Curing problems in composite manufacture

Dr Timothy J Swait

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Introduction

Composite Centre

£4.2 M turnover
42 team members
4 research themes
  • Automated production
  • Novel materials and processes
  • Machining
  • Advanced Curing
Content

● Definition
● Commercial drivers
● Technical challenges
● Solutions
Composite Material Systems

Monolithic materials

Composite materials

MATERIAL LEVEL

MATERIAL SYSTEM LEVEL

STRUCTURAL LEVEL
Definition

Curing: The act of turning the sticky gooey mass of fibres into an engineering material AND component.
Definition

• For thermosets:
  • A chemical reaction
  • Typically exponentially accelerated by temperature
• For these purposes we'll also think about thermoplastics (although not actually curing)
  • Melting and re-freezing
• So in both cases we require the controlled introduction of energy
• Pressure also typically applied
Commercial drivers
Composites are conventionally cured in (sometimes very large!) autoclaves. They have certain advantages:

- Both heat and pressure applied by the same device
- Well understood process
- Temperature uniformity is typically good
- *When fully loaded*, cost per part can be reasonable.
Commercial drivers

They also have drawbacks:

- High capital cost
- Maintenance/certification costs
- Large footprint and inflexible
- Inevitably a batch process
- Poor thermal transfer efficiency resulting in:
  - Energy intensive
  - Slow ramp rates
  - Longer than necessary dwells
  - 'Conservative' cure schedules

www.Kawasaki.com

www.flightglobal.com
The cure process

What are we trying to achieve?

Control of resin flow. As a (thermoset) resin is heated viscosity first falls, then rapidly increases. Control of this is required for:

- Uniformity of resin distribution
- Maintenance of fibre alignment
- Removal of voids

Hexcel 8552 datasheet
The cure process

What are we trying to achieve?

Control of heat transfer to achieve complete cure

- Heat flows in to accelerate the reaction
- Heat flows out due to exotherm
- Excessive temperature will degrade the resin
The cure process

What are we trying to achieve?

Toughening agents

- Magic secret ingredients added by the manufacturer
- Often a thermoplastic polymer dissolved in the matrix, precipitates out to create nano-particles
- Proprietary information – here be dragons!
The cure process

What are we trying to achieve?

In the case of thermoplastics

- Heat to melt polymer to optimal viscosity
- Cool to freeze
- Heating rate typically unimportant
- Cooling rate determines crystallinity
- Excessive temperature causes degradation
The cure process

Typical cure cycle

So what should a time/temperature/pressure profile look like in order to control these wildly non-linear processes?!
Alternatives to autoclaves

All methods of transferring energy to the part can be used for curing:

• Convective
  • Autoclaves, ovens, heated fluid such as Quickstep

• Conductive
  • Hot press, heated tooling, direct electric

• Radiative
  • UV, E beam, Microwave
Alternatives to autoclaves

Ovens (Vacuum bag only - VBO)

Certain pre-preg systems claim autoclave level properties without applied pressure. This is achieved by:

- Reduced viscosity (but still toughened) resins
- Enhanced air paths (by pre-preg manufacturer or by bagging consumables).
Alternatives to autoclaves

Heated tooling

Tool surface heated to conduct heat into part

- Tool heated by air, liquid or electrical elements
- Can be combined with VBO systems, resin infusion/injection
- Or....
Alternatives to autoclaves

Hot press

Heated platens or tooling conduct heat into part

- Any amount of pressure can be applied
- Very effective heat transfer and heat sinking
- Geometry limited
- Very well suited to snap curing thermosets or to thermoplastics
- Typical for automotive
Alternatives to autoclaves

Direct electric or induction

Carbon fibres within the part are heated electrically

• Conceptually very simple process – very little equipment required
• Volumetric heating, but uniformity always a challenge – placement of electrodes or induction coils key.
• Requires separate pressure

Alternatives to autoclaves

Ultraviolet, X ray or E-beam

Special resins are used in which the cure reaction is initiated by radiation

- No temperature required – can be a fast process
- UV cheap, but other radiation expensive
- Penetration of UV very limited
- Only niche applications (e.g. wind turbine repair)
Alternatives to autoclaves

Infra-red

Infra red radiation is used to heat the component

- IR heat lamps relatively inexpensive
- High power densities available – rapid heating
- Reasonable heat transfer efficiency
- Uniformity a challenge
- Tends to be supplementary to other methods
Alternatives to autoclaves

Microwave

Microwave radiation is used to heat the component

- Rapid heating rates possible
- Volumetric heating, although uniformity is still a challenge
- Consumables and tooling must be carefully selected
- Microwave autoclaves possible
Alternatives to autoclaves

Microwave

AMRC-CC is working on microwave curing:

• Demonstrating equivalence to autoclave
• Optimising for existing materials
• Optimising material along with the system
Conclusion

So what's the best method?

Every method has benefits and drawbacks

The best method for one component will not always be best for another

THERE IS NO CURE-ALL!
Any questions?
Thank you.
For further information please contact or visit:

Email: t.swait@amrc.co.uk
Tel: 0114 222 1747
web: amrc.co.uk
Twitter: @theAMRC