The significance and necessity of adhesive bonding technology in rail vehicle construction – today and in the future

A statement on adhesive bonding application technology by the European Committee for Adhesive Bonding in Railway Vehicles - ECARV

0 Summary

Without adhesive bonding technology, there would be no modern trains—not today, not tomorrow. The production of railway vehicles without adhesives, sealants, and adhesive tapes would be impossible either now or in the future.

The importance of the joining technique ‘adhesive bonding’ in rail vehicle construction has long been on a par with traditional joining techniques such as welding, torque tightening~~,~~ and riveting. As early as the turn of the millennium, the widespread use of adhesives led to the introduction of the DIN 6701 series of standards, which was converted into the European standard EN 17460 in 2022 and is now applicable worldwide (see chapters 1 and 5).

The reason: Rail vehicles are increasingly made from a variety of different materials (multi-material design, including ”advanced materials”) in order to meet requirements such as lightweight construction, energy consumption, durability, design, and many others (see Chapter 2). Conventional joining technologies reach their limits here, as they alter the material properties necessary to meet rail vehicle requirements.

On the other hand, adhesives and sealants, including adhesive tapes, enable the necessary preservation of material properties—even between different materials—in the form of safe, long-term stable joints. As a “material between materials,” they also allow additional functions to be integrated into the composite. **For these reasons, adhesives, sealants, and adhesive tapes are ‘‘advanced materials’’.** This makes them technologically, economically, and ecologically indispensable for innovative and future-oriented construction methods and product developments in rail vehicle manufacturing: without adhesives and sealants, there would be no high-speed trains (>200 km/h), for example. Without adhesives and sealants, the optimization of comfort, which is important for regional transport in order to attract and retain customers, would be limited and would mean restrictions for the mobility transition.

Europe also remains the undisputed global market leader in adhesive bonding and sealing technology for rail vehicle construction. Innovations in the use of adhesives, sealants, ~~and~~ adhesive tapes and their quality-assured applications come from Europe. **It is in our own European interest to maintain and expand this leading position.**

If Europe fails to maintain and expand its leading position in adhesive bonding technology, the decisive developments in rail vehicle construction will also take place in other, non-European countries such as China. As a result, as in many other areas of technology, Europe would also soon lag behind in rail vehicle construction.

Against this background, any political, regulatory, and/or administrative restriction on this necessary and progressive joining technology is an obstacle to innovation in modern rail vehicle construction that must be avoided!

1 Adhesive bonding technology in rail vehicle construction: indispensable and already an integral part of today's world, as well as the future

The European Committee for Adhesive Bonding in Railway Vehicles (ECARV) exclusively represents *users* of adhesive bonding technology (see section 5). From ECARV's perspective on adhesive bonding technology applications, the use of adhesives and sealants in today's rail vehicle construction is already *indispensable* for long-distance, regional, and freight transport. This trend is set to continue in the future.

The *importance of adhesive bonding technology in rail vehicle construction* has long been on par with conventional joining technologies such as welding, tourque tightening, and riveting. This is illustrated, among other things, by the fact that by the turn of the millennium, usage of adhesives, sealants, and adhesive tapes had reached such a scale that the Federal Railway Authority (EBA, Germany) initiated - in addition to welding (DIN 6700/now EN 15085) - a series of standards for the quality-assured organization and implementation of adhesive bonding processes in rail vehicle construction : the DIN 6701 series of standards – Adhesive bonding of rail vehicles and vehicle parts.

DIN 6701 was published in 2006 and implemented in rail vehicle construction as a national standard far beyond Germany's borders. In 2022, the DIN 6701 series of standards was transferred to the now applicable EN 17460:2022 – Railway application–Adhesive Bonding of railway vehicles and their parts.

This now European standard for quality assurance of rail vehicle construction is now being successfully implemented worldwide. Its positive impact is demonstrated in the following figure.

