Engineering with pressure-sensitive adhesives

Understand shear, tack, and peel to get the most out of PSAs.

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Key points:

- Adhesives offer advantages over mechanical fasteners such as distributing stress and not requiring drilled holes.
- Shear, tack, and peel characteristics help equate lab results to field performance

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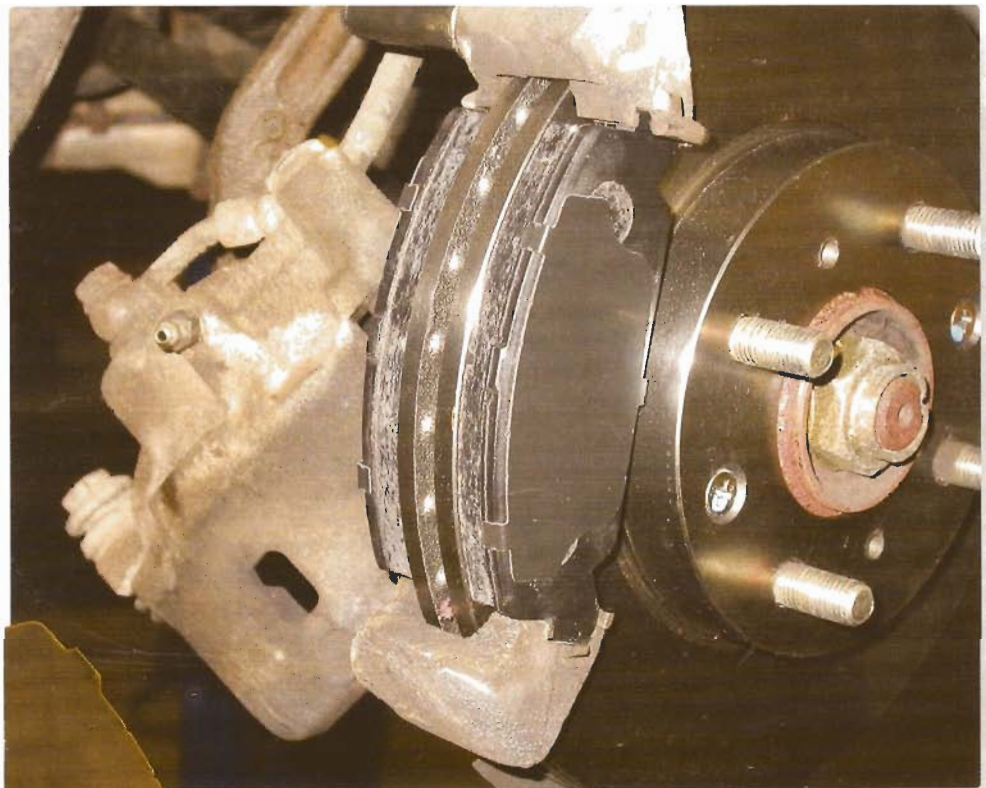
Mechanical fasteners are widely used to quickly and easily assemble components. However, they require machined holes that ultimately alter designs and can weaken parts by concentrating stress at various points. This sometimes leads to premature joint failure.

While mechanical fasteners are almost always the first choice when assemblies need maximum torque resistance and load-holding capabilities, pressure-sensitive adhesives (PSAs) offer a number of advantages over traditional screws, nuts, bolts, rivets, and welds.

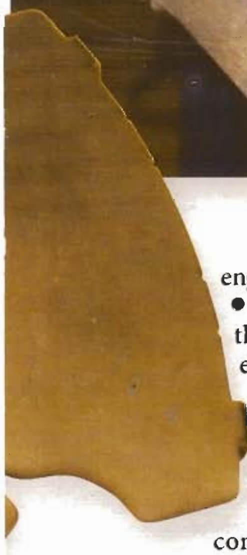
PSA pluses

Reasons for replacing mechanical or fusion fastening with PSAs run across the design, performance, and manufacturing spectrum, including:

