

BONDING METALS WITH ADHESIVES

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Adhesives are widely used in assembly processes involving metal substrates and components. Generally these adhesives fall into one of two categories: structural adhesives, which are used to bond components where the adhesive is the primary means of supporting a load; and machinery adhesives, which typically augment the seal or holding force of a mechanically joined assembly. By understanding the processing and performance benefits offered by adhesives, it is possible to streamline manufacturing operations and produce more robust assemblies while lowering overall assembly costs.

Structural Adhesives vs. Thermal and Mechanical Fastening

In order to assemble the wide range of equipment and devices made with metal substrates, manufacturers rely upon several diverse bonding methods including thermal joining, mechanical fastening, and adhesive bonding.

Thermal joining, which includes welding, soldering, and brazing, is only effective on homogeneous metal substrates with similar melting points. Thermal methods of assembly are very difficult to disassemble, and can result in aesthetic concerns such as distortion, discoloration, or “weld worms.” By grinding or sanding down the substrate to minimize the metal bump or discoloration, and painting over the problem area if necessary, manufacturers can often solve these aesthetic concerns. Distortion, which is caused by uneven heating and cooling of the part, is more difficult to repair.

Mechanical fasteners are quick and easy to use, will attach many dissimilar substrates, and can be easily disassembled. However, they require that holes be drilled into the materials to be joined, which alters the design of the assembly and can weaken the substrates. They also concentrate stress at a single point rather than distributing it evenly over a broader area, which may lead to premature failure of the joint. Mechanical fasteners have difficulty withstanding

stresses caused by flex or vibration, and can detract from the styling of the product, as they are typically visible in the design.

Whether bonding metal to metal, plastic, glass, rubber, ceramic, or to another substrate material, adhesives distribute stress load evenly over a broad area, reducing stress on the joint. As they are applied inside the joint, adhesives are invisible within the assembly. They resist flex and vibration stresses, and form a seal as well as a bond, which can protect the joint from corrosion. Adhesives easily join irregularly shaped surfaces, increase the weight of an assembly negligibly, create virtually no change in part dimensions or geometry, and quickly and easily bond dissimilar substrates and heat sensitive materials. Adhesives are one-size-fits-all, and assembly can be easily automated. Limitations include the amount of time required for adhesives to fixture and develop full strength (cure), surface preparation requirements, and the problems associated with joint disassembly.

Structural Adhesive Options

Since metals are often used in more demanding environments than other substrates, an adhesive's heat and chemical resistance are important considerations for metal bonding. Metal substrates and adhesives have widely different coefficients of thermal expansion (CTE), which, during repeated heating and cooling, can cause the bonded joint to weaken. Selected adhesives should be sufficiently resilient to accommodate these stresses. Also, for metals such as aluminum and steel that can easily form a loose oxide layer in moist environments, certain adhesives can minimize moisture's ability to reach the metal surface in the bond joint.

Of the multitude of adhesives currently available, seven families are commonly used for bonding metal substrates. The four adhesive technologies most commonly used for metal bonding-- two-part no-mix acrylics, two part mix acrylics, two-part epoxies, and polyurethanes -- deliver excellent performance and the ability to withstand harsh environments. The remaining three chemistries -- cyanoacrylates, light cure acrylics, and silicones -- all offer benefits for specific application needs but are either less capable of withstanding harsh environments or offering the

high bond strength of the other families. An understanding of the specific processing and performance benefits of each family is important to selecting the proper adhesive for a given application.

The four most commonly used metal bonding adhesives all offer high bond strength to most metals and good environmental durability. Two-part no-mix acrylics offer limited depth of cure, but are durable, tough, and can develop bond strength very rapidly. Two-part mix acrylics, on the other hand, offer many of these advantages and improved depth of cure, but tend to cure slower. Two-part epoxies offer high strength, durability, excellent depth of cure and temperature resistance, but are slower to cure than either of the acrylic families. Polyurethanes effectively deliver superior flexibility and toughness, but cure slowly and can only withstand temperatures up to 300°F.

Cyanoacrylates or instant adhesives are one-part chemistries that cure rapidly at room temperature to give very high shear strengths. The benefits of simplified processing are offset by performance limitations such as limited depth of cure and poor peel strength.

