Composite Structure Engineering Safety Awareness Course

Emerging Technologies and Special Processes

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Agenda

Emerging Technologies and Special Processes

- What are the implications of M&P Control for emerging technologies and special processes
- New material forms and products
  - Custom reinforcement forms (custom 2-D weave, 3-D weave, braid, pin or stitch)
  - Unique sandwich core materials and/or configurations
- Special Processes
  - Liquid resin molding (RTM, VARTM, RFI)
  - Metal Bonding

References

- DOT/FAA/AR-02/110, Guidelines for the Development of Process Specifications, Instructions, and Controls for the Fabrication of Fiber-Reinforced Polymer Composites
- DOT/FAA/AR-06/25, Preliminary Guidelines and Recommendations for the Development of Material and Process Specifications for Carbon Fiber-Reinforced Liquid Resin Molded Materials
- DOT/FAA/AR-03/19, Material Qualification and Equivalency for Polymer Matrix Composite Material Systems: Updated Procedure
- CMH-17 Composite Materials Handbook, Rev G
- L. Gintert, J. Bayldon “Guidelines for the Development of Process Specifications, Instructions, and Controls for the Fabrication of Fiber-Reinforced Polymer Composites by Liquid Molding”, briefing materials from September 2003

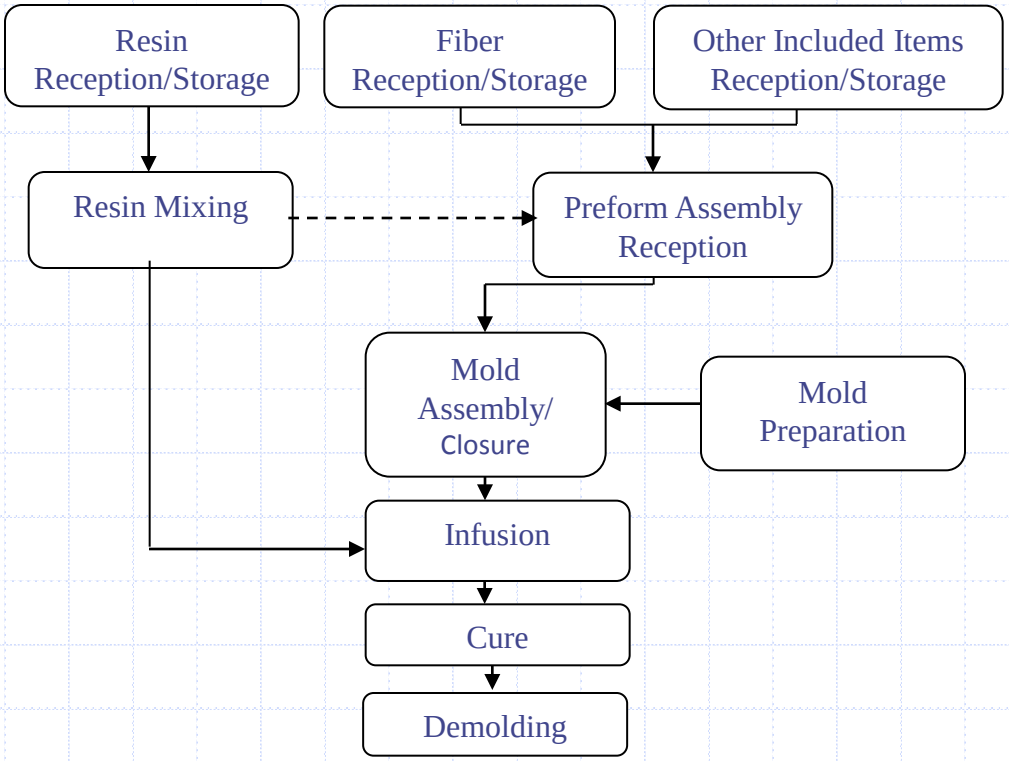
M&P Discussion Focus

- Liquid Resin Molding
  - Resin Transfer Molding (RTM)
  - Vacuum Assisted RTM (VARTM)
- Unique Material Forms
  - Specialty 2-D/3-D woven and braided preform materials
- Metal Bond

M&P Control Topics

- Documentation
- Personnel training
- Facilities and equipment
- Tooling
- As-received materials
  - Virgin material properties
  - Shelf life, storage
- Materials processing
  - Shop environment (temperature, humidity, cleanliness)
  - Processing parameters (cutting, shaping, temperature, pressure, time)

