Power Demands for Curing Carbon Fiber Composites for Automotive Components

Anthony Berejka, Ionicorp*
Dan Montoney, Rapid Cure Technologies
Dan Dispenza, Nordan Composites Technologies
Rick Galloway, IBA Industrial, Inc.
Marshall Cleland, IBA Industrial, Inc.
Len Poveromo, Composite Prototyping Center
Mark Driscoll, SUNY-ESF
Vehicle Light-weighting
Nordan Composite Technologies – NYU Eco-marathon

Concept Zero – 103 kg carbon fiber prototype vehicle
1.1 horsepower engine = 60 km/l
Water cooled Tantalum target interposed between EB source and material to be treated
X-rays effectively penetrate ~25cm unit density material

Highest voltage industrial EB (10 MV) penetrates 3.8cm
X-ray Processing in use Since 2002

5 MV and 7 MV X-ray facility

Totes ready for X-ray processing

Decontaminating mail for the US Postal Service
Commercial EB Accelerator used for X-rays

7 MV 700 kW EB accelerator X-ray treatment in use since 2010
NYSERDA co-funded X-ray Feasibility Study
Bis-phenol A diacrylate
Metal biscuit trays

2 cm aluminum block on top

Carbon fiber shape X-ray cured in the mold
VARTM for test panels

Low viscosity formulation wetting fibers

Wetted carbon fiber
NYSERDA co-funded X-ray Feasibility Study

Hand trowelled low viscosity epoxy-acrylate formulation

X-ray curing motorcycle fenders in molds
Cured fender with metal piece embedded between plies

Class A finish motorcycle fender
Dynamic mechanical analysis

Heat deflection test
No deflection up to 180° C
Automotive Acceptance of Radiation Processing
Wiring – enhanced temperature durability (under the hood) flame retardancy; lighter weight
Wiring – enhanced temperature durability (under the hood) flame retardancy; lighter weight

Tire – partial EB cure stabilizes cords during molding and curing reduction in amount of elastomer used; lighter weight
Wiring – enhanced temperature durability (under the hood) flame retardancy; lighter weight

Tire – partial EB cure stabilizes cords during molding and curing reduction in amount of elastomer used; lighter weight

Closed cell PE foam – headers; doors; cell size controlled
Wiring – enhanced temperature durability (under the hood) flame retardancy; lighter weight

Tire – partial EB cure stabilizes cords during molding and curing reduction in amount of elastomer used; lighter weight

Closed cell PE foam – headers; doors; cell size controlled

Coatings – pioneered EB curable coatings (not now in use)
Wiring – enhanced temperature durability (under the hood) flame retardancy; lighter weight

Tire – partial EB cure stabilizes cords during molding and curing reduction in amount of elastomer used; lighter weight

Closed cell PE foam – headers; doors; cell size controlled

Coatings – pioneered EB curable coatings (not now in use)

EB or UV curing in the future?
Concept Zero – 103 kg carbon fiber prototype vehicle
1.1 horsepower engine = 60 km/l
Automotive Component: Aston-Martin hood

Carbon fiber Aston-Martin hood now in use
Automotive Component

Chassis
Matrix Materials: Bis-phenol A epoxies

Bis-phenol A epoxy

Bis-phenol A diacrylate
<table>
<thead>
<tr>
<th>Resin</th>
<th>Epoxy</th>
<th>Epoxy diacrylate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>1.16</td>
<td>1.17</td>
</tr>
<tr>
<td>Viscosity at 25°C, cps</td>
<td>~13,000</td>
<td>~190,000</td>
</tr>
<tr>
<td>Molecular weight, Daltons</td>
<td>377</td>
<td>393</td>
</tr>
</tbody>
</table>
Commercial pre-preg was purchased from Cytec
Composite Prototyping Center 2.4 m diameter, 6.1 m long autoclave
Supplier’s recommended cure cycle:
  one hour ramp up at 1.7° C/minute to 121° C
  one hour cure at 121° C
  one hour cool down to room temperature
Autoclave Curing

Aston-Martin hood cured at the CPC 15 July 2015
Complete electrical demand: blowers, heaters, etc.
Integrated power consumption = 192 kWh
Renegade produced the radiation curable pre-preg using a formulation provided by Rapid Cure Technologies
X-ray curing hood in mold
X-ray cured hood
Based on total power demand when operating the 7 MV, 700 kW accelerator in the X-ray mode, the electrical demand for curing a hood within its 1.49 m by 1.53 m mold passing in front of an X-ray target at 0.425 m/minute, using three passes (back-forth-back) to use full X-ray output, would be 25.26 kWh per hood.

Using the 2.4 m diameter, 6.1 m long autoclave to its capacity to cure six hoods at a time, the power demand would be 32 kWh per hood (192 kWh/6).

X-ray curing would demand 21% less power per hood.
X-ray Curing Advantages

+ Time to cure: 47 hoods per hour; 1.3 minutes per hood

+ Cure through embedded materials

+ Cure through thick cross-sections

+ Extended shelf-life of matrix materials
  Material made for feasibility study on August 23, 2005
  used as a control over the years; pre-preg stored at
  room temperature

+ Cure activated by ionizing radiation – no curatives
Time-Temperature Constraints of Epoxy Thermoset

Thermoset curing reaction kinetics – time at temperature

1 hour cure at 130° C

15 minute cure at 130° C
Carbon fiber composites have high specific strength.

### Weight-to-strength ratios for vehicle component materials

<table>
<thead>
<tr>
<th>Material</th>
<th>Density (g/cm³)</th>
<th>Specific Strength (kN·m/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel</td>
<td>7.86</td>
<td>254</td>
</tr>
<tr>
<td>Aluminum</td>
<td>2.80</td>
<td>214</td>
</tr>
<tr>
<td>Carbon fiber composite</td>
<td>1.58</td>
<td>785</td>
</tr>
</tbody>
</table>
Vehicle light-weighting using carbon fiber composites is the most straightforward way to reduce greenhouse gas emissions. 2.3 liters of CO₂ are emitted per liter of hydrocarbon fuel used.
Carbon Fiber Composites

+ Carbon fiber composites do not require corrosion protection

+ Coatings on carbon fiber composites can be cured with non-thermal ultraviolet (UV) radiation
The authors are appreciative of the co-funding provided by the New York State Energy Research and Development Authority.
Thank You

Questions