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# Alternatives in Fiber Reinforced Thermoplastics



SPE/ACCE

September 12-13, 2002



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# Alternative Thermoplastic Materials



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# Fiber and Resin Combinations

## Standard Matrix Resins    Reinforcement Fibers

Polypropylene (PP)

Carbon

Polyamide (N6)

E-Glass

Polyphenylene Sulfide (PPS)

S2-Glass

Polyetherimide (PEI)

Aramid

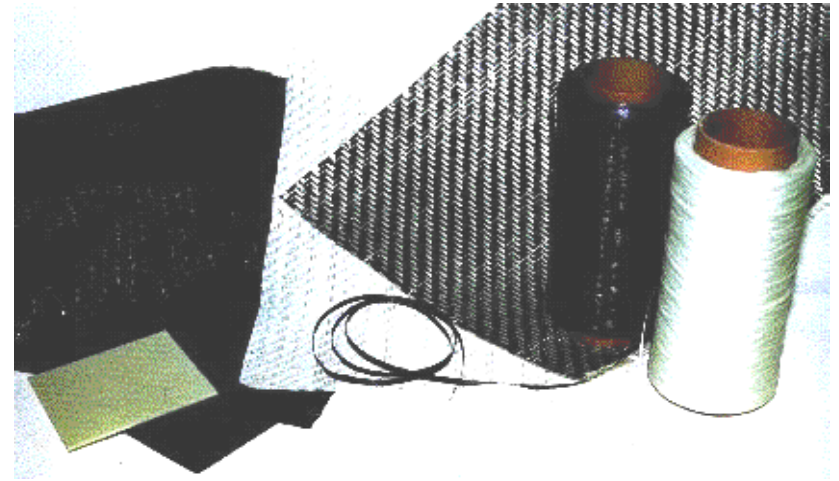
Polyetheretherketone (PEEK)

Hybrids

Other (PMMA, PET, PC, N11,  
N12, N6/6, TPI, etc.)

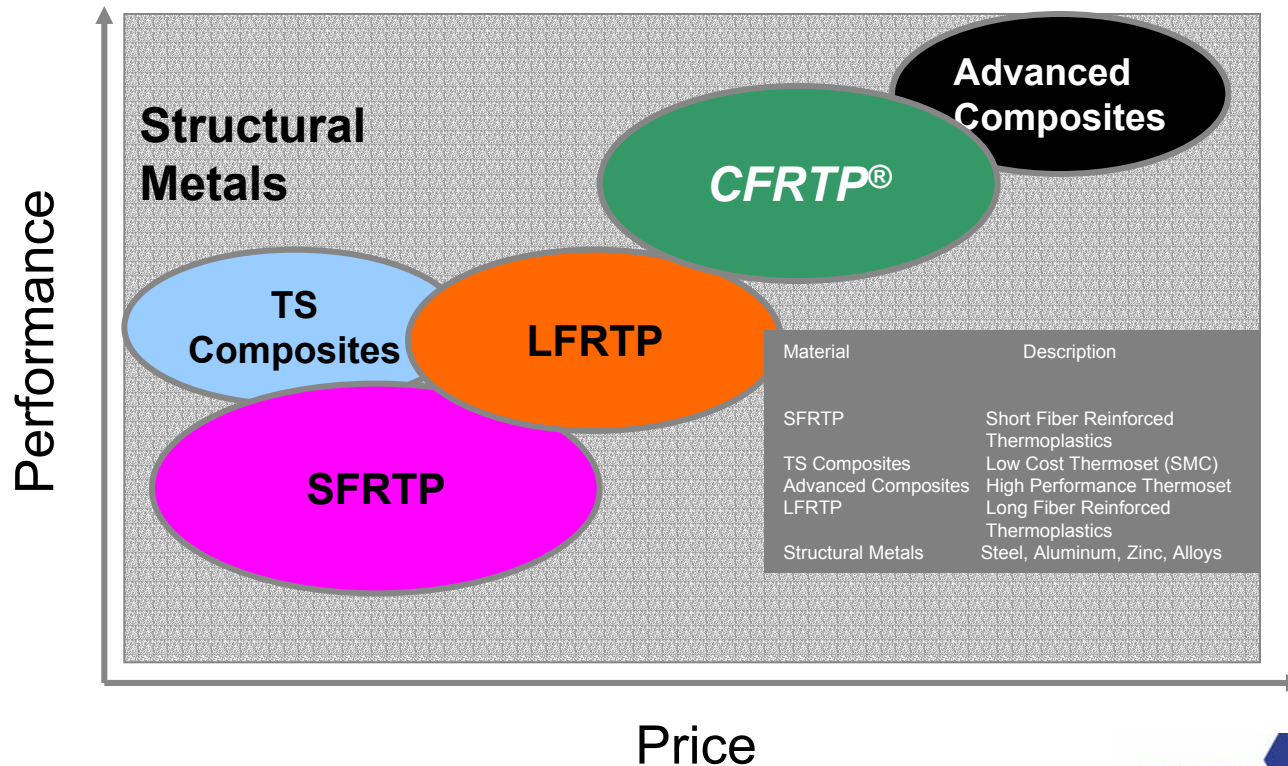
# Product Forms

- **Flexible Towpreg**
- **Woven Fabric**
- **Braided Sleaving**
- **Unidirectional Tape**
- **Chopped Compression Molding Compound**
- **Molded Plates**
- **Thermoformable Laminates**

