Novel processing strategies to enable grading of composites

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Introduction

Competing local performance requirements

- Stress concentration
- Stiffness
- Electrical continuity

Lack of enabling technologies even using liquid composite moulding techniques (LCM)

LCM limitations:
1) High viscosity of functionalised suspensions
2) Cake filtration of functionalising particles
3) Impact on resin cure kinetics

Resulting in lower practical filler loadings and minimal improvements

Continuous fibre reinforced polymer composites

- Solution
  Grading: CMC, MMC, nanocomposites

Chung et al., 2006
Explored concept

Synergy of two approaches:

**Localised resin integration:** Shorter flow lengths, enables higher resin viscosities, filtration less critical

**Heterogenous multi-scale suspensions:** CNT delivered in a particulate form => lower viscosity of suspension for the same wt% of additives
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**Concepts in detail**

- Cryomilled epoxy- 15wt.%CNT powder
- Monoepoxide diluent
- Snap-cure liquid epoxy resin

**Heterogenous suspension**

- 3.0 - 3.8 wt% solution (with diluent)
- Pure snap cure resin
- 0.75 wt% solution (with diluent)

**Injection Rig: Modified 3D printer**

- Injection: Thin layer of liquid resin in the plane of preform.
- Multiple injections: Connects layer through preform thickness
Procedure

Preparing solution:
Particles well dispersed but form homogenised solution

Printing:
Relatively low force required to inject solution

Consolidation procedure:
Tailored to chemo-rheological state of resin

Patch Morphology & Electrical conductivity:
Highly sensitive to process parameters
Consolidation procedure & Morphology

**Flow visualisation setup**
- Load cell
- Heat plate
- Glass
- Camera

**Model based DOC sensor**

**Flow evolution**
- Injected
- Thermally treated
- Consolidation ongoing
- Consolidation completed
- Curing completed

**Constant injection parameters:**
Large difference in patch size, flow mechanisms, entrapped porosity depending on tuning of consolidation procedure

1.5 wt% CNT, moderate DOC
3 wt% CNT, moderate DOC

**Intra-tow**
**Reversed**
**Inter-tow**
Tailoring of properties

Grading of electrical conductivity

- Local = High loadings of CNT (3.75% compared to 0.5% conventional)
- Electrical conductivity = Low frequency inductive heating (Eddy current)

Mechanical performance

- Open hole tension:
  - Strain-to-failure = 17% increase
  - Strength = 24% increase
- Load flow modified = Stiffness and presence of internal interfaces
Conclusions & Future Work

Key conclusions

➢ Local integration: Mechanical performance improved using cryomilled CNTs

➢ Grading: Natural filtration and consolidation parameters

➢ Grading electrical conductivity: Feasible using controlled consolidation parameters

Future work

➢ Structural modelling: Optimised grading for mechanical performance

➢ Process modelling: Consolidation parameters, suppress porosity, improved controlled filtration

➢ Optimised design space
Thank You

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