Adhesives and Metal: A Bond that Lasts (and Saves Money!)

Based on an original article by Loctite, "Bonding Metals with Adhesives"
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When most people think of adhesives, they envision small plastic bottles that occupy space in a kitchen drawer to be used to repair a broken coffee cup or to re-attach a chipped part back onto a holiday decoration. For those of us in industry, adhesives go far beyond simple repair jobs. Adhesives are rapidly replacing metal fasteners, welding, soldering and brazing in many bonding applications.

When we talk about adhesives, we're referring to a group of chemicals that are classified into two large groups: structural adhesives and machinery adhesives. Structural adhesives are used in situations where the adhesive itself primarily supports the load, whereas machinery adhesives are used to reinforce the seal of a mechanically-joined assembly."

Structural Adhesives vs. Thermal Mechanical Fastening
Assembling equipment and devices with metal substrates requires varied bonding methods, including thermal bonding (welding, soldering, brazing), mechanical fastening and adhesive bonding.

Thermal joining, while delivering a strong and lasting bond, can cause aesthetic problems (distortion, coloration) due to uneven heating and cooling of the parts. When problems arise with thermally bonded parts, repairs are both difficult and costly.

Mechanical fasteners provide a strong and fast bonding solution for both similar and dissimilar substrates. However, they require holes to be drilled into the materials to be bonded, which can result in weakened substrates. In addition, this type of bonding tends to concentrate stress in a small area rather than distributing it over a larger area, which can lead to premature failure. While suitable for stationary substrates, this bond is susceptible to flex or vibration stress damage and can reduce aesthetic appeal.

Adhesives give manufacturers many unique advantages. First of all, adhesives, whether bonding metal to metal or other substrates, evenly distribute stress over a wide area and are hidden from view since they are applied within the joint. Second, adhesives resist damage that can be inflicted by flex or vibration. In addition, the bond they provide doubles as a sealant, warding off corrosion. Another distinct advantage adhesives provide is that they allow easy joining of irregular-shaped and/or dissimilar substrates. However, adhesives may require long curing times and may also include unique surface preparation prior to application. Disassembly is also an issue, given the nature and the strength of the bond.

Structural Adhesive Options for Metal Bonding
With a comparably high resistance to heat and chemicals, metals are generally the preferred substrate in demanding environments. Due to the wide differences in coefficients of thermal expansion (CTE) between metal substrates and adhesives, selected adhesives must be able to meet the demands of repeated heating and cooling. Commonly used adhesives for bonding metal substrates are:

Adhesive	Advantages	Disadvantages
Two-part, no-mix acrylics	Durable, tough, quick bond strength	Limited depth of cure
Two-part mix acrylics	Durable, tough, improved depth of cure	Slow curing
Two-part epoxies	High strength, durable, good depth of cure and temp resistance	Slower cure than either of the acrylics
Polyurethanes	Superior flexibility and toughness	Cure slowly, good only for temperatures up to 300° F
Cyanoacrylates	Rapid cure, high shear strength	Limited depth of cure, poor peel strength
Light cure acrylics	Fast cure, good strength	Typically used when one substrate can transmit light to the bond line
Silicones	Maintain properties over a wide range of temperatures, excellent environmental resistance	Long cure times, low cohesive strength

Anaerobic Adhesives for Machinery

Machinery adhesives are anaerobic adhesives most commonly used in applications such as threadlocking, maintaining rigid circular assemblies or as a sealant between flanges. Anaerobic adhesives are in liquid form until in contact with iron, copper or other metal ions. Though many applications for anaerobic adhesives exist, they are used primarily for their high shear strength and limited flexing and peeling.

Using an anaerobic adhesive locks threaded assemblies together to prevent loosening and corrosion while maintaining the desired clamping force. They also offer controlled torque for fastener removal. As the threadlocker cures, polymer chains form and seek out even the tiniest imperfection in the threads and fill these small gaps, locking and sealing the threaded assemblies. This prevents lateral movement and protects the assemblies from the corrosive effects of moisture, gases, and fluids.

For applications where a liquid threadlocker is not viable, pre-applied dry threadlockers or thick paste adhesives are options that not only prevent loosening and galling, but also improve lubrication and sealing.

Retaining compounds are adhesives that bond assemblies that once were relegated to assembly by press or shrink fits. These adhesives counter the tight manufacturing tolerances and costly surface finish requirements of press and shrink fits that can result in distorted assemblies by opening tolerances, easing surface finish requirements and producing standard assemblies with higher strength.

Anaerobic adhesives allow manufacturers to “create joints with a line-to-line fit between metal flanges,” eliminating the need for tightly controlled flange surface finishes and problems often found with compression gaskets.

Requirements for Application

Regardless of the adhesive used, proper surface preparation is paramount. Since bond strength is largely determined by the degree of adhesion between the adhesive and the substrate, adequate surface preparation, such as removing oxidation, oils or other chemicals that can negatively affect the bonding process, is advised.

The number one cause of joint failure is rarely adhesive strength; rather, it is poor design and inadequate surface preparation that primarily causes the problem. Proper design and testing, in addition to cleaning, can ensure a lasting bond free of failure.