SMC Specific Modulus Targeting

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Outline

- Background
  - Automotive SMC advantages
  - OEM SMC needs
- SMC targets
  - Processing, Density, Mechanicals
  - Specific modulus definition
- High Modulus System
  - Material selection
  - DOE
- Summary
- Future Work
- Acknowledgement

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Background

- Automotive SMC advantages
  - Lower tooling cost, low scrap, low labor, corrosion resistant
  - SMC lightweighting advantages
    - High strength to weight ratio with good stiffness
    - Part consolidation – fewer tools/operations per part
    - Part design flexibility – difficult compound curves possible
- OEM's SMC needs going forward
  - Meet increased lightweighting goals at reasonable cost
    - Lower overall part weight but same mechanical capability
    - Carbon fiber, S-glass, directional fiber too expensive
    - Maintain design flexibility
  - Solution strategy
    - Demonstrate ability to alter mechanical properties and density to meet specific mechanical requirements

High Modulus System

- Processing
  - Must still process on existing SMC machinery
  - Must be usable in a similar way to current SMC
- Density
  - Driven by reinforcement content
  - Usable range from 1.2 to 1.9 g/cm^3
- Mechanicals
  - Limit focus to Specific Tensile Modulus
    - Specific modulus is defined as the tensile modulus divided by density: (GPa) / (g/cm^3)
    - This helps to compare the lightweighting capability of a material by density, strength and stiffness
    - Target same specific modulus in high, medium and low densities then work to improve

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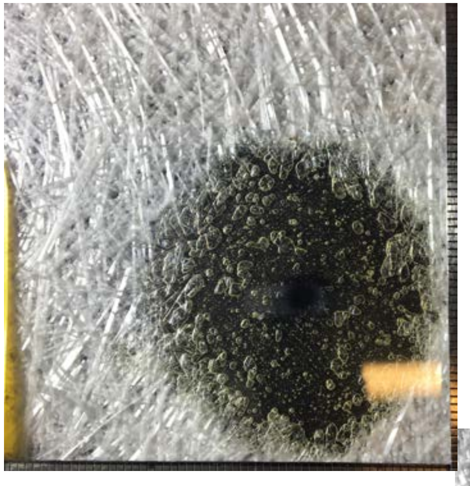
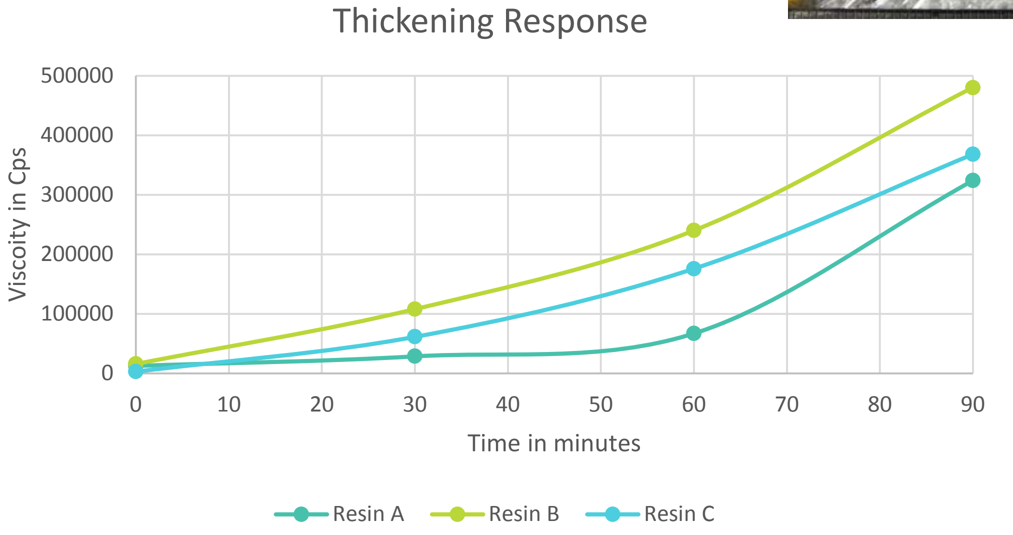
High Modulus System – Material Selection

