Epoxy Innovations Drive Adhesive Bonding Growth
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Over the past 30 years, significant technology gains in polymer engineering have greatly expanded the applications suited to adhesive bonding with epoxy resins. Advanced bonding methods that incorporate epoxy resin technology are among the most reliable and cost-effective fastening options in today’s highly demanding industries, such as aerospace, automotive, marine, construction and electronics. In many applications, epoxy resins are both technically and economically superior to mechanical fasteners and are also finding use in welding, brazing and soldering operations. High-performance epoxies combine substantial mechanical strength with dimensional stability, resistance to harsh chemicals and user-friendly handling characteristics at a reasonable cost. These advanced structural adhesives can be formulated to bond steel, aluminum and other non-ferrous metals, in addition to many thermosets and thermoplastics, fiber-reinforced composites, ceramics, concrete, brick, glass, wood and foam structures. Compared to other commercial adhesives, epoxies feature several important advantages: They fill gaps, resist water and chemicals and achieve high strength and durability within timely cure schedules.

Of all the available adhesive technologies, epoxies also feature the highest tensile shear strengths — 10,000 psi and greater — with fiber-reinforced compounds offering shear strengths in excess of 5,000 psi. Bonds are generally rigid, but can be made more pliant with flexibilizers if necessary. Service temperatures range from below -60°F to higher than 500°F. Further, these structural adhesives cure with minimal shrinkage and without creating volatile compounds. When used to join dissimilar metals, the bondline functions as a barrier against galvanic corrosion. Another key benefit of epoxy adhesives: They offer robust electrical insulation, and are therefore highly valued for applications involving electrical and electronic assemblies.

Making the Most of Epoxy Adhesives

The performance of an epoxy-based adhesive depends on choosing the right formulation for the specific application, as well as thorough substrate surface preparation, an appropriate cure time and accurate joint design. Because improper surface preparation is the most common cause of problems, special attention must be paid to this variable. Correctly prepared bonding surfaces will result in the epoxy adhesive functioning as expected.

Epoxy adhesives are easy to apply and adhere to a wide range of substrates.

Epoxies Achieve Technology Gains

Substantial technology development has occurred over the last several years with regard to improving the performance characteristics of epoxy adhesives. Many research and development projects were in response to the aerospace industry and its need for lighter weight, more fuel-efficient components. These technology advances resulted in improved toughness and peel strength, increased high-temperature service capabilities and greater resistance to water and other chemicals — including fuels and lubricants — at elevated temperatures. Further, the shelf life of one-component pastes and films has been vastly extended.
without requiring low-temperature (40°F) storage. Cure times have been shortened, while superior bonding properties have been maintained and in some cases improved on.

Gains achieved with regard to increased peel strength are particularly noteworthy. While structural adhesives have traditionally featured high tensile shear strength, they have also exhibited low peel strength, a marked disadvantage for many bonding operations. Today, this deficiency is being corrected with more sophisticated chemistry and formulation technology, including modification with liquid elastomers. Furthermore, epoxy-based adhesives with significantly improved peel strength continue to feature the high tensile shear strengths typical of these materials.

Of equal significance are recent improvements in thermal stability for one and two-component structural adhesives. Advanced epoxy adhesive systems now perform quite satisfactorily at temperatures of 500°F and higher. Key to this remarkable development is the production of new heat-resistant epoxy resins based on novel chemical structures. These advanced resins can be cured over a wide temperature range with specially designed curing agents that yield impressive bond strengths.

Beyond punishing temperatures, epoxies are also finding use in highly corrosive environments, such as those in the chemical processing industries. Specialized two-component liquid and paste adhesives now feature superior resistance to strong mineral acids, bases and organic solvents after only ambient temperature cures. One such adhesive resists 98% sulphuric acid, 30% phosphoric acid, 30% ammonia, 100% ethanol and strong organic solvents including cellosolve and butyl acetate.

Today’s advanced epoxy resins often function as exceptional thermal and electrical insulators as well. In certain electronics applications, it is now required that adhesives conduct electricity, heat, or both. Electrically and thermally

The ABC’s of Epoxy Adhesives

Most epoxy adhesive systems consist of a base resin, hardener, accelerator, flexibilizers, fillers, diluents and additives. The base resin significantly influences both thermal stability and chemical resistance. Depending on the selected hardener, an epoxy adhesive may cure quickly (in just 40 seconds) or slowly (over 48 hours), either at room temperature or elevated temperatures in the 150 to 400°F range.

