FAA Meeting
Review of Liquid Molding Specifications

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Major Factors

- Liquid Molding combines manufacturing steps from traditional pregreg hand-lay-up resin
- The prepreging and part forming-cure process have been combined into one step
- While many of the issues and concerns stay the same, they have to be approached differently. (batch acceptance, per ply thickness, fabricator process variation)
- These specs still look and feel like pregreg specifications and will have trouble adapting to many variations in materials, and manufacturing methods

Major Factors cont

- For RTM, Vf is controlled by gap in tool and will vary also by local fiber forming variation(corners, line length changes, ect.)
- As RTM parts get thin (below .80”), tooling tolerances variation can change Vf significantly
- In VARTM, factors such as vacuum level, debulking, fiber forming and other will determine the Vf (perform debulking will also effect Vf)
- The specification needs to call out the Vf range that the allowables are valid for
- Other Vfs will require their own allowables or generation of knockdown factors to current ones

Major Factors

- Because Liquid Molding in general is capable of producing more complex parts than hand-lay-up of prepreg; special considerations are required
- Liquid Molding Design Guidelines are also required to make sure parts are designed where flat panel properties will translate to complex parts repeatedly
- Liquid Molding Stress Analysis Guidelines are also valuable to determine part complexity factors in translating those flat panel properties to complex parts
- Perhaps sections should be added to cover this

Concept for Control

- Specification that controls the resin and fiber, and defines the process leads to generation of B-basis allowables. This must control both raw materials and method of documenting the exact processing details used to generate those allowables.
- Second, the individual fabricators generate a specification that defines their individual proprietary process, the testing, and controls that will demonstrate that their process produces equivalent material properties to above spec
- Third, the fabricator must have a PCD that indicates how they will control their process and ensure that the allowables are protected

Material Issues

- This specification has it right: material spec controls the raw materials that go into an RTM part (fiber,weave, resin, tackifier)
- Where I differ is I can not support the attempt to have the fabricator test every combination of fiber and resin. (Experience on F-22 says this is very difficult issue)
- Complexity of parts, variations in local fiber aerial weight and fiber angle changes makes use of generic flat panels property translation to these complex shapes questionable (process control and part testing far more valuable)

Material Issues Cont

- Fabricator Testing of each combination of fabric lot and resin batch has several problems
- Too many combinations, lots and resin batch sizes do not match, preforms maybe made months apart from part fabrication make testing almost impossible (testing hot wet takes too long)
- If you get a failure, then what??
  - Resin to spec
  - Fiber to spec
  - Process was to PCD and spec
- How do you assign cause and reject the materials, which ones (F-22 has never rejected just retested or lowered limits) that's reality they still spend money to test only every tackified fabric batch

Material Issues Cont

- Viscosity control of resin is critical
- Viscosity test, isothermal hold with requirement with time in minutes under a certain viscosity limit like 500 cps should be used
- Viscosity, in two part systems may be controlled by ratio of parts and may change based on size of part or infusion temperature and humidity
- Viscosity most critical for VARTM parts

Material Issues Cont

- Tag end testing of parts only good for Tg cure type check.
- I suggest First Part Qualification mechanical testing of entire part or section of part based on a Part Family concept and the classification level of the part.
- Allows direct testing of critical areas, can be redone on some interval, if required.
- Raw materials control and Process documentation control are the way to maintain properties

Process Specification

- I am not sure a process spec is needed, the requirements from the process spec need to be in the Cured Material Acceptance Specification
- Each fabricator will need to have a process specification or (FPS) like a PCD
- This will call out the details of how the fabricator will meet the allowables and control their process
- Individual part (or part family) specification may be a better approach

Part Classification

- Not all parts need to be controlled as well, or have as much data behind the design
- Define the criticality of the parts and the testing and control requirements for each
  - Normal Controls (secondary structure)
  - Durability Critical
  - Fracture Critical
- Limited data and controls will reduce the cost of fabrication of secondary structure and allow a near term application of this technology to commercial aircraft so that history and confidence can begin to be gained

Process

- Pressure will vary from fabricator to fabricator and are dependant on tooling, clamping system, and injector system
- There is no minimum pressure that will produce good parts, pressure
  - VARTM : 10 psi
  - RTM : 35-250 psi typical
- Fabricator must show that their combination of equipment and process that they have developed meets the requirements set by the material specification
- There is more than one way to do this.

Tooling

- Tooling is the most important feature in RTM, and a good leak free bag is the most critical feature in VARTM
- Tools and bagging leaks will introduce porosity
- Any tooling wear, repair, or change must be controlled and monitored for effects on part quality
- Tool deformation from change in clamping can effect part thickness
- Heat up rates will vary from part to part and mold temperature uniformity can be an issue
- Tool temperature surveys are critical
  - Infusion or cure dwells must not begin until lagging thermocouple placed in tools coldest area reach desired limit

Preform Defects & Rework

- Should have tables to cover preforming defects and requirements
- Should include allowances for rework back to meeting requirements
- Preform teardowns, ply by ply after final debulk can be used to check for fiber bunching, fiber alignment, cutting and darting locations and ply drop-off locations
- Will help determine Vf variations in critical areas and match fiber angles to drawing and stress analysis

After Cure Processing

- Define acceptable limits, processing limits, and processing procedures
- Cover things like surface scratches, FOD, surface porosity, machined edges, resin rich areas, and resin wrinkles, ect.
- Should give limits to what can be reconditioned back to drawing with out rejecting the part and repairing with engineering disposition

Part Families

- Parts have critical design features that must be examined, tested, and controlled
- Parts can be grouped by size, radii, general shape, materials, and other features
- By examining and testing parts or sections of parts for each part family this can reduce cost yet provide confidence of design
- Test Tg, preform teardown for fiber angle, microphotographs, mechanical coupons from flat areas, sub article tests, or whole part testing (F-22 had 11 part families that contained 350 parts)

Inspection

- All steps from receiving of materials to forming of preforms to demolding must be inspected or verified to work instructions
- Engineers should approve all work instruction changes
- Certified inspectors can be used at a cost, or shop workers can be well trained and provide self inspection stamps on paperwork
- Training is very critical and a certification course should be recommended and called out in FPS
- Post Process Non Destructive Inspection can be used, but can be reduced by gathering hard data linking control of processing parameters to part quality. Data base required.

Conclusion

- RTM has been successful from a manufacturing and performance standpoint
- Jury still out on whether manufacturing cost is 1/3 less than hand-lay-up as we first thought
- Specification, testing and documentation and been the primary reason cost savings have been difficult to achieve
- Lets not handicap VARTM and future RTM with excessive testing and requirements with questionable value. Just because that’s the way it was done with Prepreg does not necessarily mean we should do it with Liquid Molding