Composite Manufacturing Technologies for Aerospace Performance at Automotive Production Rates

Addressing the Technology Barriers for Urban Air Mobility eVTOL Aircraft Through Science and Innovation

Challenges
- UAM eVTOL aircraft require lightweight composites to achieve maximum range and payload requirements
- Production rates significantly higher than traditional aerospace composite manufacturing methods
- Total cost of ownership of aircraft is key to success
- Need for next generation labor force for UAM market growth

Barriers Addressed
- New short fiber composite can be stamped into complex parts at high rate
- Retains aerospace properties and lightweight
- Reduces cost of manufacturing: No waste

Expected
- "Save a billion people an hour a day" JoeBen Bevirt, Joby CEO
- eVTOL: Reduced emissions, low noise, societal benefits
- TuFF is key for weight reduction, meeting production rates, minimizing waste and creating a technological approach for sustainable/upcycling and reuse for reduction in carbon footprint and embodied energy
- A new paradigm for design and manufacturing of a new class of composites for applications in aerospace, automotive, space, electronics and replacement of metal stampings

Solution
- Establish fundamental science based to design and optimize TuFF microstructure for properties and processing using experimentally validated predictive models.
- Integrate our models into current CAD/CAM/CAE software to enable engineers worldwide to design and manufacture TuFF parts.
- Establish a material property database for forming and mechanical properties needed for part design.
- Develop new tooling approaches for stamp forming short fiber TuFF composite blanks.
- Transition technology to industry using our Pilot Facility for workshops, training and demonstrations and product development with our partners.
- Demonstrate sustainability by recycling TuFF to show upcycling/recovery of full properties are achievable for reuse in aerospace applications.

Results and Next Steps
- Short fiber TuFF (IM7/LM-PAEK) properties equivalent to continuous fiber aerospace composites (static and fatigue)
- TuFF tape offers 10x improvement in steerability over state-of-the-art tape placement enabling topology optimization for weight savings
- First generation structural models for microstructural design and process design establish
- Technology transfer and part demonstrations underway

Partners and/or Participants
- University of Delaware Center for Composite Materials, Lead Organization, Composites Research, Education and TuFF Technology
- Joby Toyota, UAM System Integrator
- Spirit Aerospace, Composite Aerospace Manufacturer
- ATC Advanced Thermoplastic Composites
- Southern University, HBCU, Composites Research and Education

Tailored Universal Feedstock (TuFF) Provides Aerospace Performance at UAM Production Rates

Innovation of Next Generation Composite Manufacturing

Innovation of Next Generation Sustainable Composites
- TuFF is a feedstock with near ideal aligned short fiber microstructure in tape, sheet and blank formats
- Low-cost short fiber with filament level alignment control
- Aerospace quality and properties
- Inplane stretch in fiber direction of 45-50%
- Tow steering for Automated Tape Placement
- Automotive-like forming at high throughputs
- Single step low-cost manufacturing: no waste
- Enables recycling/upcycling of composites

Innovations of Next Generation Composite Manufacturing

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Next Generation Sustainable and Self-healing TuFF Composites

- Multifunctional vitrimers: Self-healing, recyclable, shape member
- Highly aligned discontinuous carbon fibre preform (TuFF): Recyclable, upcycling and reuse

TuFF IM7 carbon (3mm) / LM-PAEK Offers Excellent Fatigue Properties

Excellent fiber/matrix adhesion
Excellent Resin Toughness Of Thermoplastics

0.9% Tensile Strain on Cross-ply Laminate (R=0.1): 1M cycles with No Transverse Cracks

TuFF aligned Short Fiber

Topology Optimization by Tow Steering During AFP
Stretchable TuFF >10x Lower Radius than State of the Art

Excellent TuFF Fatigue Properties

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Education/Workforce Training & Outreach

- Involve students including underrepresented minorities in composites activities at UD and Southern University
- ~550 students (60% were URM from grades K-12)
- >450 registered for ULI sponsored presentations and seminars
- >1000 in total registered for the NASA ImaginAviation Annual Conference and NASA Tech Talk Seminar series that highlighted our ULI students and technical activities

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Taking Flight with Anderson Cooper

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