LRM Process Flow



Documentation and Training

- Personnel training is critical
  - Experience, mentorship, qualification, accountability
- Documentation is key
  - Variability control
  - Verification of critical steps and process parameters
  - Traceability of materials and heat history

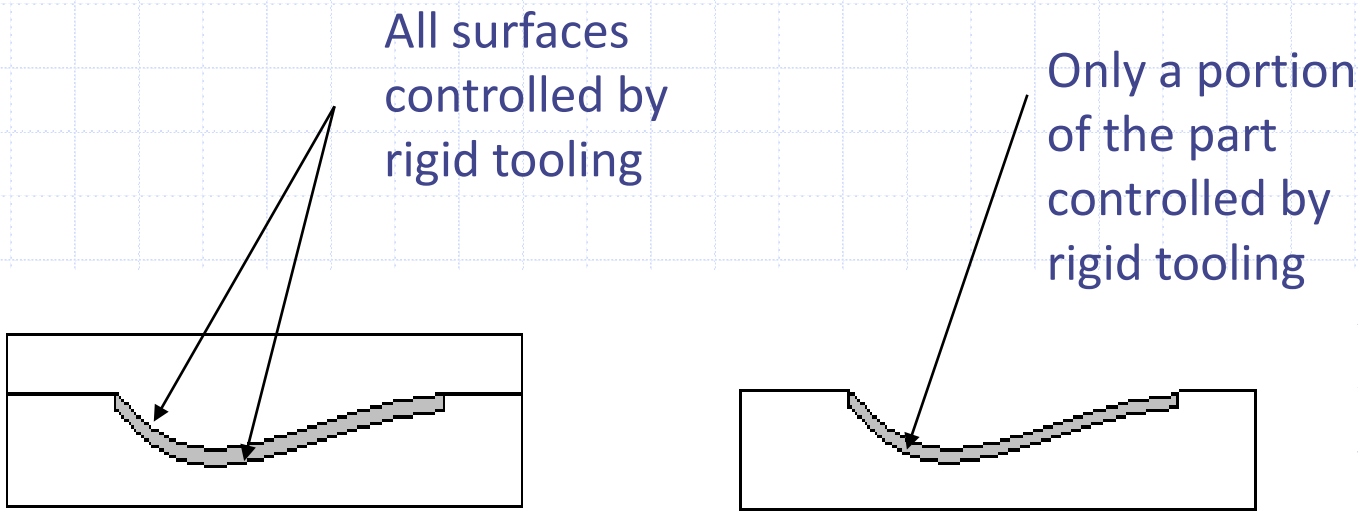
Facilities and Equipment

- Type/Model of Equipment may affect processing – understand parameters
- Equipment Calibration
  - Ovens
  - Liquid resin delivery devices (such as pumps)
  - Thermocouples
  - Vacuum gages, heat sources (e.g., hot-air guns)

Tooling

- Part surface definition
- Engineering Performance:
  - Assembly procedure, infusion parameters/pressures, cure temperature and packing pressure, surface finish, geometry tolerances
  - Injection and vacuum ports
  - Thermocouples at coldest and hottest locations
- Preform location/orientation features
- Tooling preparation/cleaning controls
  - Tooling repair
- Aids and templates

Open Mold vs. Closed Mold



Closed-cavity Mold (RTM)

Open-cavity Mold (VARTM)

