AUTOMOTIVE THERMOPLASTIC COMPOSITES . . .
INDUSTRY STRUCTURE AND NEW TECHNOLOGIES
RESPOND TO A GLOBAL RECESSION

PRESENTED BY:
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PREPARED FOR:
SPE AUTOMOTIVE COMPOSITES
CONFERENCE
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b/mydox/papers/composites 09.ppt
Robert Eller Associates LLC is a global plastics consulting company providing analysis in support of technical, marketing, and economic strategic management decision-making.

- Based in Akron, Ohio, with offices in Paris, Shanghai, New Zealand.
- Asia: Active in China, India, Middle East.
- Key Focus Areas: Thermoplastic Composites, TPEs, ETPs, Polyolefins, Automotive, Compounding, and Foams.
- Multiclient studies:
  - China TPE Market
  - North America/Europe TPE Market.
- Single-client decision support analyses.
- Mergers and Acquisitions:
  - Complete management service for small acquisitions
  - Due diligence support
  - Technical advisors.
PRESENTATION OUTLINE

• Global Macroeconomic Situation/Automotive Impacts
• Automotive Supply Chain Responses
• Thermoplastic (TP) Composites(a) in the Automotive Market
• Paths to the TP Composite Market
• TP Composite Technology Responses and Opportunities
• Future Vision/Summary

Notes: See abbreviations in Appendix
(a) Focus on long fiber reinforced thermoplastics (LF-RTP)
Notes:
(a) Talc, mica, basalt, etc.
(b) Micro-talcs opening new applications (e.g., exterior panels, hatchback on Ford Kuga)

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2009
MACROECONOMIC SITUATION/AUTOMOTIVE IMPACTS
GLOBAL ECONOMIC GROWTH: 2 YEAR TROUGH

ANN. % CHANGE (AT PPP)

ADV. ECON.
EMERG. ECON.
WORLD

SOURCE: IMF
B/mydox/papers/jec09.ppt
MACROECONOMIC IMPACTS ON GLOBAL AUTO MARKETS

- Global GDP slowdown – 2-year trough in West
- Slowed (but continued high) growth in Asia (esp. China)
- Auto overcapacity in West: Europe/U.S. have 53% of global auto capacity; 12% of global population
- Petrodollar export concerns:
  - substantial alternative energy investments (esp. battery/electric drive programs)
  - CAFE rise in U.S. (still lagging other major nations)
- Wage deflation/high unemployment
- Cash for Clunkers stimulated Europe market (2010 impact?)
- Credit lockdown (despite U.S. stimulus) → erosion of consumer purchasing power
- OEM market share shift (especially in N. America)
GLOBAL VEHICLE PRODUCTION DECLINE

GLOBAL VEHICLE SALES OUTLOOK

Annual Growth
1990-2000  2.3%
2000-2006  2.8%
2006-2014  2.2%

42% IN 15 EMERGING MARKETS; 58% IN EUROPE/U.S./JAPAN

FIRST EVER DECLINE?
(2008/9)

2007: 71
2014: 83?

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2009
r/mydoc/Auto Industry/Global Ind Volume.xls
U.S. LIGHT VEHICLE SALES

SALES, MM UNITS

SOURCE: DEUTSCHE BANK, 2009
b/mydox/auto industry/NA and EUR sales.xls
EUROPE LIGHT VEHICLE SALES

SOURCE: DEUTSCHE BANK, 2009
B/mydox/auto industry/NA and EUR sales.xls
GLOBAL REGION MARKET SHIFT IS UNDER WAY

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>2009 YTD SALES, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe*</td>
<td>-18%</td>
</tr>
<tr>
<td>N. America*</td>
<td>-26%</td>
</tr>
<tr>
<td>Japan*</td>
<td>-21%</td>
</tr>
<tr>
<td>Brazil</td>
<td>+ 5%</td>
</tr>
<tr>
<td>India</td>
<td>+ 5%</td>
</tr>
<tr>
<td>China</td>
<td>+42%</td>
</tr>
</tbody>
</table>

* = Mature markets represent 51% of global sales (U.S. 58% in 2007)

Source: Robert Eller Associates LLC, 2009
Sales Shift Toward Smaller Vehicles

- Lower discretionary spending
- Lower residual values
- Gov't. incentives favor smaller cars/hybrids
- European/Asian design imports to U.S.
- Probable fuel price increases

- **OEM profitability impact (less profitable product mix)**
- **Intensified weight savings pressure**
- **Increased penetration of TP composites**
U.S. FUEL ECONOMY OBJECTIVES: MINIMAL, BUT WITH SIGNIFICANT FLEET MIX & MATERIALS SELECTION IMPLICATIONS

AVERAGE FLEET FUEL ECONOMY BY GLOBAL REGION

SOURCE: PEW CENTER, 2008

HIGHER CAFE DRIVES COMPOSITES TECH.

