Designing for Sustainable Content and Performance in Phenolic Sheet Molding Compound

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Polymer Composites for Electric Vehicle (EV) Applications

- EV battery enclosures are an excellent application for polymer composites
  - Weight reduction compared to metallics
  - Electrically insulating
  - Enhanced thermal runaway protection
- Many existing polymer composites are highly filled to achieve flame resistance (FR)
  - Lower mechanical properties
  - Increased density
- Phenolic Sheet Molding Compound (SMC) does not require additional FR additives
  - Higher mechanical properties
  - **Great opportunity to increase sustainable content in automotive composites**

Control Phenolic SMC Properties

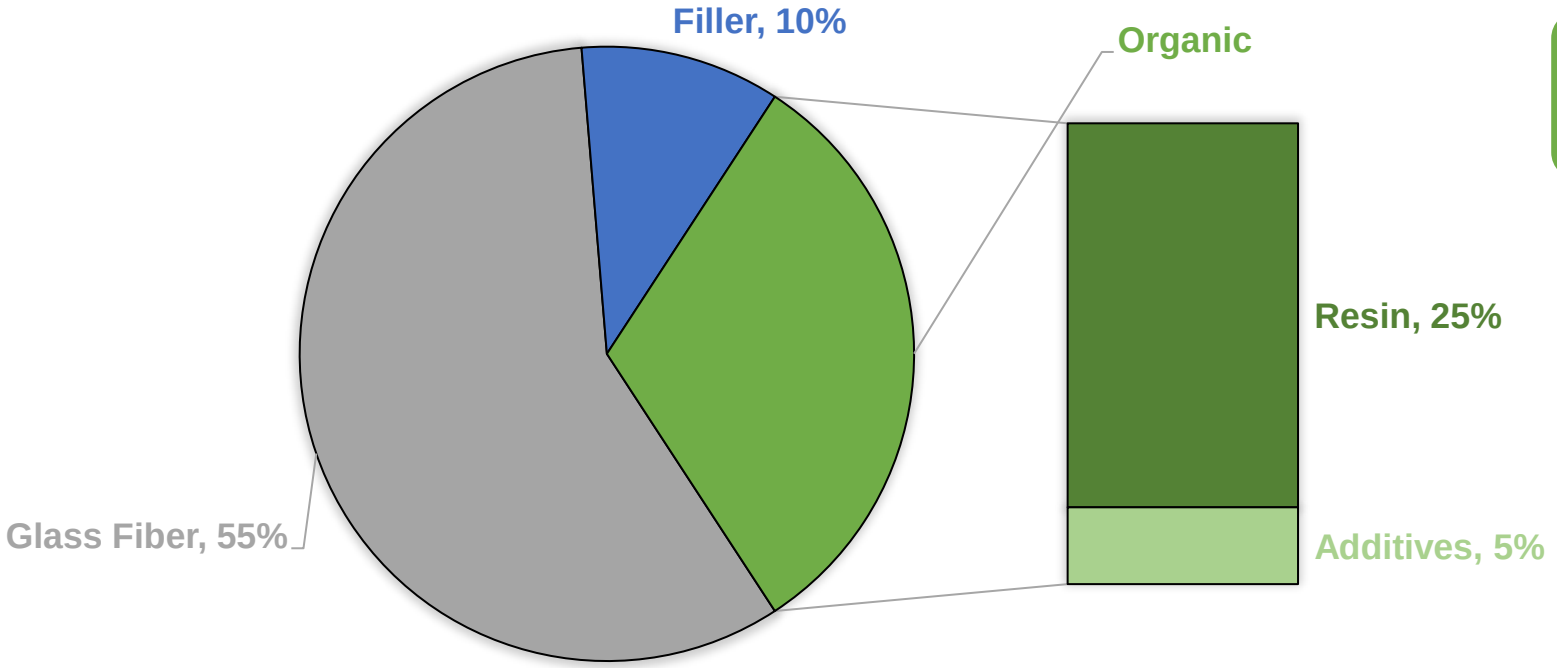
- A version of phenolic SMC was developed with 10% sustainable content utilizing a recycled filler
- The Control Phenolic SMC properties in this study are as follows:

