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Lasting Quality Through Systematic Bonding Processes

Even the most powerful adhesive systems will only reach their full potential when applied correctly. Frequent mistakes such as inadequately prepared surfaces, incorrectly selected adhesive types, or improper curing conditions will produce substandard bonds, often with expensive repercussions. Anyone who wishes to achieve stable, process-reliable bonds needs to understand the entire bonding process as a functional whole: from substrate analysis and application through to controlled curing.

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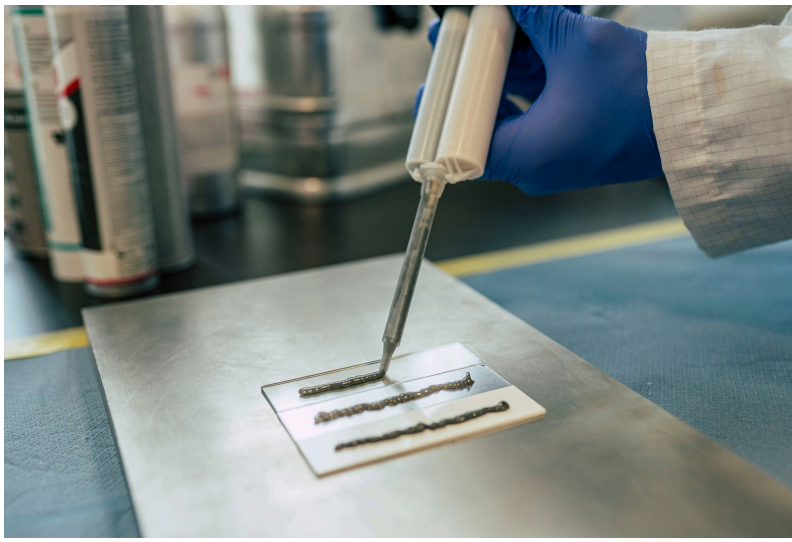
Consistent quality control is crucial from the outset for industrial bonding to achieve a reliable, lasting bond. That's why all relevant parameters must be specified, monitored and documented in a structured procedure before starting the actual bonding process. An adhesive bonding protocol as per ISO 21368 plays a central role in this regard: It ensures that all requirements are strictly met and allows possible sources of mistake to be detected and avoided at an early stage. This systematic approach enhances process reliability, making it possible to produce high-quality, stable bonds.

Selecting the right adhesive

First of all, the most suitable adhesive must be selected for the application concerned. This process can be significantly supported by bonding simulation (FEM finite element method) and professionally conducted tests such as tensile shear tests and cataplasm, helping to qualify the appropriate adhesive. These methods must take into account different parameters such as the application requirements for the adhesive, the adhesive system's curing mechanism, and material compatibilities. Metal surfaces often need additional pretreatment to prevent oxidation whereas plastics such as polyethylene (PE) or polypropylene (PP) require special adhesives due to their low surface energy. Equally crucial are the general requirements for the bond itself, such as lasting strength at elevated temperatures or resistance to chemicals and UV radiation. Temperature is crucial not only for the subsequent use of the bonded component but also during adhesive application since it has an impact on viscosity and the curing speed. Consequently, the choice of adhesive must be precisely matched to the material combination and the relevant environmental conditions to guarantee a stable bond.

Surface pretreatment for reliable adhesion

Besides the material type, the condition of its surface is also crucial. Contaminants such as dust or grease layers can prevent the adhesive from coming into contact directly with the substrate and, consequently, it only adheres to this layer. The surface texture also has an effect on adhesion: A slightly roughened substrate can enhance the bond. Another decisive factor for adhesion



Adhesive tests in a laboratory help when choosing an adhesive.

is the surface energy. The higher this is, the more effectively the adhesive can wet the surface. Surface energy can be determined using what are known as contact angle measuring instruments. These identify the curvature of a liquid droplet on the substrate and, consequently, the wetting quality or the free surface energy. If you want fast, uncomplicated quantification without the need for any further analytical equipment, there are also test inks which you can use. Materials with low surface energy, such as many plastics, require special pre-treatment – such as plasma or corona treatment, flaming, or the application of a chemical primer – to ensure reliable bonding. This causes a chemical or physical change to the surface. Additional polar functional groups are introduced, enhancing the surface energy while also serving as anchor points for the chemical bonding of the adhesive.

