Rapid Immobilisation of Advancing Resin Fronts During Vacuum Assisted Injection Moulding of Wind Energy Components

J.R. Hutchinson, P.J. Schubel, N.A. Warrior

Polymer composites group, Division of Materials, Mechanics and Structures, The University Of Nottingham
Email: Peter.Schubel@nottingham.ac.uk, Tel: 0115 9513979

Abstract

Vacuum assisted infusion is the second most popular method worldwide for the production of composite wind turbine components. Good part quality is dependent on achieving predictable and controllable resin flow paths, but variations in tool cavity thickness, non-uniform fibre content and the susceptible leaks in tool seals are almost impossible to completely eradicate.

Figure 1: Vacuum infusion of large wind turbine blade. [1]

Figure 2: Half shell root end of 5MW wind turbine blade produced by vacuum infusion.

Fabric dry spots and resin rich regions can be common with complex part geometries, such as at turbine blade roots. By restricting the resin from these high permeability areas, the vacuum can draw the flow to the low permeability regions allowing complete part wet-out. This work tests a number of potential chemical resin immobilisers, giving full control of the resin flow front during vacuum infusion.

Figure 3: Dynamic DSC degree of cure characterisation of agents for 1% addition to resin

Objectives

- Eliminate part scrapage
- Ensure complete wet-out
- Improve mechanical performance at complex part geometry
- Negate resin rich regions and dry spots
- Reduce resin flash
- Material savings
- Labour savings
- Prevent lock-off before complete impregnation
- Keep material cost minimal

Figure 4: Dynamic DSC heat flow characterisation of agents for 1% addition to resin

Agent characterisation

Differential scanning calorimetry (DSC) was used to compare dynamic degree of cure for each agent when added 1% by weight to a wind energy grade epoxy resin system. Figure 3 shows time to gel (approximately 0.4 degree of cure) reduced by up to 40%.

Figure 5: Setup for VARTM trials of immobilising agents

VARTM Trials

• 3 layers of 1200 gsm unidirectional glass fabric
• Integral random mat to aid dispersion
• Wind energy grade 2 part epoxy resin
• Blue dye added to resin prior to injection
• Immobilising agent paste applied to both sides of each layer in square pattern
• Corner gaps allow vacuum passage and prevent lock-off
• Flat tool with Perspex lid to allow observation of resin flow front

Immobilising agent

Central injection port

Vacuum port

Figure 8: Having reacted with the immobilising agent at the top and bottom of the square and gelled, flow in the transverse (90°) direction now dominates.

Figure 9: Flow continues in the transverse direction until it reaches the sides of the square where it gels. The vacuum now draws the flow to the corners to complete wet-out of the square.

Figure 10: Agent 1 used to infuse EWEC plaque.

Results

Figure 6: Initially resin travels longitudinally (0°) along the UD tows.

Figure 7: When the resin reaches the immobilising agent at the top and bottom of the square, it begins to gel. Local viscosity rises causing flow in the longitudinal direction to slow.

Conclusions

Time to fill the square for each agent was recorded allowing a comparative study of the four potential immobilisers. Agent 1, which was the most effective in the DSC analysis, also performed best in the VARTM trials. Resin flow along the tows was successfully stopped almost instantaneously and the resin forced in the transverse direction. The immobilisers demonstrated the possibility of total flow path control, allowing predictable and reliable complete part wet-out.

Future work

The technology from this research is currently being used to control the resin flow in the manufacture of 5kW turbine blades at the University of Nottingham. A technical cost model is also being constructed to quantify the potential financial savings this product offers. This work is protected by patent US 2004/0140587 A1.

References

1. http://www.powergenworldwide.com/index/display/articledisplay/251365/article.html - last accessed 30.03.2010