Assembly Adhesives

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To compete in today's global marketplace, manufacturers are under constant pressure to deliver the most reliable, lowest cost product in the shortest amount of time. This forces manufactures to look for materials and joining methods that are less time consuming, more versatile, and lower cost. More and more, design and manufacturing engineers are using adhesives due to their overwhelming benefits.

It would be difficult to name an industry that does not use adhesives in some way. Design engineers rely upon adhesives to provide solutions for structural bonding, cylindrical assembly, threadlocking, flange and thread sealing, and a range of other design challenges. Most any product used for work or leisure incorporates adhesives. These materials are commonly used in electrical and electronic devices, automobiles, aircraft, consumer products, appliances, medical devices, loudspeakers, sporting equipment, and many other products.

Assembly Methods

There are three major fastening methods that offer varying degrees of effectiveness depending on application requirements. Thermal methods weld, braze, or solder two similar metal or plastic substrates together. Mechanical fastening secures substrates with bolts, screws, or rivets. Chemical assembly bonds similar or dissimilar substrates using adhesives.

Thermal joining involves either melting two substrates together by exposing both surfaces to electricity or heat, or placing a bead of molten metal between two metal substrates. Thermal joining is only effective on homogeneous substrates with similar melting points, and parts are very difficult to disassemble. Thermal joining can result in aesthetic concerns such as distortion, discoloration, or "weld flash," a thin line that appears along a weld joint.

Mechanical fasteners are quick and easy to use, attach dissimilar substrates, and can be easily disassembled. However, they require that holes be drilled into the parts to be joined, which alters the design of the assembly and can weaken the substrate. Fasteners 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.

Why Use Adhesives?

With their ability to bond a variety of substrates including plastic, metal, rubber, and glass, adhesives offer several major benefits over other joining methods. Adhesives distribute stress load evenly over a broad area, reducing stress on the joint. Since they are applied inside the joint, adhesives are invisible within the assembly. Adhesives resist flex and vibration stresses, and form a seal as well as a bond, which can protect the joint from corrosion. They join irregularly shaped surfaces more easily than mechanical or thermal fastening, minimally increase the weight of an assembly, 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. (Figure 1)

Limitations of adhesives include setting and curing time (the amount of time it takes for the adhesive to fixture and strengthen fully), surface preparation requirements, and the potential need for joint disassembly.

Adhesive Types

When selecting an adhesive technology, engineers should consider several factors. Both adhesives and substrates should be able to withstand the end use environment of the finished assembly. Adhesives should be compatible with the substrate and safe for the manufacturing environment, and should not slow down production.

Of the multitude of adhesives currently available, there are eight families most commonly used in manufacturing processes. Each of these families offers a unique combination of performance and processing benefits.

Anaerobics are one-component adhesives that remain liquid when exposed to air. Once confined between metal substrates, anaerobic adhesives cure or harden into tough thermoset plastics which provide excellent environmental and temperature resistance.

Invented by the founder of Henkel Loctite in the 1950's, this adhesive technology is now available in a wide range of formulations. Anaerobic adhesives are commonly used for locking and sealing threaded assemblies, retaining bearings and bushings on shafts or in housings, and sealing metal flanges in place of cut gaskets. These materials are often used to enhance or replace mechanical joining methods, resulting in longer equipment service lives and reduced manufacturing costs. (Figures 2, 3, 4)

Cyanoacrylates are high strength, one-part adhesives that cure rapidly at room temperature to form thermoplastic resins when confined between two substrates in the presence of microscopic surface moisture. Since cure is initiated at the substrate surface, these adhesives have a limited cure-through gap of about 10 mils (.010"). A wide variety of cyanoacrylate formulations are available with varying viscosities, cure times, strength properties, and temperature resistance.

