



The Bonding of Engineered Structures in the 21st Century

A New Class of Structural Adhesives

John Pacanovsky
Sovereign Specialty Chemicals



The Bonding of Engineered Structures in the 21st Century

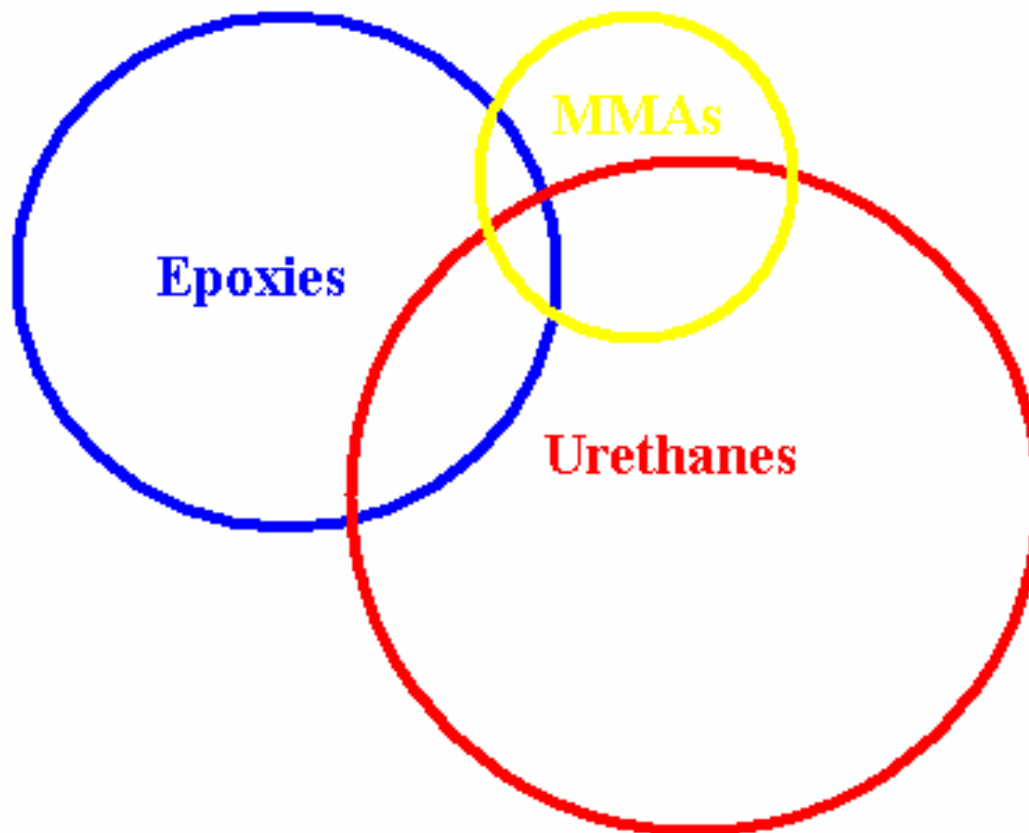
- Structural Adhesives Market Overview
 - By chemistry
- The bonding of Fiberglass Reinforced Plastic Composites
 - Mold release and its effect on adhesion
 - Class A SMC vs. structural composites
- New hybrid polymeric adhesive for composite bonding
 - Physical property comparison
 - Features and benefits
- The structural fastening of metal structures
 - Market overview
- New hybrid polymeric adhesive for metal bonding
- Review and questions



The Bonding of Engineered Structures in the 21st Century

Structural Adhesives Market Overview

Structural Adhesive Chemistries



The Bonding of Engineered Structures in the 21st Century

Structural Adhesives Market Overview

- Structural adhesives chemistry
 - When highlighting epoxies, urethanes and structural methacrylates in the land and sea transportation markets, approximately 100 MM lbs of structural adhesives are employed to chemically fasten
 - Technology has not changed tremendously in the last 10 years, the major change has been in the number of qualified suppliers and clone product alternatives
 - The last significant quantum leap in technology came in the late 80's when ITW/Plexus offered their structural methacrylates for sale.
 - Composite fabricators are changing their processes for cost and environmental reasons
 - Surface prep still occurs as the technology has not proven otherwise as many fabricators can not change due to emissions
 - The market is ripe for the next quantum leap that will expand its size and allow for more complex part fabrications





Structural Adhesives By Chemistry



SOVEREIGN
SPECIALTY CHEMICALS

The Bonding of Engineered Structures in the 21st Century

Polyurethane adhesives

- 2K polyurethane adhesives are the hold the lion's share of the structural adhesives market
- In the composites industry, urethane adhesives are well suited for success.
 - When processed correctly, good chemical interaction can be achieved with FRP substrates
 - Bond very well to closed molded composite systems; SMC, RTM, resin infusion and pultrusion processes, but ill suited for the open mold, spray applied process.
 - Offering good flexibility, urethanes offer sealant characteristics
 - No breakthrough technology in the last 10 years
- Environmental concerns still exist of moisture sensitivity and HAPS regulations
- Can not withstand the high heat conditions of e-coat paint bake ovens (400 F)
- Fairly volume stable, but tend to promote read-thru because heat must be used to cure.