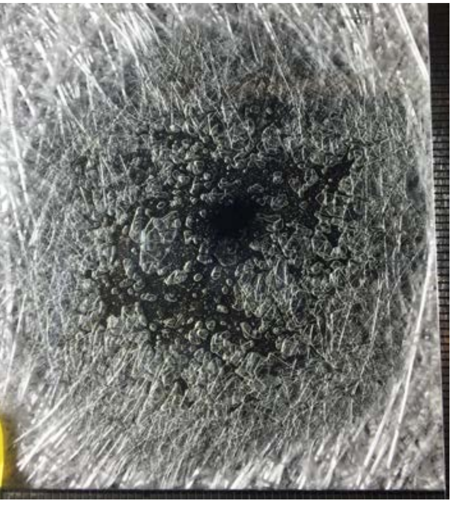
- Resin Screening –
  - Viscosity
  - Thickening
  - Reinforcement wetting – maximum fiber load
  - Mechanical properties
- Filler screening
  - Viscosity vs filler load
  - Density ranges available

High Modulus System– Resin Screening

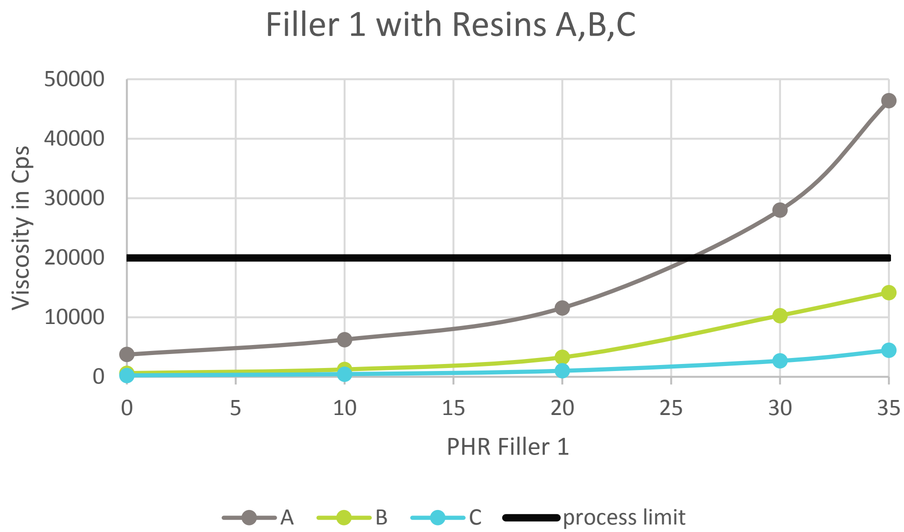
	Viscosity (cP)	
	30° C	40° C
Resin A	2212	1117
Resin B	347	189
Resin C	209	108