Cyanoacrylates achieve fixture strength in seconds and full strength within 24 hours, which makes them well suited for use in an automated production environment. Cyanoacrylates are frequently used in high volume production environments to bond parts made of plastic, metal, and rubber. (Figure 5)

Early cyanoacrylate formulations exhibited low impact and peel strength, low to moderate solvent resistance, and limited operating temperatures of 160 to 180°F. Subsequent reengineering of these adhesives has addressed many prior limitations. Rubber toughened cyanoacrylate formulations provide increased peel and impact strength. Applied to substrates before adhesive application, polyolefin primers allow cyanoacrylates to achieve enhanced bond strength on difficult-to-bond plastics such as polypropylene and polyethylene. Accelerators ensure the rapid cure of cyanoacrylates in low humidity environments.

"Surface insensitive" cyanoacrylates also provide fast cures in low humidity environments as well as on acidic surfaces. To minimize blooming or frosting -- the presence of a white haze around the bond line, specialty low-blooming formulations have been developed. And the recent introduction of thermally resistant formulations allows cyanoacrylates to withstand continuous exposure to temperatures up to 250°F.

Light Cure Acrylics are one-part, solvent free liquids with typical cure times of two to 60 seconds and cure depths in excess of 0.5 inches. Light curing acrylics provide good environmental resistance, superior gap filling properties, and clear bond lines for improved aesthetics. Like cyanoacrylates, light curing acrylic adhesives are available in a wide range of viscosities from thin liquids (~ 50 cP) to thixotropic gels. (Figure 6)

These adhesives remain liquid until exposure to light of the proper wavelength and irradiance causes them to fixture rapidly and cure. Formulations are widely available with a secondary cure mechanism (such as exposure to heat or chemical activators) that allows adhesive in shadowed areas to cure completely. Because cured acrylic adhesives are thermoset plastics, they offer superior thermal, chemical and environmental resistance.

As cure is on demand, light cure acrylics offer extended open times for positioning and repositioning parts. These adhesives offer high bond strength to a wide variety of substrates, and are available in ranging degrees of flexibility from soft elastomers to glassy plastics.

Light Cure Cyanoacrylates are a new adhesive technology that combines the benefits of cyanoacrylate and light curing acrylic technologies. Light curing cyanoacrylates fixture instantly when exposed to the proper light source (Figure 7). The remaining adhesive in the shadowed area not exposed to the light proceeds to cure due to a secondary moisture cure mechanism. This hybrid technology overcomes many of the limitations of cyanoacrylates and light cure acrylics by offering minimized blooming/frosting, increased cure depth, rapid dry surface cure, high bond strength to elastomers, and compatibility with primers for difficult-to-bond plastics.

Highly versatile light cure cyanoacrylates emit minimal vapors, surface cure immediately when exposed to light, adapt easily into production lines, and require no second-step accelerators or activators. These adhesives are surface insensitive and extremely versatile, offering excellent adhesion to a wide variety of substrates including rubber and plastics. Light Cure Cyanoacrylates minimize stress cracking on sensitive substrates such as polycarbonate and acrylic, and will bond polyolefin plastics when used in conjunction with special adhesion promoters that can either be compounded into the molded parts or applied to the part's surface prior to bonding.

Ideal for high volume bonding applications, the popularity of light cure cyanoacrylates is growing rapidly for assembing medical devices, cosmetic packaging, speakers, electronic assemblies, and small plastic parts. This new adhesive technology offers a wide range of benefits to manufacturers. Their rapid cure speed allows parts to be processed in seconds rather than minutes, often delivering 60 percent of their final strength after only five seconds of exposure to light. Manufacturers should consider using light cure cyanoacrylates for bonding applications involving overlapping, non-transparent parts.

Hot Melt Adhesives have been used in industrial and consumer product assembly for decades. Traditional hot melts are thermoplastic resins that are essentially re-flowed onto a bonding surface to facilitate assembly. Once cooled, the adhesive holds the components together. While many types of hot melts are available, higher performance varieties include ethyl vinyl acetate (EVA), polyamide, polyolefin, and reactive urethane. The primary benefits of hot melts are their ability to fill large gaps and to achieve high bond strengths as soon as they cool.

While EVA hot melts are typically used for low cost potting applications, polyamide hot melts replace EVAs in potting applications with more demanding temperature and environmental conditions. Polyolefin hot melts provide good moisture resistance, superior adhesion to polypropylene substrates, and excellent resistance to polar solvents, acids, bases, and alcohols.