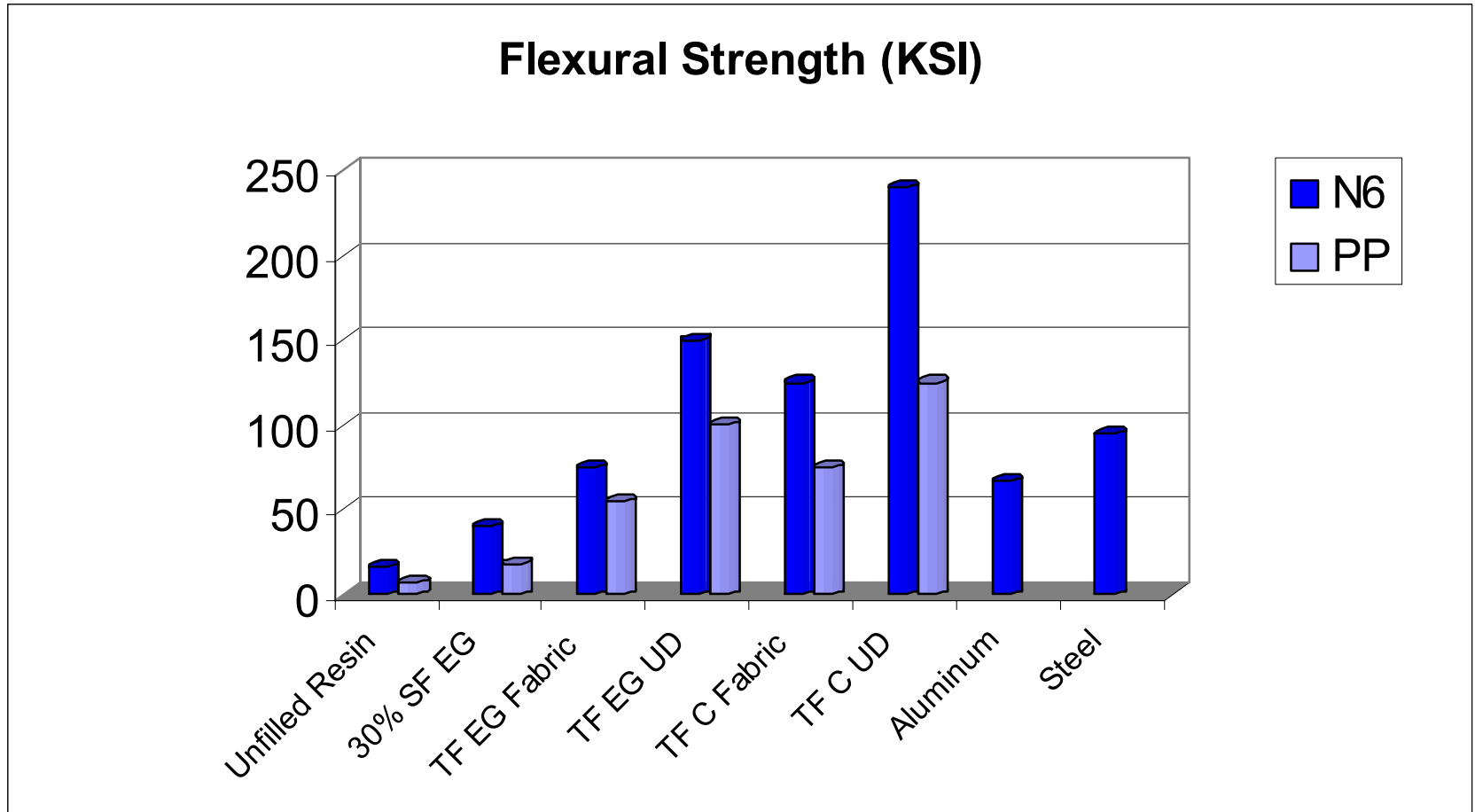


# Product Focus

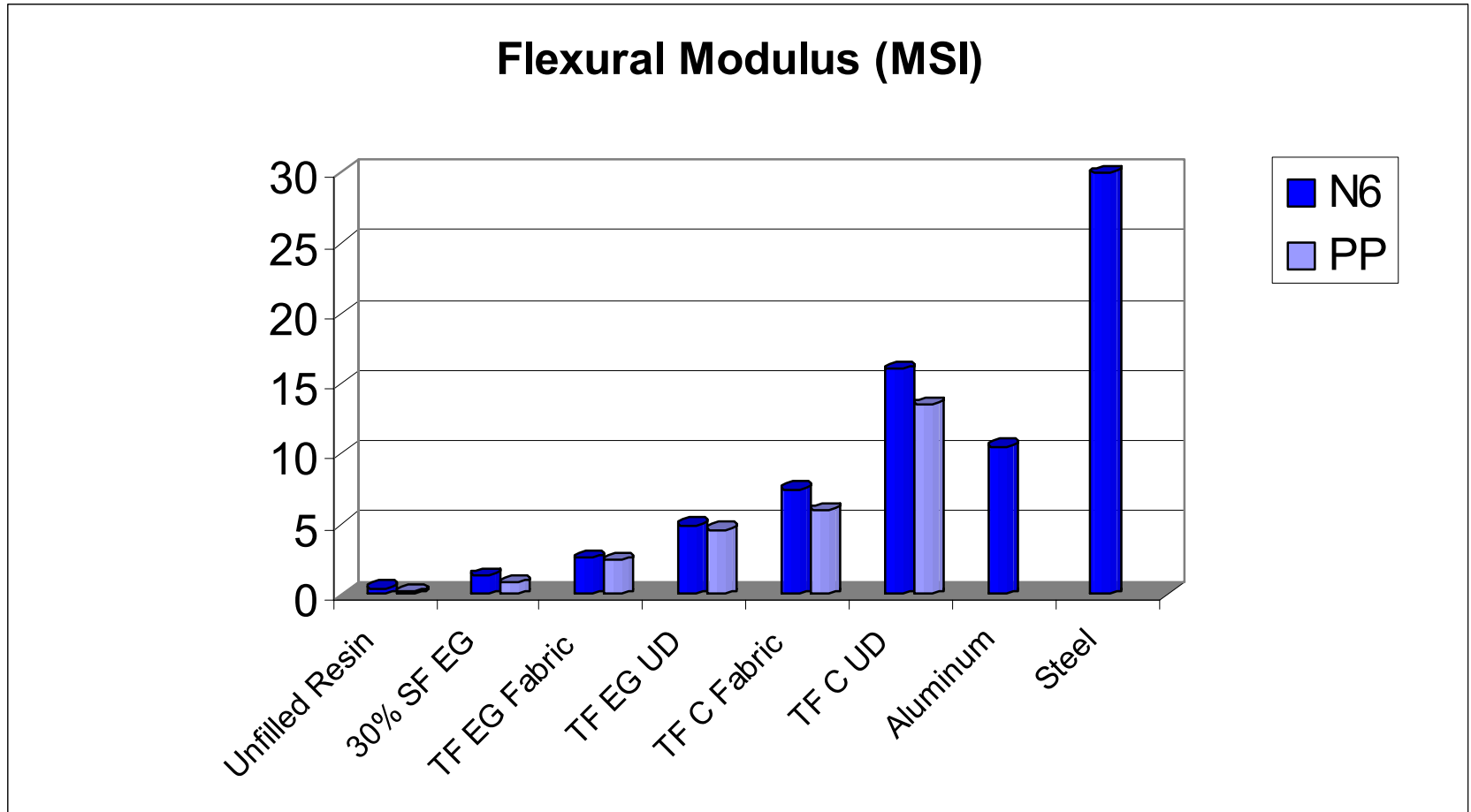
*TowFlex Continuous Fiber Reinforced Thermoplastic Materials (CFRTP) fill a cost and performance gap between long-fiber reinforced thermoplastics and thermoset advanced composites*