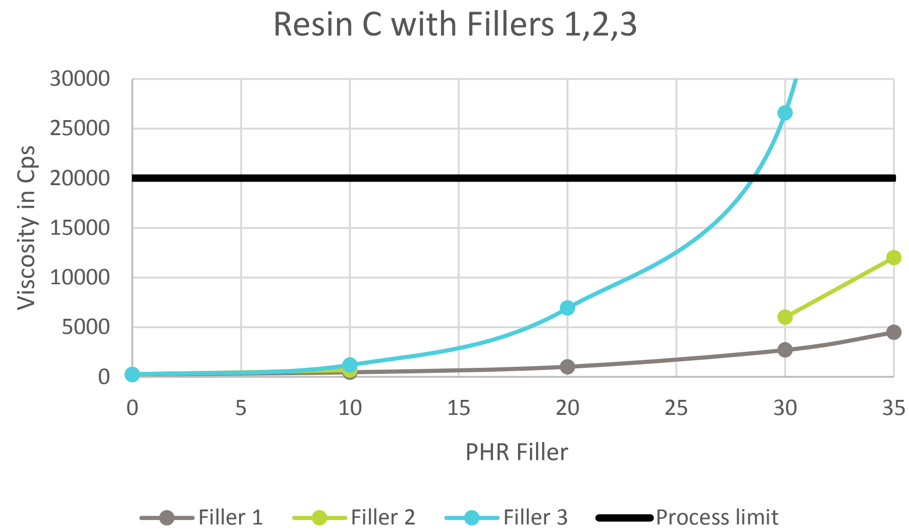


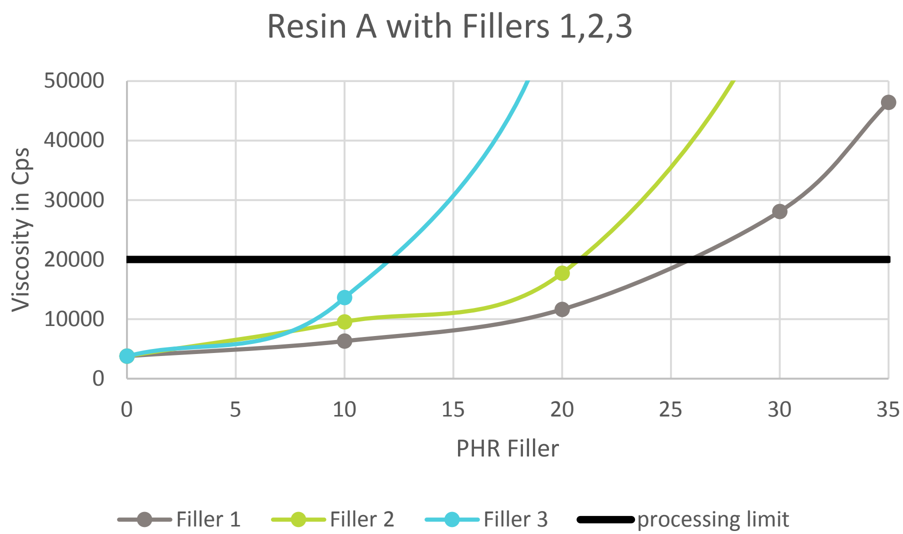




High Modulus System– Filler Screening







	Resin C PHR Filler		
Filler	10	20	30
1	1.14	0.95	0.81