Light cure acrylics cure in seconds on exposure to suitable light and offer good strength, but are typically used where one substrate is able to transmit light through to the bond line. (Many epoxy and two part no-mix acrylic formulations offer a secondary light cure mechanism to help speed production.) Silicones have longer cure times and low cohesive strength, but maintain their properties over a wide range of temperatures and offer excellent environmental resistance.

The best structural adhesive for a specific application should be determined by considering critical factors such as substrates to be bonded, end use operating environment, the manufacturing process, and other key variables. Manufacturers and design engineers should work closely with their adhesive manufacturer to determine the most appropriate adhesive chemistry for an individual application.

Anaerobic Machinery Adhesives

The term “machinery adhesives” refers to the family of anaerobic adhesives that are typically used in applications such as threadlocking, retaining rigid cylindrical assemblies, or sealing between flanges. An anaerobic adhesive remains liquid until it is isolated from oxygen in the presence of metal ions, such as iron or copper. For example, when an anaerobic adhesive is sealed between a nut and a bolt on a threaded assembly, it rapidly “cures” or hardens to form a tough crosslinked plastic with tenacious adhesion to many metals. Though anaerobic applications differ widely, in most cases the adhesive provides high shear strength and sees very little flexing or peel forces.

When anaerobic products are used to lock threaded assemblies together, they prevent loosening and corrosion of the assembly, maintain proper clamping force, and offer controlled torque for removal of the fastener. As the liquid threadlocker cures, it forms polymer chains that find their way into every tiny imperfection in the threads. The adhesive completely fills the microscopic gaps between interfacing threads (Figure 1) to positively lock and seal threaded assemblies, preventing lateral movement and protecting the joint from corrosion that can result from moisture, gases and fluids.

In manufacturing operations where application of a liquid threadlocker is not desirable, pre-applied dry threadlockers are available that will cure when the threaded unit is assembled. Thicker paste versions of these anaerobics find wide applicability in sealing threaded pipe sections together. In addition to eliminating loosening of the assembly, these materials prevent galling, offer improved lubricity, and seal the joint to prevent leakage.

For rigid cylindrical assemblies, such as joining a bushing to a shaft, anaerobic adhesives known as retaining compounds enable manufacturers to bond assemblies that once could only be assembled using press fits or shrink fits. Press fits and shrink fits often require tight manufacturing tolerances and costly surface finish requirements, involve cumbersome heating and cooling of components prior to assembly and can result in distorted assemblies. Retaining

compounds allow manufacturers to open their tolerances, ease their surface finish requirements, and produce assemblies with much higher strength than standard assembly techniques.

Anaerobic adhesives are also widely used as formed-in-place gaskets that provide a seal between flange faces. Allowing manufacturers to create joints with a line-to-line fit between metal flanges, these materials eliminate the need for tightly controlled flange surface finishes and eliminate problems associated with compression gaskets such as compression set, bolt relaxation, and fastener loosening.

Application Requirements

No matter what type of adhesive is used, surface preparation is critical in ensuring a lasting and stable adhesive bond. Bond strength is determined to a great extent by the degree of adhesion between the substrate and the adhesive. The layer of surface oxidation or rust that is frequently present on metal substrates will impede adhesion and must be cleaned off in order to ensure an optimal bond. Some metals such as steel are treated with oils or other rust preventative coatings that can also affect the bonding process. While certain adhesives can bond through surface contaminants, others may require a preliminary cleaning process before bonding.

Joint failure rarely involves adhesive strength; rather it is due to poor design, inadequate surface cleaning and preparation, or improper adhesive selection for the substrates and the operating environment. Assemblies should always be thoroughly tested in the design phase to ensure that bonding will be successful during manufacturing and over the life of the device.

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The information published in this article is taken from the "Design Guide for Bonding Metals," technical reference information created to simplify the process of selecting the best metal/adhesive combination for design engineers who specify metals in product design and assembly. For a copy of this brochure, fax a request for LT-3371 to 800-422-0460 or send an e-mail to literature@loctite.com. An online version of the Design Guide to Bonding Metals can also be easily accessed on the Loctite Website at www.loctite.com/literature/design_metal.html. Other similar bonding guides from Loctite include the Design Guide for Bonding Plastics and the Design Guide for Bonding Rubber and Thermoplastic Elastomers.