Panel Discussion Notes for CAIIAC Workshop Breakout Sessions

Scalability, Manufacturing and Composite Repair

Morning Session

1. ***What is your/your company's interest level for nano-materials and multi-scale materials (integration of nano-micro-macro scales materials)?***

    - How much interest there is in nano in the next three to five years' time range?

    - Out-of-autoclave would be a mechanism to embrace nanotechnology
    - Nanotube on fibers to improve through thickness delamination
    - Interests in: Multifunctional structures for high end applications
    - Academic research for quick and even heating to reach cure temperature
    - Self-healing composites: need more research, what do we need?
    - Durability, life cycle cost, anything that improve durability: **DOD interest**

2. ***What is the role of 3d printing for scalable composite manufacturing?***

    - 3D printing issues: size limitations,
    - Fiber reinforced 3D printing: to add more functionality
    - 3D printing for composite dies for making tools. Advantages: complex contour issues can be resolved through the use of these tools
    - Fiber glass and fiber board tools to be replaced with 3D printing
    - 3D printing with reasonable speed is needed
    - Oberste told about his research: developing a 3D printer to print composite with through thickness functionality

3. ***What are the major technical challenges, barriers, and urgent needs for R&D for composite repair?***

4. ***What is the current practice in industry for composite repair (materials, equipment, NDE/inspection, certification/regulation, etc.)?***

    - Major challenge: Repeatability of the repair, complex contour repair, kissing bonds (may be use of nanoparticle will help to resolve this problem)
    - Is NDT is adequate for porosity? Yes but quantification of porosity is not possible

- Lack of equipment in military environmental control for repair
- Various factors such as patch waviness, stress raiser point affecting the strength variations between bond strength and patch strength.
- Online monitoring of 3d shapes is required
- In field repair? Not a problem for military currently but for integrated structure in field repairing will be an issue as they are heavy weight complex structure
- Repairs in production facilities can potentially damage the primary structure
- BMW i3 composite structure repairing?
- Big issue in automotive industry repair: they don't have standardized model for developing repairs
- BMW i8 is a low volume structure. What are the high volume automotive repair issues?
- Small wind turbines repairing blades cost approaches a new blade. Therefore few blades are repaired they rather replaced.
- Boeing claims to have quick patch repairing method; however, heating rates over the patch is an issue

5. ***Are there mature/standardized modeling/design tools, databases and testing protocols for composite repair?***

- Any standard patch size for composite repair? No as the shapes are not uniform, complex.

Afternoon Session

1. ***What are the major issues and barriers for out-of-autoclave composite manufacturing? Are OOA processes mature enough to eliminate autoclaves?***

    - Prepreg that goes into OOA that needs different impregnation level
    - Lack of industry wide standard for materials, lack of standard
    - Mix results during OOA processing, selection of materials, mechanism is unknown
    - Help support with material for OOA processes: that's what Chomarat is doing
    - Need to engineer the off-the-shelf prepregs to meet the final requirements
    - To go OOA have to have a very good understanding of the materials and processes. Can OOA meet the expectations is a big question,
    - Cost issue: OOA vs autoclave processes. Cost analysis is another difficulty
    - Need an education process to convince that OOA is as good as Autoclave
    - Identification, management and measurement are the key management and materials variables that are missing
    - Volatile materials are driven back into the composites in the autoclave which is not the case for OOA processes.
    - Why only just Prepreg? Why not liquid resin processes.
    - Lack of consistency of materials from vendor to vendor: need unique process for each material

2. ***What is the state-of-the-art of automated tape placement (ATP)/automated tape laying (ATL) technology? Any notable new development in this area?***

    - ATP/ATL to make parts for A350 up to 17 m long: a specialized ATK process
    - 20' wide 75' long parts : ATK process, gantry type process
    - Fiber placement issues need to be overcomed: consolidation issue, material development is behind the equipment, change the equipment instead of changing the materials, very few suppliers for slit materials, slitting is as expensive as the actual prepreg tape itself. ATP is expensive equipment but materials science part has to catch up.
    - Dry fiber placement
    - ATP to make small sample e.g. a foot: cutting and turn around issues are there, customized patches for repair application
    - Property difference: ATP vs hand placement? Depends on fiber volume, gaps – less fiber volume
    - Resin and fiber placement together in a die is suggested as an approach to be considered

