Opportunity Brings New Challenges: The Future of Thermosets

Dale Brosius, Chief Commercialization Officer, IACMI

SPE Thermoset TOPCON

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My SPE History

- **Thermoset Division**
  - Joined SPE 1992
  - Thermoset Division BOD 1999-2009
  - Division Chair 2004-2006
  - Various conference chair positions

- **Composites Division**
  - Composites Division BOD 2006-Present
  - Division Chair 2011-2013
  - ACCE Chair four times
  - Councilor 2018-Present

- **Honored Service Member 2009**
1985 – Early days of the wind turbine market
1986 – Automotive Composites Development
Early Trek composite tubes

Circa 1989
Race car parts fabrication

Circa 1990

1991 – First all carbon chassis in IndyCar
First Class A carbon part on GM vehicle -2003
Wind turbine build - 2016
“Within ten years, all thermosets on airplanes will be replaced by thermoplastics.”

- Chemical Company Executive, 1987
>50% of structural mass in composites

of which >95% is thermoset

35 years later
Airlines will need 41,170 new airplanes over 20 years

By type:
- Regional jet: 2,120 (5%)
- Single-aisle: 30,880 (75%)
- Widebody: 7,230 (18%)
- Freighter: 940 (2%)

By region:
- North America: 23%
- Asia Pacific: 21%
- Europe: 21%
- China: 21%
- Middle East: 7%
- Latin America: 5%
- Africa: 2%

Forecast period 2022-2041, Asia Pacific does not include China
Global fleet will nearly double; half of deliveries for replacement

*Retained fleet includes 2020-21 deliveries
Thermoplastic pickup box

Limited availability

Sold only on highest model
SMC pickup boxes

Only option available – all thermoset. Total volume over 400,000 annually.

Hyundai Santa Cruz

Toyota Tundra & Tacoma

Honda Ridgeline
The Clean Energy Economy will be a boon for thermosets
Renewables, especially onshore wind, is cheaper than coal or natural gas.
Strong growth history (GW)

Source: GWEC
Strong market forecast for wind turbines

New installations outlook 2023–2027 (GW)

- Onshore
- Offshore

CAGR 15%

Source: GWEC
Wind market is already one of the largest users of thermosets.

107m blade for 12MW offshore turbine

Thermoset resins with glass and carbon fiber
Electric Vehicles will replace ICEs

Over 35 models not from Tesla available in US now
Market poised for double digit growth through 2030

Mass Savings is more important in EVs

ICE vehicles: 10% mass reduction = 6-8% improved fuel economy

Electric vehicles: 10% mass reduction = 10% further range (or smaller battery pack)
Battery enclosures are the obvious target for thermoset composites

Stiffness, impact, fire resistance, EMI shielding important

Opportunity for multifunctional solutions not offered by metals, combined with mass savings

Don’t overlook traditional applications, like body panels and structure for weight savings
Electrification of the US economy is good for thermosets

Drive to renewables: wind, solar, water

Vehicle electrification (cars, trucks, mass transit)

Electrification of heavy manufacturing

Green hydrogen (requires green electricity) replacing natural gas and coal in metals production

Thermosets excel in high voltage/high current applications
Infrastructure will be a significant market for thermosets, led by rebar.
More than rebar
It’s all sunshine so far. Where are the clouds?
“The only technical parameter that matters is cost.”

- BMW Executive
Initial vision for IACMI driven by “How do we catch and surpass Germany and the UK?”

- Fraunhofer Institutes – Pioneer in high volume composites processing for 20+ years
- National Composites Centre UK created 2009, facility operations 2011 – early focus aerospace, then automotive

**Barriers to Composites Growth**

- High price of carbon fiber and intermediates
- Slow manufacturing processes
- How to design to true minimum mass
- Confidence in manufacturing processes and performance
- Carbon fiber manufacture is energy intensive
- Traditional processes are high scrap
- Inefficient recycling technologies and infrastructure
Ecosystem of Innovation

- **Core Partnerships** with leading universities, national laboratories, gov’t agencies
- Leveraging existing networks across technical, professional, and economic development organizations
- **IACMI addresses the technoeconomic challenges facing the composites industry**
Extensive Industry Network

- **125+** Active members in 39 states
- **100** Industry members (68% SMEs)
Operating Model – Industrial Collaboration Spaces

Shared Spaces for Catalyzing **Innovation**, Expediting **RD&D**, Supporting **Workforce Development**
Wind blade fabrication

**Purpose:** Scale Technology to 13m and validate against baseline 13m epoxy blade

**Outcome:** 13m blade successfully fabricated and structural test completed (bending and fatigue), with results comparable to epoxy baseline. Technoeconomic modeling shows advantages for TP blade.
Large-scale prototype & run-at-rate capabilities
Ford carbon fiber liftgate inner panel

Molding Compound Market

![Graph showing tensile modulus and strength of different composite materials with Dow VORAFUSE™ M Performance highlighted.](image)
Ford liftgate project

In line non-contact measurement of carbon fiber properties

Mechanical strength testing and morphology

Flow simulation and crash performance correlation

Digital Image Correlation (DIC) for fiber orientation
Ford/Dow Liftgate

Enabling Manufacturing-Informed Design with Novel High-Rate Materials and Processes

Flow Orientation

Static Stiffness

Crash Performance
Ford carbon fiber liftgate inner panel
Ford/Dow Liftgate

Modal 35% cost reduction vs. baseline

- 17% reduction in base material cost
- 83% reduction in material scrap/offal
- 33% decrease in molding cost due to cycle time
- Additional savings in manual labor expected but not included