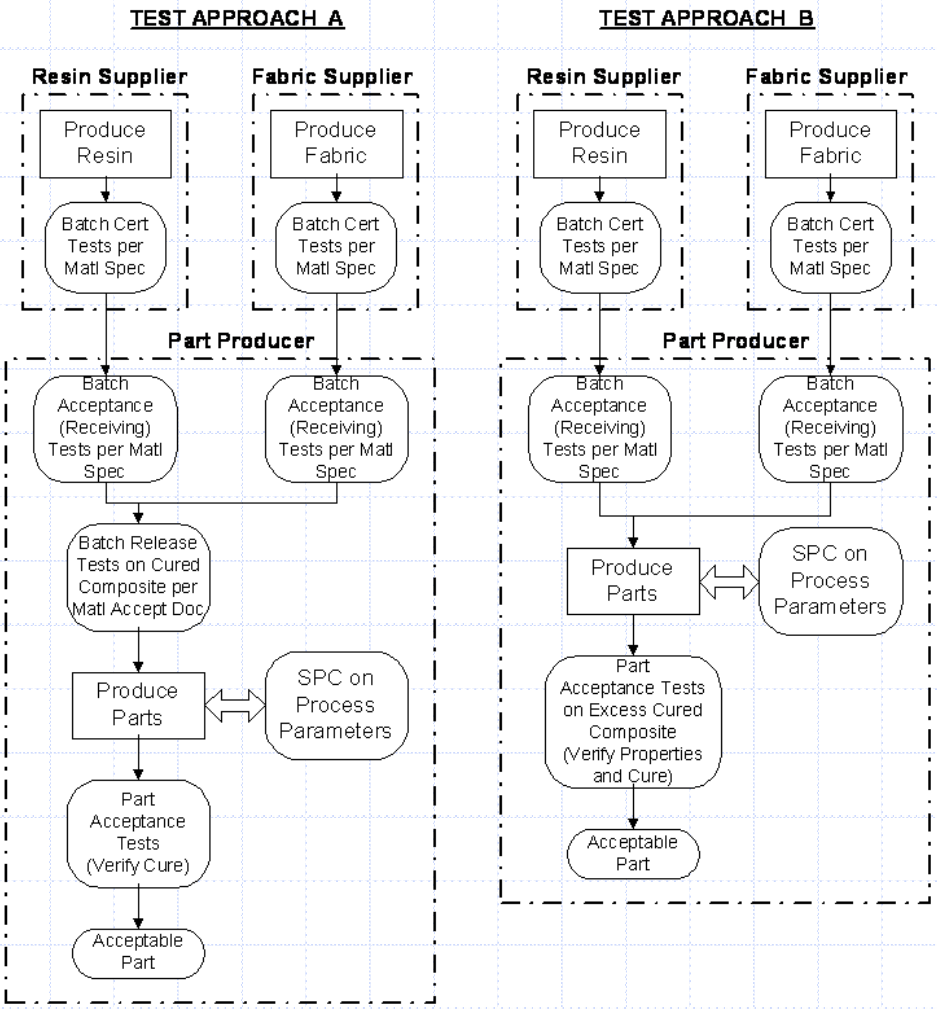
Tooling Control Considerations

- Method of cleaning, solvents, cleaning cloths
- Mold release agents
- Tool heat survey results (location of coldest and hottest thermocouples)
- Scribe marking
- Template inspection intervals
- Template surface conditions
- Template material
- Templates, number of
- Tool heat-up rate
- Tool surface conditions
- Tool, method of moving, transportation
- Tooling condition (mold release applied, and no mold release)
- Tooling configuration (flat, vertical)
- Tooling status identified (approved, unapproved)
- Tooling storage conditions and locations
- Tooling, expansion and contraction rate
- Tooling material
- Location and number of vacuum ports
- Orientation rosette
- Tool repair procedures
- Tool inspection intervals
- Tool (molding cavity) vacuum leak rate (must be measured at temperature)