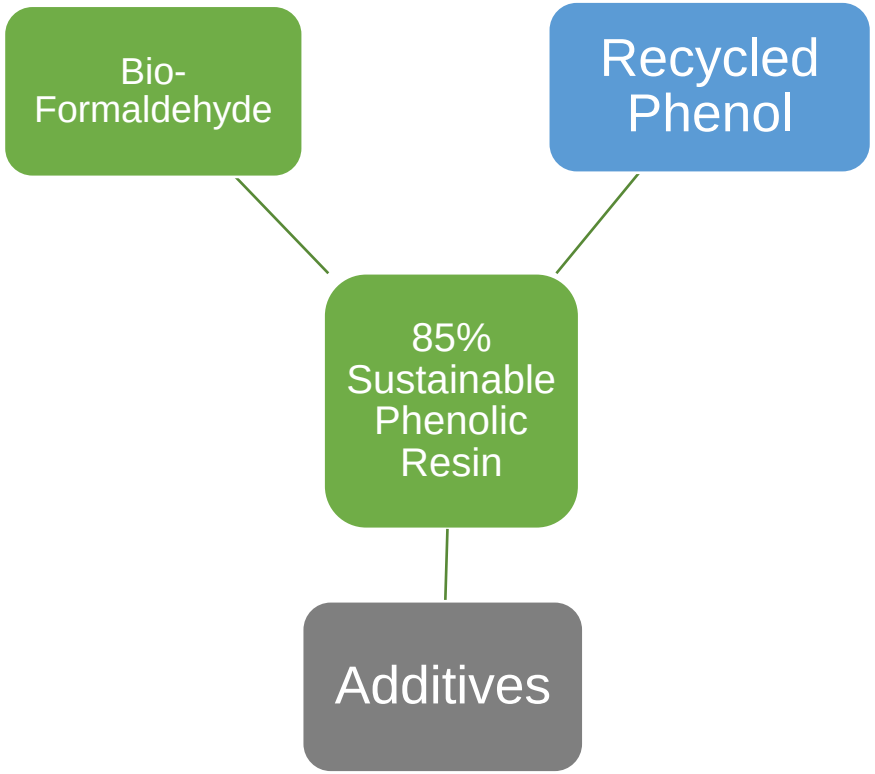
Tensile Strength (MPa)	Young's Modulus (GPa)	Flexural Strength (MPa)	Flexural Modulus (GPa)	Glass Content (%)
125	21	265	20	55

Opportunities to Increase Sustainable Content in Phenolic SMC

- This study investigated maximizing **sustainability of resin** to increase the overall **sustainable content** of Phenolic SMC from **10% to 31%**

PHENOLIC SMC WT.% COMPOSITION

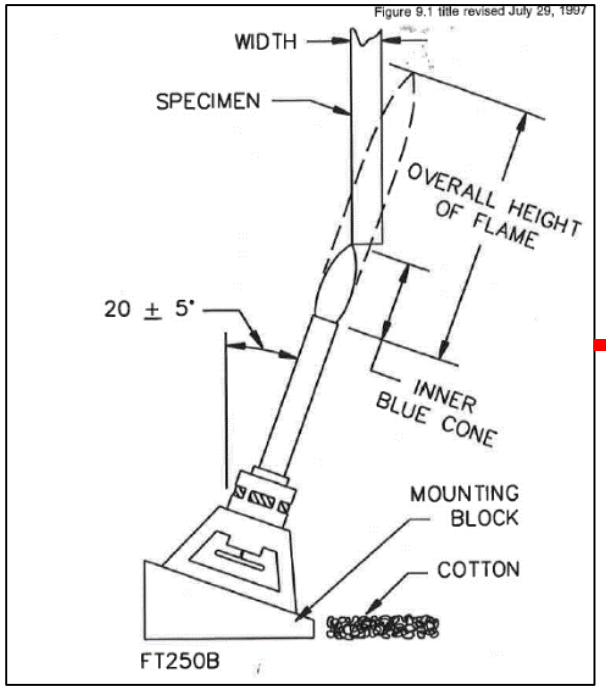




Experimentation Methods

- Rheology Flow and Cure Analysis
  - Dynamic Temperature Oscillatory Evaluation, 10^{o} C/min
  - 25 mm parallel plates, 0.5 mm gap
  - 1 Hz frequency, 0.1% strain rate
- 30 Minute Burn Char Strength
  - 30 minute vertical burn with UL94-5VA flame
  - Residual char strength determined by 16 mm diameter probe
- Mechanical Evaluation
  - Tensile – ISO 827
  - Flex – ISO 178
- Glass Content Determination
  - Sample burn-off at 600^{o} C for 3 hours
  - Glass fiber washed and dried

