Mapping the Course to Advance Composites Manufacturing in the U.S. through the FIBERS Roadmap

James A. Sherwood
University of Massachusetts Lowell
james_sherwood@uml.edu

CAMX 2017
December 12-14, 2017
Orlando, FL
Mapping the Course to Advance Composites Manufacturing in the U.S. through the FIBERS Roadmap

James Sherwood, Christopher Hansen, Patrick Drane, Jennifer Gorczyca, Kari White, Emmanuelle Reynaud, UMass Lowell
Daniel Walczyk, Rensselaer Polytechnic Institute
Suresh Advani, University of Delaware
Vinay Dayal, Iowa State University
Michael Overcash, Environmental Clarity
Brad Kinsey, Todd Gross, David Lashmore, Igor Tsukrov, U. of New Hampshire
Steve Nutt, University of Southern California
Raymond Boeman, ORNL, Michigan State U., IACMI
Tom Dobbins, Daniel Coughlin, ACMA
Andrew Schoenberg, Stephen Von Vogt, Maine Composites Alliance
University / Non-Profit / Government Participation

UMASS Lowell

Southern Maine Community College

University of New Hampshire

Iowa State University

American Composites Manufacturers Association

University of Delaware

Rensselaer

Oak Ridge National Laboratory
Consortium Activities

NIST awarded a 2-year grant (June 2014 to May 2016) to the FIBERS Team to strengthen U.S. Composites manufacturing and innovation.

• National and Regional Meetings
  – Roadmap Identifies
    → Industry/Sector Drivers and the associated Challenges/Barriers
    → Opportunities for growth
  – Aggressively and cooperatively address identified Challenges/Barriers – Actionable Items
    → Pre-competitive research and demonstration projects

• Targeted Roadmapping Workshops for Industry Sectors

• Surveys

• Site visits with companies
Growth Opportunities for Composites

Industry Survey Results

• Conducted in 2014 and 2015
• 354 demographically balanced participants

Three sectors identified as having the greatest opportunities for growth
Growth Opportunities for Composites

Survey results
- Greatest Growth: Automotive & Infrastructure
- Highest Penetration: Aerospace

Automotive
- Require widespread use of automation
- Increased use of predictive modeling
- Low-cost carbon fiber
- Composites can facilitate a 40% wt reduction
- 2-min. cycle time

Infrastructure
- Require the materials to be low specific cost ($$/mass)
- Long service life
- Large parts → long cure time to fully wet the part

Aerospace
- Has been the leader in the use, processing and advancement of composites – can justify cost
- Critical to pushing the envelope on composite performance and processing

Wind, Marine and Sports & Recreation -- Continued but slower market penetration
Growth Opportunities for Composites

All sectors will benefit from the advancements in
• Materials
• Processing
• Automation
• Modeling
• Workforce development
Growth Opportunities for Composites

• Automation and cycle-time reduction
  ➔ Research and development
    o New quick-curing resins
    o Forming processes

• New resins and processes
  ➔ Increased use of modeling to explore in a virtual environment how these innovations will impact the design and tuning of composite manufacturing processes
Grand Challenges

Four grand challenges to the growth of the U.S. Composites manufacturing industry were identified through the roadmapping activities.

1. Advancing Processing Methods → Reduce Cycle Time
2. Expansion of the knowledge and access to the tools that enable manufacturers and designers to use new processing methods and materials
3. Advancement of the material performance
4. Development of a well-trained and sufficiently-sized workforce
Advancing Processing Methods

**Drivers**
- Reducing variability
- New process development
- High cost of composite structures due to the labor-intensive, time-consuming processing methods
- Reduce cycle time

**Barriers**
- Lack of a deep understanding of the physics
- Lack of automation

---

**Survey Question:** Identify the primary challenges that would be overcome with the development of new processes at your company (please check up to three)
Opportunities/Challenges

- Develop new and innovative manufacturing processes
- Understanding the physics associated with a processing method
- New resins to reduce processing time and lower per part cost
- Automation
  - Driven by need for shorter processing times and lower labor costs
  - Next 15 years will see increase in aerospace and automotive

Survey Question: Rank the impact of the following actions on the development of new processes

Actions

| Develop robust predictive modeling tools to reduce risk before committing to equipment or process changes |
| Develop automation with process sensing, monitoring and control |
| Develop reliable and repeatable NDE (non-destructive evaluation) techniques to detect and characterize defects |
| Establish regional centers and industry consortia to provide the technological resources and document best practices |
| Investigate thermoplastic processing methods |
| Develop additive manufacturing processes for composite materials |