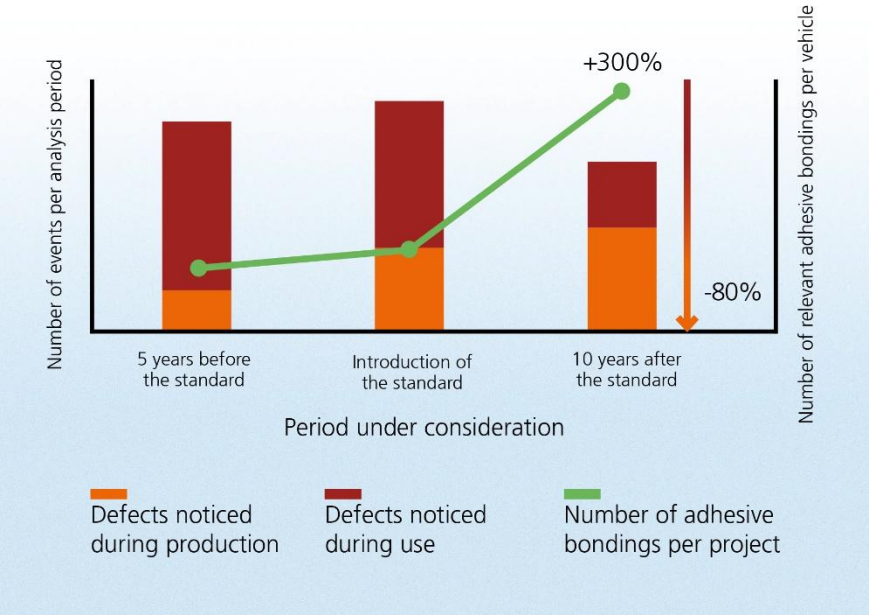

Figure: Influence of quality assurance standardization on the application of adhesive bonding technology in rail vehicle construction

The figure demonstrates the positive influence on the development of adhesive bonding applications in this industrial sector: Compared to the use of adhesive bonding technology five years *before* the introduction of the QA standard (left bar), the scope of adhesive bonding technology has increased by 300% ten years *after* the introduction of the QA standard (right bar). At the same time, in the ten years following the introduction of the QA standard, the detection of errors (which now occur less frequently) and thus the opportunities to correct them could be clearly shifted from the “utilisation” phase of the product life cycle to the “manufacturing” phase, and overall, the number of errors occurring has been reduced by 80% compared to the starting point without the QA standard (Source: Siemens Mobility).

2 Rail vehicle construction today and in the future: material diversity and multi-material design

Today's rail vehicles are products with a *multi-material design*. As in other industrial sectors, this development will continue steadily in the future.

Multi-material design is also key in rail vehicle construction for developing modern and future-proof products that combine several material advantages in one system. Future products such as people mover, trams, metros, commuter-, regional- and highspeed-trains will therefore be composed of a wide variety of different materials, both conventional and advanced.

Only this diversity of materials makes it possible to meet the *current and future requirements* for rail vehicles and rail transport as a whole. Examples of increasing requirements that must be met by materials with their specific properties include, among many others, lightweight construction, visual design, longevity, aerodynamics, noise reduction, energy consumption and comfort optimization.

In order to meet these complex and interrelated requirements, the properties of the materials used *must be preserved*. The joining technology used must fulfill this condition: it must be suitable for both the materials and the requirements for the rail vehicle specified in the list of requirements.

This is where *conventional joining technologies reach their limits*: welding causes thermal stress in the joint area, which leads to changes in properties. When riveting, screwing, and nailing, the drilled holes destroy and weaken the substrate material exactly in the highest stressed area at the joints. This inevitably leads to changes in the material properties, which then diametrically oppose the fulfillment of necessary product requirements.

3 Rail vehicle construction today and in the future: multi-material design and adhesive bonding technology

This is precisely where the *unique selling point of adhesive bonding technology* comes into play—for both current and future rail vehicle construction: *Only adhesive bonding technology* makes it possible to join identical and dissimilar materials safely and with long-term stability while preserving the material properties. In addition, adhesives and sealants can be used to integrate additional functions into the product. As specifically illustrated in Chapter 4 with various examples, the adhesive bonding joining technology leads to combined property

profiles of the multi-material compound in rail vehicles that cannot be achieved with other joining technologies.

Therefore, usage of adhesives and sealants is a technology that enables to meet current and future requirements for the design and construction of rail vehicles. From a technological, economic, and ecological perspective, it is the foundation to an innovative and future-oriented design and also for manufacturing methods for this industrial sector in the 21st century.

4 Examples of the necessary use of adhesives and sealants in rail vehicle construction

4.1 Preliminary remark on the following examples

The following examples of adhesive bonding applications in rail vehicle construction are not exhaustive. However, they illustrate the need to focus on maintaining the relevant material properties in rail vehicle construction and therefore to always consider “materials/material properties” and “joining technology” together and treat them equally.

This is the only way to ensure that the innovation and sustainability potential of modern rail vehicles can continue to be fully exploited in the future.

4.2 Adhesively bonded joints in safety class A1 – high safety requirements according to EN 17460

In the case of safety class A1, failure of the adhesively bonded joint leads to consequential events with serious personal injuries or to failure of the overall function.

- The *pantograph contact strips* are purely adhesively bonded constructions. Adhesive bonding is a basic requirement for electrically powered rail vehicles. There is no alternative to this, unless you want to return to rail vehicle operation using fossil fuels.
- The *windshields of rail vehicles*, especially high-speed trains, are usually adhesively bonded into the train structure. These are purely adhesively bonded joints without any additional joining technology. This is related to the design appearance of modern vehicles, but also with their optimized aerodynamics and the resulting optimization of energy consumption during operation.
- *Front masks* are often made of glass fiber reinforced plastic (GFRP). In addition to reasons of lightweight construction, design (appearance) also plays an important role here, as do aerodynamic and energy efficiency aspects during operation. For these reasons, the front masks are joined by adhesive bonding technology to the rail vehicle structure.
- Due to the required tightness, the *headlight glazing* is joined using purely adhesive bonding technology.
- The *doors of rail vehicles* are also adhesively bonded. The key requirement here is pressure tightness in high-speed trains (examples: tunnel entrances or encounters between oncoming trains traveling at high speed).