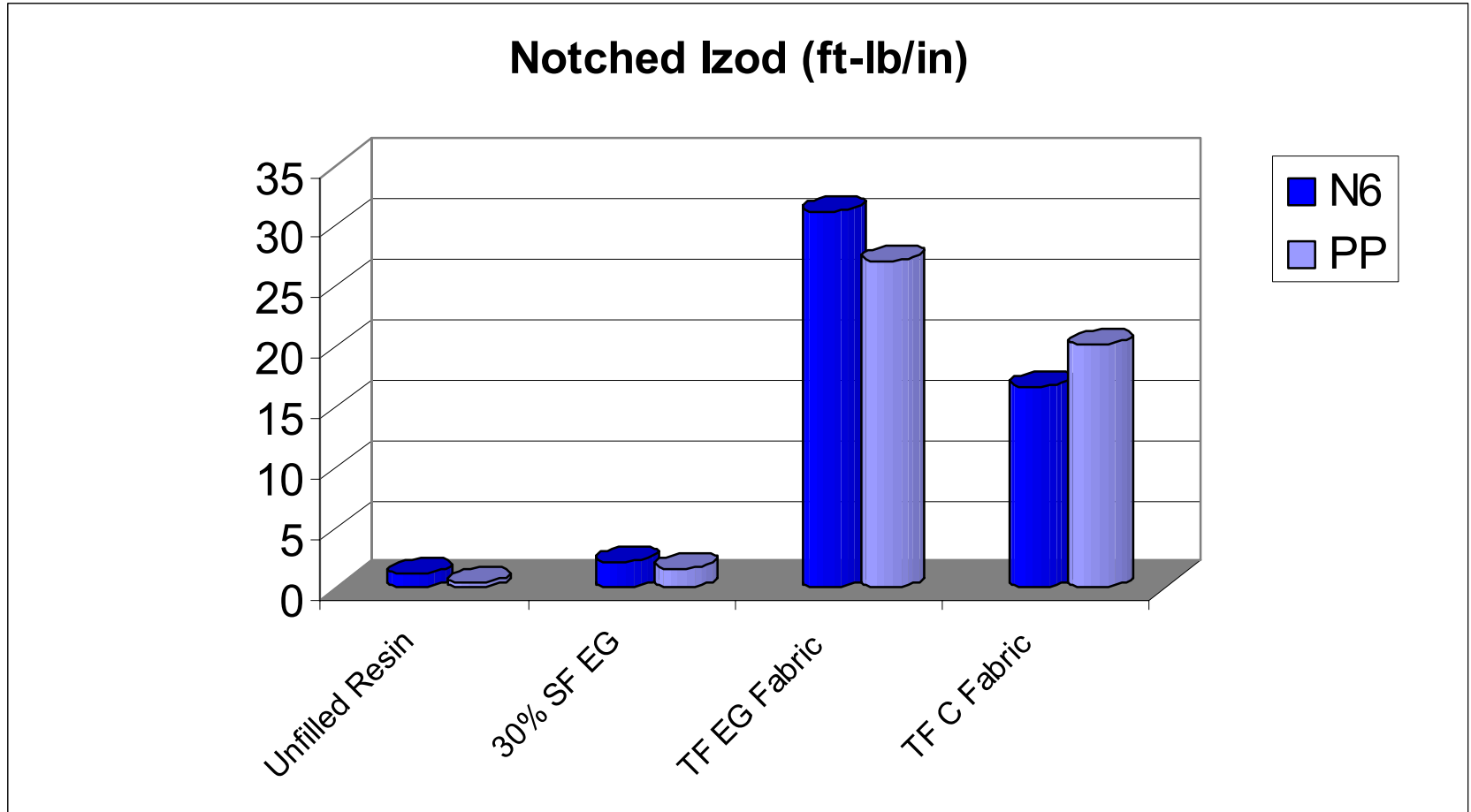
# Mechanical Properties



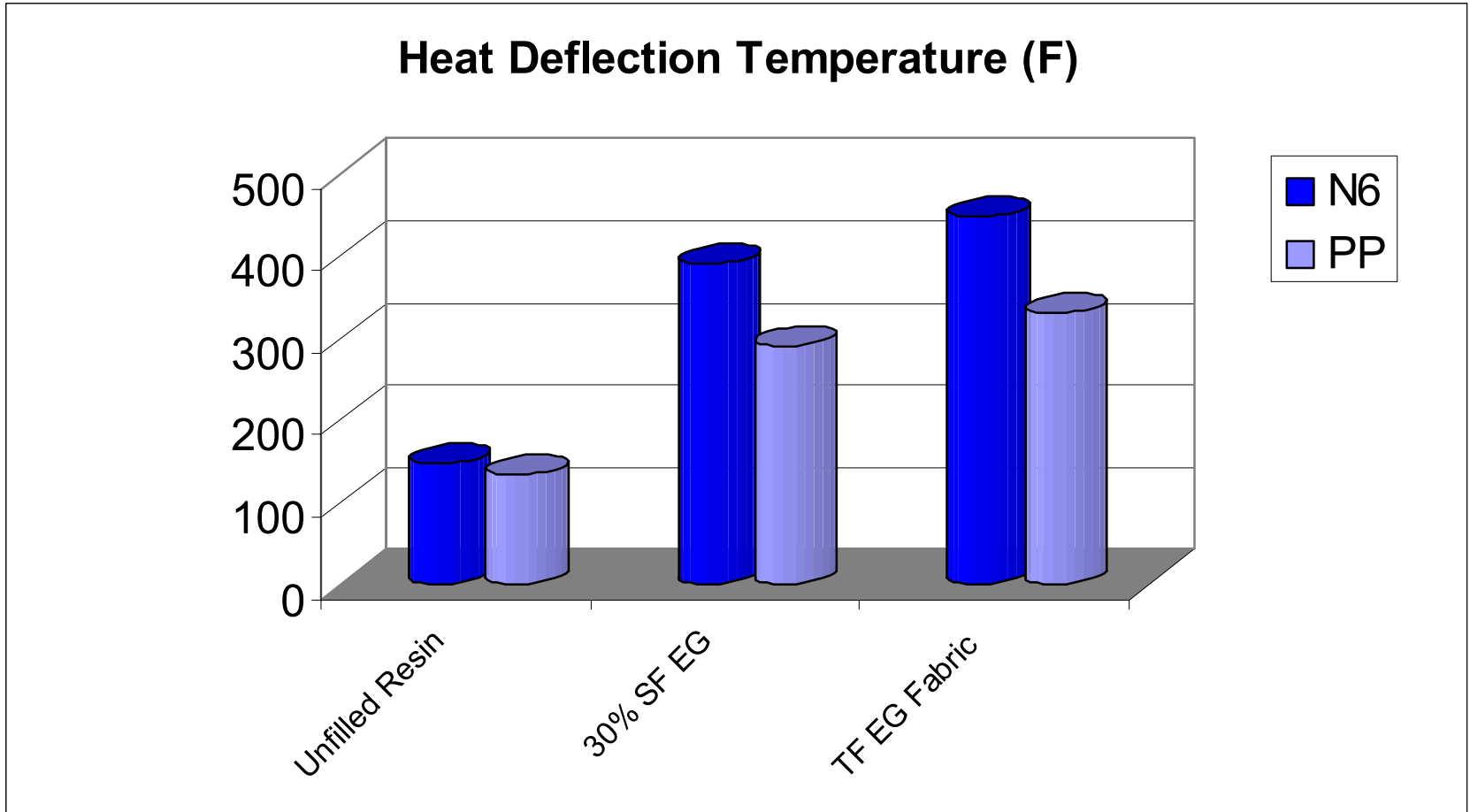
# Mechanical Properties



# Mechanical Properties



# Mechanical Properties



# BMW M3 Bumper System



# BMW M3 Bumper System

- Selected E-glass/Nylon 6 vs. E-glass/PP due to:
  - Higher service temperature (>100F increase)
  - Improved flexural/tensile/compressive strength properties (>25% increase)
- Processing:
  - Continuous sheet produced from *TowFlex*<sup>®</sup> fabric
  - Bumper beams and crush column boxes matched-mold thermoformed from sheet
  - Crush column profiles continuously produced from *TowFlex*<sup>®</sup> fabric
