PROCESS OPTIMIZATION OF COMPOSITE PRESSURE VESSEL USING LINER-ASSISTED RESIN TRANSFERT MOLDING OF REACTIVE THERMOPLASTIC RESIN

Henri Perrin[1]

[1]Luxembourg Institute of Science and Technology (LIST), Design and Manufacturing of Advanced Composite (DMAC), University/Company, 5 rue Bommel, 4940 Bascharage- Luxembourg
Email: henri.perrin@list.lu

Keywords: Composite pressure vessel, Resin Transfer Molding, Process optimization and control, reactive thermoplastic,

Abstract

Transport industry is preparing a change of a paradigm shift, targeting the replacement of oil and gas energy carriers. One of the promising routes is the adoption of hydrogen fuel cell technology. However, a critical challenge remains the storage of hydrogen, which must be solved before a technically and economically viable hydrogen fuel system can be established. For mainstream automotive applications, targeting production volume of 50,000 to 100,000 CPVs per year, conventional wet winding or thermoplastic towpreg approaches offer limited potential of industrialization. The final void content is significant, typically between 4% to 5 % by volume and this is the main limiting factor in increasing the winding speed necessary to achieve a viable economical model.

To address these challenges, LIST has recently developed an innovative approach based on low-pressure Resin Transfer Moulding (RTM). The technique involves through-thickness impregnation facilitated by resin channels shaped on the surface of the liner. The dry winding prior to injection allows for rapid winding without the constraints of in-line impregnation. Fast curing resin systems are employed to meet the desired production rate. A thermal gradient is applied to control the polymerisation gradient the outside to the inside, assuring the effectiveness of the post-pressure phase. Reactive thermoplastic resin Elium© supplied by Arkema is selected for their ability to be separate from carbon fibre and re-use both the fibre and the resin in the initial application.

To investigate the interrelationship of process parameters, a lab-scale device has been developed, enabling the manufacturing of a thick tube with a full hoop lay-up. This paper will discuss the influence of the fibre tension during winding. In addition to the obvious changes in preform morphology and permeability and subsequent impregnation velocity, the typology and density of induced defects, particularly the fibre buckling, voids and crack resulting from resin shrinkage at different stage will be highlighted as function of the injection flow rate.

The shrinkage behaviour of Elium© is barely studied in the literature, but represent the major difference compared to conventional resin. The total volume reduction of the resin reaches 16

% to 20 % and increases almost constantly both in the liquid and gel states. An experimental methodology is proposed to catch the shrinkage and mechanical strength as a function of the degree of cure.

On this basis, a thermo-chemo-mechanical model is proposed to replicate the driving phenomena and enhance the understanding of the coupling effects between the fibre volume ratio, the resin flow during impregnation, the residual stresses during polymerisation, driven mainly by resin shrinkage.

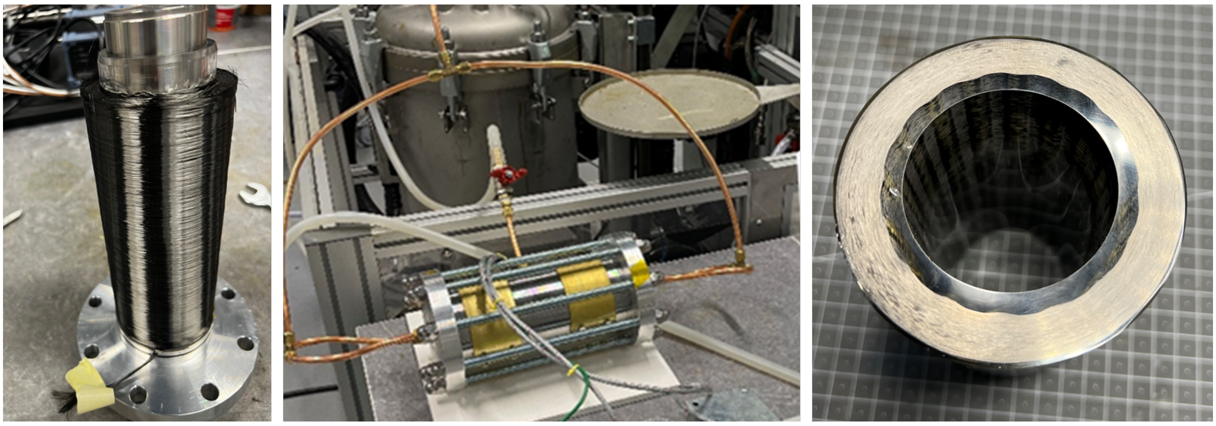

Figure 1: Dry wound preform (left), injection mold (middle), ring view after cuttng and polishing (right)

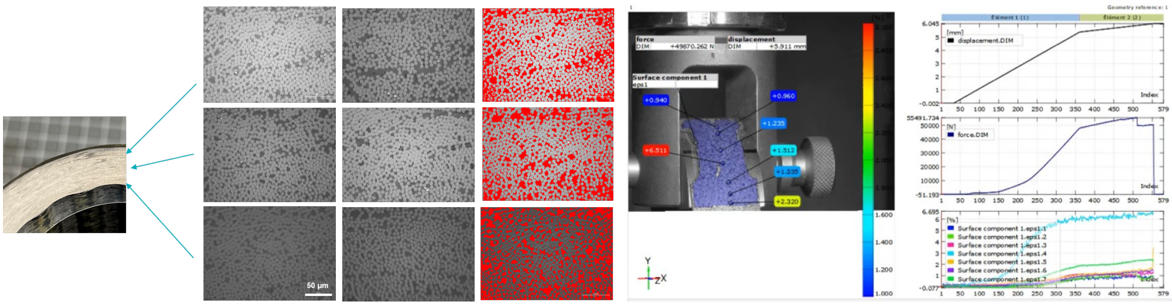

Figure 2: Cross sections trough the thickness of a ring(left), Digital image correlation of a ring sample under tension (right)