U.S. CAFE LAG CONTINUES

SOURCE: PEW CENTER, 2008
FUEL PRICES: THERMOPLASTIC COMPOSITE EFFECTS

- 2008: $3.50-4.00/gal. → 100BN fewer miles driven
- Tipping points → shifts in vehicle preference
- Price will rise and change auto and autoplastics paradigms:
  - rising demand/decreasing capacity
  - economic expansion (eventually)
  - global population jump by 1.0BN in next 12 years
  - “middle” class increase by 1.8BN (600MM in China)
  - U.S.: 750 cars/1,000 people
    China: 4 cars/1,000 people – If Chinese → ½ ownership rate of the U.S., adds 400MM cars
  - easy-to-get oil has gotten harder to find
  - gas taxes (remain constant at $0.184/gal.?)
- Plug-in hybrids: emerging, bridge to a (composite intensive) electric car/alternative propulsion world
- At $?/gal.: Bioplastics and natural fibers reach price equality with petro-based plastics
AUTOMOTIVE SUPPLY CHAIN RESPONSES
U.S. AUTOPLASTIC SUPPLY CHAIN PRESSURES/RESPONSES

- **GLOBAL COMPEITITION**
  - OFFSHORE COMPOUNDERS ENTER
  - IMPORTED COMPETITORS/ SUPPLIER REDUCTION
  - OEM AGGRESSIVE SUPPLY CHAIN COST SAVE

- **RAW MATERIALS**
  - PRICE COMMODITIZATION
  - - RESIN SUPPLIER SHIFT TO LOW COST MONomer REGIONS
  - - REDUCED SERVICE FOR AUTO ACCOUNTS
  - IN-LINE (D-LFT) COMP'DG. BY TIER 1s(a)
  - ELIMINATION OF EXTRA STEPS

- **COMPOUNDER**
  - TIER 1 FABRICATOR
  - U.S. TP COMPOSITES TECHNOLOGY LAG vs. EUROPE
  - ELIMINATE/REDUCE THE INEFFICIENCIES:
    - - MULTIPLE UNIT OPERATIONS
    - - INEFFICIENT PROCESS TECHNOLOGIES
    - - EXCESSIVE LOGISTICS
    - - SALES/MARKETING COSTS
    - - SCRAP GENERATION
    - - EXCESS LABOR COSTS

- **TIER 2, 3 SUPPLIERS**
  - OEM OWNERSHIP SHIFT(b)
  - TRANS-GLOBAL OEM PARTNERING
  - SHIFT TO EUROPEAN/ASIAN DESIGNS

- **OEM ASSEMBLY**
  - HYBRID ELECTRIC DRIVE SHIFT
  - TECHNOLOGY TRANSFER

**PRESSURES PASSED DOWN THE SUPPLY CHAIN**

- BANKRUPTCIES
- SUPPLY CHAIN GLOBALIZATION
- GLOBAL VEHICLE DESIGNS
- VEHICLE DEMAND SLOWDOWN
- SPECIFICATIONS
- GLOBALIZATION PRESSURES
- INCREASED EUROPEAN/JAPANESE INFLUENCE

**NOTES:**
(a) STARTED FOR LGF-TPs
(b) e.g., MAGNA, BID FOR OPEL, FIAT/CHRYSLER, ETC.

**SOURCE:** ROBERT ELLER ASSOCIATES LLC, 2009

Robert Eller Associates LLC
N. AMERICAN AUTOPLASTIC TIER 1s SERVE MULTIPLE OEMs - BANKRUPTCY CAN HAVE INDUSTRY-WIDE IMPLICATIONS

Source: Company Filings
r/mydox/papers/Comp09-Tier1sOEMs_09.xls
THE AUTOMOTIVE MARKET and THERMOPLASTIC (TP) COMPOSITES
GLOBAL MACROECONOMIC EFFECTS ON AUTO TP COMPOSITES