Transportation & Industrial Specialties

Epoxy adhesives

- 1 and 2K epoxy adhesives are the workhorse for bonding metals and certain plastics
 - Mature technology with a strong reputation
- Epoxy adhesives well suited for metal to metal bonding
 - High strength and high heat resistance
- In the composites industry, epoxy adhesives are popular in niche situations.
 - Low flexibility makes them poor choice when bonding unlike materials with drastically different CTE
 - Surface prep is generally not necessary, epoxies rely on strong mechanical bonds
 - Only adhesive of choice when assemblies are baked at 400F
 - No breakthrough technology in the last 10 years
- Environmental concerns are relatively low



Transportation & Industrial Specialties

Methacrylate adhesives

- Newest addition to the structural adhesives market (>1990)
 - MMA adhesives perceived as technically superior, especially in the plastics markets
- MMA adhesives utilize free radical cure mechanism
 - Room temperature cure systems, can not be heat accelerated
 - Free radical cure produces adhesives that gain strength more quickly than other adhesives
- In the composites industry, MMA adhesives are popular in niche situations.
 - Offer high elongation (> 200%) with high heat resistance, popular for bonding large assemblies and materials with very different CTE
 - Surface prep is generally not necessary on FRP, MMA etches the FRP to offer a chemical bond
 - SMC has been a nagging problem over the years due to incompatibility with some mold releases
- The exotherm of cure (~ 250F) and high volume shrinkage (> 10%) produce read through
- Environmental concerns are relatively high due to odor and flammability

The Bonding of Engineered Structures in the 21st Century

The bonding of FRP

- When bonding fiberglass reinforced and other plastic composites, special considerations must be realized as compared to bonding metals.
- Mold releases that aid in the manufacturing process of Fiberglass Reinforced Plastic Composites are a natural barrier to the bonding process.
 - Traditionally, mold releases must be removed to assure a good bond.
 - However, in recent years technology has improved to effectively displace most mold releases.
 - Aggressive curing mechanisms can lead to print through
- When bonding any material to FRP, the different CTE's must be considered
 - Especially across the wide temperature service range
 - Typically high strength adhesives may not dissipate the energy across the bond line effectively



The Bonding of Engineered Structures in the 21st Century

All SMC is not alike

- When bonding most materials, “more is better.”
- If Class A SMC that has a shear strength of 600 PSI and an adhesive that has a tensile strength of 4000 psi may be ill suited for each other.
 - Even with outstanding adhesion, more rigid adhesives will actually offer lower strength values than those adhesives with higher elongation.
- Class A SMC susceptible to read thru
 - Many bonding cycles actually promote read thru
- Structural composites including SRIM, can have strength in excess of 2000 psi, which exceeds the tensile strength of many commercially available structural adhesives



The Bonding of Engineered Structures in the 21st Century

New hybrid polymeric adhesive for composite bonding

- Novel urethane / epoxy / acrylate hybrid adhesive combines the positive aspects of all three chemistries and minimizes the negatives.
- Offers a combination of physical properties not commercially available in the market.
- Cures at room temperature with open time easily altered from 5 minutes to 90 + minutes, with virtually no change in cured properties
 - Can withstand all paint ovens and bake cycles, optimal properties are obtained when system is post baked.
- Bonds thru mold releases to closed molded and open molded FRP
- Volume shrinkage is less than 2%, read through is minimal
- Technology has been formulated into a 1K system



The Bonding of Engineered Structures in the 21st Century

New hybrid polymeric adhesive for composite bonding

- Strength and toughness allows for more efficient joint design
- When large bond lines are fabricated, epoxy adhesives typically do not provide the flexibility for plastic substrates.
- The ability to cure at room temperature and the low volume shrinkage allow for thinner substrates which means lower overall weight
- The ability to influence joint design has just been realized with the pultrusion process
 - FRP bridgedeck overlays are pultruded in interlocking segments
 - The geometry is complex and costly to fabricate
 - Using the hybrid technology vs. a 2K urethane offers 2X the tensile strength with the same elongation
 - The joint has been redesigned for a less complicated and more cost effective part