2	1.05	0.82	0.68
3	0.95	0.7	0.56

Calculated A paste density

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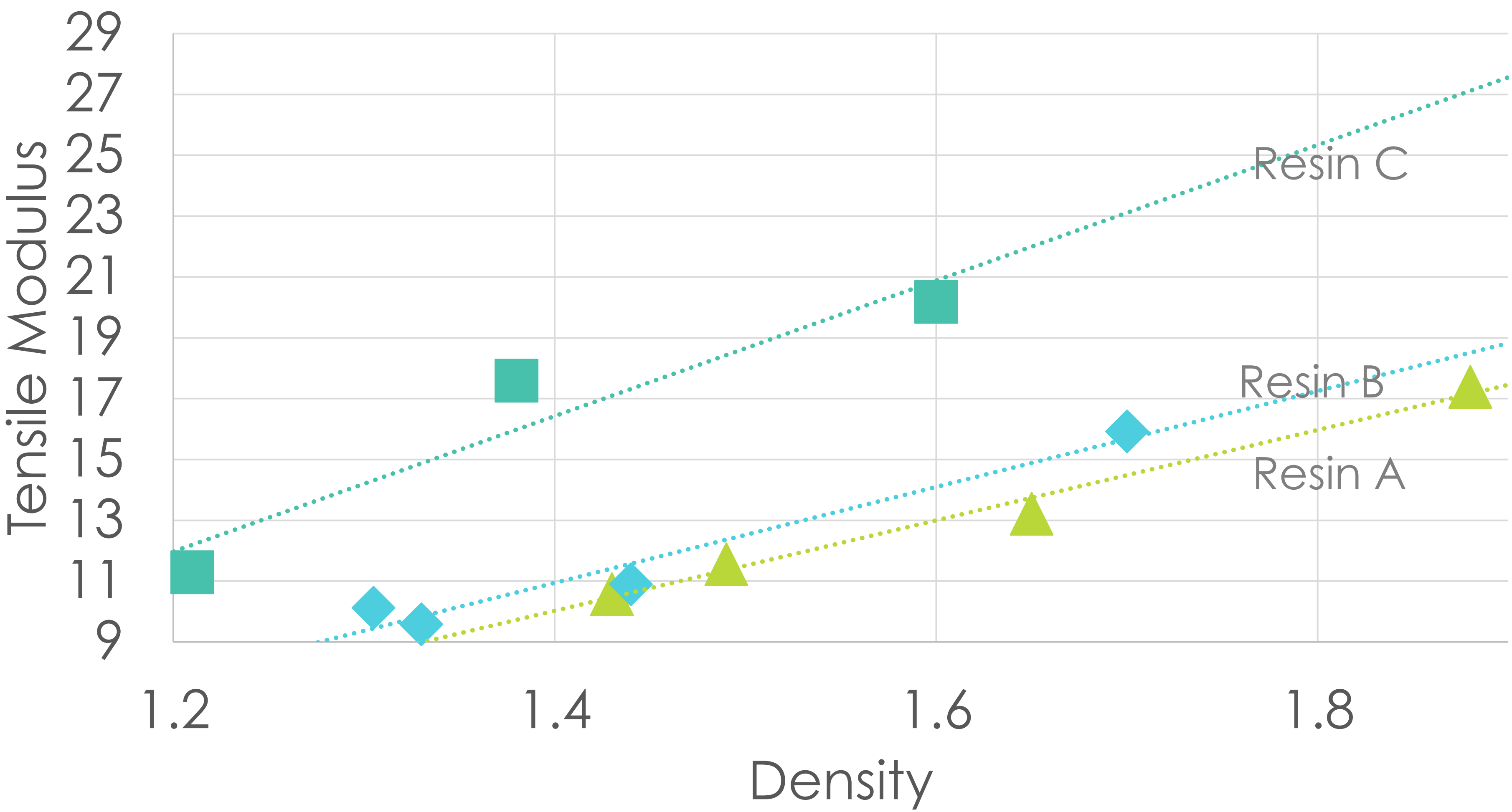
High Modulus System– DOE 1

