Adhesives for Bonding Polyurethane: A Process Review

PTS Seminar
Polyurethane Manufacturers Association

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Outline
- Overview of the Bonding Process
- Substrate Preparation
- Adhesive Processing
- Cast Polyurethane Processing
- Troubleshooting Bond Failures
- Summary

Bonding Process

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Substrate Types and Preparation Guidelines

- Various grades of steel and aluminum, others include urethane, rubber and engineered plastics
- Sequence of steps include:
  - **Degreasing** (MEK, toluene, etc.) removes fabrication oils, greases, dirt, etc. prior to abrasion step
  - **Abrasion** (blasting, grinding, machining or sanding) removes surface oxidation and increases surface area for primer or adhesive wetting
  - **Final degreasing** removes any carryover residuals from abrasion, a “clean” air blow-off can be substituted
    - Exception is plated metals, adhesion depends on the type

Blast Media Types

- **Grit**, angular shape “cuts”:
  - G25 - 80 grit media is typical
  - Good anchor profile for primer or adhesive wetting

- **Shot**, round shape “peens”:
  - Less surface area, potential for embedded contamination
  - Typical for rough surfaces like cast iron

Substrate Preparation Precautions

- For stainless steel substrate, use aluminum oxide **only**, steel media can cause under-bond corrosion
- For glass-filled engineering plastics, break surface “skin” to expose glass to increase adhesion
- Avoid excessive machine grooving in substrate, forms adhesive puddles > poor adhesion or failure
- Inspect blast media periodically, worn down or contaminated media > poor adhesion or failure
Substrate Preparation Precautions

- Once prepared, apply primer or adhesive ASAP (typically <2 hours), avoids formation of an oxide layer
- Oxides are a weak, non-bonded layer, influenced by substrate composition and plant conditions
- If oxide forms, primer or adhesive can pull it off > poor adhesion or failure
- Caution during summer months, increased temperature and humidity speed the oxidation rate

Preparation Summary

- Successful substrate adhesion depends on:
  - Consistent, aggressive anchor profile
  - Clean, contaminate-free profile
  - Minimal layover prior to primer or adhesive application
- Proper preparation is the “foundation” for subsequent steps, determine best steps with testing
- ~25% of bond failures result from inconsistent or improper preparation of the substrate

Adhesive Types and Selection

- **Two coat approach**: Primer + Adhesive:
  - primer may improve adhesion for hard-to-bond substrates
  - improved bond for environmental and temperature resistance in service
- **One coat approach**: Adhesive only:
  - designed to bond in one step
  - products vary by composition, viscosity and color
  - solvent-based and aqueous technology
  - Majority of industry use
- Testing will determine best product with your specific materials and processes
Adhesive Bonding Mechanisms

Mechanical

Chemical

Handling and Mixing Guidelines

- Always use fresh product, FIFO practices
- Adhere to shelf life/associated storage conditions
- Use proper thinner/solvent and amount, mix during addition of thinner/solvent to avoid “shock”, never add product to thinner/solvent
- Seal cans when not in use to reduce solvent evaporation and minimize contamination
- Store in approved safety cabinets/areas when not in use

Application Techniques

- Applied by brush, spray, roll or dip, since most are manual process, consistent operator technique is key
- Brushing is popular, use clean, dedicated, properly sized brush
- Avoid thick and thin areas, puddles, tears and bare spots > poor adhesion or failure
- If application produces globs or brush marks, try 2 thinner coat applications, with drying between coats:
  - 4 parts product to 1 part thinner/solvent by volume
Dry Film Thickness Guidelines

- **Two coat**: Primer at 0.2 - 0.4 mils plus adhesive at 0.6 - 0.8 mils
- **One coat**: Adhesive at 0.75 - 1.25 mils, same target as two coat system
- 1 mil target = 0.001" or 25.4 microns, based on historical data
- 2 options for measurement: digital dry film gauge or 1-2 mil shim with a micrometer
- Another method is color contrast by using a coated witness panel

