length the reinforcement at the edges. This was used with glass and carbon fibre and worked very well even on 8m high vertical panels which were approximately 15mm thick.

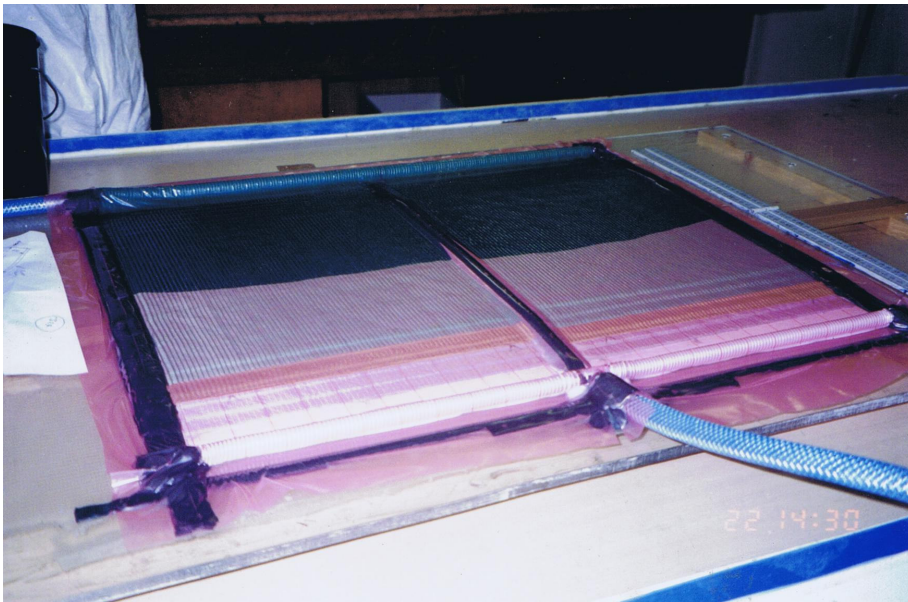


Photo 1 : Wet out in progress using a diffusion medium

Although this arrangement reduced cycle times, the use of consumables made the process costly in a manufacturing environment, even though this was offset by the improvement in quality and labour costs. The interesting point here is that resin viscosity and reinforcement architecture, although important, were less of an issue, the distance travelled was smaller and so the likelihood of the process stalling was reduced. At this point, fibre architecture modification was not widespread as off-the-shelf fabric weights and styles were all that were routinely available, a situation which has now changed considerably.

The issue of resin flow was well known from RTM and similar processes; however these had set tooling voids, and relatively large driving pressures, the use of vacuum with a flexible bag or splash tool makes the void variable, and where previously the reinforcement was loaded and within reason took up the space within the tool uniformly, the vacuum effectively squeezed the fabric together to occupy the smallest volume, compounding the problems of fibre wet-out whilst minimising voids and increasing mechanical properties. As such a whole new area of research was born and various Universities who leapt onto this were successful especially in Europe in gaining research funding.