- Two factors investigated for each resin:
  - Fiber volume %
    - Values determined thru SMC wetting
      - High values 60-65% fiber by weight, ~ 40% by volume
      - Low values 40-45% fiber by weight, ~ 20% by volume
  - Low density filler weight %
    - Values determined thru viscosity measurements
      - High value limited to 20000 cps A paste viscosity
      - Low value set to 2000 cps A paste viscosity

High Modulus System– DOE 1 Results

	density	tensile modulus	specific modulus	vol % fiber
Resin A	1.88	17.4	9.3	51.4
	1.65	13.2	8.0	37.1
	1.49	11.6	7.8	26.7
Resin B	1.7	15.9	9.4	43
	1.44	10.9	7.6	28.7
	1.305	10.1	7.8	21.3
Resin C	1.6	20.2	12.6	39.9
	1.38	17.6	12.7	28.6
	1.21	11.3	9.3	17.7

High Modulus System– DOE 1 Results



High Modulus System– Resin B and C

- Investigate resins B and C for density effect on tensile modulus:
  - Hold fiber volume % constant
    - Target ~ 25-30% fiber by volume
  - Vary density with filler
    - High value limited to 20000 cps A paste viscosity
    - Low value set by resin viscosity without filler

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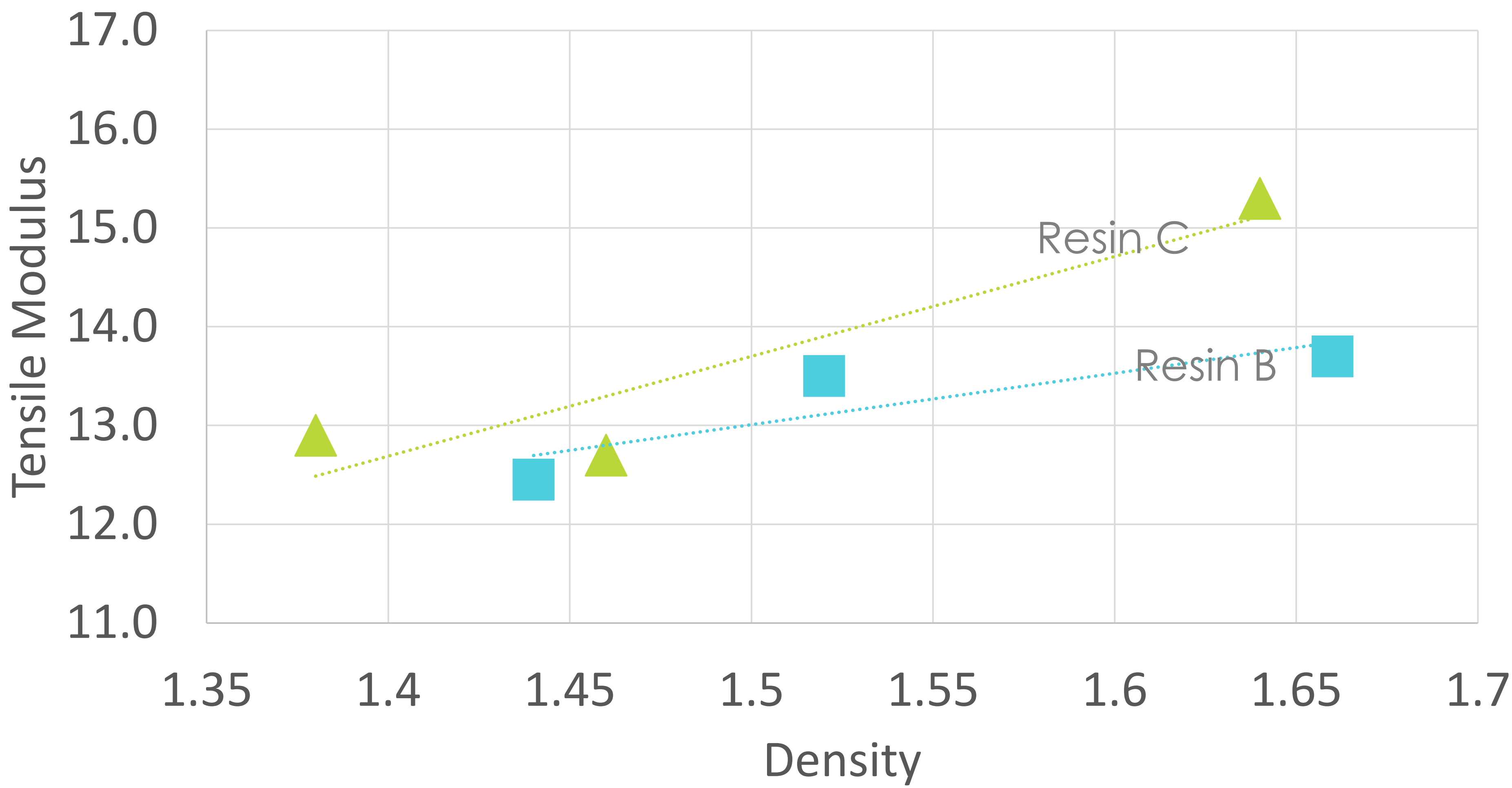
High Modulus System– Resin B and C

	density	tensile modulus	specific modulus	vol % fiber
Resin B	1.66	13.7	8.3	31.2
	1.52	13.6	8.9	31.0
	1.44	12.5	8.6	31.0
Resin C	1.64	15.3	9.3	33.4
	1.46	12.7	8.7	29.4
	1.38	12.9	9.3	28.0

High Modulus System– Resin B and C



High Modulus System– DOE 2

- Investigate Resin A,B and C across narrower fiber volume range:
  - Test resins across three fiber volumes
    - Target 35 % to 45% by volume
  - With three filler loads
    - 0, 15 and 30 phr filler

