SESSION 15: SUSTAINABLE COMPOSITES

Post-Consumer Recycled Based High-Heat PA6,6 Development for Turbocharged Air Intake Ducting

JAMES KEMPF
WELLMAN ADVANCED MATERIALS
PROBLEM/OPPORTUNITY

1. **TURBOCHARGER MARKET GROWTH:** Through the year 2025, global automotive engines with turbochargers are predicted to see a 9.39%\(^1\) compounded annual growth rate (CAGR) through the year 2025 reaching an installation rate for light-vehicles in the US of well over 36%\(^2,3\)

2. **GLOBAL MARKET GROWTH:** The global car and light commercial vehicle market of 86 million vehicles is expected to see growth of 2.4-7.1%\(^4\) through the year 2025

3. **C.A.F.E. = HIGHER BOOST = HIGHER UNDERHOOD TEMPERATURES:** The EPA and National Highway Traffic Safety Administration (NHTSA) is forecasting 3 boost levels based on the engine brake mean effective pressure (BMEP), 18 bar, 24 bar, and 27 bar with fuel-consumption reductions of ~12%, 16% and 18%, respectively\(^3\)

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VALUE PROPOSITION

1. **MARKET SIZE**: With a global turbocharging growth of at least 36%, at least a 2.4% market growth through the year 2025 and at an average of 5 pounds usage/vehicle for high heat turbocharged ducting, there will be a market opportunity of more than 187 million pounds by the year 2025.

2. **EXPENSIVE RAW MATERIALS**: Due to a necessity for turbocharged ducting to perform at extremely high temperatures, resins operating in this space are generally more expensive which may permit a value proposition to exist through sufficient research, optimization and testing.

3. **MARKET SEGMENTATION**: Despite ~ 20% of the market expecting to see turbocharger duct temperatures above 210°C, Wellman believes there is potential to create a sustainable PA6,6 high-heat solution that will cover up to 80% of the market in the 170°C-210°C range.
WELLMAN’S SUSTAINABILITY EFFORT

WELLMAN ANNUALLY DIVERTS 42 MILLION POUNDS OF CARPET FROM LANDFILLS

NOT REALLY. IN 2017, 2.9 BILLION POUNDS WENT INTO LANDFILLS (WE RECYCLE 1.4% OF THE TOTAL CARPET THAT WAS REPLACED)

THERE IS ENOUGH PA6,6 AND PA6 CARPET DESTINED FOR LANDFILLS IN THE US TO COVER THE ENTIRE HIGH-HEAT PRODUCT MARKET IN 2025.

THIS IS PRETTY GOOD RIGHT?

SO IS THERE ENOUGH CARPET FOR THIS MARKET?
PRIMARY PROJECT GOALS

B.I.C Performance/$

Function: LTHA for 170-210 @3000 Hrs

High Productivity

Global Sustainability
INTERNAL BUSINESS MODEL

Global Partners
We will focus on our global partners willing to optimize our product in exchange for early adaptation benefits/value.

Market Share
Prior to commercialization, we will confirm we will have sufficient market share to offset development costs.

Functional Optimization
To achieve Best-in-Class balance of function and price, we expect that three optimization/testing loops will be required before commercialization.

Cost Optimization
We will focus on multiple feedstock compounds, prioritizing function first and then backing off for best pricing.
GO-TO-MARKET PLAN: SCREENING

Functional Optimization Screening
3000 Hour Heat Aging @ 170C, 190C, 210C

Retained Tensile Testing Strength [retention %]
Retained Charpy Impact Strength [retention %]

Functional Processing Trial
Total Cost Evaluation

Yield Evaluation Processing Loss and Associated Cost
Raw Material Costs & Heat Stabilization Package

Each Optimization Loop

1. Ranking
2. Ranking

Option A
Option B
Option C
Option D
Option E
Option F
Option G
Option H

Option A
Option B
Option C
Option D
Option E
Option F
Option G
Option H
COMPETITIVE BENCHMARKING

Long Term Heat Aging Temperature (°C)

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Resin A</th>
<th>Resin B</th>
<th>Resin C</th>
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<tbody>
<tr>
<td>170°C</td>
<td></td>
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<td></td>
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<tr>
<td>190°C</td>
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<td>210°C</td>
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3000 Hours Long-Term Heat Aging Competitive Benchmarking

Tensile Strength (MPa)
PHASE 1 TESTING RESULTS

Ecolon High Heat Benchmarking

- Ecolon High Heat Phase 1 Target
- Ecolon High Heat Phase 1 Results
- PA6.6 High Heat w/Special HS
- PPA/PPS/PA66

FELL SHORT OF BUSINESS TARGET
EXCEEDED TARGET
EXCEEDED TARGET
EXCEEDED TARGET

S/Performance
Sustainability
Weldability
Processibility
PHASE 1 TESTING RESULTS

- Testing conducted at 0, 500, 1000, 1500, 2000, 2500 and 3000 Hours
- All testing for screening done only at 23C/room temperature
PHASE 1 TESTING RESULTS

3000 Hours Long-Term Heat Aging Competitive Benchmarking

- Resin A
- Resin B
- Resin C
- Wellman
CURRENT STATUS/TIMELINE

August 2019
- Initial results assessment and presentation to partners
- Phase 1 Screening Testing Complete
- Reformulation Loop Optimization of costs.

September 2019
- March 2020 – August 2020
- Tier I/OEM Test Plan
  - Focus on customer specifications considering realistic metrics and commercialization

February 2020
- Phase 1 and Phase 2 results shared with potential customers & welding evaluation
- Phase 2 Screening Complete
- Reformulation Loop Balancing of function and costs

March 2020
- Focus on customer specifications considering realistic metrics and commercialization
- Tier I/OEM Test Plan
TARGETED PRODUCTS

TARGETED PRODUCTS ARE THOSE WHICH WILL SEE LONG DURATIONS AT ELEVATED TEMPERATURES UP TO 210 C INCLUDING:

1) HOT-SIDE TURBOCHARGED DUCTING

2) INLET-SIDE HEAT EXCHANGERS

3) AIR INTAKE MANIFOLDS WITH INTEGRATED INTERCOOLERS SEEING ELEVATED TEMPERATURES
Thank You for your attention