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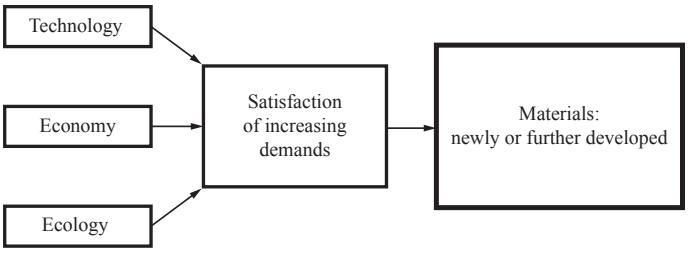
Adhesive Bonding – Advantages and Limitations

Abstract: Adhesive bonding is becoming increasingly important among industrially applied joining techniques. Growing demands for all kinds of products necessitate the development of new materials and material combinations. The ability of adhesives to join very different materials creates new application opportunities. In addition, the original properties of materials are usually maintained as, if compared with welding or brazing, adhesive bonding is a process poor in heat. The use of adhesive bonding makes it possible to eliminate other weaknesses accompanying, for instance riveting or screwing. In addition, this method enables the integration of real joint properties (sealing, vibration damping or anticorrosive protection) with a structural element. However, according to ISO 9000 adhesive bonding is a special process, which means that the quality of an adhesive bonded connection cannot be 100% verified by NDT methods. This fact entails the necessity of maintaining an appropriate quality management system in order to obtain and ensure high production quality.

Keywords: adhesive bonding, joint properties, quality management

Smaller, faster, lighter. Constantly increasing requirements set for new products are the flywheel of technological progress.

Each new product must be not only technically better (smaller, faster and lighter) and cheaper than its predecessor but also comply with increasingly restrictive environmental requirements. These growing demands can often be satisfied only by new developments in products or materials.



A good example of such a process is the development of the first lot-produced vehicle in the world, Benz Patent-Motorwagen "Velo" produced in 1200 units between 1894 and 1902. That car with its solid rubber tyres met those days' requirements related to speed (maximum 20 km/h), comfort and active life. The vehicle structure was made of steel, iron, rubber, wood and leather.

Today's cars are made of 20 various alloy steel grades, over 10 various aluminium alloys, magnesium, titanium, fibre-reinforced plastics, glass etc. meeting present, obviously more restrictive, requirements as regards speed, comfort, active life and safety. The car is just one example; others could include mobile phones today and 20 years ago, skiing equipment, footballs etc.

The objective of the material technique is to catch up with constantly rising requirements by developing entirely new materials or improving those already existing. This results in a growing demand for joining presently available materials as well as in the growing importance of material combinations (multimaterial design) as requirements are often so challenging that they

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cannot be satisfied by a single, even very modern material. Other consequences include the fact that highly developed single materials are more sensitive while undergoing various treatments. For instance, high strength steels or aluminium alloys partly or completely lose their strength or become deformed while subjected to heat-based joining methods such as welding.

Adhesive bonding potential consists in its ability to join all materials with one another or between each other. Although there are other joining techniques such as riveting or screwing, adhesive bonding does not compromise material properties and condition.

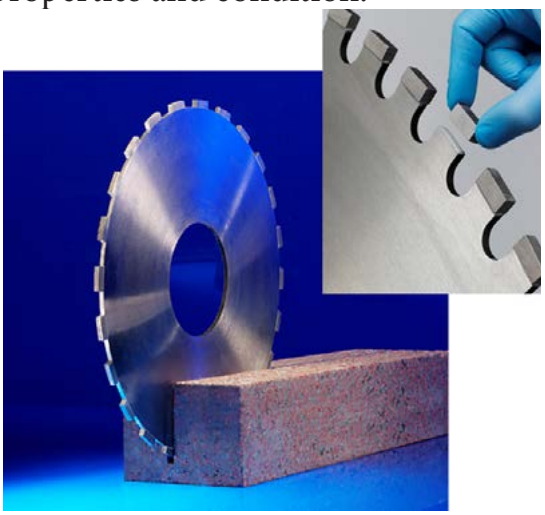

Fig. 1. Granite cutting disc with affixed cutting elements (Source: Fraunhofer IFAM)

An example of innovative adhesive bonding application is the granite cutting disc of a saw used for separating big stone blocks. Cutting elements are adhesive bonded to the disc base. In conventional solutions such elements are brazed. Heat input deforms the disc which requires subsequent straightening. Present solutions involve heat-hardenable epoxy resin-based adhesive which below 200°C fully hardens within 1 minute. This manner of producing saw cutting discs does not change their shape and makes straightening unnecessary.

Another example is the science-based logical combination of various materials. In radio telescope construction, adhesive bonding proves its advantages connected with the possibility of joining various materials. Requirements related to the construction of parabolic mirrors are extremely restrictive as regards the dimensional stability during mirror operation. Even in the case of temperature changes caused by surrounding conditions, tolerances should not be greater than 17 µm over the length of 15 metres. This requirement can only be satisfied by the intelligent selection of material combinations. Elements binding cross braces of the base are made of the INVAR alloy characterised by a very low thermal expansion coefficient. Cross braces themselves are made of glass fibre-reinforced plastic (CFK). In its operational temperature range, CFK demonstrates a negative thermal expansion coefficient, i.e. it contracts while being heated. Steel expands only very slightly when subjected to heat. The materials mentioned above are joined using adhesive bonding.