  - Beams, crush columns, boxes assembled via HF welding

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# Value Points

- Performance
  - Crash Performance @ High Under-Hood Temperatures
- Reduction in Part Numbers
  - Sub-Assembled
- 60% Weight Savings (2.8 kg/6.2 lbs total)
  - Fuel Economy/Emissions/Weight Distribution
- Recyclable
- M3 Volume/Specialty Vehicle
  - Reduced Tooling Cost

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# BMW Process Flow

Assembly, BMW

Bumper  
Manufacturer,  
Jacobs

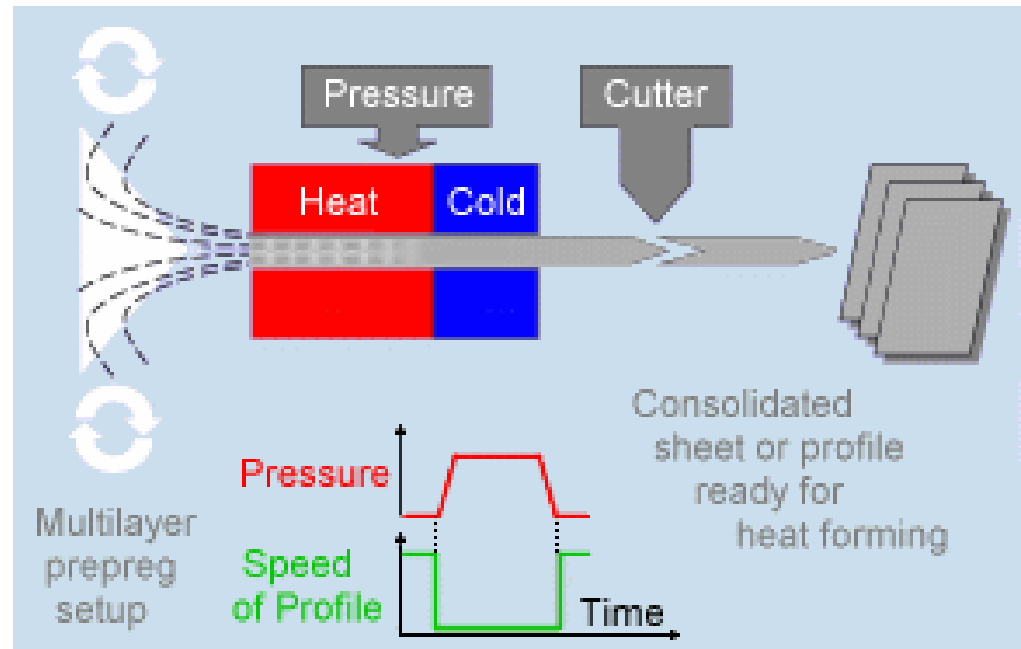
*TowFlex*<sup>®</sup>  
Consolidator,  
AC.S