4.3 Adhesively bonded joints of safety class A2 – medium safety requirements according to EN 17460

In the case of safety class A2, failure of the adhesively bonded joint can lead to consequential events involving personal injuries or failure of the overall function.

- The *passenger windows* are adhesively bonded for aerodynamic reasons. The flatness of the outer skin achieved by adhesive bonding technology also reduces driving noise, which is beneficial for passengers. This is often also applied as design in safety class A1.
- Adhesive bonding technology is used for *floor panels* for reasons of lightweight construction and the integration of additional functions such as underfloor heating.
- Adhesive bonding technology is the most suitable joining technology for *mirrors*. It also makes cleaning easier.
- The *interior trim* is adhesively bonded for design and lightweight construction reasons.

4.4 Adhesively bonded joints in safety class A3 – low safety requirements according to EN 17460

In the case of safety class A3, failure of the adhesively bonded joint does not lead to a direct impairment of the overall function, and consequential events involving personal injuries are unlikely.

- *Various seals* are purely adhesively bonded joints for reasons of corrosion protection, tightness, and the longevity of the vehicle as a whole.
- There is no serious alternative joining technology for *floor coverings* that are adhesively bonded in rail vehicle construction.
- The same applies to various *sandwich composite components* such as tables, panels for walls and ceilings.
- In the case of adhesive bonding *insulation*, there is no alternative joining technology without thermal bridges.

4.5 Adhesively bonded joints in safety class Z – no safety requirements according to EN 17460

In the case of safety class Z, failure of the adhesively bonded joint does not impair the overall function and does not result in personal injuries under normal operating conditions (e.g., only a reduction in comfort).

- Adhesively bonded joints in this safety class include *pictograms, cable bases, design joints, and mounting fixings*.

5 The European Committee for Adhesive Bonding in Rail Vehicles – ECARV

The European Committee for Adhesive Bonding of Railway Vehicles (ECARV) is an association of various stakeholders from twelve European countries *who use adhesive bonding technology*. ECARV recognizes the *importance of adhesive bonding technology* in today's rail vehicle construction and its potential for the future. The committee promotes the further development and dissemination of this essential, future-oriented, and innovative joining technology, which is indispensable for rail vehicle construction. At the same time, ECARV supports cooperation at a superordinate level in the technological context between the parties involved in the manufacture of adhesively bonded rail vehicles and its components at the European level.

The ECARV is based on the EN 17460:2022 standard – Railway applications – Adhesive bonding of rail vehicles and their components.

On this basis, ECARV's tasks include the approval and control of ISO 17065-accredited certification bodies and their auditors in the field of adhesive bonding technology, harmonizing the global certification activities of certification bodies, and passing resolutions on the implementation and interpretation of EN 17460, which also forms the basis for the upcoming EN 17460 revisions.

The members currently represented in ECARV consist exclusively of users of adhesive bonding technology: rail vehicle manufacturers and their suppliers, rail operators, and certification bodies.

- Most European and multinational OEMs operating beyond Europe's borders are represented among *rail vehicle manufacturers*: Alstom (France), CAF (Spain), Hitachi UK (United Kingdom), PESA (Poland), Siemens Mobility (Germany), StadlerRail (Switzerland).

- The following *rail operators* are currently involved in ECARV: Deutsche Bahn – DB (Germany), Nederlandse Spoorwegen – NS (Netherlands), Österreichische Bundesbahnen – ÖBB (Austria), Schweizerische Bundesbahnen – SBB (Switzerland), Société Nationale des Chemins de fer Belges – SNBF (Belgium).

- The *supplier* member group consists of Bodo Möller Poland, Knorr-Bremse RVS (Germany), LCI (Italy), Teknoware (Finland), Wabtec (USA), Faiveley (France) and tec-n (Germany).

- The group of *certification bodies* consists of IIS Genoa (Italy), SVV Prague (Czechia), TBBCert (Germany), and TC Kleben (Germany).

ECARV and its certification bodies represent approximately *800 companies worldwide*, beyond the borders of Europe, which have been certified for the implementation of the “adhesive bonding” joining technology in accordance with the EN 17460 quality assurance standard.

All globally certified companies (www.en17460.com) are regularly audited by the approved certification bodies at intervals in accordance with ECARV rules. The issued certificates give certified companies a head start in terms of trust in the use of adhesive bonding technology among railway regulatory authorities, customers, and clients in terms of the organizational and professional implementation of adhesive bonding technology in their respective companies.

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