Materials Control

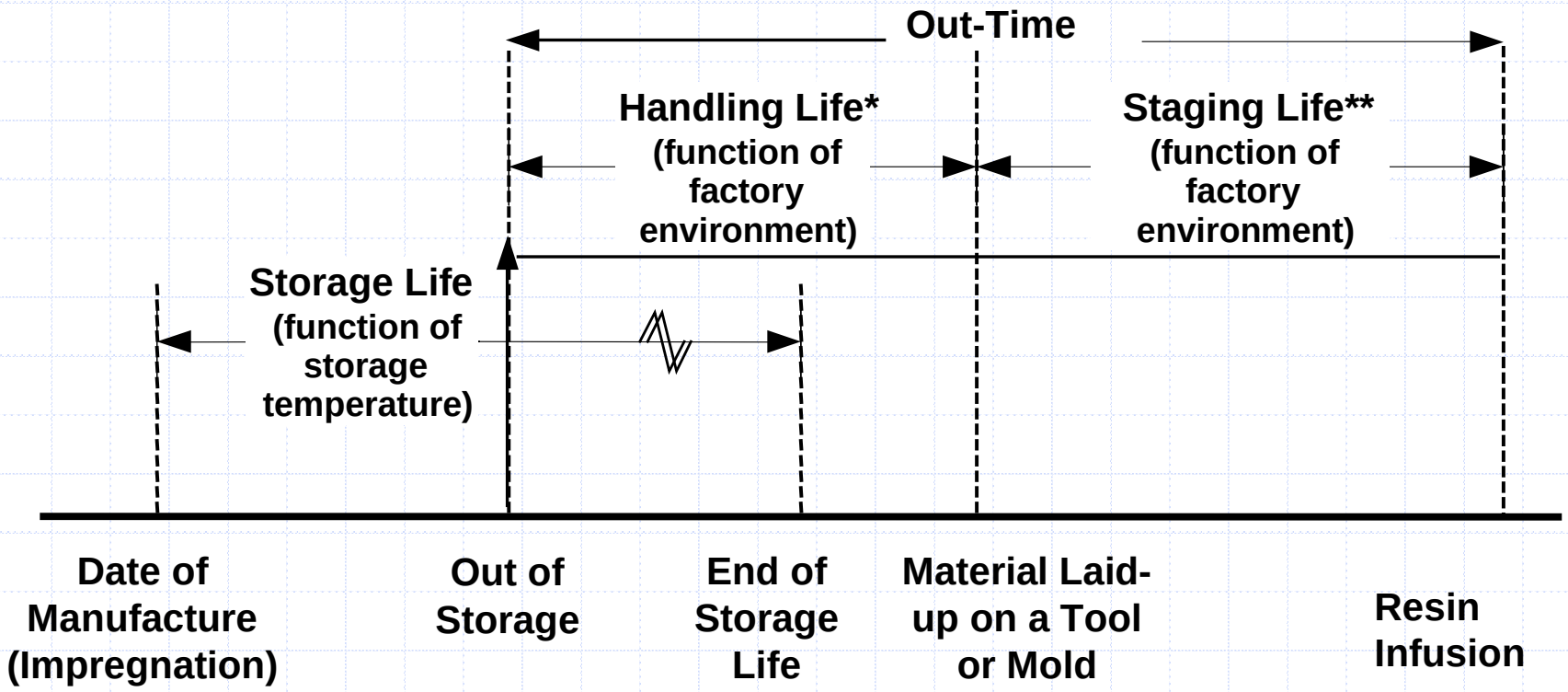
- Traceability
  - From raw fiber, or basic raw materials
- Storage Requirements
  - Humidity
  - Temperature
- Records

LRM Materials Batch Testing



* Batch testing of combined fiber and resin are completed at the Part Producer for LRM (differs from prepreg materials where it is done at the material supplier)

Material Storage and Out-Time Life Relationship



*a.k.a. application, assembly, or work life

**a.k.a. mechanical or tool life

Preform Parameters

- Fiber pedigree
- Ply dimensions, alignment and stacking sequence
- Shaped preform contours
- De-bulked preform fiber volume
- Fiber sizing level and type
- Quantity of tackifiers and/or binders used, and heat history during processing
- Compatibility of constituent materials with each other

Preform Fabrication

- Frozen reactive materials warmed to room temperature prior to opening
- Materials should be cut on surfaces specifically dedicated to cutting
- Individual materials should be identified and marked at the time of cutting
- Preform tooling
  - Inspection step with a translucent shaped caul
- Accurately align the materials with respect to the tool zero-degree reference direction

Preform Assembly

- Mold assembly repeatability
  - Positive location features and methods that ensure that the preform is not distorted or damaged
  - Inspection features with acceptable limits for measured gaps (RTM)
  - Thickness gages and templates (VARTM)
- Thermocouples
  - Direct measurement of processing temperature
  - Thermocouples placed against the preform to ensure the material is heated to the specified temperatures
  - At least two thermocouples per part recommended

