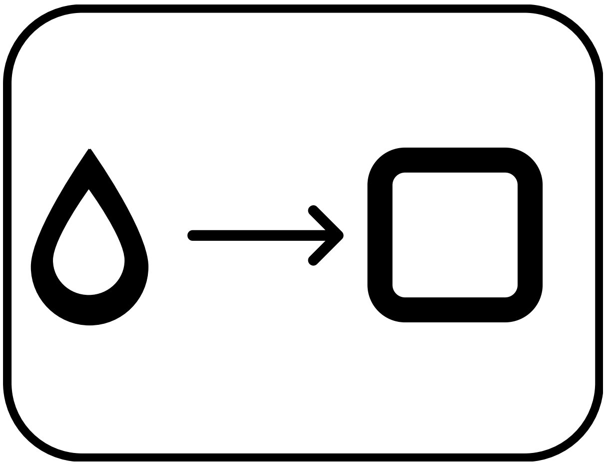
A151

Processing science
Foundational knowledge article



Document Type	Article
Document Identifier	151
Themes	• Thermal management • Material deposition management • Flow and consolidation management • Residual stress and dimensional control management
Tags	• Governing science

Overview[edit | edit source]

A unique aspect for polymer matrix composites (PMC) is that the material itself is concurrently made during the part manufacturing process. During processing, the matrix material (polymer) and reinforcement (fibre) combine together forming the resulting composite material. For the polymer matrix, changes in physical state take place in order for the part to be set into shape. For thermoset polymers, additional chemical state changes are also occurring during this process.

The composites manufacturing itself process can be broken down into the following processing themes – each with various aspects of material evolution taking place:

- State variables for processing
- Thermal behaviour
- Material deposition/flow and consolidation behaviour
- Stress deformation behaviour

State variables for processing[edit | edit source]

Link to main State Variables for Processing page

In the processing of polymer matrix composites (PMC), a fundamental set of state variables define the current state of the material system as the material evolves during the manufacturing process.

For example, for a uni-directional reinforced polymer matrix material, the three most basic state variables are:

- x: degree of cure
- T: temperature
- V_f: fibre volume fraction

From the above list, all other material properties are dependent on x, T and V_f:

- Mechanical properties$_{(x,T,V_f)}$ - e.g. viscosity, modulus
- Physical properties$_{(x,T,V_f)}$ - e.g. thermal expansion, cure shrinkage
- Thermal properties$_{(x,T,V_f)}$ - e.g. thermal conductivity, density, specific heat

The state variable list is complete when one can predict the future response of the material system based on the material's current state independent of prior process history/path. Additional state variables may also be required depending on the material system being described. For fabric reinforcement, additional variables necessary include orientation (θ), porosity (V_v), etc.

Thermal behaviour[edit | edit source]

Link to main Thermal Behaviour page

Thermal behaviour is one of the key KPC themes involved in the composite manufacturing process. The related pages in the foundational knowledge volumes provide KPC users an understanding of the thermal topics that drive the processing science in the manufacturing of composite materials.

The foundational knowledge volume contains pages for the following thermal behaviour topics:

- Basics of heat transfer
- Thermal phase transformation of polymers
- Curing of thermosetting polymers
- Melt and crystallization of thermoplastic polymers
- Chemical degradation of polymers
- Physical aging of polymers

Click here to explore the thermal behaviour topics.

Material deposition/flow and consolidation behaviour[edit | edit source]

Link to main Material Deposition/Flow and Consolidation Behavious page

Material deposition and flow and consolidation behaviour involves the process(es) in which the reinforcement and matrix constituents come together in the composite shape forming process. These steps are generally considered as the different composite manufacturing processes (click here to read more about some common process examples).

The basic topics within this processing theme include:

- Dry fabric forming
- Infusion
- Prepreg forming
- Automated fibre placement (AFP)

Stress-deformation behaviour[edit | edit source]

Link to main Stress-Deformation Behaviour page

Stress-deformation behaviour, and in particular residual stress development, occurs at many length scales in a composite structure. At the microscale, phase-level residual stresses accumulate due to the mismatch between thermal expansion of resin and fiber, as well as the resin cure/crystallization shrinkage. At the mesoscale, ply-level residual stresses accumulate due to mismatch between the layers in the laminate. Finally, at the macroscale, contributors to residual stress include geometric features and constraints, thermal and cure gradients, volume fraction variations due to resin flow, interaction between components in an assembly, tool part interaction, and machining.