- *Distributing stress over the entire bonded area.* PSAs eliminate the concentrated stresses of mechanical fasteners, letting engineers specify lighter, thinner materials without sacrificing durability or product integrity.
- *Bonding dissimilar materials.* Pressure-sensitive adhesives can bond two totally different substrates, which can bolster product strength and performance. PSAs are an ideal counterbalance for surfaces with different coefficients of thermal expansion, such as laminating layers of various metals and nonmetals. They also provide a protective barrier to prevent abrasion and corrosion, resist flex and stress, and dampen noise and vibration.
- *Maintaining substrate integrity.* Less machining and finishing means more latitude for



Automakers have long used durable PSAs to bond brake components and dampen noise and vibration.



engineers and better aesthetics.

- *Fatigue resistance.* PSAs are more flexible than mechanical fasteners, allowing for high extension and recovery under heavy loads. And their energy-absorption properties provide up to 20 times the fatigue resistance of mechanically joined assemblies.
- *Durability.* PSAs fill voids and gaps and can bond loose-fitting parts. Continuous contact between mating surfaces effectively seals against dirt, water, chemicals, and debris. PSAs are also good heat and electrical insulators.
- *Increasing production efficiency.* PSAs generally require less material — reducing product weight — and fewer assembly and finishing steps. Installing them properly requires minimal training. Bonding with PSAs actually requires fewer skilled workers and is much faster than welding. Excess adhesive can be removed prior to painting — a significant advantage over grinding and abrading to smooth a welded finish.

PSA types

Getting the most out of adhesives demands a full understanding of the product, its intended use, and substrates earmarked for adhesion. The good news for design engineers is that there are hundreds, if not thousands, of PSAs. However, choosing the best one can be challenging. Some decisions are readily apparent, such as the choice between permanent and removable adhesives. Other factors are not so obvious.

First, designers need to decide on the adhesive family which best meets specific end-use requirements. Also consider the role of shear, tack, and peel, key physical properties, when deciding on the right adhesive.

There are four main PSA polymer families: acrylic, emulsion, rubber, and silicone. Each offers different characteristics.

Acrylic adhesives provide the widest range of performance characteristics, and they work well with metals, ceramics, thermoplastics, thermosets, and other materials. They're durable, often bond with minimal surface preparations, and have an operating range of –20 to more than 450°F.

Emulsion polymers have a temperature range of –40 to 176°F and are widely used as bases for a variety of general-purpose adhesives. One of the larger markets for these materials is paper and paperboard packaging, including boxes, folded cartons, and paper bags. Emulsions also serve as binders for PSAs used in transfer, single, and double-coated tapes; in nonwovens such as diapers; and in consumer products like household and wood glues.

Rubber and silicone adhesives often work in niche applications. For example, if bonded parts will be exposed to temperatures as high as 500°F, a silicone-based adhesive might be the best choice because they survive the highest temperatures.

Likewise, an application primarily for interior use that requires a strong, permanent bond within a normal range of room temperatures may best suit a rubber-based adhesive (–20 to 200°F).

Shear, tack, and peel

Along with load capacity and durability, important PSA attributes include the frequently misunderstood trio of shear, tack, and peel. Although it is sometimes challenging to measure these parameters and relate them to performance, they help predict how bonds withstand actual applications.

Shear adhesion is the force required to move a PSA affixed with a predetermined pressure along a standard flat surface. Shear adhesion is measured in terms of the time

Pressure-sensitive adhesives can be formulated to withstand temperature extremes and harsh environments. They are increasingly used to bond photovoltaic backsheets.

required to pull a standard adhesive from a test panel under a standard load. Usually, tack and adhesion decrease as shear strength increases.

The ASTM D 3654 Method A test (1-hr dwell, 1 sq-in. sample, and 4-lb load) defines low shear as <10 hr, medium shear as 10 to <100 hr, and high shear as 100 hr or greater.

High-shear, silicone-based adhesives offer good bond strength and resist environmental extremes. They are ideal for high and low-temperature gasketing and sealing, vibration damping across wide temperature variations, and applications calling for limited flammability. These PSAs survive temperatures from −300 to 500°F.

