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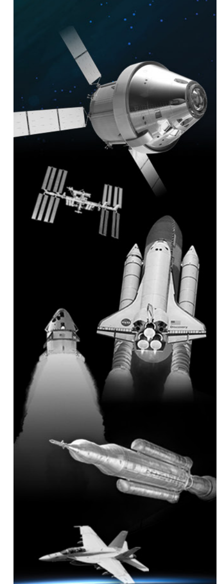

NESC tech bulletin

Evaluation of Adhesive and Solvent Alternatives for Polymeric Bonding Applications

The NASA Engineering and Safety Center (NESC) conducted a technical assessment to evaluate alternatives to dichloromethane, traditionally used for bonding transparent polymeric materials. This effort was initiated in response to potential regulatory restrictions under the EPA Toxic Substances Control Act (TSCA), which could impact critical bonding processes used in spaceflight hardware and experimental systems.

Background

Solvent welding has long been used to bond transparent thermoplastics in aerospace applications due to its simplicity and strength. However, regulatory changes targeting dichloromethane (DCM) have prompted the need to identify safer, effective alternatives. The NESC assessment focused on evaluating a range of adhesives and solvents for bonding two common transparent thermoplastics (polycarbonate and acrylic) used in spaceflight systems. The assessment included standardized mechanical testing to quantify bond strength and evaluate manufacturability, with the goal of identifying viable replacements that meet mission-critical performance requirements.

Discussion

The evaluation included sixteen adhesives and four alternative solvent candidates which spanned multiple chemical families. Testing was conducted using the standardized block shear method, ASTM D4501[1], to ensure consistent and comparable results across all materials. Coupons were 1x1x0.5 in. thick and bonded with an 0.5 in. overlap using the bonding fixture in Figure 1 below.

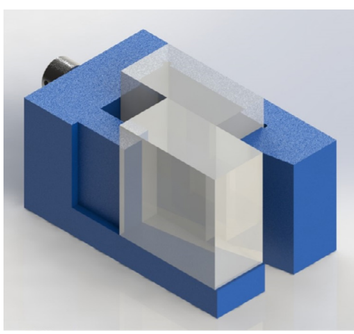

Figure 1.
Block Shear Coupon Bonding Fixture

Adhesive Types Evaluated:

- **Cyanoacrylates:** Fast-curing, single-component adhesives known for high strength and ease of use. These adhesives demonstrated strong performance, often exceeding the baseline solvent in shear strength. However, their short working time and sensitivity to humidity may limit their use in some applications.
- **Two-Part Acrylics:** These adhesives offered a balance of strength, toughness, and manufacturability. Several formulations achieved shear strengths comparable to or exceeding the baseline solvent, with cohesive or substrate failure modes indicating strong adhesion. Their rapid cure and short pot life may require process adjustments for larger assemblies.
- **Epoxies:** Room-temperature curing epoxies were evaluated for their mechanical performance and ease of use. While they offered long pot life and good handling characteristics, they generally exhibited lower bond strength and adhesive failure modes.
- **Urethanes:** These adhesives provided moderate bond strength with cohesive failure modes on one of the substrates. Their longer pot life and toughness make them attractive for applications requiring more flexible bonding processes, though they did not match the performance of the baseline solvent.
- **UV-Curable Adhesives:** These adhesives showed potential for bonding transparent substrates, offering unlimited pot life and rapid cure. However, challenges with light penetration and fixture adhesion limited their evaluation. Further process development is recommended.

Solvent Welding: Four solvents were evaluated, including the baseline DCM solvent and three alternatives selected based on solubility parameters[2] and toxicity profiles. The baseline solvent consistently produced the highest bond strengths, particularly on one of the substrates. All solvents showed varying degrees of fusion and strength, with one cyclic ketone demonstrating promising fusion behavior but reduced mechanical performance.

Conclusion

The assessment identified multiple adhesive types capable of achieving bond strengths comparable to traditional solvent welding. Two-part acrylics and cyanoacrylates emerged as the most promising alternatives, offering high strength and cohesive failure modes. Urethanes may be suitable for applications requiring longer working times, while epoxies and UV-curable adhesives require further optimization. Solvent welding with non-halogenated solvents remains limited, particularly for higher molecular weight thermoplastics, though further exploration may yield viable options. Results for each substrate and solvent/adhesive family are shown in the box plot, Figure 2.

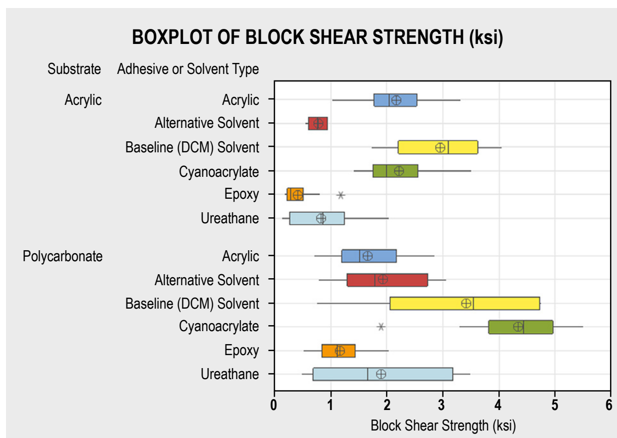

Figure 2. Boxplot of block shear strength (ksi) for each substrate and solvent adhesive family; inside each box, the vertical line depicts the median and the ⊕ depicts the mean.

Recommendations

1. **Prioritize two-part acrylic adhesives** for bonding transparent thermoplastics where high strength and cohesive failure are required.
2. **Use cyanoacrylate adhesives** for rapid bonding applications with short assembly times and minimal gap requirements.
3. **Investigate urethane adhesives** for applications requiring longer working times and moderate strength.
4. **Refine UV-curing processes** to enable broader evaluation of UV adhesives, particularly for transparent substrates.
5. **Continue solvent exploration** using solubility parameter modeling and fusion screening methods.
6. **Standardize block shear testing** for future adhesive qualification on low-modulus polymeric substrates.
7. **Implement environmental controls** (e.g., humidity, surface prep) to ensure consistent bonding performance.

References

- ASTM D4501 – Standard Test Method for Shear Strength of Adhesive Bonds Between Rigid Substrates by the Block-Shear Method
- Hansen, C.M. – Hansen Solubility Parameters: A User's Handbook, 2nd Edition