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Adhesive Bonding as a Joining Technique

Bonding is the surface-to-surface joining of similar or dissimilar materials using a substance which usually is of a different type, and which adheres to the surfaces of the two adherents to be joined, transferring the forces from one adherent to the other. According to DIN EN 923, an adhesive is a nonmetallic substance capable of joining materials by surface bonding (adhesion), and the bond possessing adequate internal strength (cohesion). Bonding is a material joining technique that, in the traditional sense, cannot be broken without destruction of the bond. Recently, specific bonding-on-demand techniques have been developed (see Section 8.16.5), for example as an assembly tool without further function, or for recycling based on a separation of materials, a method that today is becoming increasingly important.

Bonding is by far the most universal joining technique. Virtually all technically useful materials can be joined with each other, and one with another, by means of this surface-to-surface and material-joining technique.

Adhesive bonding technology offers great design flexibility as it can be easily integrated into almost all available industrial sequences of single-piece work or mass production. Historically, bonding has long been recognized as a high-performance joining technique. The large majority of original natural binding materials have now been replaced by synthetically prepared adhesives. For example, phenolic resins were first introduced in the late 1920s, while during the 1940s epoxide resins and polyurethane were developed which have since made possible the production of synthetic adhesives (see Chapter 2).

As polymer chemistry has advanced in terms of knowledge, specific adhesives have been developed that bind very strongly to organic or inorganic materials. With regard to adhesive strength and deformation, these adhesives meet very specific requirements that result from the configuration of the adhesive joint. Meanwhile, high-strength adhesive assemblies have been created with quite short curing periods. In fact, the longstanding problem of extensive curing times necessary to obtain high-strength joints has been almost completely resolved with the introduction of new chemical developments in the creation of adhesives. Moreover, skepticism is no longer justified as to the long-term durability of adhesive joints exposed to adverse environments, provided that the bonding is properly conceived.

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Table 1.1 Characteristic features of adhesive joints.

Advantages	Disadvantages
• The adherents are not affected by heat	• Limited stability to heat
• Uniform stress distribution	• Long-term use may alter the properties of the bond-line
• Possibility to join large surfaces	
• Possibility to join different materials	• Cleaning and surface preparation of the adherents is necessary in many cases
• Possibility to join very thin adherents	• Specific production requirements to be met
• Gas-proof and liquid-tight	• Specific clamping devices are often required to fix the joint
• No crevice corrosion	• Nondestructive quality testing is only possible to a certain extent
• No contact corrosion	
• No precise fits of the adherent surfaces are necessary	
• Good damping properties	
• High dynamic strength	

Bonding rarely competes with other joining techniques used in industry. For example, one would not consider bonding a steel bridge or a gantry, but for the lightweight construction of car bodies using steel, aluminum, glass and plastics, adhesive joining offers extremely interesting applications. Adhesive joining is particularly well suited to the joining of large-sized surfaces of different materials, such as in the construction of sandwich assemblies.

The possibilities, advantages and disadvantages of adhesive bonding compared to other joining techniques are summarized in Table 1.1

One of the many advantages of bonding is that little or no heat is needed to create the joint. As a result, the material structure of the adherents to be joined is not macroscopically affected, and deformations or internal stress – which generally are related to the application of heat – rarely occur. Even those materials with finished surfaces or coated materials can easily be bonded without any heat supply. From this point of view, there are no limits with regard to the combinations of materials that can be joined.

One important disadvantage of adhesive bonding, however, is the relatively poor heat resistance of the bond-line as compared to inorganic materials such as metal or glass. Hence, in order to obtain high-performance assemblies the production parameters must meet the specific requirements of the material used. This applies not only to the manufacturing sequences but also to the ambient conditions in which the joints are produced, because adhesion generally develops only during the production process, and the production parameters can have a decisive effect on the quality of the bond. The same more often than not applies to the cohesion of the adhesive layer. The technical properties of cohesion only develop during the course of the production process (with the exception of pressure-sensitive adhesives) after

different setting processes. In this case, too, the production parameters mostly have a considerable effect on the quality of the final joint. By way of contrast, the joining process itself has only a minimally significant effect on the quality of traditional joining techniques, such as screw joints.

As the mechanisms of adhesion and the long-term behavior of adhesives are not yet completely known, it has not been possible to develop strict mathematical models for adhesive joints. Although this may be considered to be a disadvantage of bonding, the empirical values obtained with adhesive joints have meanwhile made it possible to conceive safe and sufficiently reliable bonded structures.