30 Minute Burn Char Strength



UL94-5VA Flame

30 Minute Vertical Burn

Char Strength Test

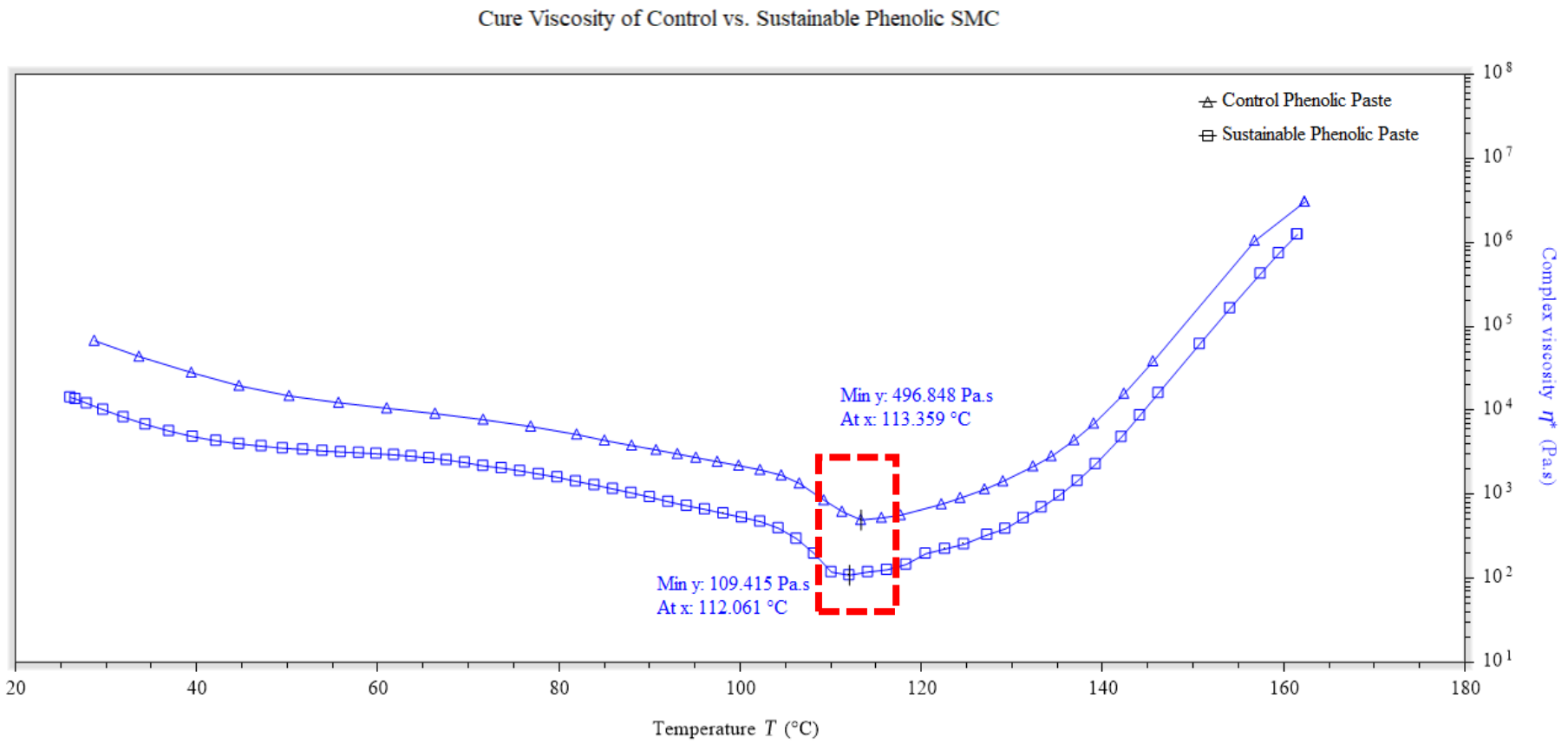
30 Minute Burn Char Strength

- Both resins achieved the target of 200 N char strength
- The control resin seemed to perform better than the sustainable resin
  - This may be optimized with sustainable resin synthesis optimization

