Choice of Polyurethane Elastomers for Demanding Applications

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Outline

• Applications
• Urethane Tech Overview
• Why use Urethane elastomers
• Types of Applications
• Comparisons to metal, rubber, and plastic
• Limitations of Urethane
• What Controls Urethane Properties
• Urethane Selection
• Selecting Urethane for a new application
• Field Testing

Types of Polyurethane Materials

• Castable Elastomers
• Foams:
  – Flexible
  – Rigid
• Shoe Soling
• Textiles
• Adhesives & Sealants
• Thermoplastics
• Millable Gums
• Coatings
Major Applications for High-Performance Castable Polyurethane Elastomers

- Mining Parts
- Oil and Gas Pipeline Service
- Office Machinery
- Recreational - Golf Balls, Skate and Skateboard Wheels, Swim Fins
- Rolls - Papermaking, Printing, Industrial
- Tires and Wheels
- Thousands of Others
Handbatching

Machine Processing

Polyurethane Elastomer Structure
Earth Mover Door Snubber

Why Use Castable Urethane Elastomers? 1

• **Performance**
  – Abrasion Resistance
  – Toughness
  – Tear Resistance
  – Load-Bearing Ability
Why Use Castable Urethane Elastomers? 2

- **Cost-Effectiveness**
  - Reduced Down Time in Process Operations

  *For example:*
  - Mining
  - Machine Parts
  - Paper Mills

  - Lower Tooling and Equipment Costs for Small Production Runs

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**Lift Truck Wheels & Tires**

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**Flexible Pipe Coupler**
Fifteen Ways to Mold Urethane Prepolymers

- Open Casting (Most Common, Easiest, Cheapest)
- Compression Molding (Precision Parts)
- Centrifugal Molding (Pipelining, Sheet Goods, Multi-cavity Molds)
- Liquid Injection Molding (Low pressure, Bottom Fill)
- Ribbon Flow® Moldless Casting (For Rolls, etc.)
- Spraying (High Pressure Solventless & Low Pressure Solvented)
- Rotational Molding (Makes Hollow Items)
- Vacuum Casting (Wire or Fiber Inserts in Item)
- Transfer Molding (Multiple Precision Parts)
- Reaction Injection Molding (High Pressure Impingement Mixing)
- B-Staging (When Molds Can’t Hold Liquids)
- Pressure Casting (Pressure Chamber)
- Solvent Casting (Low Viscosity for Fabric Penetration)
- Trowelling (Repairs and Special Applications)
- Dipping (Caytur 21, 31 Long Pot Life, Heat Activated)

Lined Steel Pipe - Centrifugal Cast

Lined Steel Pipe
Advantages vs. Metal

- Lighter Weight
- Less Noise
- Better Wear
- Corrosion Resistance
- Cheaper Fabrication
- Non-Sparking
- Non-Conductive
- Impact Resistance
Advantages vs. Rubber

- Abrasion Resistance
- Cut and Tear Resistance
- Oil Resistance
- Higher Load Bearing
- Harder Durometer Range
- Clarity; Translucence
- Non-Marking, non-Staining
- Pourable; Castable
- Ozone Resistance
- Microorganism Resistance *
- High or Low Hysteresis
- Versatility

* Polyether

Advantages vs. Plastics

- Non-Brittle
- Abrasion Resistance
- Elastomeric Memory

Limitations of Polyurethane

- High Temperature Service
- Moist, Hot Environments
- Certain Chemical Environments
- Cost versus other Polymers
What Controls Properties?

- Type of Prepolymer
  - Diisocyanate Type
    - TDI
    - MDI
    - Other (PPDI, Aliphatic, Etc.)
  - Polyl Type
    - PTMEG Premium Polyether
    - PPG Low-Cost Polyether
    - Polyesters
    - Other (Polycaprolactone, etc.)

Diisocyanates

- TDI
- PPDI
- MDI
- HMDI

Prepolymer Backbones

- Polyethers: PPG, PTMEG
- Polyesters: PEAS, PC1
- Polycaprolactone
Relative Performance Ratings

MDI Systems (1 = best, 10 = worst)

<table>
<thead>
<tr>
<th>Material</th>
<th>Abrasion</th>
<th>Low Temp</th>
<th>Hydrolysis</th>
<th>Oxidation</th>
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<tr>
<td>Ester (std)</td>
<td>3</td>
<td>8</td>
<td>6</td>
<td>1</td>
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<tr>
<td>Ester (high abr)</td>
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<td>8</td>
<td>6</td>
<td>1</td>
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<tr>
<td>Polycaprolactone</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>1</td>
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<tr>
<td>Premium Ether</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>4</td>
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<tr>
<td>Low Cost Ether</td>
<td>8</td>
<td>2</td>
<td>1</td>
<td>7</td>
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What Controls Properties?

