Aerospace and Automotive Seat Frames from Carbon and PPS Thermoplastic Tape

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Outline

- Background
  - Aerospace and Automotive Seat Frames
  - Trends Supporting Change
  - Composites Benefits and Challenges

- New Thermoplastic Composite Offset
  - PPS/Carbon Tape Preform
  - Processing Options

- Award-Winning Seat Design

- Summary
Background

- Aviation and automotive seat frames
  - Most are multi-piece aluminum designs
  - Frames represent a significant proportion of
    - Total seat weight
    - Total vehicle weight
  - Both industries face significant pressure
    - To reduce vehicle mass and improve fuel efficiency
    - To maintain or reduce production costs
New materials and processes that offer opportunities to reduce weight and cost, and add functionality are welcome, but …

Unit cost vs. aluminum remains a key issue that must be overcome in order for change to occur
Background

Composites could be a good alternative because they offer the opportunity to:

- Reduce weight
- Reduce or eliminate assembly operations
- Add functionality (molded-in features, more complex geometry with better ergonomics, less buzz, squeak and rattle (BSR) etc.)
Background

But...

- Costs must be competitive with aluminum
- Materials must meet cabin requirements for
  - Fire / smoke / toxicity (aerospace)
  - Emissions / fogging (automotive)
Background

- High-performance composite alternatives to aluminum seat frames
  - Continuous carbon fiber reinforcement
  - High-temperature matrix options
    - Thermosets: epoxy, urethane, polyimide
    - Thermoplastics: PEEK, PEKK, PPS, and PEI
  - Each system offers challenges and opportunities
Background

- High-performance thermoset resins
  - Lower base resin but higher prepreg and production costs
  - Lighter than metals with excellent mechanicals and thermal performance
  - Most require halogenated additives to meet flame retardance requirements (achieved at the expense of smoke and toxicity)
  - VOC emissions can also be an issue
  - Scrap and end-of-life parts not easy to recycle
Background

- High-performance thermoset processes
  - Tooling can be low cost depending on process
  - Many processes are slow, hard to automate, and require skilled labor
  - Post-mold finishing can add significant time and expense

Thermosets Offer Definite Benefits vs. Aluminum but Can be Improved Upon
Background

- High-performance thermoplastic resins
  - Higher base resin costs but lower prepreg and production costs
  - Lighter and more damage tolerant than metals or thermosets
  - Some resins inherently flame retarded with low smoke and toxicity
  - All thermoplastics are melt-reprocessable, facilitating in-plant and end-of-life recycling
Background

- High-performance thermoplastic processes
  - Tooling can be more costly but most processes are fast and highly automated, which can lower production costs for medium-to-high volume programs
  - Much less post-mold finishing and more decorating options
  - VOC emissions lower (processing and use)
Background

- If you could combine...
  - Low cost but rapid manufacturing process that allows high-performance assemblies to be produced even at low volumes, with
  - Performance benefits of thermoplastics (lighter, more damage tolerant, recyclable, low VOCs, faster processing, inherent flame resistance with low smoke and toxicity)

That would be a Game-Changing Seat Frame Technology for both Aerospace and Automotive
New Thermoplastic Composite Offset

- High-performance thermoplastic matrix
  - Linear polyphenylene sulfide (PPS)
    - Semi-crystalline for excellent and broad chemical resistance (no known solvent at rm. Temp.)
    - High thermal performance (tg \(=90^\circ\text{C}\), tm\(=285^\circ\text{C}\))
    - Produces stiff but lightweight parts (SG\(=1.34\text{ g/cm}^3\)) with performance similar to aluminum
    - Inherently flame retardant (UL\(^\circ\) 94 V-0; LOI >40)
    - Easy to process; viscosity tunable to different production methods
New Thermoplastic Composite Offset

- High-performance thermoplastic composites
  - PPS offers good wetout of reinforcement
    - Glass, aramid, or carbon fiber
    - Tow or fabric weaves
  - Processable via
    - Hand layup with oven/autoclave consolidation
    - Resin infusion
    - Thermoforming / thermostamping / compression molding
New Thermoplastic Composite Offset

- Developing a low-cost process for thermoplastic composites
  - Must produce high-quality parts in a repeatable process
  - Must be cost effective for small and large parts at low as well as high production volumes
  - Must work with a variety of reinforcements
  - Must be able to produce prepreg / semipreg or preform
New Thermoplastic Composite Offset

- Cost-effective composite form factors
  - PPS / carbon films, tapes, and sheet products
    - Melt PPS and produce crystal film
    - Join PPS film with carbon fiber tow or fabric, consolidate under heat and pressure
      - Form thin films that subsequently are slit and braided
      - Form thick sheets that are cut into blanks and subsequently molded
    - Automated processes with excellent control over fiber positioning
Step 1: PPS Film Production

