Bringing Industry 4.0 into Aerospace Composite Production

The aerospace composites industry has been successful in getting composites to be a mainstream material. Since its beginnings with the Air Force Project Forecast report in the early 1960's due to their great potential, composites have gone from a curiosity and limited use on military aircraft to being the material of choice for military fighters and bombers, the Boeing 787, and the Airbus 350. Looking to the future, composites will be central to any aircraft. It is estimated by both Boeing and Airbus that around 40,000 commercial aircraft will be required over the next twenty years (as compared to about 25,000 commercial aircraft in service today). In addition, the US military is researching concepts of swarms of unmanned aircraft (UAVs) with limited life (or even disposable) and very low cost. Finally, the Air Taxi concept is no longer a 60 year old dream of a flying car. The first air taxis are projected to be in service in 2023. They will require composites for these aircraft to meet their range and speed requirements, but these concepts are likely to use construction methods more akin to automotive than aerospace. While all of this is happening, OEMs will be demanding bigger and/or more complex composite structures than have been built to date. In addition, they will demand better performance at lower cost.

All of this cannot happen in today's aerospace composites industrial base. It is currently predicated on hand lay up or current automated layup machines that have only 20-50% machine utilization. In addition, it is still more analog than digital. Companies are dabbling in digital to solve specific pain points such asset tracking, but few manufactures have a true enterprise wide Industry 4.0 environment. A state change must happen if the aerospace industry is to achieve production rates for the future aircraft mentioned above. First, the industrialization of the automation of composites is going to be a major component to enable this next generation of aircraft. Without it, the industrial base will be spending significant money to add capacity. In addition, they will struggle with finding enough skilled labor to produce these aircraft. Automation, if done right, will alleviate the need for significant capital investment and lessen the number of new skilled workers for manufacturing aircraft. Second, the composites community will need to fully embrace Industry 4.0 concepts to get actionable insights from data generated during fabrication and assembly.

In November 2018, the Air Force Research Laboratory (AFRL) convened industry experts for a two day workshop to identify "The Next Big Thing" in composites to serve as a rallying cry for the industry to justify future AFRL investments in composites applied research and advanced technology demonstrations. The focus of the workshop was on organic matrix composites for subsonic and supersonic aircraft. Any high temperature composites for future air vehicles flying faster than supersonic are adequately covered by current investments. The workshop's findings were:

- Next Generation Composite Materials
    - Problem: Little investment in new materials since the 1980s.
    - Future State: Development of new composite material solutions in the next 5 years to be available for trade studies for future Air Force aircraft requirements. Government hosted database of material properties for those materials.

- Potential solutions: 3D fiber architectures, new resin chemistries, thermoplastic component demonstrations, large component demonstrations

- Manufacturing Science Tools
  - Problem: Designs are based on current/legacy assets, experience and manufacturing practice.
  - Future State: Set of design for manufacturing democratized tools that can coherently assess trade space depending on point in the manufacturing life cycle.
  - Potential solutions: integration of artificial intelligence/machine learning, automation, data, analytics, manufacturing and products. Use of an integrated, computer-based system comprised of simulation, three-dimensional (3D) visualization, analytics and various collaboration tools to develop a virtual representation of the entire manufacturing process.
- Low Cost, Agile Manufacturing and Processing
  - Problem: Composite M&P current platforms are: too costly in the raw state, too expensive to process into cured laminates, requires costly long lead time tooling and design practices, and is too dependent on touch labor process methods.
  - Future State: Robust understanding of low cost manufacturing process capabilities and ensure the design is constrained by identified processes resulting in 50% reduction in design cycle time. Manufacturing lines that can be rapidly reconfigured to meet surge demand and various product mixes to cost effectively manufacture aircraft structure.
  - Potential solution: Next generation automation. Improved utilization of AFP/ATL equipment. Robotic solutions for hand layup and forming of complex shape parts (thermoset and thermoplastic). Collaborative robots that interact with humans, as opposed to performing a set of prescribed operations with limited or no interaction. Flexible robot systems that are able to be reprogramed or repurposed for integration into another system.
- Inspection
  - Problem: There is a general lack of techniques for both in-process quality assurance and inspection of structural assemblies.
  - Future State: We desire non-interfering in-process sensors and an alternative to the proof test which applies to both as-manufactured and in-service conditions.
  - Potential Solution: Move from inspection to measurement. This requires manufacturing simulation and in process measurement, as well as in-service structural simulation and measurement, at a level good enough to satisfy regulatory requirements. Use of Industry 4.0 tools to provide an understanding of the state of the part or assembly, not just to track them.
- Composite Aircraft Certification
  - Problem: The time and cost for the certification of new aircraft structures is excessive and limits innovation. Conventional structural analysis tools for composites lack sufficient data to ensure confidence in their use by Air Force certification officials.

- Future State: Reduce certification cost by 75% and time by 50%. High confidence in the accuracy of new structural analysis tools. Ability to use those tools across multiple material systems and architectures.
- Potential solution: Process models that take realistic manufacturing variations into account, massive parallel damage models, modeling of damage arrest features in composite structures, large structural demonstrations to validate analysis tools at aircraft scale.

These focus areas are generic to commercial and military aviation as well as air taxis. For AFRL the next step will be to identify which of these potential solutions are unique to the needs of military aircraft and then make investments to bring them to reality. We at AFRL look forward to working with the aerospace composites community to solve these problems and improve the capability of the industrial base.

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