GLOBAL MACROECONOMIC SITUATION

DEMAND SLOWDOWN
BANKRUPTCIES
BANK CRISIS

GDP DECLINE
CREDIT TIGHTENING
REDUCED PURCHASING POWER

GLOBAL MACROECONOMIC EFFECTS

- SLOWED CAPITAL FOR NEW TP COMPOSITE TECHNOLOGY?
- INCREASED GLOBAL PLATFORMS

DEMAND SLOWDOWN

- SEVERE DROP IN EUROPE/U.S.
- SLOWED GROWTH IN EMERGING MARKETS (e.g., BRIC)

AUTOMOTIVE DEMAND

AUTOMOTIVE OEMs

- PROFIT DECLINE
- DEEPER COST CUTS
- JOB CUTS
- TRIM CAPITAL EXPENDITURES
- REDUCE R/D
- SEEK OEM PARTNER/GLOBAL SYNERGIES
- CONTINUED EMERGING MARKET INVESTMENT
- RE-TOOL FOR SMALLER VEHICLES

- SLOWED CAPITAL FOR NEW TP COMPOSITE TECHNOLOGY?
- INCREASED GLOBAL PLATFORMS

GOVERNMENT SUBSIDIES/LOANS/AID PACKAGES

FLEET COMPOSITION

- SHIFT TO SMALLER CARS

FUEL ECONOMY AND ALTERNATE ENERGY SUPPORT

- INCREASED USE OF TP COMPOSITES
- PART WEIGHT REDUCTION PRESSURES
- PARTS CONSOLIDATION/MODULARIZATION
- INCREASED VALUE OF $/LB. SAVED
- ELECTRIC DRIVE/BATTERY INITIATIVES

VEHICLE COST PRESSURES

SUPPLY CHAIN

- BANKRUPTCY
- RESTRUCTURE
- GLOBALIZE

- IN-LINE COMPOUNDING
- AT-PRESS COMPOUNDING
- MULTI-SHOT PROCESSES
- CAPTIVE COMP’DG. BY TIER 1s
- PRESSURE ON INDEPENDENT COMPOUNDERS
- SEEK NON-AUTO OPP’Y.

$18.5BN SUBSIDY REQUEST (REC’D. $5BN) (U.S.)

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2009
AUTOMOTIVE MARKET DYNAMICS AND TP COMPOSITE SUPPLY CHAIN RESPONSES

TP composite substitution driven by:

- Supply chain restructuring
- Weight save pressures (value weight savings [10% weight reduction yields 7% fuel economy improvement])
- System cost savings potential/parts consolidation
- Material cost savings for D-LFT vs. other LGF processes
- Green pressures and improved capabilities for natural fiber composites
- Other plastic substitution (e.g., exteriors) stimulates TP composites (e.g., hatchback inner panel)
TP COMPOSITE TECHNOLOGY RESPONSES and OPPORTUNITIES
PATHS TO THE LGF-TP COMPOSITE MARKET

1. COMPOUND:
   - **COMPOUNDER** → **LGF COMPOUND** → **INJECTION PRESS** → **MOLDED PART**
   
   **COMPOUNDING FACILITATED EARLY GROWTH OF LGF-TPs; DOES NOT REQUIRE CAPEX**

2. D-LFT:
   - **ROVING** → **RESIN** → **ADDITIVES** → **IN-LINE COMPOUNDING EXTRUDER** → **COMPRESSION PRESS** → **MOLDED PART**
     - **IN-LINE COMPOUNDING EXTRUDER** → **INJECTION PRESS** → **MOLDED PART**
   
   **HIGH GROWTH POTENTIAL; CAPEX REQUIRED (FAVORED BY MAJOR TIER 1s); LARGE PARTS, HIGH VOLUME REQUIRED FOR COMPETITIVE ECONOMICS, GOOD FIBER LENGTH RETENTION**

3. LGF CONCENTRATE:
   - **CONCENTRATE**: **NEAT RESIN** → **INJECTION PRESS** → **MOLDED PART**
     - **USE EXISTING EQUIPMENT**

4. GMT OR LW-RT:
   - **ROVING** → **MAT** → **NEAT RESIN** → **EXTRUDER** → **BLANKS** → **PREHEAT** → **COMPRESSION PRESS** → **MOLDED PART**