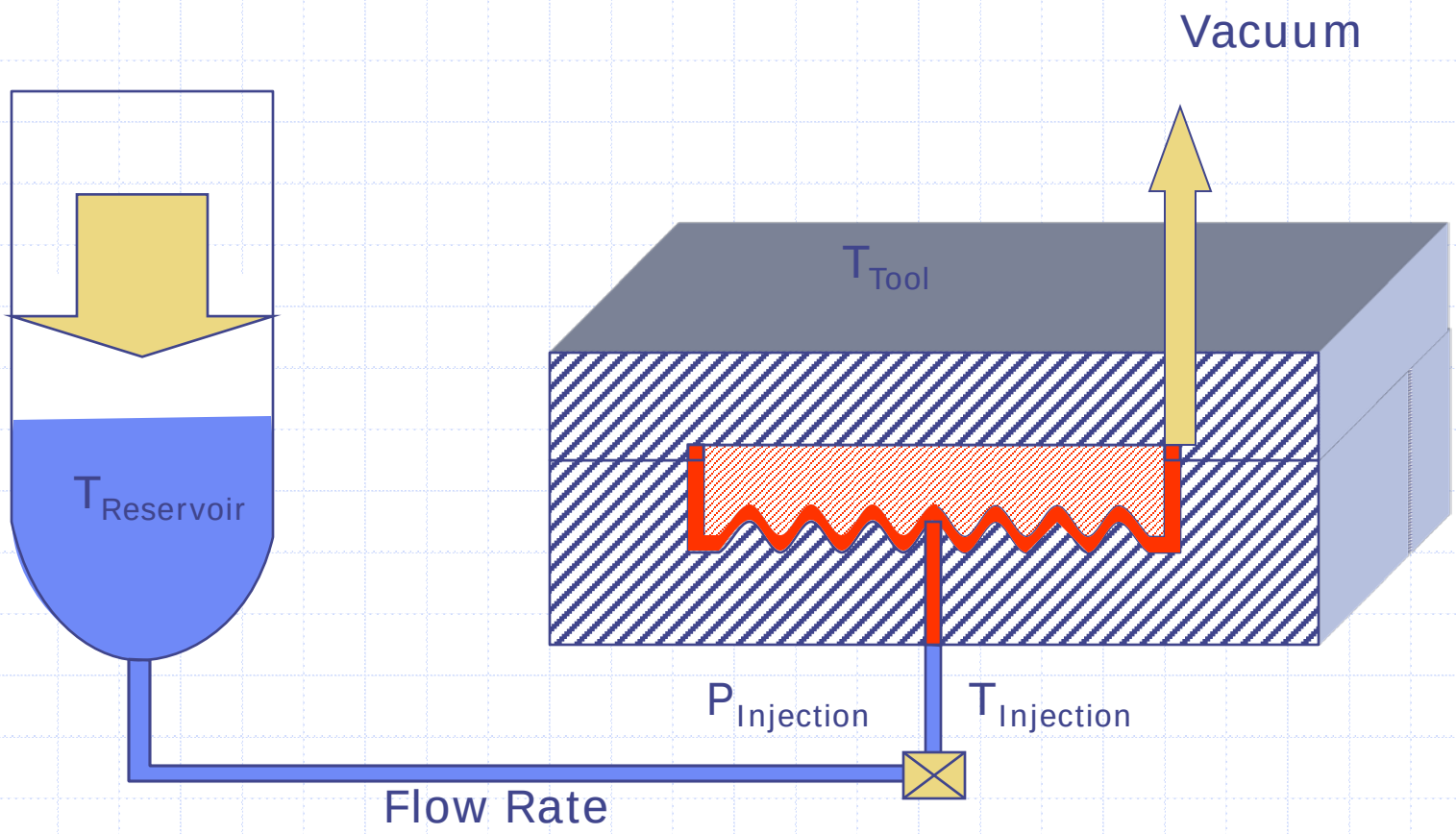
Preform Room Considerations

- Limit access by other equipment (gas powered fork lifts)
- Limit access by non-lay-up personnel
- Air flow through the room
- Equipment for monitoring environmental control
- No Contamination by other processes (chemical processing, painting, and sanding)
- Treatments and cleanliness of floors
- Humidity (minimum and maximum)
- Temperature (minimum and maximum)
- Isolation from other contaminates
- Lay-up area status (approved, unapproved)
- Lighting (lumens)
- Particulate count
- Pressure (positive)
- Proximity to molding area
- Hose status (approved, unapproved)
- Treatment and cleanliness of walls
- Use of rubber gloves by personnel handling fabric or resin is recommended for the safety of the employee and to prevent possible contamination of the materials