Starting product:
Linear PPS pellets
- Temperature stability
- High level of hardness and impact strength
- Excellent resistance to chemicals
- Broad temperature range
- Inherent flame resistance

Film production
Station 1 – PPS pellets are converted into films with a thickness of 50 to 200 µm. The film is wound onto rolls of 100 kg in a flawless state, crystal clear and with the required characteristics with regard to strength and dimensional stability.
Step 2: PPS / Carbon Film / Sheet Production

Starting product:
Basic Matrix of Linear PPS / Carbon Fiber Fabric

Laminate production

Step 2 – The carbon fiber fabric and linear PPS film are bonded together in a press, under high pressure and high temperature, into high-strength, dimensionally stable and resistant films or sheet products in the desired thickness for the molding process selected.
Step 3a: PPS / Carbon Braided Preform

PPS / carbon film is
- Slit and braided
- Used in bladder molding, resin infusion or other tape layup processes

Braided preform variables
- Braid angle
- Braid diameter
- Spacing
Step 3b: PPS / Carbon Molding Processes

Starting product:
Composite sheets (blanks) cut to the required size

Thermoforming
(1- or 2-sided tooling, with or without plug or vacuum assist)

Composite Sheet

Positive Side of Tool

Negative Side of Tool

Shaping / Molding
Step 3 – The composite sheets are pre-heated and subsequently shaped into the desired form under pressure and high temperature.
Step 3c: Other PPS / Carbon Molding Processes

Automated Dynamics – Fiber Placement

Lingol – Thermoforming

FiberForge – Compression Molding
Award-Winning Seat Design

- Owing to versatility of preform and molding technologies available for PPS/carbon, many different seat components can be produced.

- To demonstrate the versatility of the technology, a demonstration modular composite seatback and top seat frame were developed.
Award-Winning Seat Design

- Developmental seatback partners
  - Cutting Dynamics, Inc. (CDi)
  - Ticona Engineering Polymers
  - TenCate Advanced Composites
  - A&P Technology (A&P)

- Work began in 2009
Award-Winning Seat Design

- (Top) seat frame
  - Early challenges (A&P and CDi)
    - Identify a thin tape that would run through a braiding machine
    - Develop design tools to predict type of braid required to meet geometry of seatback
    - Modify braiding equipment to manipulate the PPS / carbon tape into a preform
    - Identify preform configuration
    - Develop innovative tooling
Typical Tool for Tubular TP Composite

- Matched metal tool for rapid, quality parts
- Split mandrel for ease of removal
- Silicone sleeve for additional expansion of tool from ID
- Heating/cooling channels to reduce process time
Award-Winning Seat Design

- (Top) seat frame
  - Proprietary CDi forming process
    - Uses braided PPS/carbon tape
    - High speed (capable of production volumes of 400,000 annually)
    - Excellent repeatability and reproducibility (R&R)
    - Produces complex geometry, hollow-section parts
Award-Winning Seat Design Version One

- Seatback
  - Sourced from recycled content PPS and chopped carbon fiber, which in turn is recyclable
Award-Winning Seat Design Version 2

- Hollow braided frame (formed from PPS / carbon braided tapes) behind seatback
- Seatback molded from recycled PPS and carbon fiber
- High-speed production process developed to produce seat frame
- Seatback drilled for rivets and joined to frame
Award-Winning Seat Design

- System won the JEC Thermoplastic Composites award in April 2011
- Currently in production for aerospace seat suppliers by Cutting Dynamics using a commercial viable process.
Award-Winning Seat Design

Benefits of modular seatback system

- vs. Aluminum
  - 30% lighter
  - Meets functional mechanical performance
  - Cost competitive

- vs. Thermosets
  - Lighter parts
  - Non-toxic manufacturing process
  - Fully recyclable (in-plant and post-consumer)
  - Much faster manufacturing process with less post-mold finishing
  - Eliminates fasteners and adhesives with welding process
Award-Winning Seat Design

- Benefits of modular seatback system
  - Meets aerospace industry’s strict flame/smoke/toxicity requirements without halogenated flame retardants
  - Lower cost vs thermoset due to high throughput process
  - Significant weight reduction per aircraft

Addresses Needs of Both Aerospace and Automotive Industries
Summary

- Both aerospace and automotive need seat options that
  - Offer comparable or better mechanical performance while lowering weight and costs
  - Comply with cabin safety requirements
  - Meet production volumes
  - Reduce VOCs, carbon emissions, energy use
  - Improve passenger comfort
- New thermoplastic PPS/carbon modular seatback system answers these needs and more
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