   **EARLY GMT BEING REPLACED BY HIGH QUALITY; LW-RT COMPETES WITH D-LFT IN UNDERBODY SHIELDS**

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2009
INTERMATERIAL/INTERPROCESS COMPETITION IN LONG FIBER,
AUTOMOTIVE THERMOPLASTICS

Target Applications
2008 N. America volume ~ 120MM lbs., excluding S-GMT and LW-RT
- Front end carrier
- Door hardware module
- Instrument panel substrate
- Underbody shield
- Running board
- Hatchback door inner
- Overhead console/Headliner structure
- Instrument panel structural ducts
- Load floor
- Spare tire well/Storage module
- Seating
- Engine covers (start in natural fiber composite)
- Lithium-ion battery related

Note: Currently primarily glass; some shift to natural fibers

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2009
<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>STATUS / NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front end module/ carrier* (6-8)</td>
<td>- Major near-term D-LFT and LGF-PP pellet driver in N. American market</td>
</tr>
<tr>
<td></td>
<td>- Established in Europe</td>
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<tr>
<td>Door hardware module* (7-8)</td>
<td>- Facilitates strong trend towards hardware consolidation</td>
</tr>
<tr>
<td></td>
<td>- Brose is early leader</td>
</tr>
<tr>
<td>Instrument panel substrate* (7)</td>
<td>- Started in Europe (Faurecia and JCI)</td>
</tr>
<tr>
<td></td>
<td>- Both D-LFT injection and compression</td>
</tr>
<tr>
<td>Underbody shield* (8)</td>
<td>- Will come from Europe with OEM transplants</td>
</tr>
<tr>
<td></td>
<td>- LW-RT competes with D-LFT</td>
</tr>
<tr>
<td></td>
<td>- Add-on acoustic layer being offered</td>
</tr>
<tr>
<td>Running board</td>
<td>- Started in N. America</td>
</tr>
<tr>
<td>Hatchback door*</td>
<td>- 2012 Ford Escape (see Ford Kuga photo)</td>
</tr>
<tr>
<td></td>
<td>- Combination with talc/PP exterior</td>
</tr>
<tr>
<td>Overhead console/ Headliner structure</td>
<td>- Stimulated by changes in overhead design and construction</td>
</tr>
</tbody>
</table>

(Cont’d.)
### AUTO APPLICATIONS FOR TP COMPOSITES (a) (Cont’d.)

<table>
<thead>
<tr>
<th>APPLICATION</th>
<th>STATUS / NOTE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Instrument panel structural ducts (15-18)</td>
<td>- Early Chrysler innovation (2007)</td>
</tr>
<tr>
<td></td>
<td>- Requires vibration welding</td>
</tr>
<tr>
<td>Load floor</td>
<td>- Early GMT application</td>
</tr>
<tr>
<td>Spare tire well/storage module* (9-10)</td>
<td>- Competes with SMC, GMT; natural fiber candidate?</td>
</tr>
<tr>
<td>Seating*</td>
<td>- Competes with SGF-TPs</td>
</tr>
<tr>
<td>Engine covers*</td>
<td>- Starting in natural fiber composites in Europe</td>
</tr>
<tr>
<td>Battery carriers</td>
<td>- Stimulated by trend to electric drive vehicles?</td>
</tr>
</tbody>
</table>

**Notes:**

Numbers in ( ) indicate typical weights per vehicle

* = technology transfer from Europe

(a) Includes both LFTs and GMTs

**Sources:** Dieffenbacher; Robert Eller Associates LLC
LFT-D-ILC COMPRESSION

Source: Dieffenbacher
IMC Injection Molding Compounder

Melt buffer

Shut-off nozzle

Redirection valve

MX- or CX-clamp

Source: Krauss Maffei

Start up valve with container

Twin screw extruder

Shot-Pot-Injection piston

Weighing, dosing & conveying systems
Plasticomp Pushtrusion™ Direct In-Line Compounding

Source: PlastiComp
LFT COMPOSITE OPPORTUNITY TARGETS

NOTES: * = HIGH PERFORMANCE MINERAL FILLED
(a) MAY CONTAIN ADDED ACOUSTIC ELEMENTS
(b) COMPETES WITH SGF-TP
(c) D-LFT AND LW-RT COMPETE FOR UNDERBODY SHIELD

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2009
rmomydox/papers/Compo09-LFT Comp Oppy 09.vsd // lg/myfiles/visio/Compo09-LFT Comp Oppy 09.vsd