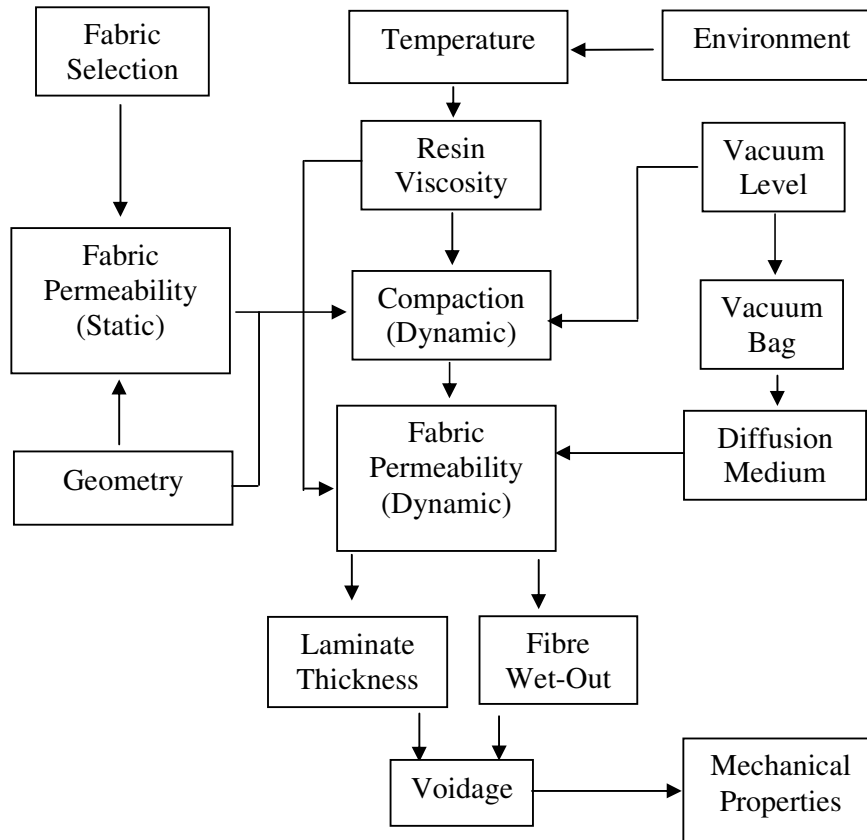
The work to explore the interaction of reinforcement and resin had at this point referred to a well known scientific paper published in 1856 (yes - 153 years ago!) by HPG Darcy, called "Les fontaines publiques de la ville de Dijon", wherein Henry Darcy perfected his law on the permeability of fluids through porous media, in his case water through sand. Nowadays we use resin viscosity and fabric permeability to achieve somewhat different outcomes to help us predict the success of a good infusion but also infer the quality of the composite in terms of voidage and hence mechanical properties.

The difference with resin infusion was that as the resin infuses, a flow front is created that on one side is being drawn by the vacuum and the other where there is resin is at atmospheric pressure and the reinforcement compaction now varies across this leading edge. Once the inlet is closed off the resin then passes through until the vacuum can not draw any more resin and you are left with your final thickness. By this point the resin has impregnated the tows and the voids created by the reinforcement architecture and may also have started

to increase in viscosity, creating more resistance. Air is much easier to draw out of the reinforcement than resin.

In 1997 I attempted to lay-out the interaction of resin infusion variables, as shown below;

RESIN INFUSION PROCESS VARIABLE INTERACTION



This flow diagram shows two permeabilities for the reinforcement, static (without vacuum or resin) and dynamic (with resin and vacuum). The issue of resin is important as through the lubrication of the fabric, the reinforcement can compact further than dry, thus increasing the fibre ratio but also decreasing the permeability. Compaction of the fibre is achieved through the reduction of internal and ply friction permitting the fibre tows to slide and nest. A number of experiments were undertaken with packs of fabric which were subject to repeated compression and the resulting thickness measured. A distinct improvement was noted with wet fibres than dry but in both cases a reduction in thickness was noted, one of the many features of the infusion process.

The growth in interest from manufacturers and material suppliers has changed the face of resin infusion considerably in the last 10 years. With resin formulations better suited to the process and reinforcements that promote resin flow, the complexities of the process are much easier to contend with. It would be reasonable to assume that with new materials, the problems facing anyone new to the process are restricted to placement of the inlet and outlet connections. In the SCRIMP process this was easily overcome as the distance was

effectively very small. Modern infusion relies almost completely of in-plane infusion and therefore the opportunity to stall the process or to achieve incomplete wet-out is greater. A number of computer models were developed at the time, which (considering the computing power at the time) was remarkable from today's standards. These models allowed the testing of simple shapes and placement of the various connection points. Modern models are far more complex and predictive, and allow combinations of reinforcements and resin parameters combined with complex geometries, and will with reasonable accuracy predict the subsequent laminate properties. However a computer model is not necessary to start using the resin infusion process.

In the last 20 or so years the resin infusion process has come a long way technically, although its adoption still seems to be hesitant. Nonetheless, the process is more practical to employ to meet toughening environmental legislation, improved cleanliness and economic realities of efficiency. For those looking to take up this process there is plenty of information in the public domain and willingness within the industry to assist. It is not a quick fix, and most recommend a trial and error approach by starting small and working your way up. Practice does make perfect and a great deal can be learnt in a short time.

The science behind infusion is over a 150 years old, but the process and techniques are relatively new, giving infusion the sense of mystery which it only partly deserves. My suggestion would be: give it go - you may be surprised at what you can achieve!