Choice #1 More impact Choice #7

0 10 20 30 40 50 60 70
Innovations in Predictive Modeling Tools

**Drivers**

- Decrease product development costs while improving performance compared to existing composite and metal products
- Need for a virtual environment
  - for investigating
    - new composite designs and
    - processing methods
  - to redesign
    - existing processes or
    - add new processes that can facilitate improvements in the manufacturing process
- Ability to link manufacturing process conditions to the models of in-service performance
- Help to explore the benefits and consequences of such changes as
  - material choices,
  - processing conditions and
  - capital equipment options
  before going down the long and expensive path of product and process development.
Innovations in Predictive Modeling Tools

Barriers

• Lack of a comprehensive Material Property Database
• Limited recognition of the advantages that can be gained from modeling
  – Continued attraction to rely on past experiences
• Cost and access to training in the proper use of the tools
Innovations in Predictive Modeling Tools

Current Practices

- Reliance on past experiences in lieu of a virtual model
  (Virtual models can expand the range of possibilities)
- Overdesigned parts
- Structural modeling tools for
  - predicting part stiffnesses and completing stress analyses are relatively mature,
  - but their use by SMEs has been limited
- Modeling tools are still emerging
  - for process simulation,
  - predicting in-service fatigue life and
  - life-cycle inventory (LCI)
- Tools are often underutilized for such reasons as
  - limited access to the tools,
  - lack of qualified personnel with experience using them or
  - lack of awareness that the tools even exist. Cost of materials, particularly carbon fiber and epoxy resins, are prohibitively high for widespread use in market segments such as wind power and automotive
Opportunities/Challenges

• Pursue demonstration projects and initiatives, which include the use of predictive modeling tools,
  – Can educate industry about the capabilities of these tools and
  – Show their value in expediting the design of manufacturing processes
• Expand materials databases to include the properties needed by these simulations
  – Ideally, a central clearinghouse for the data should be freely available.
  – Could be a collaboration of one or more federal agencies, e.g.
    • Department of Energy
    • Department of Defense
    • Department of Commerce
    • NASA
    • NTSB
    • IACMI
• Life-cycle predictive tools also need further development
  – Need representative, non-proprietary composite life-cycle inventory data for the largest composite end-use product groups
  – Require data for the majority of chemical constituents and composite assembly techniques
  – Develop life-cycle profiles of composite recycling and benefits in recycled or repurposed composite materials.
Drivers

• Need to develop new resin materials, with the primary aim (2/3 of survey respondents)
  – To reduce cycle times
  – To decrease part cost
• Reduce raw material costs
• Desire for attractive processing parameters

Survey Question: Identify the primary challenges that would be overcome with the development of new processes at your company (please check up to three)
Future of Materials

Barriers

• Lack of materials with tight tolerances to produce parts with minimal intervention during manufacturing – especially needed for automation

• Cost of materials, particularly carbon fiber and epoxy resins, are prohibitively high for widespread use in market segments such as wind power and automotive

• Lot variability: forces users to always bias to the most extreme condition – worst-case scenario, which errs on the side of a long cure time

• Costly certifications of both material systems and processes
## Future of Materials

### Opportunities/Challenges

Rank of the impact of actions in reducing the cost of materials

<table>
<thead>
<tr>
<th>Action</th>
<th>Choice #1</th>
<th>Choice #7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investigate low-cost carbon fiber manufacturing processes for non-aerospace applications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Develop material performance standards to transition between alternate materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investigate high-strength glass or glass hybrid fibers</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investigate the use of short-fiber composites for high-strength/stiffness applications</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Investigate the use of recycled or reclaimed materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conduct research and scale-up on high-modulus fibers to replace carbon (e.g., CNT, BNNT)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Increase the supply of fiber reinforcement</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduce the cost of non-styrenated resins</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Developing a Skilled Workforce

Background

- Composites workforce resides along a spectrum from no composites-specific training to engineers with doctoral degrees.

- Until there is a significant population of engineers with knowledge on how to design composite parts and who understand the processes used to make such parts, growth in the number of composites applications will continue to be slow.