The Bonding of Engineered Structures in the 21st Century

Physical property comparison

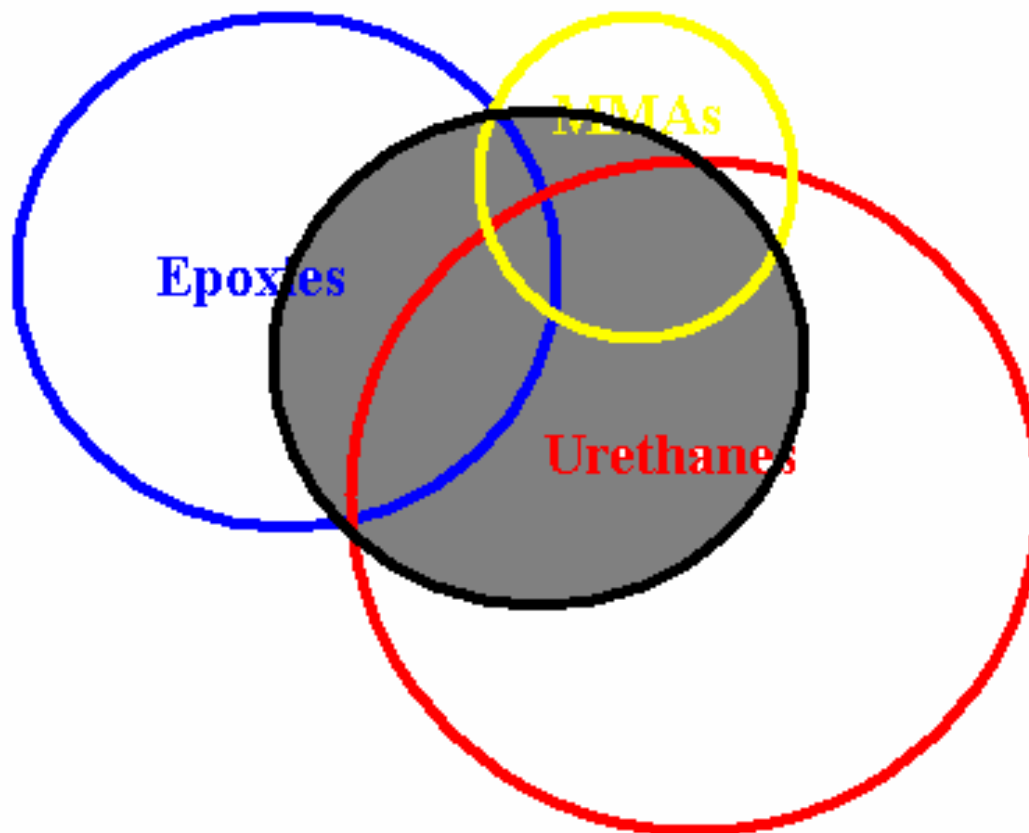
Adhesive	Epoxy	Urethane	MMA	Hybrid
Tensile Strength	3,000 – 4,000 psi	2,000 – 3,300 psi	1,100 – 2,500 psi	4,000 psi
Tensile Elongation	~ 10%	~ 50%	~ 100 %	~ 40%
Exotherm of curing	150 F	150 F	270 F	150 F
Volume Shrinkage	2-5%	2-5%	>10 %	2%



The Bonding of Engineered Structures in the 21st Century

Hybrid adhesives market position

Structural Adhesive Chemistries



The Bonding of Engineered Structures in the 21st Century

Structural fastening of metal structures

- When assessing the structural fastening market, structural adhesives account for only 3 – 5% of the market.
- Bolts, rivets, welds, etc are still the norm as adhesives can not compete economically.
- However, in some cases the cost can be justified
 - Spot welding of Class A metal surfaces
- When bonding galvanized steel and aluminum, significant cost is built into the process at the inception
- A structural adhesive allows for load dissipation across the entire bond line, instead of several point loads.
- The proper structural adhesive will also offer sealant properties which will eliminate the added step.



The Bonding of Engineered Structures in the 21st Century

New hybrid polymeric adhesive for metal bonding

- Plastilock 5003 has been developed from hybrid epoxy technology which has proven Mack ® tough
- Two component toughened epoxy has been replaced by a 1 component, heat curable system.
 - Cure cycle: 20 minutes @ 300F; followed by a paint cure @ 300F for 30 minutes
- The aluminum to aluminum bond for the Mack Vision Class sleeper compartment has proven virtually indestructible
 - Bondline has been pulled, beaten, drilled, stomped and produced metal failure
- Adhesion strength and adhesive tensile strength greater than the peel strength of the aluminum
 - 4,000 – 5,000 psi
- Galvanized steel usage at Mack has influenced the trial and success of this technology on galvanized substrates
 - Class A reinforcements under current review



The Bonding of Engineered Structures in the 21st Century

Conclusion

- Sovereign Specialty Chemicals has developed a new class of structural adhesives that will prove to be a quantum leap in technology
- By offering a novel composite bonding adhesive, Sovereign will allow fabricators to work with designers to reduce weight, material cost and process time.
- A novel adhesive that will structurally bond aluminum and galvanized steel will change the way structures are fabricated.
- By understanding the intersection of polymer physics and engineering, Sovereign is poised to grow the size of the adhesives market.
 - New technology will allow engineers to develop new system geometries
 - By understanding the system expectations and adhesives limitations, cost savings can be engineered into the program at its inception.