3. ***What are the needs and major barriers for fiber performing and its automation?***

- 3D properties resulting from preforms are necessary for complex shapes
- Is handling an issue while preforming? Not really
- We can design and build far more complex preforms than we can analyze. Therefore an analysis gap exists. Stress analysis is very difficult
- Lack of training in advanced composites
- Slow to inspect a single complex preform, people aren't used to using these preforms
- Corner inspection of preform structures is difficult
- Data/knowledge share, more collaboration is required to fully understand 3d preforms
- Debulk and compaction factors are another things that need to be understood with 3d preforms, Otherwise meeting stress allowable is difficult
- Cradle to final assembly: need an integrated process to avoid issues along the way. There are variations at every step of the process
- Manufacturing, inspection, tolerance issues need to be overcomed

4. ***Is there need for developing demonstration facilities for composites scalable manufacturing and repair R&D?***

- Yes we do

➢ **What are the drives? What kind of facilities do we need?**

- Existing test beds are not well served: large companies have their own facilities and small companies can't afford the cost of paying for the test beds.
- Ability to protect trade secret in a test bed environment: trust factor in the people operating the test bed will protect your trade secret: overcoming that is an issue
- Agreement as to what is precompetitive as opposed to post competitive
- Small businesses need very affordable access to the test beds
- Implementation grant for small companies to have access to the test beds when they are made. Test bed must be able to draw in potential users to come and propose solution for existing problems

5. ***What are the roles for government, industry and academia to develop better composites manufacturing and repair technologies?***

- There needs to be geographical colocation of the test beds for the users so that they are easily accessible to most of the users more specifically to the small companies.

Panel Discussion Notes for CAIIAC Workshop Breakout Sessions

ICME and Standardized Design

Morning Session

1. What is the state-of-the-art of ICME, specific to Aero, Auto and other industries?

- ICME is currently not used on a day-to-day basis for composites for either industry (it is still in the research phase). The process is not integrated yet, and is used in an ad-hoc fashion and/or as a last resort.
- A potential exception is for small fiber composites, where ICME is further advanced, e.g. simulation packages for injection molding of short fiber-filled thermoplastics
- Does a roadmap already exist?
- There are often IP concerns for ICME tools for composites (greater concern compared to high strength metals)
- Use of simulation tools is common for metals
- Simulation industry has done a poor job setting expectations
    - ICME should be used to see trends and identify issues
- When is ICME integrated with know-how subjected to export control laws?

2. What are the major barriers for developing and deploying effective ICME tools?

- Lack of confidence—lots of fine tuning
    - Need to verify material properties for different materials and for different environments
- Lack of knowledge, particularly related to damage propagation
- Export control for composites (usually relating to processing information)
- Licensing—large expense for small companies
- Transfer of information through the supply chain
- Standardization for data transfer, protocols, vocabulary, etc.
- Oil and Gas industry issues are rarely addressed
    - Need to consider environmental effects on performance
    - e.g. glass fibers don't work well in high temperature/wet environments
    - Part thickness for tubular parts—most work is focused on thinner parts in aero or auto industry (exception is for helicopter rotors which have thick sections)
- Lack of cross industry collaboration (auto/aerospace/oil and gas etc.)
- IP is the largest issue

    - Processing is the "secret sauce" for companies

3. ***How can ICME reduce time and cost of composite certification/qualification? Any specific successful case of application of ICME?***

- Computation methods reduce cost to obtain necessary data
    - E.g., crash testing in the auto industry (every vehicle is not tested to certify a model)
    - Aircraft seat was virtually qualified for crash tests with computation testing (FAA approved / NIAR)
- However, ICME is more applicable in development cycle
    - Time to market is reduced, even if regular certification/quality testing is done
    - Example is GE's use of ICME to cut in half the development time of nickel-based alloys
- Test areas of higher concern - not every point must be tested
- Identify parts that are difficult to produce
- Work is ongoing via NASA Advanced Composites Program, which has a good roadmap (includes certification cycle, damage analysis, etc.)
- Identify programs that can be modeled pre-competitively