Robert Eller Associates LLC
EXAMPLE OF TP COMPOSITE TECHNOLOGY RESPONSES TO AUTOMOTIVE MARKETPLACE PARADIGM SHIFTS: INSTRUMENT PANEL

• Current methods for making instrument panels are inefficient:
  • Multiple step process
  • Multi-materials vs. a single material
  • Difficulty of recycling
  • High scrap rate
  • High labor content
  • Use of coatings
  • Multiple step process
  • Multi-materials vs. a single material
  • Difficulty of recycling

• D-LFT (combined with 2-shot molding):
  • Saves unit operations
  • Improves recyclability
  • Will be growth trend
  • Can be from same materials family
  • Started in Europe; moving to the U.S.
FRONT END MODULES: PROVEN HIGH GROWTH TECH

- HOOD LATCH POINT
- CARRIER
- RADIATOR/HEAT EXCHANGERS
- BUMPER BEAM
- ENERGY ABSORBER
- FASCIA

SGF-PP CHALLENGING SGF-PA
FRONT END CARRIERS: STRONG GROWTH DRIVER FOR D-LFT PROCESSES AND LGF-PP COMPOUND

VEHICLE: Audi A3
MATERIAL: 30% LGF-PP
PROCESS: D-LFT (injection)
WEIGHT: 3 kg
EQUIPMENT: Krauss Maffei
PHOTO: Krauss Maffei

VEHICLE: Ford Fusion
MATERIAL: 40% LGF-PP
PROCESS: D-LFT (compression)
EQUIPMENT: Dieffenbacher
PHOTO: Dieffenbacher
UNDERBODY PANELS

- Established in Europe. Shifting to N. America. (German OEM shift accelerates N.A. penetration)
- Substitution driven by:
  - Component protection
  - Lithium-ion battery/electric drive share gain
  - Improved aerodynamics
  - Acoustics improvement (new target/value add zone)
- Many process/materials contenders:
  - GMT
  - LW-RT (lightweight GMT gaining share, approvals in place)
  - LGF-PP pellets
  - D-LFT processes/examples (Compression, Injection, Krauss Maffei, PlastiComp Pushtrusion™, others)
  - Aluminum, steel
  - Thermoset composites
UNDERBODY PANELS

Vehicle: BMW 7-SERIES
Part: Underbody Shield
Material: 30% LGF-PP
Supplier: SABIC - Stamax 30YK430
Weight: 6.7 kg (total)
Drivers:
- Acoustics
- Aerodynamics
- Component protection
- Cost (vs. GMT)

Note:
Most European BMW passenger cars have LW-RT UB shields
**EXAMPLE UNDERBODY SHIELD**

<table>
<thead>
<tr>
<th>Part:</th>
<th>Typical underbody shield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process:</td>
<td>D-LFT compression</td>
</tr>
<tr>
<td>Equipment:</td>
<td>Dieffenbacher</td>
</tr>
<tr>
<td>Material:</td>
<td>25-30% LGF-PP</td>
</tr>
<tr>
<td>Notes:</td>
<td>- LW-RTP competes</td>
</tr>
<tr>
<td></td>
<td>- Acoustic function being added (e.g., by Rieter, Carcoustics, others)</td>
</tr>
<tr>
<td>Photo:</td>
<td>Dieffenbacher</td>
</tr>
</tbody>
</table>
INSTRUMENT PANEL CARRIER: GROWTH TARGET

- Filled and fiber-reinforced TPs compete for substrate
- LGF-PP pellets and D-LFT compete
- Combo with 2-shot D-LFT molding saves unit operations
- Integrated cross-car beam/structural duct potential
- Example shown: Ford C-Max, Mazda 3, Volvo S40
- Material supplier: Quadrant Plastic Composites AG
- System supplier: Faurecia
SPARE TIRE WELL: SUBSTITUTION TARGET

Vehicle: Mercedes C-Class

Weight: 4.3 kg
Substitution drivers:
- Impact strength for crash resist.
- Ability to integrate shape features
- Corrosion resistance

Material: GMT-PP combination (random glass mat & fabric)
SPARE TIRE WELL: NATURAL FIBER TARGET

Vehicle: Mercedes A-Class

Material: Abaca fiber/PP

Substitution drivers:
- Good stiffness weight balance
- Green solution
- Energy saving (natural fiber vs. glass roving)
DOOR HARDWARE MODULES: GROWTH APPLICATION