- Type of Curative
  - Diamine
  - Diol, Triol
- Processing Conditions
  - Curative Ratio
  - Temperatures
- Additives
  - Plasticizers
  - Fillers
  - Protectants

Common Curatives

- MBOCA
  - $C_{10}H_{12}ClN_2$ 267.16
  - Vibracure A157, Polacure 740M
- HQEE
  - $C_9H_8O_8$ 198.22
- BDO
  - $C_6H_8O_4$ 90.12 Butanediol
Selection of a Polyurethane Elastomer for a Specific Application

- Properties Needed for the Job
- Processing Characteristics
  - Pot Life
  - Ratio Control
  - Viscosity
  - Demold Time
  - Process Temperatures

Selection Guidelines: 1

<table>
<thead>
<tr>
<th>Property</th>
<th>Greatest</th>
<th>Least</th>
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<tbody>
<tr>
<td>Hardness</td>
<td>~</td>
<td>~</td>
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<tr>
<td>Tensile Strength</td>
<td>Ester</td>
<td>Ether</td>
</tr>
<tr>
<td>Elongation</td>
<td>~</td>
<td>~</td>
</tr>
<tr>
<td>Modulus</td>
<td>~</td>
<td>~</td>
</tr>
<tr>
<td>Tear Strength</td>
<td>Ester</td>
<td>PPG Ether</td>
</tr>
<tr>
<td>Compression Set</td>
<td>TDI</td>
<td>MDI</td>
</tr>
<tr>
<td>Rebound</td>
<td>MDI Ether</td>
<td>PPG Ether / Ester</td>
</tr>
<tr>
<td>Low Temperatures</td>
<td>MDI Ether</td>
<td>TDI Ester</td>
</tr>
<tr>
<td>High Temperatures</td>
<td>TDI</td>
<td>MDI</td>
</tr>
<tr>
<td>Abrasion Resistance:</td>
<td></td>
<td></td>
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<tr>
<td>- Sliding</td>
<td>Ester</td>
<td>PPG Ether</td>
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<tr>
<td>- Impingement</td>
<td>MDI Ether</td>
<td>PPG Ether</td>
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<tr>
<td>Heat Buildup</td>
<td>Ester</td>
<td>Ester</td>
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<tr>
<td>Hydrolysis Resistance</td>
<td>MDI Ether</td>
<td>TDI Ester</td>
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<tr>
<td>Oil Resistance</td>
<td>Ester</td>
<td>Ether</td>
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<td>Heat Aging</td>
<td>Ester</td>
<td>PPG Ether</td>
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**Selection Guidelines: 2**

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<tr>
<th>Property</th>
<th>Greatest</th>
<th>Least</th>
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<tr>
<td>Low Duro Formulation (cBA)</td>
<td>TDI Ester</td>
<td>Ether</td>
</tr>
<tr>
<td>FDA Approval (Wet &amp; Dry Food)</td>
<td>MDI</td>
<td>TDI</td>
</tr>
<tr>
<td>Formulation Flexibility</td>
<td>MDI</td>
<td>TDI</td>
</tr>
<tr>
<td>Cost</td>
<td>PPG Ether</td>
<td>MDI Ether</td>
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**Specific Applications**

<table>
<thead>
<tr>
<th>Application</th>
<th>Urethane Type</th>
<th>Basis of Choice</th>
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</thead>
<tbody>
<tr>
<td>Roller Skate Wheels</td>
<td>MDI Ether</td>
<td>High Resistance</td>
</tr>
<tr>
<td>Printing &amp; Coating</td>
<td>TDI Ester</td>
<td>Solvent Resistance, Good Physicals at Low Durometers</td>
</tr>
<tr>
<td>Oil Pipeline Pipe</td>
<td>TDI/MDI Ester</td>
<td>Oil &amp; Abrasion Resistance</td>
</tr>
<tr>
<td>Grain Handling</td>
<td>MDI Ester</td>
<td>Abrasion resistance, FDA Approval</td>
</tr>
<tr>
<td>Fork Lift Ices</td>
<td>TDI Ether (LFTDI Ester)</td>
<td>Low Heat Buildup</td>
</tr>
<tr>
<td>Hammers</td>
<td>TDI Ester</td>
<td>Tear Resistance, Low Resistance</td>
</tr>
<tr>
<td>Sandblast Curtains</td>
<td>MDI Ether</td>
<td>High Resilience, Impingement Abrasion Resistance</td>
</tr>
<tr>
<td>Laundry Equipment</td>
<td>MDI Ether</td>
<td>Hydrolysis Resistance, Hardness Stability, Dynamics</td>
</tr>
<tr>
<td>Paper Mill Rolls</td>
<td>TDI Ether</td>
<td>Hydrolysis Resistance</td>
</tr>
<tr>
<td>Meat Processing</td>
<td>MDI Ester (Special)</td>
<td>FDA Wet Food Approval</td>
</tr>
</tbody>
</table>

**Low-Free Diisocyanate Prepolymers**  
(< 0.1% Free TDI, MDI, PPDI, HMDI)

- Easier Processing  
  - Lower Viscosity  
  - Longer Pot Life  
- Better Dynamics  
  - Less Heat Buildup  
- Health & Safety  
  - Easier Plant Engineering  
  - Control
Selecting a Urethane Elastomer for a New Application: 1

• Decide What Properties are of Key Importance - Physical and Environmental Resistance
• Select Prepolymer / Curative Systems Which are Likely Candidates
• Consider Engineering Design
• Consult Your Suppliers for Recommendations and Further Information
• Review Your Plant Capabilities

Selecting a Urethane Elastomer for a New Application: 2

• Run Whatever Preliminary Tests are Available
• Make Prototype Units of One or More Candidate Systems
• Field Test in Actual service, Make Comparisons, Get Approval from Future Customers
• Gear up for Production

Field Testing - Scrapper Blades

How does abrasion resistance compare in new formulation?
Field Testing – Track Pads
How does cut and tear resistance compare in the new material?

Field Testing – Tension Roll
How does the compression set vary with the new curative?

Review
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