4. ***How will you define "Standardized Composite Design?"***

- Two attributes would be that there is confidence in modeling, and the practices must be enforced.
- Challenge—metal standards for designs are often carried over to composites, but the standards don't apply.
- Standards for composites are unique and held proprietarily to each organization as well as application. Therefore, composite design standards should not be universal.
- Long-term durability, reparability and sustainability must be taken into account (the "ilities")
- Difficult to purchase some materials in small quantities to test:
    - Materials database is useful
    - Work should continue in this area
- Standard cannot be universal; it must consider materials, structure, or application.
- BMW example:
    - Parts were designed from scratch to take full advantage of composite advantages.
    - Standards weren't carried over from previous models.

5. ***What are the major differences between standardized composite designs for aero and auto industries?***

- Aerospace:
    - Fail-safe redundant systems
    - Some structures are more critical
    - Higher safety factors
    - Product performance is very important
    - Catastrophic failure can result in loss of life
    - Drivers are divergent between commercial aircraft industry and military industry
    - Low volume drives design
- Automotive:
    - Noise vibration harshness is considered
    - Crash requirements
    - Customer experience is very important
    - High volume products
    - Design for pennies on the pound
    - Data sharing among material suppliers can be more prevalent to save on cost

Afternoon Session

1. Are there major databases for standardized composite design?

- Mostly for aerospace industry
    - Smaller scale aerospace design
- Focused on material properties
- Wichita University
- Many aerospace companies have their own databases because the data is proprietary and they don't trust where the data comes from
    - Companies do their own testing and do not accept test results from suppliers
- It depends on how much data is shared
- Databases aren't complete enough for the design process

2. What are the barriers/challenges for developing composite design databases?

- Composites are variable across the properties, processes
- IP issues and lack of funding for testing
- Funding can cost millions
- It takes large numbers of combinations to make various materials
- It's not cost effective to design and qualify 30 materials
- Can't guarantee the material properties because humans make the parts and it's a variable process
- Versatility is the good and the bad about the material

3. ***What are the major differences between design of composite structures and metal structures?***

- Not confident or reliable for damage
- Risk of catastrophic failure has huge implications in the aerospace industry
- Fixed costs for composites are high (FEA, testing, material data, etc.)
- Metal performance is predictable
- Tough to design composites on a mass scale
- Historical database for composites keeps us from moving forward because when improvements and changes are made, we no longer have confidence in the properties
- Composite design is continuously changing and improving
- Limited number of experts in composite structures
- Repair ability needs to be accounted for in the design
  - Structures and materials groups need to collaborate at the beginning of the design process

4. ***Are there any mature ICME and standardized design tools for composite joining (composite to composite and composite to metal)?***

- It's a simple answer--No
- It's an art
- Surface preparation is key and needs to be done properly
- It's no different than joining unlike metals like steel and aluminum…same challenges exist
- Modeling joints in the auto industry is important to understand crash analysis
  - Doesn't exist for composites
  - Clean rooms aren't available in the auto industry and/or repair environment
- Room for improvement in adhesive joined parts
- Non-destructive evaluation is a necessary tool for adhesive bonding

5. ***What are the roles for government, industry and academia to develop effective ICME and standardized design tools?***

- Need more of a collaborative environment
- Industry looks to government and academia for new ideas
- Government is pushing automotive industry
  - Consume massive amounts of fuel
- Academia needs to focus on problems that industry views as important not what they want to work on
- Industry focuses on economic issues and must be profitable
- National Laboratories focus on issues in between academia and industry
- Government can help with funding and limited information can be shared from industry (IP issues)

- Academia is producing the workforce. Government needs to fund the composites research area to help develop the workforce
- Government can help with funding small business through SBIR/STTR

6. Challenges in integrating multi-scale models

- Data transfer and data modeling
- Need to understand how the data was collected and how it will be used