Bond strength, mechanical strength, flexibility, heat and chemical resistance, electrical and thermal conductivity and many other properties all may be adjusted according to the type and amount of various chemical components added to the epoxy formulation. The list of additives used to alter the properties of an epoxy adhesive in any given industry is extensive and steadily increasing. What is most useful will depend on the specific application.

Epoxy adhesives are usually produced as one or two-component formulas and as either ambient or heat-cured liquids, pastes or films. Films are available as supported or unsupported tapes, with the principal supporting elements made of glass, cloth, graphite fibers or nylon film.

Two-component liquid and paste epoxy adhesives are widely used in the construction, marine, electrical/electronic and various mechanical industries as well as for repair and maintenance in consumer applications. Two-component epoxies are usually cured at ambient or moderately elevated temperatures in the 75 to 200°F range and tend to achieve somewhat lower strengths and more limited service temperature capabilities compared to one-component formulas.

Single-component paste and film epoxy adhesives are often used in the aerospace and transportation industries because they offer the highest shear strengths, service temperature capabilities and ease of processing. These epoxies require elevated temperature cures, frequently in the 250 to 400°F range.
Conductive adhesives have been developed in response to this demand. Electrically conductive epoxies contain metallic fillers — such as silver, copper and nickel — in finely divided powder form. For less stringent requirements, graphite fillers are acceptable. Thermal conductivity is achieved using either specialized metals or inorganic fillers, including alumina. Both one and two-component conductive adhesive systems are available with either ambient or elevated temperature cures. Advanced adhesive systems are also being utilized in NASA-compliant low outgassing and fiber optic applications.

For further information on this article, for answers to any adhesives applications questions, or for information on any Master Bond products, please contact our technical experts at Tel: +1 (201) 343-8983.

Advantages of Structural Adhesives

- Improved stress distribution: Stresses are evenly distributed over the entire bonded area, eliminating localized stress concentrations.
- Outstanding fatigue resistance of adhesively bonded joints, as well as excellent shock and vibration resistance.
- Adhesively bonded joints provide continuous contact between substrates, providing strong seals and superior load-bearing properties.
- Ability to bond dissimilar materials including metal, plastic, elastomers, ceramic, glass and wood.
- In contrast to mechanical fasteners, adhesively bonded surfaces offer smooth contours, free of gaps and external projections.
- Capability to bond materials at low or moderately elevated temperatures, vital for protecting heat-sensitive substrates.
- Less critical tolerances required when components are joined, due to gap-filling ability.
- Substantial weight and cost savings without a corresponding loss of strength.

Advanced bonding methods that incorporate epoxy resin technology are among the most reliable and cost-effective fastening options in demanding applications, such as those found in the transportation, optical and electronics industries.
## TYPICAL MASTER BOND ONE- AND TWO-COMPONENT EPOXY ADHESIVE SYSTEMS

<table>
<thead>
<tr>
<th>Properties of Master Bond High Performance Toughened One- and Two-Component High Shear/High Peel Strength Epoxy Adhesives</th>
<th>Two-Component Liquid Epoxy (Master Bond Supreme 11)</th>
<th>One-Component Epoxy Paste (Master Bond Supreme 10HT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition of adhesive</td>
<td>Part A: elastomer modified epoxy Part B: modified hardener</td>
<td>Elastomer modified epoxy compound with hardener</td>
</tr>
<tr>
<td>Viscosity, cps, 75°F</td>
<td>Part A: &gt;140,000; Part B: &gt;100,000</td>
<td>&gt;250,000 cps</td>
</tr>
<tr>
<td>Mix Ratio, Part A/Part B</td>
<td>1:1 (weight or volume)</td>
<td>No mix system</td>
</tr>
<tr>
<td>Working (pot) life of mixed compound, 100 gram batch</td>
<td>30 minutes at 75°F</td>
<td>12 months at 75°F</td>
</tr>
<tr>
<td>Cure time</td>
<td>18-24 hours at 75°F</td>
<td>30-40 minutes at 300-350°F</td>
</tr>
<tr>
<td>Tensile shear strength, Al/Al, psi 75°F 180°F 300°F</td>
<td>2,300 920 520</td>
<td>3,670 2,860 1,830</td>
</tr>
<tr>
<td>after 30 days exposure at 160°F measured at 75°F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>after 30 days water immersion at 75°F</td>
<td>2,240</td>
<td>3,350</td>
</tr>
<tr>
<td>T-peel, pli, 75°F 2024T-3 alloy</td>
<td></td>
<td>30</td>
</tr>
</tbody>
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