This presentation is courtesy of ADHESIVES.ORG
Overview

- Adhesive Bonding Overview
- Joint Design Considerations
- Hot Melts - One Choice of Many
- Hot Melts - Types and Composition
- Hot Melts - Raw Materials Feedstocks
- Adhesive Bond Testing
- Questions
Adhesive Bonding Overview
Key Points about Adhesion & Adhesives

- **Adhesion**
  - is a performance factor
  - that is it’s defined by the way a structure responds to the environment it is placed in.
  - test design is key understand long term performance

- **Adhesives**
  - are neutral
  - They can only be judged by how well they meet the function they were selected for.
Key Points about Adhesives

- **Adhesives**
  - to bond the substrates the adhesive must be a fluid and flow onto the surfaces.
  - Adhesives function by distributing the force applied to the substrates
  - Throughout the life of the bonded assembly some resistance to stress is required
    - the forces applied to the bond will vary
    - the environment the bond is exposed may also vary
Process Steps When Using an Adhesive

- Prepare the materials of construction – (substrates, equipment & adhesive)
- Apply the adhesive to one substrate
- Combine the first and second substrate
- Apply pressure
- Hold under pressure
- Remove pressure
- Transfer to secondary process
- Secondary process
- Transfer to end user
- Final use
Process Parameters in Adhesive Bonding

- **Adhesive storage**
  - Temperature
  - Humidity
  - Time

- **“pot” life**
  - conditions during application
    - Plant conditions – temperature, humidity, air flow
    - Applicator conditions – temperature, time

- **Storage and preparation of substrate**
  - storage environment
  - clean, treat, prime
Process Parameters in Adhesive Bonding

• **Adhesive application to first substrate**
  – Part shape and size
  – Method of coating
  – Time to coat substrate

• **Mating of the second substrate**
  – open time from point of coating first substrate
  – Time from first contact until compression

• **Assembly compression**
  – amount
  – duration

• **Time to down stream processing**
  – minimum strength requirements

• **Time to final end user**
  – final performance requirements
Generic Adhesive Bond

- Bonded substrates are only as strong as the weakest link
- The interface between substrates and adhesive is critical to bond strength
- Surface preparation can have significant impact on the strength of the structure
Failure Modes

Substrate Failure

Adhesive Failure

Cohesive Failure

Substrate failure is generally the preferred mode of failure
Adhesive / Equipment Interaction - Rheology

• The rheology of the adhesive affects how it coats on application equipment.
• Rheology is the effect of shear rate exerted on the material on the viscosity
• The shear rate will vary with the type of equipment used
• Some common conditions:
  • Shear thinning - too thick for leveling, too thin under high speed conditions
  • Shear thickening – too fluid at low shear and too viscous to wet the substrate at high shear
Joint Design Considerations
Joint/Bond Design

• Consider the substrates
  – Do they have the strength required for the application?
  – Is there a significant difference in the thermal expansion properties of the substrates?

• Will surface treatment be used?

• Is the joint designed to maximize shear forces?

• Is the joint designed to minimize peel forces?

• What is the joint geometry relative to the load?
  – Compressive, Lap shear, cleavage, peel

• Consider the worst conditions when designing the joint
Joint Effects of Thermal Expansion

• Thermal expansion of the substrates and adhesive are rarely the same.

• Differences in thermal expansion in any of the three layers creates stress in the laminate.

• The stress can be:
  – absorbed by the adhesive if elastomeric, or
  – cause a failure at the weakest point in the laminate
Factors influencing Adhesive Bond Performance

Application Process

Joint Design

Adhesive Bond Performance

Secondary Processing

Adhesive Selection

Substrate Selection
Hot Melt Adhesives - One Choice of Many
Choosing an Adhesive

- **End Performance Requirements**
  - Does the adhesive adhere to the substrates?
  - Will the adhesive sustain the load on the substrates?
  - Can the load be sustained over the operating temperatures?
  - What is the level of flexibility that is required?
  - Aesthetic requirements?
  - Chemical and water resistance?
  - Thermal and electrical properties?
  - Standardized or certification test? (ASTM, UL)
  - Environmental testing?
  - Design for repairability?
Choice of Adhesive