Tack, another important component of adhesion, is a measure of the force required to remove, say a foam gasket and its adhesive, from the substrate. It usually refers to the initial attraction of the adhesive to the substrate. The degree of tack is a function of adhesive components, and manufacturers control it to create PSAs with different characteristics.

According to ASTM D 2979, very low tack ranges from 0 to 100 gm/cm^2, while low tack is up to 400 gm/cm^2. Medium to medium-high tack ranges from 401 to 700 gm/cm^2, and high to very high tack ranges from 701 to more than 801 gm/cm^2.

High-speed labeling, for example, requires excellent initial tack. Without that strong, immediate bond labels can be misapplied. Low-tack adhesives, on the other hand, are better for removable graphic advertising for floors or "fathead" wall graphics. High tack is equally important with low-surface-energy plastics and metals. LSE materials are used in products ranging from automobile components to durable medical devices and sound-damping materials.

Peel, last but not least, is the measure of bond strength between adhesive and substrate after pressure has been applied and the adhesive has "wet-out" or bonded to the substrate. Much like tack, manufacturers control adhesion to create different products based on user requirements. After a PSA has been applied to the substrate, adhesion continues to increase for a period of time — typically 24 hr.

A peel test measures the force required to overcome an adhesive bond and results are heavily influenced by the adhesion surfaces. Peel readings are generally taken at 90

PSAs drive transdermal delivery

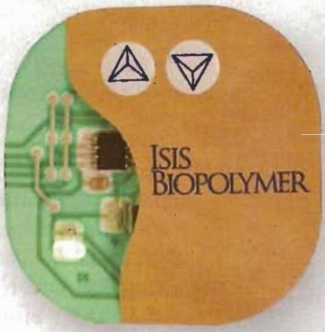
Transdermal or through-the-skin delivery of drugs has assumed an important place in drug therapy, eliminating many of the shortcomings of syringes and pills.

Among the latest medical devices is the IsisIQ, a transdermal drug-delivery system from Providence, R.I.-based **Isis Biopolymer Inc.** The company's selective-barrier membrane lets certain compounds pass through the skin but completely blocks the passage of others. Its single electrode eliminates skin irritation, which is common with many transdermal delivery devices.

While it appears similar to passive nicotine-replacement patches, the ultrathin, Band-Aid-like IsisIQ is an active device. A passive nicotine patch, while effective, combines the active pharmaceutical ingredient (API) with a medical-grade adhesive. IsisIQ, in contrast, uses a technique called *iontophoresis*, which applies a small electrical current to maintain controlled delivery of the drug — basically an injection without the needle. It propels high concentrations of a charged medication through the skin by creating a repulsive electromotive force.

Several FLEXcon adhesives are used in the IsisIQ. The device attaches to patients with FLEXmount H-566, a hypoallergenic acrylic adhesive that meets U.S. Pharmacopeial Class 6 requirements for medical-grade materials. To simplify manufacturing, the company recommended dermaFlex, a white, polyethylene foam coated with the H-566 adhesive and backed with a semibleached Kraft release liner.

The device also uses FLEXmount V-66 to encapsulate iontophoretic and biosensing components. This general-purpose, permanent acrylic adhesive gives good tack and adhesion to a variety of surfaces. In particular, it adheres well to cross-linked polyethylene foam.



The IsisIQ uses Blue Tooth LE, microprocessor control, thin-film batteries, and medical-grade adhesives to meter drug delivery to a patient.

and 180° angles to the surface. In films, for instance, both film thickness and tensile strength will have an impact on adhesion. Peel measurements let application designers determine whether or not external forces will break an adhesive bond.

According to the ASTM D 903 Standard (modified for 72-hr dwell time), very low to low peel is 0 to 34 oz/in.; medium to medium-high peel is 35 to 74 oz/in.; and high to very high peel is 75 to more than 95 oz/in.

PSAs in action

Applications for PSA vary widely, from improving the efficiency and cost effectiveness of assembly processes to mounting vehicle components and constructing intricate and fortified products.