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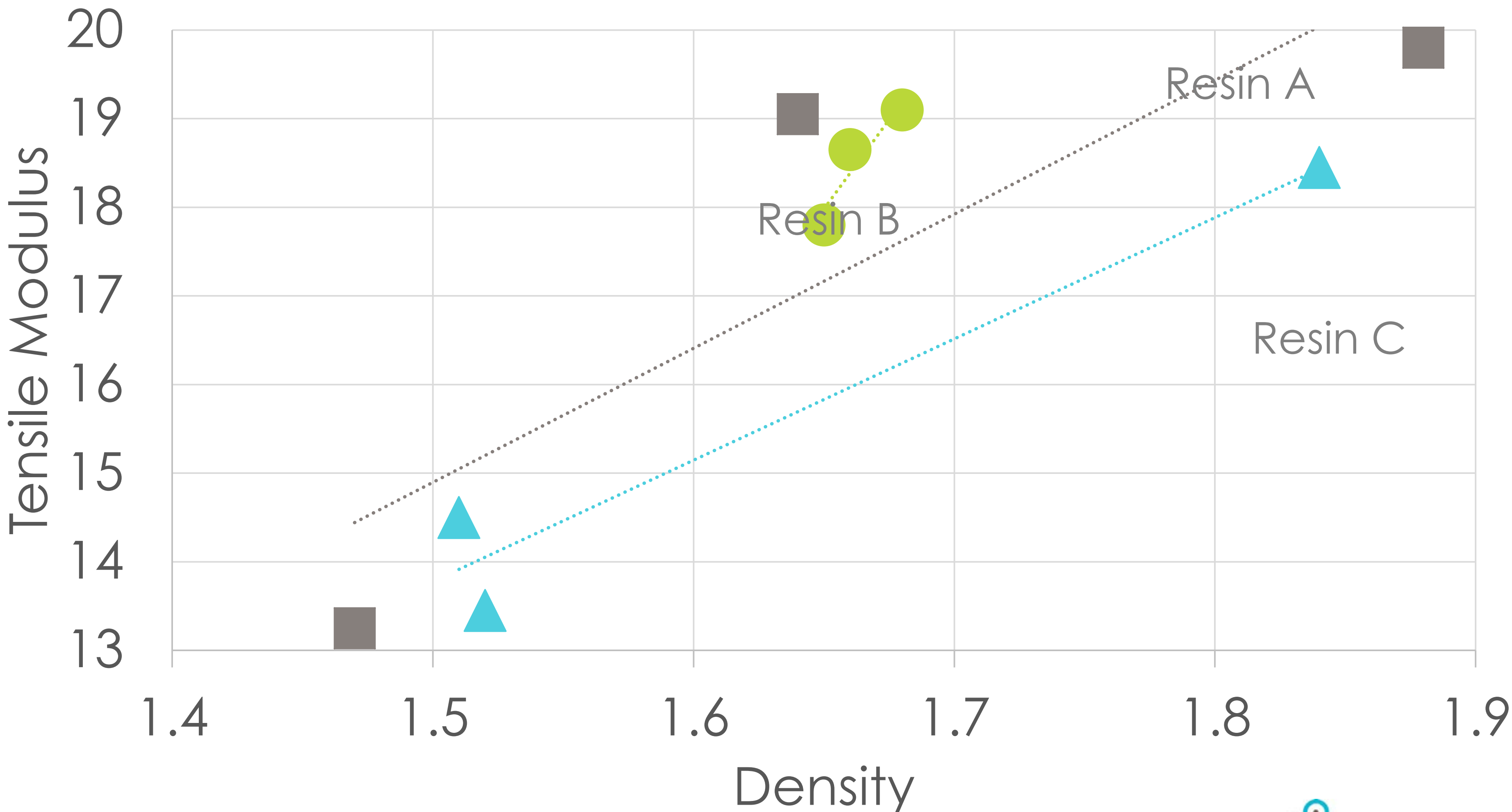
High Modulus System– DOE 2

	density	tensile modulus	specific modulus	vol % fiber
Resin A	1.88	19.8	10.5	46.7
	1.64	19.05	11.6	49.2
	1.47	13.25	9.0	50.2
Resin B	1.65	17.8	10.8	39.6
	1.68	19.1	11.4	46.8
	1.66	18.65	11.2	37.1
Resin C	1.84	18.45	10.0	47.6
	1.51	14.5	9.6	39.4
	1.52	13.45	8.8	46.9

High Modulus System– DOE 2



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High Modulus System– Physicals

avgs	density	Flex Str Mpa	Flex Mod Gpa	SBS Mpa
Resin A	1.88	318	16.5	35.5
	1.64	208	13.6	21.1
	1.47	115	10.8	12.2
Resin B	1.65	300	15.4	25.6
	1.68	259	14.5	26.0
	1.66	179	13.9	19.1
Resin C	1.84	138	17.2	40.1
	1.51	269	12.6	28.0
	1.52	260	13.2	20.0

Summary

- Demonstrated Feasibility of SMC with a specific modulus can be achieved over a range of densities.
  - Low to high density SMC
  - Fiber Volume control
  - Resin effect
- Specific Modulus improvement
  - Fiber loading optimization
  - Resin selection
- Good processing properties
- Good physical properties

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Future Work

- Optimize high modulus system for better processing
- Additional testing of high modulus system to ensure reproducibility of physical performance
- Explore approaches to increase specific physical characteristics to match needs – lots of levers
  - Optimize filler%, fiber% and resin additives to achieve specific physical parameter target of interest
    - Interlaminar shear, impact resistance, flexural strength etc

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Abstract

- Demand for lightweight manufacturing options in the automotive industry is increasing in response to mandated fuel efficiency standards. Specific modulus, the tensile modulus of a material divided by its specific gravity, is one method used to compare the lightweighting capability of one material to another allowing manufacturers to better design parts. SMC can be formulated with various tensile moduli or specific gravities, balancing the two to achieve a high specific modulus at a variety of specific gravities is the goal of this paper. This paper will demonstrate that SMC with a specific modulus target can be formulated for over a range of specific gravities.

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