Description	Thickness (mm)	Char Strength
Control Phenolic SMC	3.05	**612.3**
Sustainable Phenolic SMC	3.05	**249.7**

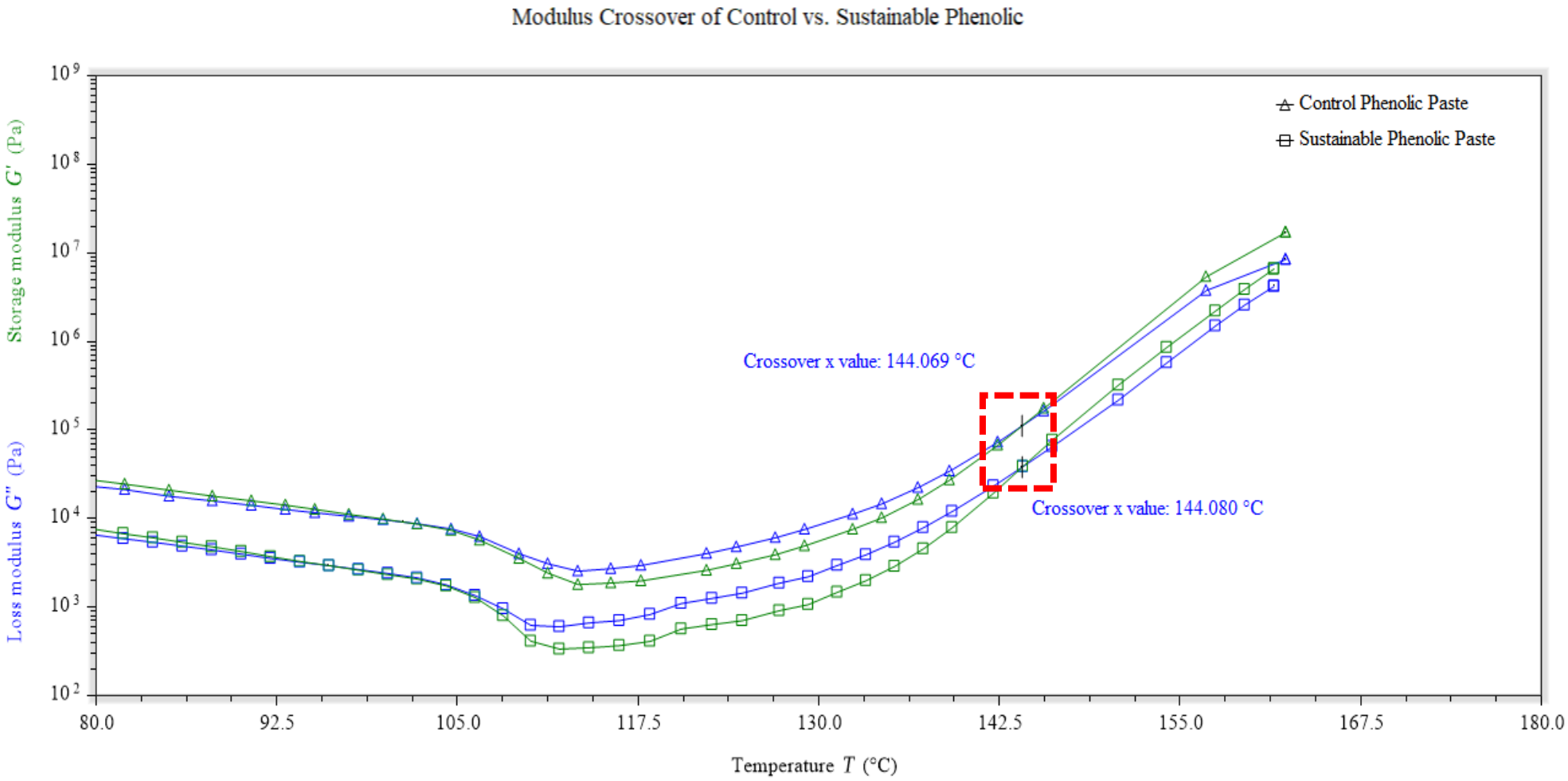
Rheology Results – Minimum Viscosity

- Control and Sustainable resins have near identical melt behavior (112º C & 113º C)
- Difference in room temp. viscosity due to minor maturation differences