*TowFlex*<sup>®</sup>  
Hexcel



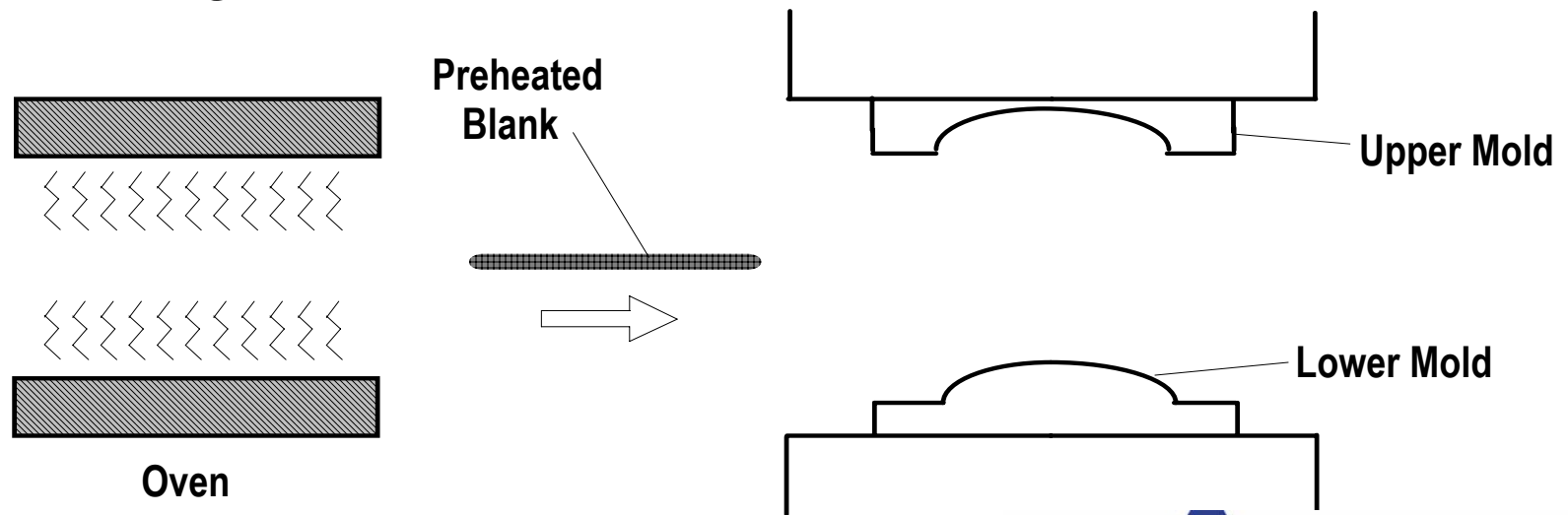
# Continuous Sheets and Profiles

- Produced by AC.S from TowFlex fabric
- Multiple fabric rolls for multi-layer sheets and profiles
- Sheets used for beam and crash box thermoforming
- Profiles used for crush columns



# Matched-Mold Thermoforming

- Parts produced by Jacob Composites
- Beams and Crash Boxes formed from consolidated sheet
- Beams, crash boxes, and crush column profiles assembled via HF welding



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# Compression Molding

- Use unconsolidated fabrics/tapes (vs. preconsolidated sheets)
- Use flat preforms
- Matched molds form and consolidated preforms (no hand-layup)
- Heated and cooled molds or shuttle press

