Recent Developments in Thermoplastic Processing & Part Mfg.
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SME Advanced Thermoplastic Composites Seminar
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www.barrday.com
Why Thermoplastics?

- Extremely light, tough, durable & moldable
- Two types of plastics:
  - Thermoplastics
    - Remeltable/remoldable
  - Thermosets
    - Chemical reaction, cannot be remelted/reprocessed

Plastics have revolutionized the world
- Used in all walks of life, from clothing to household goods, to transportation, etc.
- Over 299 million tons produced worldwide in 2013*

* www.worldwatch.org
Why Thermoplastics?

Source: Plastics Industry Producers’ Statistics Group, April 2016
Why Thermoplastic Composites?

**Thermoplastic Composites**

- Superior mechanical / physical properties
  - Excellent toughness / impact resistance
  - Superior wear / abrasion resistance
  - Very low moisture absorption
  - Excellent hot / wet properties
  - Outstanding corrosion / solvent resistance
  - Outstanding flame / smoke / toxicity
  - Environmentally friendly / low volatiles

**Thermoplastic Processing**

- Reduction in per part costs:
  - Rapid processing possible → no cure
  - Net shape processing → no bleed
  - Lower scrap → recyclable / reprocessable
  - No out of date → infinite shelf / pot life
  - Multi step manufacturing → thermoform / remold
  - Thick part processing → no exotherm
  - Easier bonding → welding / fusion
  - Damage repair → reconsolidates
Relative Toughness/Impact Properties

- CAI: PEKK/C = ~325 MPa, Epoxy/C = ~200 MPa
- G1C: PEKK/C = ~1,400 J/m², Epoxy/C = ~300 J/m²
The Nano-Technology of the 1980’s

Product format
- Difficult to prepreg / RTM
  - Viscous (Pushing taffy through cheesecloth)
- Limited government (military) support (1990’s)

Limited processing technologies/know-how
- High temperature processing
- New capital investment required
- Small/niche parts makers

F-22 as a show case for thermoplastics
- Processing issues & costs limited applications
- Stunted growth in aerospace
Thermoplastic Composites Now

Processing technologies becoming more robust
- Base of qualified processors is growing
  - ATL/AFP, Continuous Compression Molding (CCM), Composite Over-Molding, Stamp/Thermo Forming, Oven Consolidation, Pultrusion, etc.
- Now being tested and qualified in a variety of high performance applications

Growth in a wide variety of markets
- Aerospace, defense, industrial, automotive, oil & gas, medical, et. al.
- Europe historically ahead of US, but is this changing?
Advancements in Processing

- Get out of the autoclave!
- Fabricate high quality parts rapidly
- Processes:
  - Thermo / Stamp Forming
  - Continuous Compression Molding (CCM)
  - Composite Overmolding
  - Pultrusion
  - Automated Fiber Placement / Tape Laying (AFP / ATL)
  - Discontinuous Long Fiber Compression Molding (DLF)
Thermo / Stamp Forming

- Great for shaped / molded parts
- High volume capability
  - Rapid processing (i.e., < 2 minutes)
- High speed automated lay-up
- Wide variety of polymer / fiber options
- Wide range of thicknesses / sizes

Automated lay up

Low porosity consolidation

Press form complex shapes

Courtesy Tri-Mack Plastics Mfg.
Thermo / Stamp Forming Examples

Engine mounting bracket
- Thick composite part
- Fatigue resistance
- Temperature resistance

Courtesy Olimunllum
Thermo / Stamp Forming Examples

- Formed box and brackets
  - Tailored lay ups
  - Short cycle times
  - Finish milling / machining
  - Large / fully assembled parts

Courtesy Tri-Mack Plastics Mfg.
Thermo / Stamp Forming Examples

- Deep draw
- Complex geometries
- High volume
- Rapid processing

Courtesy Oribi Mfg.
Continuous Compression Molding (CCM)

- Flat laminates or shapes – continuous lengths
- Prepreg tapes, fabrics, mats
- Speeds up to 80 m/hr
- Low porosity
- Widths up to 50 in (1.27 m)

Courtesy xperion GmbH
CCM Examples

- Structural & semi-structural parts
- In production – aerospace, industrial, et al.
- Wide variety of polymer/fiber combinations

Courtesy xperion GmbH & Cutting Dynamics
Composite Overmolding

Combine properties of continuous fiber composites with flexibility and cost savings of injection molding
– Tailored / “localized” reinforcement
– Complex shapes / geometries
– Automated processing
– High speed molding
– Create complete assembly (inserts, fasteners, etc.)

Courtesy Tri-Mack Plastics Mfg.
Overmolding Examples

TP UD & injection mold – process and examples

In-mold forming & assembly

Steel inserts

UD Thermoplastic Composite

Injection Molding

Courtesy Tri-Mack Plastics Mfg.
Thermoplastic Pultrusion

- Continuous lengths
- Geometric shapes & profiles available
  - Consistent geometries
- Low cost process
  - Low labor costs

Courtesy Hutchinson Aerospace
Thermoplastic Pultrusion

Thermoplastic Composite Profiles

TPC stringers for primary structure

Overmolded TPC profiles for secondary structure

Courtesy Hutchinson Aerospace
AFP / ATL Processing

- Robotically controlled – automated laydown
  – Ability to orient fiber directions automatically
- In situ processing or combined with low cost consolidation techniques
- Wide range of part sizes and geometries

Courtesy Automated Dynamics
AFP / ATL Examples

- Cobonded, skin stiffened aerospace structures
  - No adhesives
  - No fasteners

Courtesy Automated Dynamics
AFP / ATL Examples

Thermoplastic Composite Pipe

Courtesy Airborne Oil & Gas
AFP / ATL Examples

Representative fuselage A350 : 6m x 2.2 m x 22 ply
Panel lay up : 16 bobbins x ¼ in wide TP UD

Courtesy Coriolis Composites SAS
Discontinuous fibers
- Long fiber, high fiber volume, random orientation

Semi-structural parts

Great for complex shapes / geometries (3-D)

Near-net mold
- Low scrap, minimal secondary operations

Courtesy Greene-Tweed & Co.
Mold in features

- Fasteners
- Inserts / bushings
- Bosses
- Ribs

Courtesy Greene-Tweed & Co.
In Conclusion

TPCs beginning to fulfill their promise!
- The future has never been brighter

Parts processing technologies leading the way
- High volume low cost processing progressing rapidly
- Complex shapes / contours being developed
- Expanding financially stronger supply chain

Can thermoplastics eventually overtake thermosets as the matrix of choice for high performance composites?
SME Thermoplastics Seminar

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