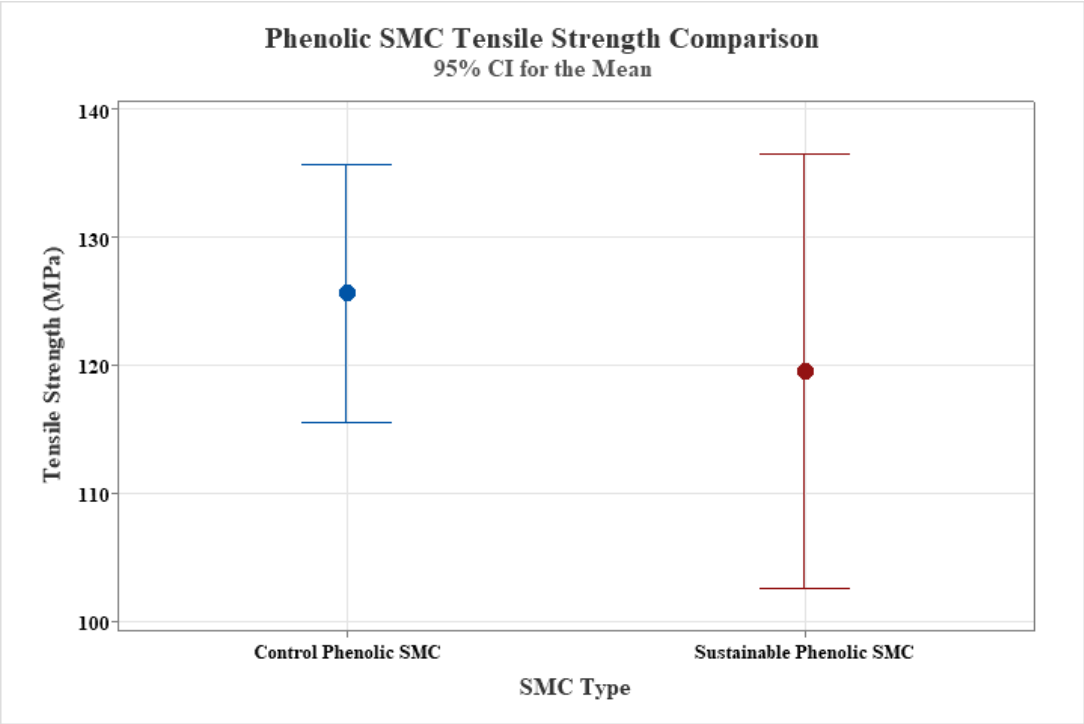
Rheology Results – Gel Point

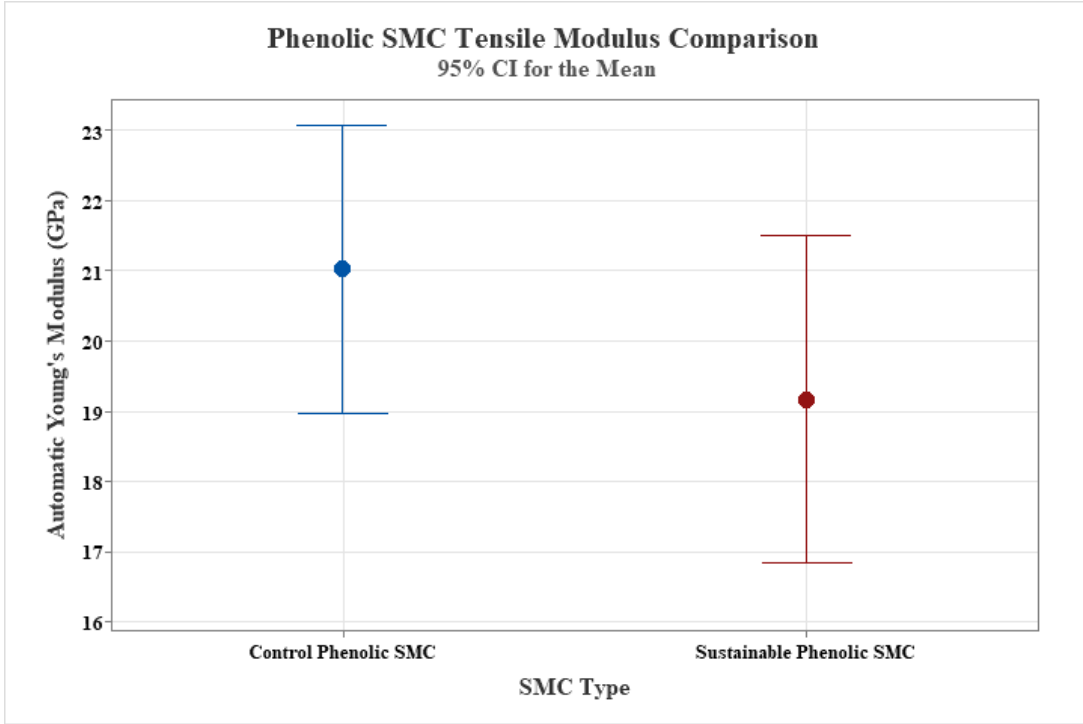
- Identical modulus crossover points, indicating similar rate of cure (144º C)



Mechanical Results – Tensile

- No statistical difference in tensile performance between Control and Sustainable resins

