Composite Manufacturing Technologies for Aerospace Performance at Automotive Production Rates

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

National Aeronautics and Space Administration

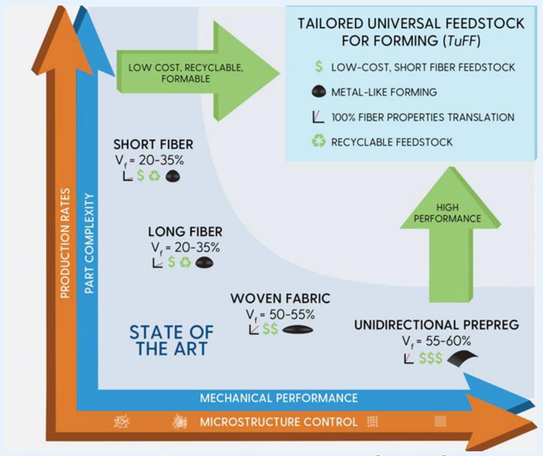
Challenges

- 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

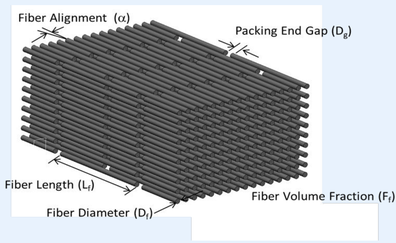
CLICK FOR IMAGE FOR VIDEO

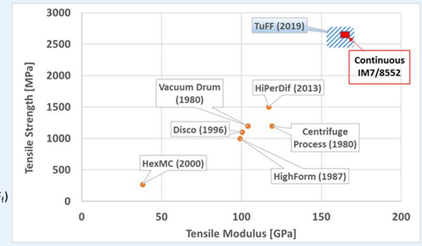


Tailored Universal Feedstock (TuFF) Provides Aerospace Performance at UAM Production Rates

Expected

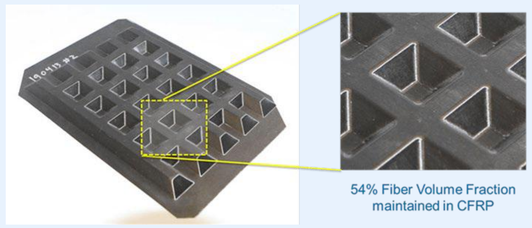
- "Save a billion people an hour a day" JoeBen Bevirt, Joby CEO
- eVTOL: Reduced emissions, low noise, societal benefits
- *TuFF* is key for weight reduction, meeting production rates, minimizing waste and creating a technological approach for sustainable/upcycling and reuse for reduction in carbon footprint 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





- *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

Innovation of Next Generation Sustainable Composites



- 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

Innovation of Next Generation Composite Manufacturing

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
- Spirt Aerospace, Composite Aerospace Manufacturer
- ATC Advanced Thermoplastic Composites
- Southern University, HBCU, Composites Research and Education

50 YEARS OF INTERNATIONALLY RECOGNIZED EXCELLENCE
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1974 - 2024

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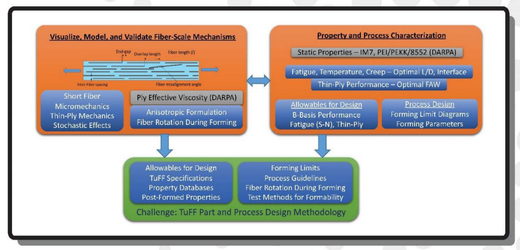
ULI Research Goals

Develop Physics-Based Modeling and Simulation Tools for Aerospace/UAM Applications

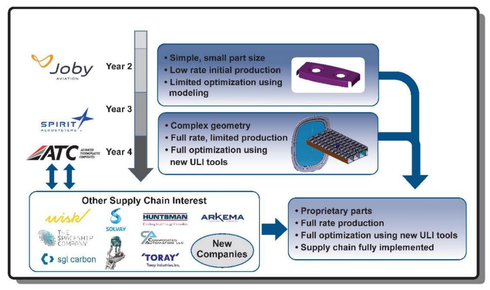
- *Physics of fiber alignment*
- *Microstructural design of mechanical properties*
- *Thin-ply effects on laminate properties*
- *Micromechanics of forming, constitutive models and forming limits*
- *Process modeling for complex geometry parts*
- *Experimental validation*



Part Design and Manufacturing

- *Experimental validation (quality, repeatability)*
- *Cost models*

Creation of Property Database & Integration into Commercial Software



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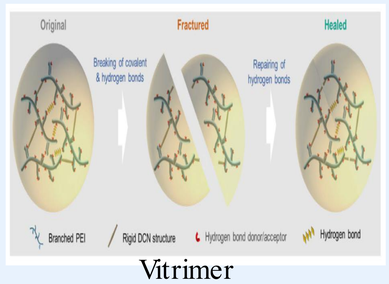
Next Generation Sustainable and Self-healing TuFF Composites