• **Process Requirements**
  – Is this an existing or new process?
  – If existing, what are the process conditions?
    • open time, initial strength requirements, line speed, etc
    • In process heat resistance (paint bake ovens)
    • Flexing of the bold line during handling
  – If this is a new process, how much has been selected?
    • Product joint design
    • Substrates
    • Application equipment
    • Production rate
  – OSHA and EPA restrictions
# Comparison of Technologies

<table>
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<th></th>
<th>WB</th>
<th>SC</th>
<th>THS</th>
<th>HM</th>
<th>RHM</th>
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<tr>
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<td>++</td>
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WB = waterbased adhesive; SC = solvent cement; THS = thermoset epoxy; HM = hot melt, RHM = reactive hot melt
Economic Choice of Adhesives

- **Look at true cost not just as provided cost**
  - On a provided basis
    - SC < WB < HM
  - On same solids
    - SC ~ WB ~ HM for the same base polymeric system

- **Adhesive fill gaps**
  - Cost /volume solids better reflects true costs
  - Foaming reduces density and total cost

- **Filler vs no filler**
  - Filler decreases cost/lb, but also increases lbs/volume
  - Filled adhesive may not be lower use cost

- **Cost/part manufactured**
  - Higher cost adhesive may provide greater savings elsewhere
Adhesive “Setting”

- Hot melts – loss of heat
- Solvent or Water – loss of solvent or water
- Reactive hot melts – cooling and then reaction with moisture
- Urethanes –
  - 2 part – reaction of the two components
  - 1 part – reaction with moisture
- Epoxies – reaction of the two components
Hot Melt Adhesives

• A Hot Melt Adhesive is a 100% solid thermoplastic substance that softens when heated and flows when placed under stress.

• A Hot Melt sets solely by the removal of heat.
Hot Melt Adhesives

• **Advantages**
  – speed of set
  – High speed application
  – Variation in open time
  – Excellent storage stability
  – Can bond to a variety of substrates
  – Can gap fill.

• **Disadvantages**
  – Limited heat resistance except reactive HMs
  – high temperature application can cause
    • burns
    • distortion of thermally sensitive substrates
    • Increased oxidation
  – Limited adhesion to metals and polar surfaces
Hot Melt Equipment

• Application equipment
  – extrusion
  – spray – swirl
  – controlled fiberization
  – roll coating
  – slot die coating
  – foaming equipment
Reactive HM: Special Considerations

- Better adhesion to polar surfaces and metals.
- Thin films cure faster than thick films.
- Cure rate is dependent on the migration of the moisture from the substrate through the cured urethane.
- Optimum cure temperature is above 55 F.
- Moisture cure reaction effectively stops below 50F.
- Dry or non-cellulosic substrates may require humidification.
- Humidification is best done during substrate storage prior to lamination not on line.
**Hot Melt Design Criteria**

- Adhesion - substrates
- Open time and Set time
- Hi/Low temperature performance
- Viscosity – application method
- Initial Green Strength – amount/length of compression
- Chemical Resistance
- Thermal stability
Hot Melt Adhesives - Types and Composition
Basic Formulation Ingredients

- Polymer
- Tackifying Resin
- Wax
- Oil/plasticizer
- Antioxidant
- Filler
Polymer

- High molecular weight
- Backbone
- Provides cohesive strength that increases with higher molecular weight
- Major influence on formula viscosity
- Provides toughness and flexibility
- Selection dependent upon end application
Typical Polymers Available

- EVA - ethylene vinyl acetate
- Specific site catalyst polyethylene, polypropylene and copolymers
- Styrenic block copolymers (SIS, SBS, SEBS)
- Polyamides and Polyesters
- APAO
- Polyurethane prepolymer
- Thermoplastic acrylic
Tackifying Resin

- Improves specific adhesion
- Reduces melt viscosity
- Imparts or increases tack
- Influences peel strength
- Affects shear strength
- Improves compatibility
Typical Tackifying Resins

• Four general groups
  – Hydrocarbon
    • Aliphatic – C$_5$, hydrogenated C$_5$ and hydrogenated DCPD
    • Aromatic – C$_9$ and hydrogenated C$_9$
    • Aliphatic/ C$_9$ hybrids
  – Rosin esters
  – Polyterpenes
  – Terpene phenolics
• Molecular weight range 500-2000
• Softening point range 50 to 150°C
Wax

