A NEW VACUUM INFUSION TECHNOLOGY: PULSE INFUSION

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Abstract
A new vacuum-assisted technology for the manufacturing of polymer-based composite materials has been developed and called Pulse Infusion. It is a variant of the traditional Vacuum Infusion Process (VIP, VARTM). Its main innovation is based on the use of a proper designed pressure distributor, that allows to control the pressure of the vacuum bag on the dry fiber reinforcement and induce a pulsed transverse action to promote the through thickness resin flow. The final part is characterized by an improvement of the flexural ultimate strength. In addition, a reduction of the resin consumption and waste are attained at the end of the processing cycle

1 Introduction

Vacuum film or liquid infusion technologies out-of autoclave have been gaining popularity to manufacture composite parts for automotive or nautical applications aiding to cost saving. In fact, Vacuum Infusion Process (VIP, VARTM) requires only one tool side being the other a polymer flexible bag, as a consequence it is more economical than RTM. In addition, the impregnation of the dry fiber reinforcement by a thermoset liquid resin is carried out by vacuum application.

These processes are characterized by several advantages, such as low tooling costs, possibility to separately design the fiber architecture and the infusion stage, and the capability to manufacture complex parts with inserts or encapsulated foam core in one operation [1, 8]. On the other hand, during the VARTM process some limitations can be observed [9], such significant through-the-thickness impregnation gradients and local variation of compaction pressure that can negatively influence the mechanical properties and determine not uniform thickness for the final composite part. In addition, since several ancillaries not reusable materials are required, a great amount of waste is observed with negative effect on the costs and the environment.

In order to overcome these drawbacks, a new vacuum-assisted technology, called "**Pulse Infusion**" (Pending Italian patent [11]), has been developed and industrially implemented. Its main innovation is based on the use of a proper designed pressure distributor, that allows to control the pressure of the vacuum bag on the dry fiber reinforcement and induce a pulsed transverse action to promote the through thickness resin flow.

The Pulse infusion has been developed and experimentally implemented. Infusion tests have been carried out to manufacture simple composite parts that showed better quality surface and more uniform thickness. The fibre glass/epoxy composites, manufactured by conventional

Vacuum Infusion process (VIP) and Pulse Infusion, have been mechanically characterized by performing flexural tests. An improvement up to 13% for the modulus and up to 24.5% for failure strength has been found for the pulse composites. In addition, due to the use of a reusable pressure distributor, a reduction of production and labor costs and a significant waste decrease are attainable indicating that the Pulse Infusion could result a totally viable alternative to the conventional VIP.

2 Technology description

In the conventional Vacuum Infusion Process (VIP, VARTM) the impregnation of the dry fiber reinforcement by a thermoset liquid resin occurs by vacuum application. The process basically involves three steps: lay up of a fiber preform, vacuum application and fiber impregnation by a thermoset resin, cure of the resin. The reinforcement, typically carbon or glass fabric, is placed onto a one-sided rigid mold, a formable vacuum bag material replaces the common RTM matched metal tool. The resin is injected through one or more inlet gates, depending on part size and shape. Vacuum is applied through a single or multiple vents in order to remove the air from the fiber preform and to drive the fiber impregnation of the part by resin. A resin distribution net medium is placed onto the reinforcement to promote the resin flow, to allow complete wet-out of the preform and to eliminate voids and dry spots.

In the case of the Pulse Infusion, two vacuum bags are adopted and the resin distribution net is eliminated. The lower vacuum bag determines a lower chamber where the resin infusion occurs almost likely in the VARTM. The lower vacuum bag is stacked on the dry fiber reinforcement without placing the resin distribution net. A proper designed pressure distributor (figure 1) is positioned on the lower vacuum bag and under the second upper vacuum bag allowing to identify an upper chamber. By applying a different vacuum pressure in the two chambers and controlling timely the pressure difference between the two chambers, the resin flow is pulsed and promoted both in the plane and through the thickness of the reinforcement.

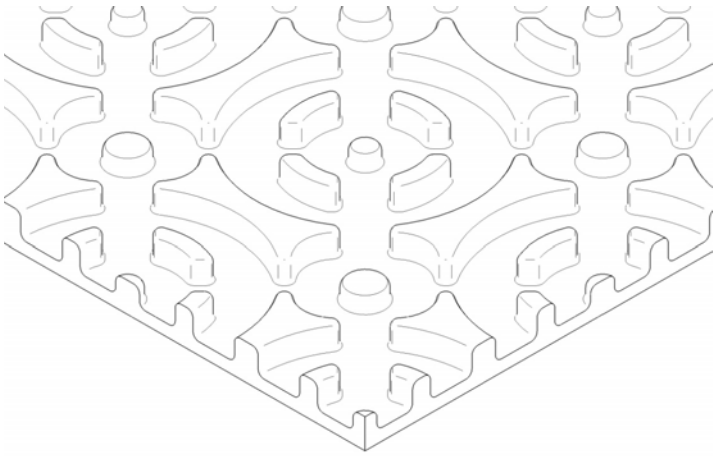

Figure 1. Schematic of the pressure distributor.