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



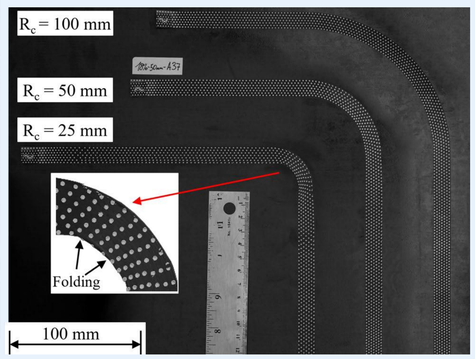
Vitrimer

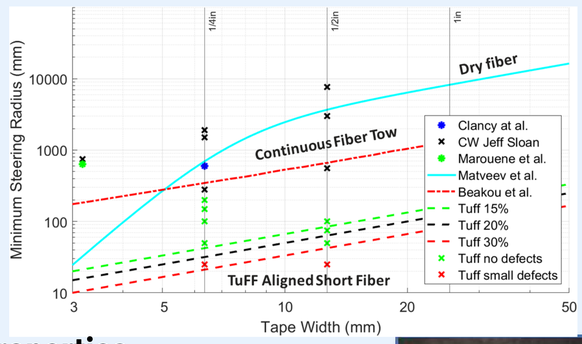
TuFF

Obed Tettah, SU Masters, ME

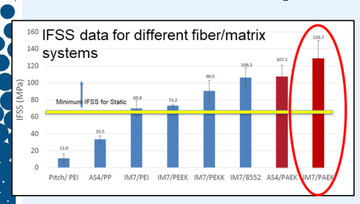
Lukas Fuessel UD PhD student, ME

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

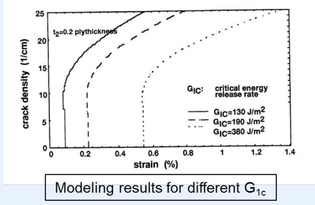




TuFF IM7 carbon (3mm) /LM-PAEK Offers Excellent Fatigue Properties



Excellent fiber/matrix adhesion



Modeling results for different G_{1c}

Excellent Resin Toughness Of Thermoplastics

Excellent TuFF Fatigue Properties

Branndon Chen UD PhD student, MSEG

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

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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*
- *>1,000 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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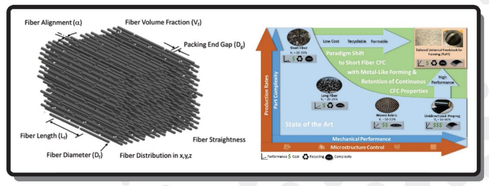
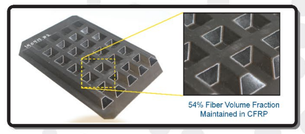
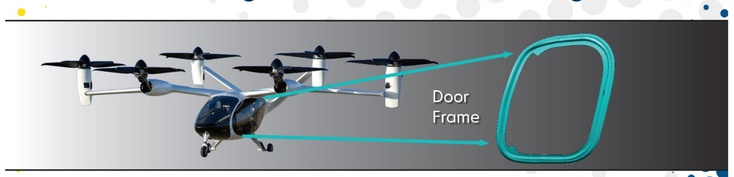
TuFF: Tailored universal Feedstock for Forming World's Strongest Short Fiber Composite



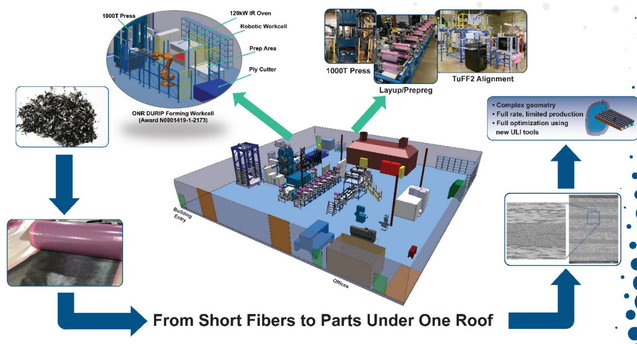


ULI Addresses Technology Barriers in Manufacturing of Complex Geometry Composite Parts for UAM & Commercial Air Platforms (2020-2024)

- *Meeting aerospace performance at automotive-like production rates*
- *Transition TuFF technology to our industrial partners followed by the US industrial base*
- *Train next generation of scientists and engineers*



UD-CCM TuFF Integrated Manufacturing Facility



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