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Adhesive Dry Film Thickness

- Low <0.5 mils
- Target ~ 1.0 mil
Dry Film Thickness Precautions

- Use caution with gauges on aggressive profile on substrate, measurements may be inaccurate, an non-abraded substrate can be used as a guideline
- Too thin (<0.5 mils): Lack of adhesive active ingredients to provide bond, common occurrence
- Too thick (+3 mils): Shearing (cohesive) within adhesive layer, occasional occurrence
- Optimal dry film thickness is determined with testing of your specific materials and processes

Drying, Handling and Storage of Coated Parts

- Dry for 30 - 60 minutes at room temperature between coats, forced air < 200ºF for 15 minutes (don't place coated parts in oven immediately after application, blistering may result)
- Minimize handling coated areas, bare hand or dirty gloves > poor adhesion or failure
- For coated parts layover, tote in containers or cover to minimize airborne contamination
- Suggest coated parts be bonded within several shifts, typical maximum 30 day layover

Application Summary

- Produce a uniform application, avoid thick and thin areas, puddles, tears and bare spots
- Target a dry film thickness or color contrast
- Once the process is established, ensure all operators are consistent in technique
- 50%+ of bond failures result from inconsistent or insufficient adhesive application
Coated Part Prebake Guidelines

- Prebake coated parts of a minimum of 2 hours at ~250°F, maximum of 325°F, then load immediately to mold
- Prebake allows an equilibrium between all materials when substrate and polyurethane come in contact
- Prebake is known to improve environmental performance of adhesives
- Suggest convection oven type (natural gas or electric) for uniform heat distribution
- Monitor oven and part temperatures with thermocouple to minimize temperature fluctuation

Coated Part Prebake Guidelines

- Typical prebake cycles: 2-12 hours at 250°F, depends on number/mass of parts and oven efficiency
- Previous experience indicates several prebake cycles (cool-down to RT) still allow good bond
- Determine optimal prebake times and temperatures with testing of your specific materials and processes
- ~10% of failures result from insufficient prebake conditioning

Casting Guidelines

- Caution with silicone containing agents, specifically edges where mold and coated substrate meet
- Typical casting cycle: <2 hours in mold at 212°F, then postbake of 16 hours at 212°F
- Follow supplier’s instructions for specific casting and post bake parameters
- Final assembly is de-molded, may require trimming, post painting, additional fabrication, etc.
- A destructive bond check for small parts should be done prior to shipment, such as push-off or peel test
Troubleshooting Tips for Bond Failures

1) Provide background of the failure, new or existing job, production or service failure?
2) Define the amount, location and mode of failure(s)
3) Review processes, materials, equipment and operators, what's changed?

4) Discuss/list potential problem areas, use previous history, process of elimination and common sense
5) Implement an action plan, change only one parameter at a time
6) Periodic auditing of work instructions to compare against actual production work
7) Periodic/proper training of production staff can reduce or prevent future bond failure incidents
Failure Modes Per ASTM International D429B

- **R** = Rubber retention
- **RC** = Rubber-to-Cement
- **CP** = Cement-to-Primer
- **COH** = Cohesive
- **CM** = Cement-to-Metal

Cement-to-Metal Mode

- Designated as CM, cement = primer or adhesive
- Primer or adhesive failure at the metal or substrate interface
- Bare substrate with primer or adhesive transferred to polyurethane surface

**Possible Cause**
- Grit and/or substrate residue contamination after preparation
- Insufficient anchor profile on substrate
- Excessive oxidation of prepared substrate
- Contamination on substrate before, during or after preparation

**Corrective Action**
- Remove grit or substrate residue with solvent wash or clean air blow off
- Install new belts/wheels or re-fresh blast media to improve anchor profile
- Reduce layover time
- Remove greases, oils, etc.
**Rubber-to-Cement Mode**

- Designated as RC, cement = adhesive
- Failure occurs between polyurethane and adhesive
- Look for evidence of adhesive adhering to substrate, but not to polyurethane surface

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## Possible Causes

- Improper application thickness of adhesive
- Adhesive surface contaminated
- Prebake cycle not sufficient
- Expired or contaminated material

## Corrective Action

- Consult product technical data sheet
- Remove airborne contaminates/use clean gloves to handle surfaces
- Re-adjust prebake cycle
- Dispose of expired material and use fresh

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**QUESTIONS?**

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