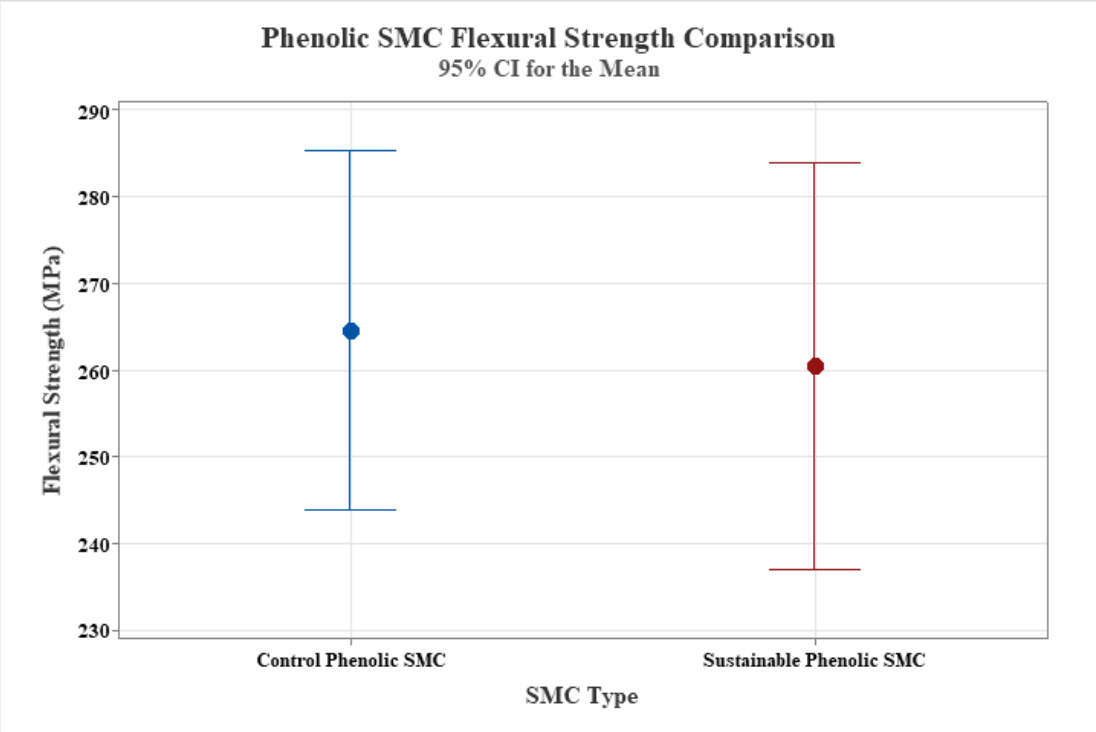


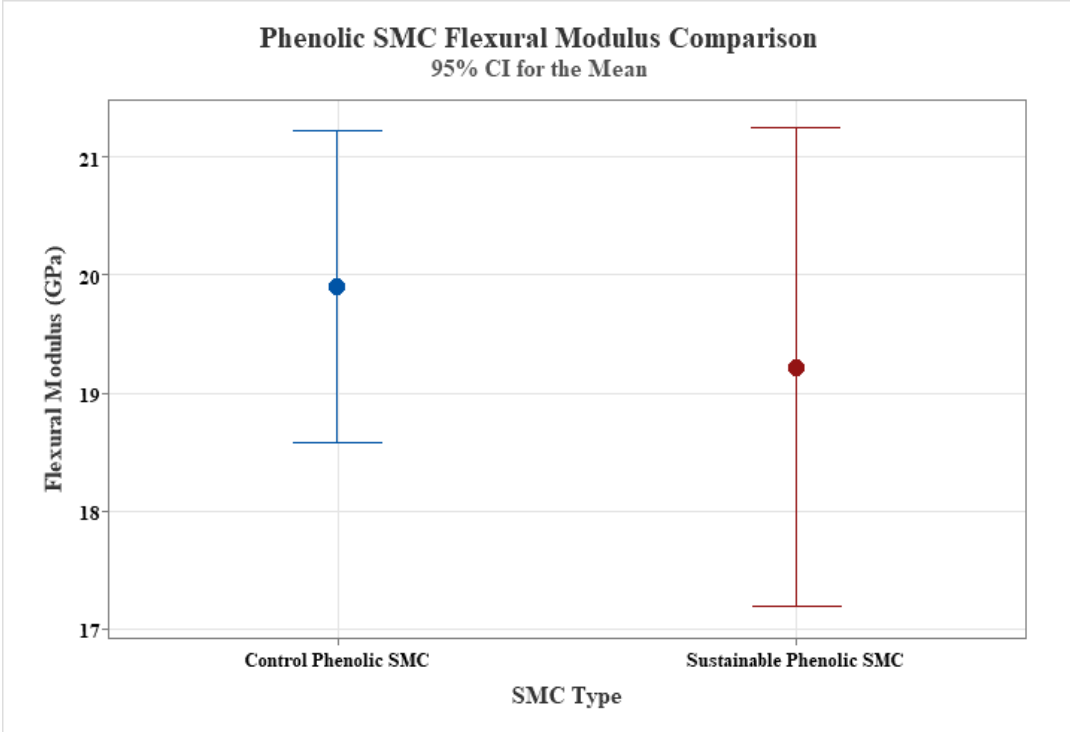


Resin	Tensile Strength (MPa)	Young's Modulus (GPa)
Control	125	21
Sustainable	119	19.1

Mechanical Results – Flexural

- No statistical difference in flexural performance between Control and Sustainable resins





Resin	Flexural Strength (MPa)	Flexural Modulus (GPa)
Control	265	20
Sustainable	260	19.2

Glass Content Analysis

- No statistical difference in glass contents between the control and sustainable SMCs
- However, the sustainable SMC was found to be slightly lower in fiber content

Description	Glass Content (%wt.)	Standard Deviation
Control Phenolic SMC	55.95	1.19
Sustainable Phenolic SMC	54.70	0.42

Conclusions

- The sustainable content of phenolic SMC was **increased from 10% to 31% by utilizing a highly sustainable resin**
- Processing, cure speed, and mechanical performance of sustainable resin was identical to control
- A slight decrease in FR properties observed in the sustainable resin
  - May be addressed with resin synthesis optimization
- **Now possible to have composite battery enclosures with over 30% sustainable content**

Special Thanks

- Austin Pakkala
  - Teijin Automotive Technologies R&D
  - Auburn Hills, MI

- Frank Ludvik
  - Senior Sales Specialist – Bakelite Synthetics
- Bakelite Synthetics R&D
  - Dexter Johnson
  - Ramji Srinivasan
  - Alex Muzzillo