For example, one aerospace manufacturer uses PSAs to assemble sheet-metal components into subassemblies. The PSA does not bond components together structurally. Rather, it rectifies misfit between components due to inherent flatness tolerance variations. The adhesive ultimately prevents burrs from forming when components are drilled in preparation for riveting.

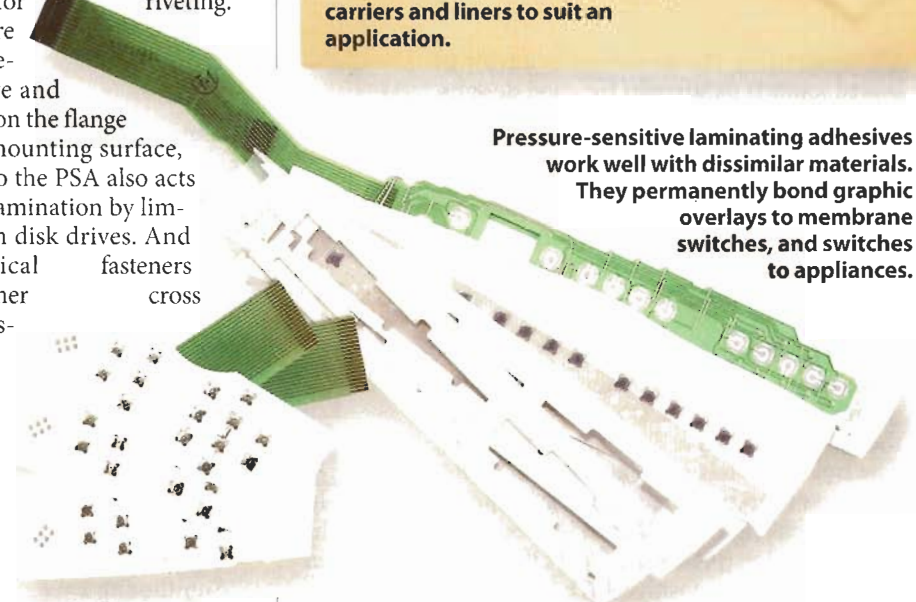
In a typical disk drive, PSAs are applied to the base casting to secure the motor-mounting flange and motor assembly. Three standoffs on the flange keep the spindle square to the mounting surface, and keep the bond line precise so the PSA also acts as a seal. Adhesives reduce contamination by limiting sliding and abrasion within disk drives. And using PSAs instead of mechanical fasteners eliminates operator fatigue, fastener cross threading, and contamination issues caused by touching and handling screw drivers. The adhesive is also applied by automation equipment for precise, consistent dispensing.

Automotive and aerospace industries also rely heavily on PSAs. In fact, most vehicle components are suitable candidates for PSAs because they bond "incompatible" substrates — and auto components are a mix of lightweight and heavy-duty materials.

For instance, automobile manufacturers once riveted nameplates and insignias into door sills. This involved riveting two metallic surfaces together. Such methods weaken the structure and create a trap for dirt. Now, these decorations are printed on pressure-sensitive films that provide the look of metal but securely bond without taxing the integrity of the substrate. And they are lighter than mechanical fasteners, making them ideal for applications where weight is critical.

Adhesives are especially adept at laminating panels to rough-textured substrates. With adhesives, wood grain and other types of paneling inside airplanes and recreational vehicles get a seamless, aesthetically pleasing look.

Manufacturers can tailor PSAs to give them specific physical characteristics, as well as develop carriers and liners to suit an application.



Pressure-sensitive laminating adhesives work well with dissimilar materials. They permanently bond graphic overlays to membrane switches, and switches to appliances.

They do not require solvents to be activated, making them safe for workers and the environment. Because they do not require expensive application equipment, they help reduce production costs.

Design engineers shouldn't hesitate to tap the materials knowledge, technical capability, and applications experience of leading PSA manufacturers to keep their projects on track. Whether providing an off-the-shelf formulation or developing a customized adhesive, carrier, or liner, the focus is on meeting specific application needs. In fact, in many cases, using an adhesive over more traditional bonding and mounting technologies can be more practical, cost effective, and yield a better product. **MD**