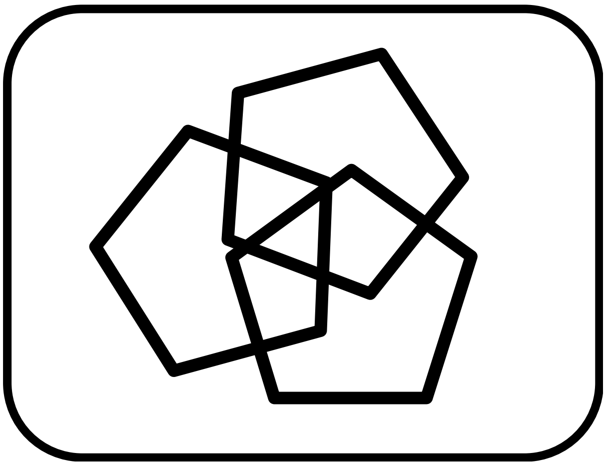
Explore this area further

- Processing science - A151
  - Thermal behaviour - A232
    - Heat transfer - A132
      - Conduction - A118
      - Convection - A106
    - Thermal phase transitions of polymers - A102
    - Cure of thermosetting polymers - A162

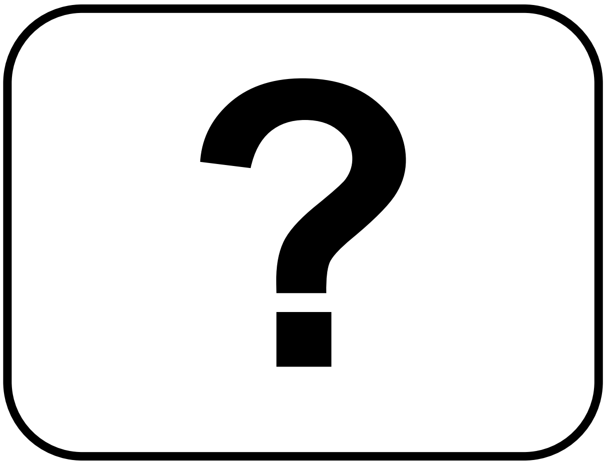
Related pages

Page type	Links
Introduction to Composites Articles	
Foundational Knowledge Articles	• Conduction - A118 • Convection - A106 • Heat transfer - A132 • Materials science - A235 • Processing science - A151 • Thermal behaviour - A232
Foundational Knowledge Method Documents	
Foundational Knowledge Worked Examples	
Systems Knowledge Articles	
Systems Knowledge Method Documents	
Systems Knowledge Worked Examples	
Systems Catalogue Articles	
Systems Catalogue Objects – Material	
Systems Catalogue Objects – Shape	
Systems Catalogue Objects – Tooling and consumables	
Systems Catalogue Objects – Equipment	

- Dr. Anoush Poursartip's cdmHUB global composites expert webinar - A136



About



Help

The continuous material phase that binds the reinforcement together, maintains shape, transfers load, protects the reinforcement from environment and damage, and provides the composite support in compression.

Desirable characteristics:

- Moisture/chemical resistance
- Low density
- Processability

Polymer Matrix Composites (PMC).

Engineered materials (designed to have specific properties) made from two or more constituent materials with different physical or chemical properties. The constituents remain separate and distinct on a macroscopic level within the finished structure.

Thermosets are a class of polymer that undergo polymerization and crosslinking during curing with the aid of a hardening agent and heating or promoter. Initially they behave like a viscous fluid. During curing, they change from viscous fluid to rubbery gel (viscoelastic material) and finally glassy solid.

If heated after curing, initially they become soft and rubbery at high temperatures. If further heated, they do not melt but decompose (burn)

Comes in two parts: part A (resin) and B (hardener). When mixed, curing reaction starts and is not reversible.

Examples include epoxy or polyester.

Key components of all composite manufacturing processes. Collectively, the four themes represent the time-temperature-pressure-vacuum history, which is traditionally used to define a manufacturing cycle.

The four processing themes are:

- Thermal management
- Material deposition management
- Flow and consolidation management
- Residual stress and dimensional control management

(Same as "Theme")

In composites processing, viscosity is an indicator of how easily the resin matrix will mix with the reinforcement and how well it will stay in place during processing. The lower the viscosity, the more easily resin flows. Resin viscosity ranges considerably across chemistries and formulations.

By scientific definition, viscosity is a measure of a material’s resistance to deformation. For liquids, it is in response to imposed shear stresses.

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(Same as "Processing themes")

For polymer matrix composites (PMCs), resin refers to the matrix; the continuous material phase that binds the reinforcement together, maintains shape, and transfers load. Resins are divided into two main groups: thermosets and thermoplastics.

Volume fraction of either matrix or fibres with respect to total composite volume (matrix + fibre).