FORD FIESTA

- LGF-PP
- Front Door Carrier plate wt. = 1042 grams
- Rear Door Carrier plate wt. = 670 grams
DOOR HARDWARE MODULE: GROWTH APPLICATION

VEHICLE: Chrysler Sebring convertible
MATERIAL: 40% LGF-PP
PROCESS: D-LFT (injection compression)
EQUIPMENT: Krauss Maffei
PHOTO: Krauss Maffei
HATCHBACK DOOR INNER: GROWTH APPLICATION

VEHICLE: Ford Kuga (2010)
APPLICATION: Roof spoiler and tailgate outer panel
GRADE: LyondellBasell Hifax TRC 280X
MOLDER: Plastal
REA NOTES:
- Inner panel is Stamax (SABIC)
- Potential for design transfer to the U.S. (2010)
PHOTO: Robert Eller Associates LLC

PART: Hatchback door inner panel
MATERIAL: 40% LGF-PP
STATUS: Prototype
PROCESS: D-LFT (injection)
EQUIPMENT: Krauss Maffei
COMPETITION: LGF-PP compound
PHOTO: Krauss Maffei
BIOPOLYMER CANDIDATES FOR AUTOMOTIVE APPLICATIONS

NOTE: (a) USED IN BRAZIL, RECENT U.S. INTRODUCTION IN NYLON

SOURCE: ROBERT ELLER ASSOCIATES LLC, 2009

Robert Eller Associates LLC
FUTURE VISION/SUMMARY

- Like other auto plastics, TP composites (especially LF-RTPs) are affected by:
  - The global economic downturn
  - Market growth shift to Asia
  - Sharp global automotive production downturn
  - European/Asian OEM share gain in N. America
  - Share gain for smaller vehicles in the global fleet
  - Expected fuel price increase and slow penetration of hybrids and electric drive vehicles
FUTURE VISION/SUMMARY (Cont’d.)

The LF-RTPs have strong growth potential:

• Substitution on multiple (high weight) applications
• Growth in modular construction
• Renewed weight/cost save pressures
• Supply chain restructuring/direct fabrication savings
• Parts consolidation potential
• Front end modules/carriers, door hardware modules, and underbody shields will be near-term growth driver
• European/Asian share gain in N. America brings technology and designs to accommodate vehicle market shifts
FUTURE VISION/SUMMARY (Cont’d.)

• Intermaterial and inter-process competition:
  • Multiple materials/processes are competing.
  • D-LFT will make rapid share gains due to raw material cost savings but could be restricted by capex requirements in a difficult investment environment.
  • Natural fiber reinforcement will gain some share.
• TP composites bring opportunities for adding value, e.g.,
  • Parts consolidation in most applications
  • Adding acoustic functionality to underbody shields
  • Crosscar beam/structural duct integration in instrument panels

TP COMPOSITES: PART OF MANAGING IN A DOWNTURN
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>D-LFT</td>
<td>direct long-fiber thermoplastics</td>
</tr>
<tr>
<td>ETP</td>
<td>engineering thermoplastic</td>
</tr>
<tr>
<td>GMT</td>
<td>glass mat thermoplastic</td>
</tr>
<tr>
<td>ILC</td>
<td>in-line compounding</td>
</tr>
<tr>
<td>LF-RTP</td>
<td>long fiber reinforced thermoplastics</td>
</tr>
<tr>
<td>LGF-PP</td>
<td>long-glass fiber polypropylene</td>
</tr>
<tr>
<td>LGF-RTP</td>
<td>long-glass fiber reinforced thermoplastic</td>
</tr>
<tr>
<td>LW-RT</td>
<td>lightweight GMT (GM’s designation), also LW-GMT</td>
</tr>
<tr>
<td>PA</td>
<td>polyamide</td>
</tr>
<tr>
<td>PP</td>
<td>polypropylene</td>
</tr>
<tr>
<td>s-GMT</td>
<td>structural GMT</td>
</tr>
<tr>
<td>SGF-PP, PA</td>
<td>short-glass fiber polypropylene or nylon</td>
</tr>
<tr>
<td>TP</td>
<td>thermoplastic</td>
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</table>
ACKNOWLEDGEMENTS

• Roger Young (REA-Asia) for Asian inputs
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• Conrad Zumhagen (The Zumhagen Co. LLC) for inputs on fiber-reinforced examples
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• Krauss Maffei - photos
Thank You!

Robert Eller Associates LLC
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