- Reduces melt viscosity
- Reduces cost
- Can improve high temperature resistance
- May provide anti-blocking properties
- Affects set time
- Improves barrier properties
Typical Waxes

• Refined petroleum waxes
  – Paraffin waxes – 150-160°F m.p. typically used
  – Microcrystalline waxes – 160-195°F m.p. typically used

• Synthetic waxes
  – Synthesized from ethylene - 210-245°F m.p. typically used
Oil

- Reduces melt viscosity
- Reduces cost
- Decreases high temperature resistance
- May result in softness and blocking properties
- Affects set time
- May bleed or stain substrates
- Can be volatile at application temperature
Typical Oils

- Two basic types that are useful in hot melts
  - Paraffinic – white oil
  - Naphthenic
Antioxidants

- Improves resistance to thermal degradation
- Improves resistance to oxidation
Typical Antioxidants

- Hindered phenols - Primary
- Phosphites - Secondary
- Zinc dibutyl dithiocarbamate - Secondary
- Hindered amines - Secondary
- DLDTP - Secondary
Fillers

- Increases hardness
- Increases modulus
- Improves abrasion resistance
- Increases density
- Lowers cost
- Increase viscosity
Typical Fillers

- Clays
- Talcs
- Calcium Carbonates (Whitings)
- Zinc Oxide
- Titanium Dioxide
- Barium Sulfate (Barytes)
Basic Formulating Principles
EVA, Block Polymers, Olefins

- Typically three to five components
- Polymer - 20-90+% 
- Tackifying resin - 10-50%
- Wax – 0-90%
- Oil – 0-30%
- Filler – 0-30%
- Antioxidant – 0.2-1%
- Quantity and relative amount governed by performance requirements of the adhesive.
Basic Formulating Principles
EVA, Block Polymers, Olefins

<table>
<thead>
<tr>
<th>Component</th>
<th>EVA</th>
<th>Block Polymer</th>
<th>Olefin</th>
<th>Wax</th>
<th>Oil</th>
<th>Resin</th>
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<td>30%</td>
<td>60%</td>
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<tr>
<td>EVA</td>
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<tr>
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<tr>
<td>Resin</td>
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<td>Resin</td>
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<td>40%</td>
<td>Resin</td>
<td>50%</td>
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</tbody>
</table>
Basic Formulating Principles
Polyurethane Hot Melts

- Typically three to five components
- Polyol - 70-90%
- Isocyanate - 10-30%
- Thermoplastic Resins – 0-40%
- Thermoplastic polymers – 0-20%
- Filler - 0-20%
- Antioxidant – 0.2-1%
- Quantity and relative amount governed by performance requirements of the adhesive.
Hot Melt Adhesives - Sources of Raw Materials
Key Hot Melt Feedstocks

• Oil and natural gas are the basic feedstocks for the majority of the hot melt raw materials:
  – Polymers – EVA, PE, APAO, SBS, SIS, SEBS, acrylics, urethanes
  – Resins – C5, C9, Hybrids
  – Waxes and oils

• The second major source is tall oil rosin from the paper making industry
  – Rosin esters, Polyterpenes, Terpene phenolics

• Smaller but important resin sources are:
  – Limonene from citrus industry
  – Tree and wood rosin
Adhesive Bond Testing
General Bond Testing

• **Bond strength depends on:**
  – Adhesion to the substrates
  – Test temperature
  – Rate of separation of the substrates
  – Type of force applied
    • peel, shear, tensile, cleavage
  – Adhesive properties
    • Storage modulus
    • Complex modulus
    • Loss modulus
  – Adhesive contact area
  – Prior moisture or heat exposure
  – Age of the bond and aging conditions
Strength Testing Modes

180 degree peel

Shear  Tensile  Peel  Cleavage

Strength

High ___________________________ Low

Shear  Tensile  Peel  Cleavage

shear

cleavage
For Best Adhesive Results

1) Select the design
2) Select the substrates
3) Select the adhesive
4) Define the process to achieve the desired adhesive results in the design
5) Select the equipment to best implement the process
For more information…

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