Applying adhesives correctly

Two application methods have proven effective for applying adhesive: Depending on the production unit, the adhesive is either applied manually using cartridges or automatically with dispensing systems. Manual application with cartridges is for example widely established for smaller lot sizes or flexible manufacturing processes. There are different cartridge

Bond quality being verified during a tensile test.
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presses with a pneumatic or electric drive available for this purpose. Dispensing systems are used in automated processes for mass production or parts that are consistently the same, for instance. These systems process adhesives from larger containers. When two-component adhesives are used, comprising of a resin and a hardener, the bonding quality heavily depends on the correct mixing ratio. Mixing is typically performed using a mixing nozzle (static mixer) that is connected to the cartridge. Before the mixing nozzle is attached, the user first needs to check whether both components are discharged equally. Once the mixing nozzle is attached, it is important for the user to first ensure that a certain amount of adhesive, normally a bead equal to the length of the mixing nozzle, is discarded to guarantee thorough mixing. While the mixing ratio is already pre-set in cartridges, the components must be actively metered out when using larger containers such as buckets or drums. In automated dispensing systems, it is extremely important to monitor the mixing ratio to prevent mistakes due to the components' different densities. Devices such as gear, reciprocating and eccentric screw pumps are used for this purpose. The temperature is also an important factor which shouldn't be underestimated during application. It affects both the adhesive's viscosity and the pot life: Higher temperatures reduce the viscosity, thus making it easier to apply the adhesive. However, they also shorten the pot life significantly.

Joining components precisely

Once the adhesive is applied, the next step is the joining process. The goal is to position the components accurately, fix them securely, and, if necessary, join them together by applying a specific pressure. The requirements for this process depend on the adhesive system being used. To ensure a reliable bond, the components must be aligned after applying the adhesive and fixed during the curing process. This is particularly important once the pot life – the open time during which the adhesive can be processed – has expired. This is when a three-dimensional polymer network starts to form. Afterwards, movements within the adhesive bond may cause internal structural fractures at a molecular level, reducing the bond's strength. The need for mechanical fixation depends on the component, its installation location, and the adhesive's viscosity. In the case of conventional, reactive adhesives such as epoxy and polyurethane systems, a specific bonding pressure is not necessarily required but can help to prevent air bubbles and ensure uniform distribution of the adhesive. It is different for substances such as pressure sensitive adhesives (PSA), like double-sided adhesive tapes. These require a specific contact pressure during a given time period to ensure they are fully bonded to the surface and thus deliver reliable adhesion.

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Curing creates adhesion

Curing is the last step in the bonding process. The bond doesn't gain its full strength and durability until it reaches this stage. The curing speed depends on the temperature and environmental conditions. An increase in temperature by 10 °C can roughly double the reaction rate. This means the higher the temperature, the shorter the working time and the faster the curing time. An adhesive with a working time of 30 min at 25 °C may no longer be usable after just 15 minutes at 35 °C. Conversely, lower temperatures extend the curing time and the adhesive may fail to cure completely below 20 °C in some cases. For this reason, the ambient temperature should remain within the recommended range during the entire curing process.

Aging tests are used to simulate how the bond behaves under high stress loads over time. © Bodo Möller Chemie GmbH

The curing method used generally depends on the type of adhesive applied. When choosing an adhesive, it is essential to ensure that the production environment is compatible with the chosen curing technology. Besides two-component adhesives that cure automatically once mixed, at room temperature, for example, there is also a wide range of single-component adhesives that do not require mixing. An external stimulus needs to trigger the curing reaction. In such cases, two widely used mechanisms are UV curing and moisture curing. UV curing is the fastest method, allowing curing within seconds. However, this method only works for translucent substrates or open joints since the UV rays need to fall directly onto the adhesive and only achieve a limited penetration depth. Moisture curing comprises a chemical curing method, during which the adhesive reacts as it comes into contact with water in the ambient air, causing it to set. This requires a consistent, controlled level of humidity in the production environment.

In-process tests

Destructive and non-destructive test methods form an integral part of the bonding process. A simple visual inspection can detect air bubbles and possible problems with mixing during application and bonding. Ultrasound, thermography or X-ray spectroscopy can also be used to check that the adhesive is uniformly distributed and cured. Ultimately, the quality of a bond can only be verified through destructive testing, such as tensile tests. Such tests can be conducted using standardized lap shear test specimens. If feasible, the test should be conducted directly on the bonded component to ensure that the entire process and the component's specific geometry are taken into account.

Conclusion: Systematics as the basis for quality

Industrial bonding is a specialized process which will only work reliably if all stages of the process are systematically integrated and harmonized. The quality of an adhesive bond depends not only on selecting the right product but also on understanding and controlling the entire bonding process. Digital tools such as apps for process documentation and monitoring allow efficient, error-free recording of all relevant parameters. Automated systems assist operators by enhancing repeat accuracy and ensuring complex tasks are completed precisely. Continuous training of the personnel involved is also a key factor in establishing and optimizing bonding processes. If adhesive bonding is approached as a systematic, quality-assured overall process, it can achieve lasting strength, safety, and process stability.

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