In particular, at the beginning in the upper chamber an higher depression is imposed. Thus, the lower bag will move up and, due to the shape of the distributor, some preferential channels for the resin flow will be created. The resin will fill these channels. When all resin should be entered, the vacuum will be applied to the lower bag to promote the transverse infiltration.

Figure 2 shows a picture of the Pulse Infusion assembly.

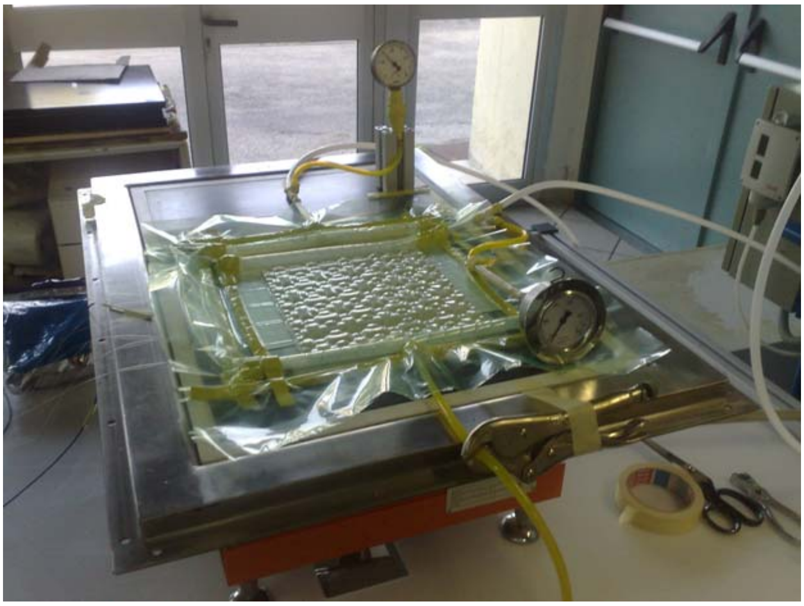

Figure 2. The pulse Infusion assembly.

The process can be performed in static and dynamic way. In the dynamic way, the pressure difference between the upper and lower bag is controlled by a pressure regulator with a certain frequency.

3 Experimental

The process has been developed and implemented experimentally. Infusion tests have been carried out to manufacture simple composite parts that show better quality surface and compaction.

Three point bending tests according to the ASTM D790 standard have been performed on fiber glass/epoxy composites that have been manufactured by conventional Vacuum Infusion process (VIP), Pulse Infusion in static way and Pulse Infusion in dynamic way (Frequency: 1HZ). The composites have been produced by using the two components epoxy resin ISX10 (by Mates Italiana) and eight plies of unidirectional glass fibers (600gr/mq) with orientation [0,90]. In order to compare the flexural behaviour for the different specimens the flexural strength σ, flexural modulus E and the maximum strain ε in correspondence of the load drop was calculated by following formulae:

$$\sigma = \frac{3PL}{2bd^2} \tag{1}$$

$$E = \frac{L^3 m}{4bd^3} \tag{2}$$

$$\varepsilon = D\frac{6d}{L^2} \tag{3}$$

where L is the span, P the maximum load, m the ratio load/displacement, d and b respectively the thickness and width of the specimen and D the maximum deflection at the center of the sample.

Table 1 shows the flexural properties for the different specimens.

Strength (MPa)	**Modulus (GPa)**	**Std Dev**	**Strength (MPa)**	**Std Dev**	**Maximum strain (mm/mm)**	**Std Dev**
VIP	20,380	613	385	14	0.024	0.001
Static Pulse	21,864	500	455	9	0.038	0.001
Dynamic Pulse	22,235	1326	480	16	0,025	0.002

Table 1. Mechanical results.

An improvement up to 13% for the modulus and up to 24.5% for failure strength can be noticed.

Conclusion

In this study, a new infusion technology is introduced for the production of fiber reinforced composites, using a silicone membrane in place of the VIP traditional distribution media and an automation system to promote the transverse resin flow. The composites produced by Pulse infusion were tested in order to have preliminary information on their mechanical performances. An improvement of the flexural modulus and strength has been found for the composites produced by Pulse respect to the traditional VIP ones.

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