Adhesive bonding action is often "invisible". For instance, car brake pads are adhesive bonded to the base using phenol-formaldehyde resin and for some time can without malfunction withstand temperatures exceeding 400-500°C. Adhesive bonding also enables making surface connections which, in conjunction with new material implementations creates new potential for structural possibilities in lightweight civil

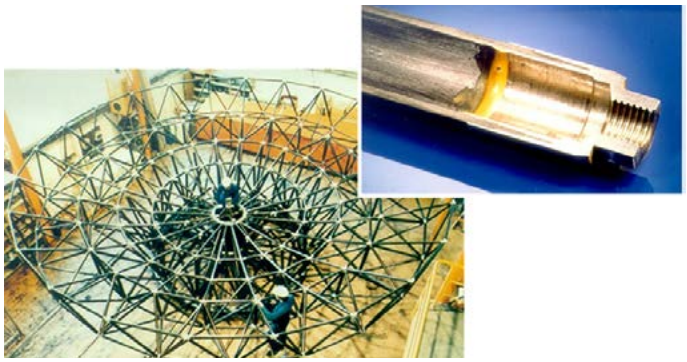

Fig. 2. Adhesive bonded radio telescope (Source: Thyssen-Krupp / Fraunhofer IFAM)

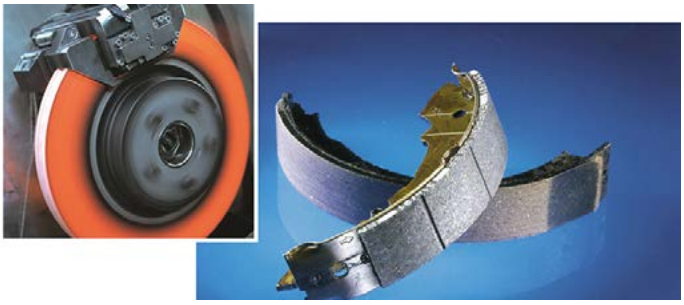

Fig. 3. Brake pads (Source: Fraunhofer MEV/IFAM)

engineering. In addition to bonding, adhesives can integrate other functions such as sealing, vibration damping, conductivity, compensation tolerance etc. Such integration significantly improves the overall functionality of products subjected to properly applied adhesive bonding technique.

However, on the other hand, adhesive bonding, just like any other joining technique, has its own limitations. To illustrate this, one can use a less scientific and more literary example, i.e. the myth about Daedalus and Icarus. Daedalus was a renowned architect who had built a labyrinth for king Minos on the island of Crete, where the monstrous Minotaur was kept. To prevent Daedalus from building a similar or more impressive structure for other monarchs, the famous architect and his son Icarus were confined by Minos on Crete. Yet, they invented a solution. Using wax as an adhesive, the father and son glued feathers to their arms and flew away. Daedalus warned Icarus not to fly too high or too low. The youth was too proud to obey his father's instruction, soared high enough for the wax to melt under hot sun rays and got killed by falling to the sea. Professionally, the story warns us today of exceeding adhesive bonding technological and temperature limits.

Another factor limiting adhesive bonding is the fact that, similarly to welding, according to ISO 9000 [1] this process is referred to as special, which means that important properties such as strength or formability cannot be 100% tested using NDT methods. As the quality of an adhesive bonded joint cannot be 100% checked, it must be "produced". This necessity imposes restrictive requirements related to production processes and the application of quality management systems. All processes connected with adhesive bonding, ranging from planning through design to production, must be described, controlled and documented. This can be done only by personnel because the personnel know what they do. Therefore, an essential part of the quality management system is made up by the qualifications of personnel. For this reason, similarly as in other joining techniques, there is a fast supra-company training system in adhesive bonding. The offer includes a weekly DVS/EWF-Adhesive Bonder course for workers, a three weeks' DVS/EWF-Adhesive Specialist course for process implementation or quality assurance personnel, and eight weeks' DVS/EWF-Adhesive Engineer course for decision-making personnel related to adhesive bonding processes. In the construction of rail vehicles the requirements related to the qualification of personnel dealing with adhesive bonding have been for some time regulated by standard DIN 6701 [2].

Fig. 4. Certified training in adhesive bonding techniques

The courses have been run for over 20 years and continue to be well received worldwide. In this area of Klebtechnische Zentrum des Fraunhofer IFAM (adhesive bonding equivalent centre for Schweißtechnischen Versuchs-und Lehranstalt, SLV) collaborates with national and overseas partners such as Instytut Spawalnictwa in Gliwice.

In conclusion it should be repeated that adhesive bonding, like any other joining technique, has its unquestionable advantages but is not free from limitations which must not be ignored. In each case, to ensure the formation of reliable high-quality joints adhesive bonding must be properly implemented by sufficiently qualified personnel.

References:

1. EN ISO 9000: 2005 – Quality management system – Fundamentals and vocabulary.
2. DIN 6701 – Adhesive Bonding of Rail Vehicles