The diverse training landscape for the domestic composites industry workforce.
Developing a Skilled Workforce

**Driver**

- Continual growth of the composites industry requires skilled labor at all levels

**Barriers**

- Manual, complex and craftsman nature of composites manufacturing impedes the influx of employees from other manufacturing sectors
- Many design engineers are unfamiliar and uncomfortable with the design flexibilities associated with composites restricts the broad adoption of composites.
- Retention of a qualified workforce
  - Company size correlates with length of employment

The average turnover rate for hourly workers in the composites industry.
Developing a Skilled Workforce

Current Practices

• High school graduates enter the workforce or college unaware of composites manufacturing as a career
• Education and training programs may not be tailored to match regional industry requirements
  – Despite a significant fraction of workers remaining geographically local to their respective educational institution.
• No national standards or accreditation body exists for the industry
  – Hinders uniform education standards and transfer of skills between composites companies.

One Word: Composites!
Developing a Skilled Workforce

Actions as ranked by industry respondents regarding employee retention in the composites manufacturing industry.

<table>
<thead>
<tr>
<th>Action</th>
<th>Percent Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Provide training and education in transferable skills</td>
<td>60%</td>
</tr>
<tr>
<td>Increase upward mobility potential</td>
<td>50%</td>
</tr>
<tr>
<td>Increase pay rate to be competitive with other industries</td>
<td>40%</td>
</tr>
<tr>
<td>Provide options for continuing education</td>
<td>30%</td>
</tr>
<tr>
<td>Improve work environment cleanliness</td>
<td>20%</td>
</tr>
<tr>
<td>Improve work place health and safety</td>
<td>10%</td>
</tr>
</tbody>
</table>
Some General Conclusions

• The **Federal Government** should:
  
  1. Increase funding to train both engineers and technicians in composites manufacturing
  
  2. Provide long-term support for R&D activities to assist the U.S. composites manufacturing industry to be on par with foreign competitors – especially in the European Union, where government support for composites is very high
  
  3. Share Department of Defense knowledge in composites manufacturing automation with U.S. industry
  
  4. Set up regional technology centers with process and simulation capabilities and technical support services for use by SMEs
Some General Conclusions

- **Opportunity** for the researchers to develop new and innovative manufacturing processes.

- Innovations will require a
  - Fundamental understanding of the physics associated with a processing method
  - Access to modeling tools that can explore how changes in process conditions influence throughput and part quality.

- Companies need to learn to work together for the overall benefit of the composites manufacturing industry
  - Overcome fears about intellectual-property protection are
    - Forcing many parties along the composites manufacturing supply chain to duplicate research and development investments
    - Use outdated processes and approaches.
  - Smaller firms faced with limited to no access to new equipment and analysis capabilities, thereby limiting their ability to explore and justify the cost of new-process adoption.
Some General Conclusions

• Companies need to come together and work with academia to be proactive in lobbying the federal government to make significant investments to support fundamental research collaborations in composite manufacturing.

• IACMI is playing a major role in taking fundamental research results into composite manufacturing demonstration projects, but there needs to be a process for sustaining a pipeline to develop and deliver
  – new material systems
  – innovations in processing techniques
  – advances in modeling.

→ Provide fuel future advances in composites manufacturing
Drivers, Challenges, Barriers and Actions

**Drivers**
- Required fuel economy targets

**Challenge 1**
- Reduce weight with use of composites

**Barriers**
1. High cost of materials
2. Crashworthiness

**Barriers**
- Cost of carbon fiber, need for automation, high cycle time

**Challenge 2**
- Develop an understanding of how to design for crashworthiness with composites

**Barriers**
- Lack of predictive modeling tools, lack of material standards, process variability

**Actions**
- Hood demonstration project
- Material standard initiative
- And more....
**IACMI Project Title:**

**Techno-Economic Modeling and Manufacturing Simulation for the Insertion of Automation to Advance the State of Composite Wind Blade Manufacturing**

**Driver:**

- Reduce LCOE

**Challenge:**

Reduce Composite Wind Blade manufacturing costs and increase throughput by implementing automation into manufacturing

**Challenges (1):**

- Identify opportunities to insert automation + Design cost-effective solutions

**Challenge (2):**

Develop a techno-Economic Model to evaluate ROI

**Barriers:**

- Lack of cost-effective high-throughput automation solutions
- Return on Investment (ROI)

**Barriers:**

- Lack of a comprehensive model of the factory floor
- Lack of a full understanding of all inputs to use in the Techno-Economic model

**Build model in DELMIA**
Thank you for listening...

Questions?

Contact information

• Patrick_Drane@uml.edu
• James_Sherwood@uml.edu