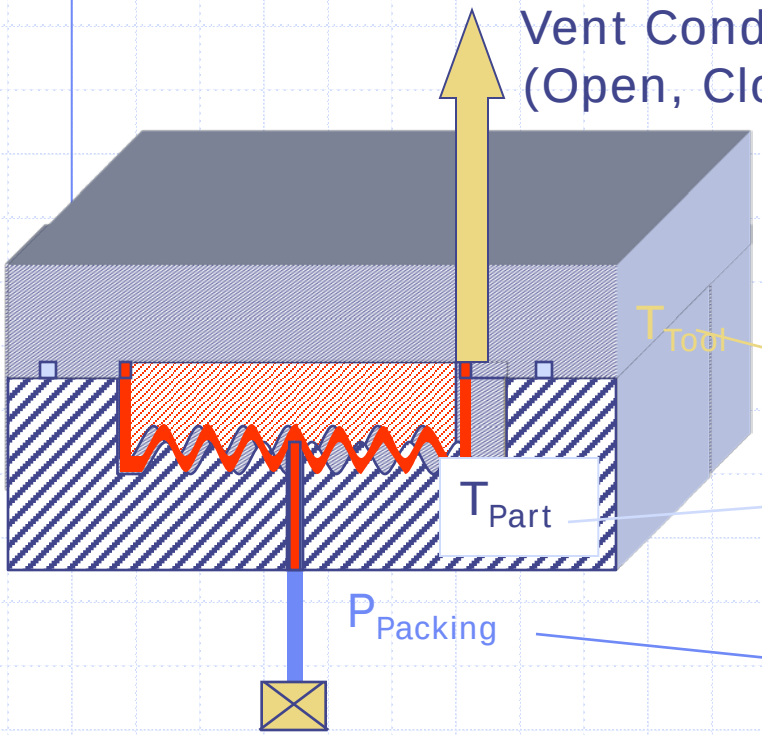
Liquid Resin Attributes

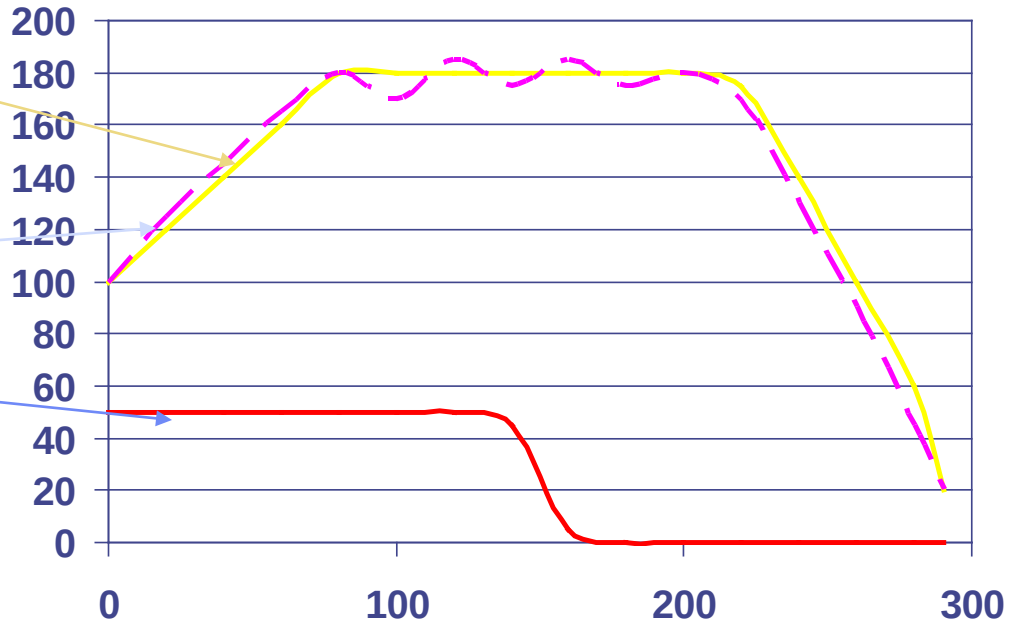
- Initial mix viscosity (at a defined temperature)
- Initial mix heat of reaction (ΔH_{ult})
- Mix chemistry (e.g. ratio of epoxide:amine groups in some epoxy chemistries)
- Amount of entrained air or solvent
- Thermal conductivity

Resin Infusion



Resin Cure


Vent Condition
(Open, Closed, Vacuum, Pressurized)
T Tool
T Part
P Packing


200
180
160
140
120
100
80
60
40
20
0
0
100
200
300

2-D/3-D Weaving/Braiding

- Fiber pedigree for multiple fiber types
- Weave tow count/orientation/configuration
- Shaped weave (airfoil/polar)
- Processing parameters (tension/feed)
- Take-up process
- Start/end of run and trim considerations
- Stitching and pinning considerations

Metal Bond Materials Control

- Metal-to-metal and metal-to-composite
- Material control of substrate faying surfaces
  - Cleaning/corrosion (oxidation) control
  - Coatings control (thickness and cure)
- Adhesive material controls
  - Chemistry, mix ratio, mix quality, time/temperature

Metal Bond Process Control

- Metal surface contamination
- Adhesive mixing (certified operation)
- Film adhesive processing
  - Chemistry/time/temperature history
  - Ply count, geometry, location (backing film removed?)

Other Metal Bond Considerations

- Global thermal processing compatibility (CTE mismatch)
- Fluid/moisture ingress/corrosion control
- Repair and maintenance

Questions?