Reactive urethane adhesives, the latest in hot melt technology, perform well on difficult-to-bond plastics. Whereas most traditional hot melts are thermoplastic resins that can be repeatedly reheated, reactive urethanes form thermoset plastics when fully processed. Initial strength is developed a bit slower than traditional thermoplastic hot melts; however, for structural bonding, reactive urethanes are generally the hot melt adhesive of choice. These hot melts are processed at temperatures of approximately 250°F, up to 200°F cooler than other hot melt chemistries.

Epoxies are common one- or two-part structural adhesives that bond very well to a wide variety of substrates, give off no by-products, and shrink minimally upon cure. Cured epoxies typically have excellent cohesive strength, very good chemical resistance, and good heat resistance. These adhesives also offer the ability to fill large volumes and gaps. The major disadvantage of epoxies is that they tend to cure much slower than other adhesive families, with typical fixture times between 15 minutes to two hours. While heat can be used to accelerate the cure of epoxies, the temperature limitations imposed by certain substrates such as plastics, can often preclude heat cure.

Polyurethanes are tough polymers that offer greater flexibility, better peel strength, and lower modulus than epoxies. Available as one or two-part systems, these adhesives consist of soft regions that add flexibility to the joint, and rigid regions that contribute cohesive strength, temperature resistance, and chemical resistance. By varying the ratio of hard and soft regions, a range of physical properties can be achieved.

Like epoxies, polyurethanes bond well to a wide variety of substrates, although a primer is sometimes required to prepare the surface. Polyurethanes also have fixture times similar to epoxies (15 minutes to two hours), which can require racking of parts and large amounts of work-in-progress. Polyurethanes offer good chemical and temperature resistance. However, long-term exposure to high temperatures will degrade them more rapidly than epoxies. When bonding with polyurethanes, moisture must be excluded from the adhesive components since it can impair both performance and appearance.

Two-Part Mix Acrylics are similar to epoxies and polyurethanes in that they offer good gap filling abilities and good environmental and thermal resistance. Two part acrylics can be formulated to fixture faster than epoxy and polyurethane adhesives and to offer improved adhesion to many substrates. Acrylics are highly flexible and bond well to many metals and plastics, which makes them a good choice for applications where long term fatigue resistance and durability are required. (Figure 8)

Surface Preparation

No matter what type of adhesive is used, surface preparation is critical to ensure a long lasting and reliable bond. The treatment method selected depends on the level of surface contamination, the types of substrates, the initial and long-term bond performance required, and the financial practicality of the treatment process.

For most applications, surface preparation is as simple as cleaning the surfaces with a solvent to remove oils, greases and other potential contaminants that could hinder bond strength. Other applications may require surface abrasion, chemical surface etching, heat treatment, plating processes or plasma treatment to obtain adequate adhesion.

For difficult-to-bond substrates, such as polyolefin plastics, many adhesive manufacturers offer surface primers that microscopically alter the surface to increase adhesion. From the various methods of surface preparation, engineers should select the most effective method that fits into the manufacturing process at a reasonable cost.

Troubleshooting and Resources

The most frequent causes of adhesive joint failures do not involve adhesive strength. Typically, adhesive joint failure may be attributed to poor design, inadequate surface preparation, or improper adhesive selection for the substrate and the operating environment. Thorough testing is critical during the design phase to ensure the success of an adhesive assembly during manufacturing and over the life of the device.

The growing variety of adhesives available often makes selecting the proper adhesive a challenge. To assist design engineers in narrowing their search for the right product, adhesive manufacturers such as Henkel Loctite offer a variety of value added services. These resources include local sales and application engineering contacts, technical and material safety data, design guides, product selector charts, and Web sites. Some adhesive manufacturers also offer local seminars to train engineers on how to design with and effectively use adhesives. Combined, these resources allow engineers to save valuable time and money, and help ensure that the most reliable and cost effective adhesive solution is specified for an application.

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