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Improved</th>
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<tbody>
<tr>
<td>Part weight</td>
<td>5.9 kg (13 lb)</td>
<td>5.9 kg (13 lb)</td>
</tr>
<tr>
<td>Annual volume</td>
<td>100,000</td>
<td>100,000</td>
</tr>
<tr>
<td>Molding time</td>
<td>10 minutes</td>
<td>3 minutes</td>
</tr>
<tr>
<td>Material Cost</td>
<td>$26.40/kg</td>
<td>$22.00/kg</td>
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<tr>
<td>Material Scrap/Offal</td>
<td>30%</td>
<td>5%</td>
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VW Atlas SMC liftgate project

Full-SMC Design

<table>
<thead>
<tr>
<th></th>
<th>Steel</th>
<th>Composite</th>
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<tbody>
<tr>
<td>Part Count</td>
<td>10</td>
<td>3</td>
</tr>
<tr>
<td>Weight</td>
<td>21.1 kg</td>
<td>13.6 kg</td>
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</table>

-7
-36%
VW liftgate project

Fiber orientation prediction and measurement using Digital Image Correlation (DIC)

Iterative part design and load case structural modeling
VW SMC liftgate project

Recurring cost comparison (performed by VW)
Transition to Series Production

Project Partners

Volkswagen Group Transfers/Influence

- Volkswagen ID.Buzz Liftgate
- Lamborghini Aventador Rear Fender
- Bentley Continental GT Deck Lid
- MAN TGX Roof Deflector

Partnering along the supply chain allowed for a batch of SMC Liftgate to be produced, painted and tested.
“Thermosets aren’t sustainable and can’t be recycled.”
Achieving sustainability in thermosets

Thermosets reduce energy use during use (mass reduction), produce clean energy (wind), and last far longer than traditional materials (infrastructure and corrosion), all of which contribute to a sustainable economy.

Some material options to further improve sustainability:

- Recycling of process scrap and end of life thermosets
- Using bio-based thermoset resins and/or natural fibers
- Using reversible thermosets, including:
  - Vitrimers, e.g. VITRIMAX
  - “Unzippable” thermoset resins, e.g. Recyclamine
## Recycling Levels – easiest to hardest

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>IACMI Member (Project Number)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0</td>
<td>Waste minimization, avoid landfill, feed back into process</td>
<td>Many companies/projects</td>
</tr>
<tr>
<td>Level 1</td>
<td>Repurposing of uncured scrap (prepreg, dry fiber)</td>
<td>CRTC (6.7)</td>
</tr>
<tr>
<td>Level 2</td>
<td>Grinding and remolding of cured scrap and end of life with new resin for alternate applications</td>
<td>Greentex (6.27)</td>
</tr>
<tr>
<td>Level 3</td>
<td>Recover fibers from thermoset/thermoplastic prepregs or compounds via pyrolysis or solvolysis</td>
<td>Vartega (6.20) ELG Carbon Fiber Carbon Conversions (6.5)</td>
</tr>
<tr>
<td>Level 4</td>
<td>Recover fibers and/or other products from cured scrap</td>
<td>CHZ Technologies (6.4, 6.29) ELG Carbon Fiber (6.7) Carbon Conversions (6.5)</td>
</tr>
<tr>
<td>Level 5</td>
<td>Recover fibers and/or other products from EOL parts (Typically, pyrolysis or depolymerization)</td>
<td></td>
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IACMI portfolio contains projects at all recycling levels
Seven Years of IACMI Recycling Innovation
### Reducing Embodied Energy via Recycling

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<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Recycled fiber</th>
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<tbody>
<tr>
<td>Carbon fiber @10%</td>
<td>115 MJ/kg</td>
<td>5 MJ/kg</td>
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<tr>
<td>PA 6/6 @90%</td>
<td>52 MJ/kg</td>
<td>52 MJ/kg</td>
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<tr>
<td>Compounding</td>
<td>8 MJ/kg</td>
<td>8 MJ/kg</td>
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<tr>
<td>Injection Molding</td>
<td>11 MJ/kg</td>
<td>11 MJ/kg</td>
</tr>
<tr>
<td>Total energy</td>
<td>186 MJ/kg</td>
<td>76 MJ/kg</td>
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- 96% reduction
- 60% reduction
The U.S. Department of Energy (DOE)'s Office of Energy Efficiency and Renewable Energy publicly announced its decision to renew funding for its Institute for Advanced Composites Manufacturing Innovation (IACMI). IACMI becomes the first Clean Energy Manufacturing Innovation Institute to be renewed by DOE.

IACMI will receive federal funding across five fiscal years, with a first-year investment of $6 million to further technological R&D and accelerate commercialization in the domestic composites manufacturing sector. This federal funding builds upon initial institute funding of $70 million from DOE and $130 million from IACMI’s member partners.

“Today, I am thrilled to announce DOE is extending our partnership with IACMI with a continued investment over another five years.”

- U.S. Department of Energy Secretary Jennifer Granholm

DOE and IACMI cut a ribbon on a new IACMI Collaboration Facility in Knoxville, TN
The market for thermosets is strong and offers continued growth opportunities
- Driven by clean energy and need to reduce carbon footprint
- Low mass = lower energy usage
- Thermosets meet the most demanding applications for polymer materials
- Durability a major asset in resilient and sustainable infrastructure

Industry must continue to address key challenges to remain the preferred material
- Focus on cost reduction via cycle time and scrap reduction, improved design
- Implement thermoset recycling strategies to reduce landfill at all stages of life
- Demonstrate sustainability by incorporating recycled materials, reversible resins, and bio-based materials
Thank you!

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