# Compression Molding Concept

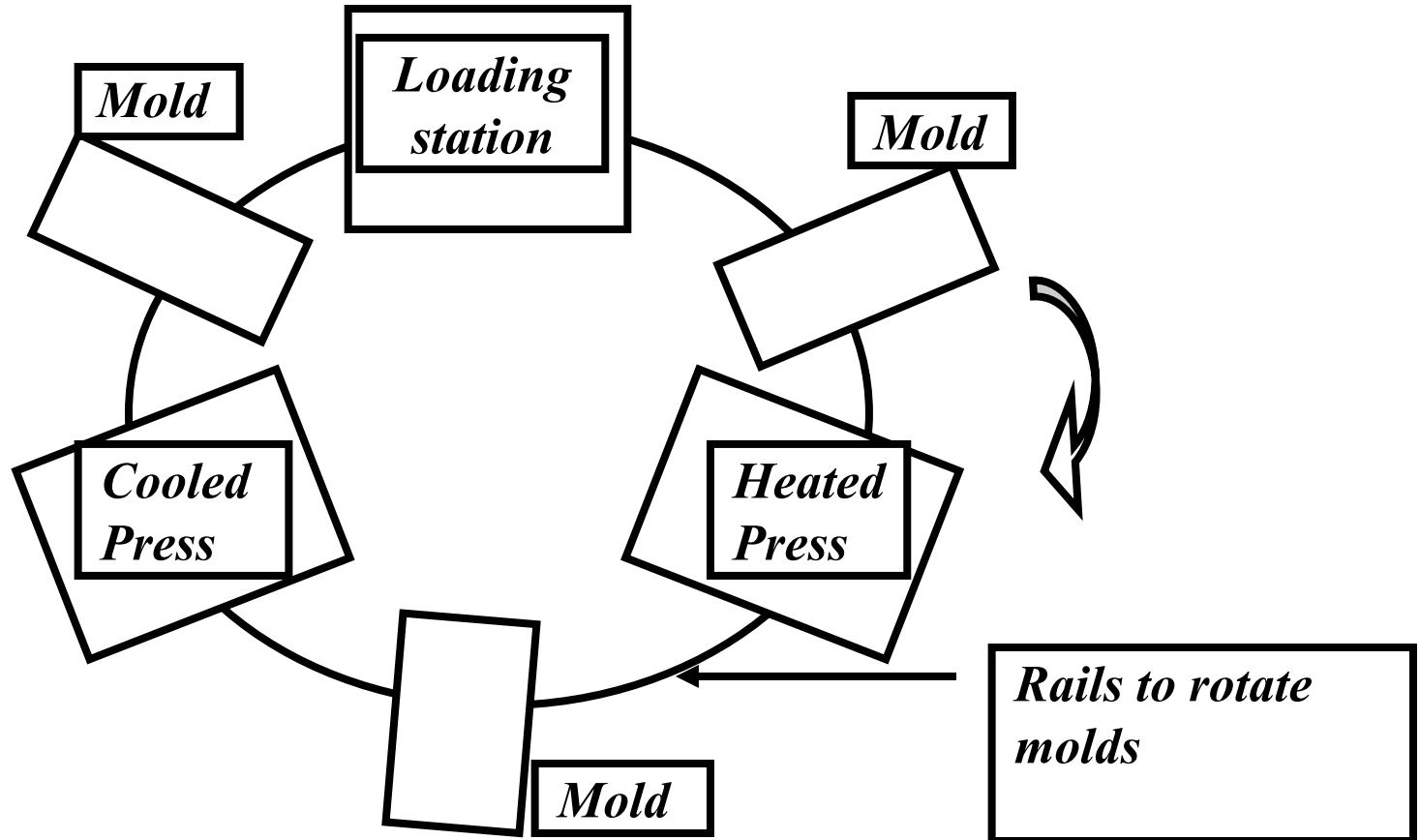


Figure 5.1: Three rotating mold-shuttle system

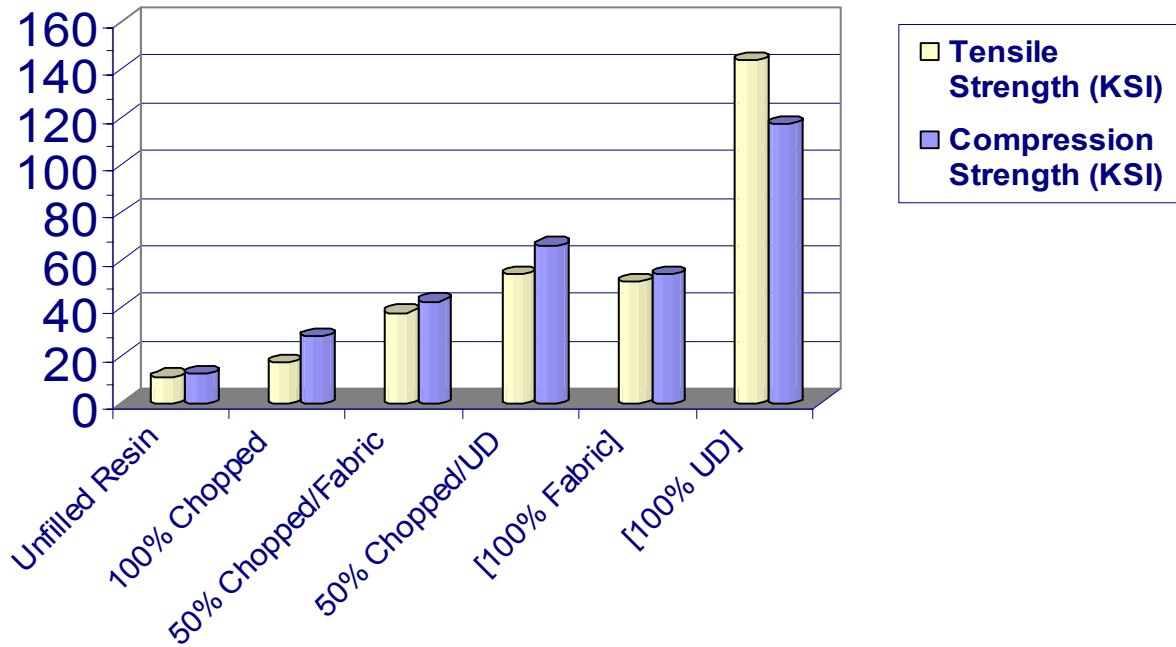
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# Co-molding Concepts

