Design News

Designing for Assembly with Adhesives

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Adhesives have found widespread design acceptance in many industrial manufacturing applications, providing solutions for structural bonding, cylindrical assembly, threadlocking, flange and thread sealing, thermal management, wire bonding and harnessing, and a range of other design challenges. The ability of adhesives to bond dissimilar materials quickly, efficiently, and cost-effectively has enabled the actual production of many designs that would have been impossible using only mechanical fastening methods.

Adhesives offer significant benefits over mechanical and thermal fastening methods. Rather than concentrating stress at a single point, adhesives distribute stress load over a broader area, resulting in a more even distribution. A joint bonded with adhesive better resists flex and vibration stresses than, for example, a riveted joint. Adhesives form a seal as well as a bond, eliminating corrosion, which often occurs in a mechanically fastened joint. They join irregularly shaped surfaces more easily than mechanical or thermal fastening, 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.

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.

Mechanical fasteners and adhesives can work together to form a stronger bond than either method alone – two cases, threadlocking and gasketing, are good examples. Design engineers that want to improve the safety and quality of an assembly will use a mechanical fastener with a torque setting in tandem with a threadlocking adhesive. The anaerobic threadlocker guarantees that the assembly will not fail or loosen, and that corrosion will not shorten the life of the fastener. Liquid form-in-place gasketing materials are used to dress conventional rubber, paper, and cork gasketing materials and can often completely replace cut gaskets. These liquid anaerobic gasket dressings fill surface imperfections in the mating flanges and extend the life of the gasket.

Fundamentals of Adhesive Joint Design

Stress plays a significant role in the success or failure of a joint bonded with adhesives. Engineers must have a solid understanding of how stress is distributed across two mating substrates in order to design the strongest possible joint.

There are five types of stresses that commonly effect assemblies bonded with adhesives. Tensile stress (Figure 1) tends to pull an assembly apart and elongate it. Compressive stress (Figure 2) squeezes an assembly together. Shear stresses (Figure 3) pull parallel objects apart lengthwise, causing a sliding motion in opposite directions. Peel stress (Figure 4) occurs when a flexible substrate is lifted or peeled away from the substrate to which it is bonded. Cleavage stress is similar to peel stress but occurs with inflexible substrates when a joint is forced open at one end.

Most adhesives offer excellent resistance to tensile, shear, and compressive stresses, but are very weak in cleavage and peel strength. Therefore, in order to design the strongest possible adhesive joints, engineers should eliminate cleavage and peel forces from the basic joint design. The best joint designs allow for maximum possible bond area, and rely upon both mechanical locking methods and the strength of the adhesive bond for long-term success. Since the ends of a bond resist a greater amount of stress than the middle, joint width is more important than substrate overlap to successful joint design. By increasing the width of a bond, the bond area at each end increases and the overall joint is made stronger. However, by simply increasing overlap, there is little if any change in bond strength.

Five types of joints are commonly found in assemblies bonded with adhesives. A lap joint, also called an overlap joint, is formed by placing one substrate over another (Figure 3). A joggle lap joint is very similar to a lap joint, but one substrate wraps or molds around the other substrate (Figure 5). A butt joint is formed by bonding two objects end to end (Figure 6), and can also be called a cylindrical joint when cylindrical objects are bonded. A scarf joint is an angular butt joint where the substrates to be bonded are cut at an angle to increase bonding area (Figure 7). Finally, a strap joint combines a butt joint with one or two overlap joints (Figure 8a and 8b).

The simple lap joint illustrated in Figure 3 can be improved in a number of ways. By simply increasing the joint’s width, the bond area at the ends of the joint is increased, strengthening the adhesive bond. The joint can be redesigned to become a single or double lap shear with a larger bond face for increased strength (Figure 8a and 8b). The joint can become a joggle lap joint with perpendicular bonded faces (Figure 5). In all cases, peel and cleavage forces on the end of the joint are reduced. Figures 9a and b, 10a and b, and 11a and b illustrate poor initial joint designs that redesigned for increased strength.

The growing variety of adhesives available in the marketplace makes selecting the proper adhesive a challenging experience. Adhesive selection should start by answering questions about the parts to be bonded and the end use application. One of the most important considerations is the environment in which the device will operate. The adhesive selected for an application must be able to resist the stresses that the device will encounter not only initially, but also after exposure to the most severe factors possible in its end use environment. Heat and humidity usually have the most damaging effects on bonded joints; although exposure to solvents and ultraviolet light can also take a toll. Thermal expansion stresses between dissimilar substrates with widely different coefficients of thermal expansion require low modulus, flexible adhesives for best performance.

The most frequent reasons for joint failure do not involve adhesive strength. Typically, the failure of an adhesive joint is due to poor design, inadequate surface preparation, or improper adhesive selection for the substrates and the operating environment. Assemblies should always be thoroughly tested during the design phase to ensure that bonding will be successful during manufacturing and over the life of the device.

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