- Use TowFlex as a stiffening element combined with unreinforced or discontinuous reinforced TP resins
- Overmold using “conventional” TP molding processes
  - Injection Molding
  - Compression Molding
  - Thermoforming
  - Blow Molding

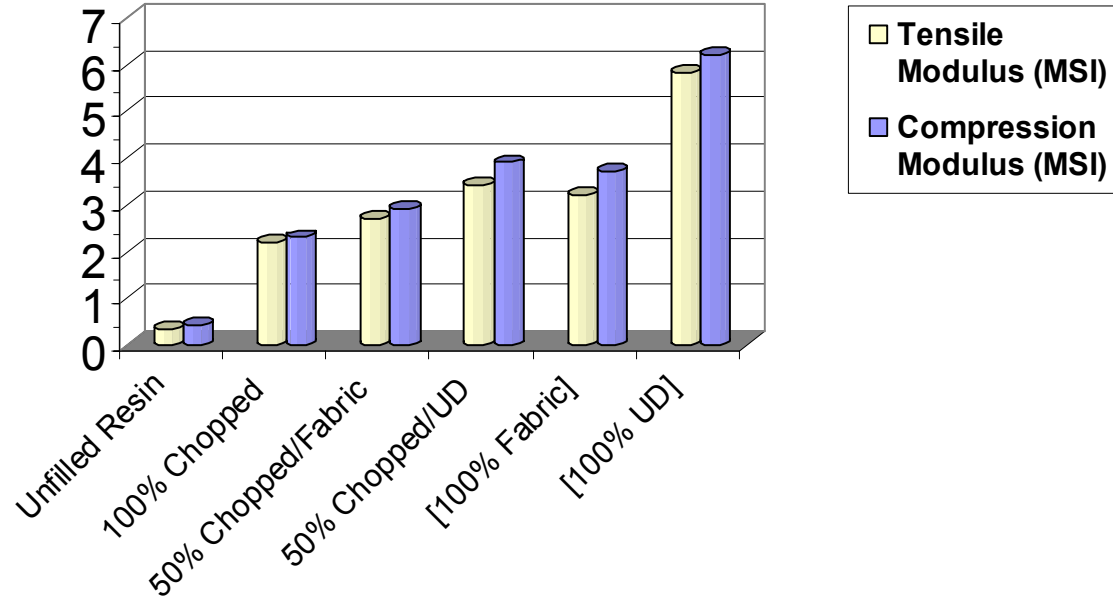
# Co-molding Preliminary Data

**N6 Overmolding: Tensile/Compressive Strength Comparison (KSI)**



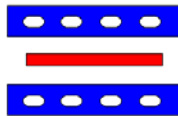
# Co-molding Preliminary Data

**N6 Overmolding: Tensile/Compressive Modulus Comparison (MSI)**



# Injection Overmolding

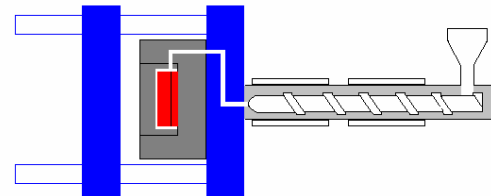
Step 1 : TowFlex IR heating



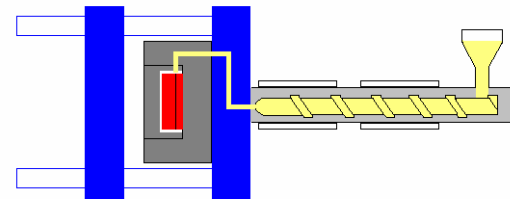
Manual transfer



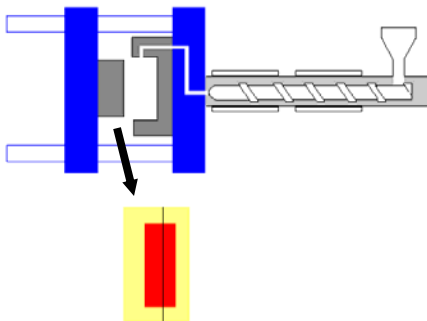
Step 2 : forming in molding press



Step 3 : Resin injection for overmolding



Step 4 : demolding



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# Co-Forming

## With GMT Sheet



## With Unreinf. Sheet

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# Joining Processes

## Standard TP Joining Processes Evaluated

- Adhesive Bonding
- Vibration Welding
- Ultrasonic Welding
- Spin Welding
- Hot Plate Welding

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# Application Development Support

- Material recommendations and data
- Part and tooling design support
- Prototype parts development
- Materials and molded parts testing/analysis
- Production molding technology transfer and support

# Summary

- Solutions in Fiber Reinforced Thermoplastics
  - Multiple Resin & Fiber Combinations
  - High Temperature
  - High Stiffness and/or Strength Requirement
  - Maintain/Reduce Design Weight
  - Utilize and Expand Existing Thermoplastic Processes