EAA Aluminium Automotive Manual – Joining

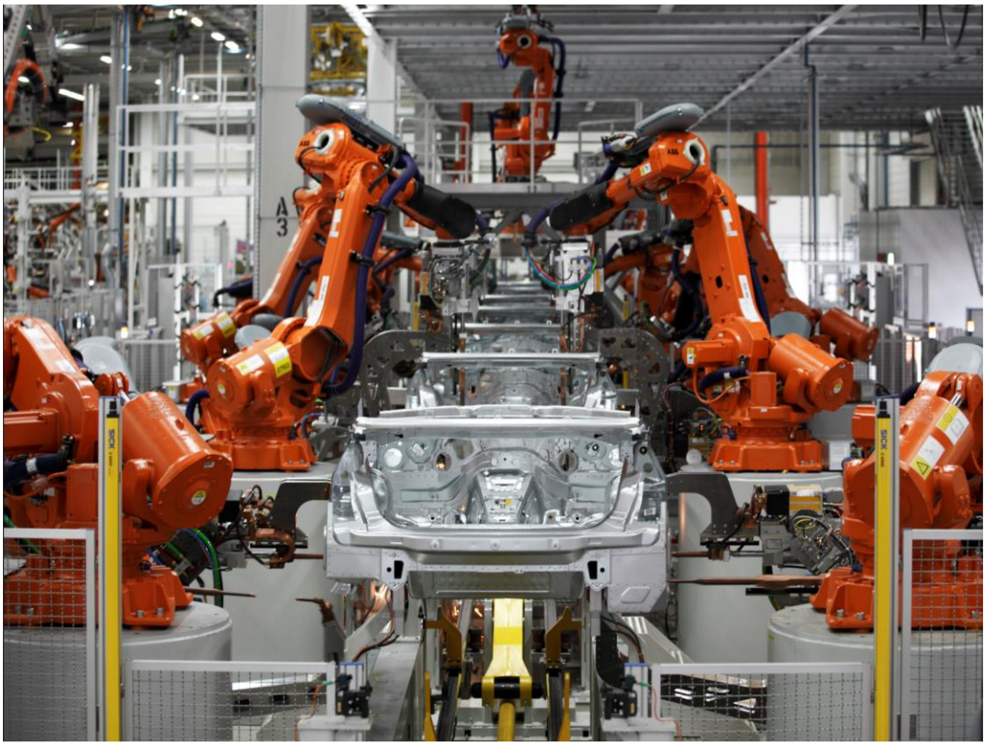
Content

1. Introduction

Joining is a most important fabrication technology in automobile manufacturing. The standard joining technique for the production of conventional steel car bodies has been resistance spot welding. With the advancement of new, innovative joining technologies and the simultaneous introduction of high and ultra-high strength steel grades, additional joining methods have found limited application. However, resistance spot welding still remains the dominating joining technique for steel cars.

On the other hand, joining of aluminium components by resistance spot welding of aluminium presents some problems. When substituting steel by aluminium, the sensitivity of the mechanical properties of work-hardened and age-hardened aluminium alloys to heat input generated during the welding process and their specific physical characteristics ask for specific attention in design and engineering as well as production planning (equipment and process parameters). Consequently, the growing application of lightweight aluminium solutions in automobiles posed significant challenges both for the automobile manufacturer as well as for the supplier of the aluminium materials and components. The key enabler for the use of aluminium in automotive applications proved to be the series application of non-heat involving joining techniques like mechanical joining and adhesive bonding.

Today, appropriate qualitatively outstanding and highly efficient joining methods are available for aluminium and will be described below in more detail. The integration of aluminium components and modules required the development and introduction of well adapted processing procedures and in some cases even novel joining techniques both for the realisation of aluminium to aluminium joints as well as for mixed material joints. Nevertheless the application-specific selection of the optimum joining method for technical performance and cost efficiency is still a challenging task. Also, there is a clear need for further developments in order to meet more and more demanding future quality and cost targets.

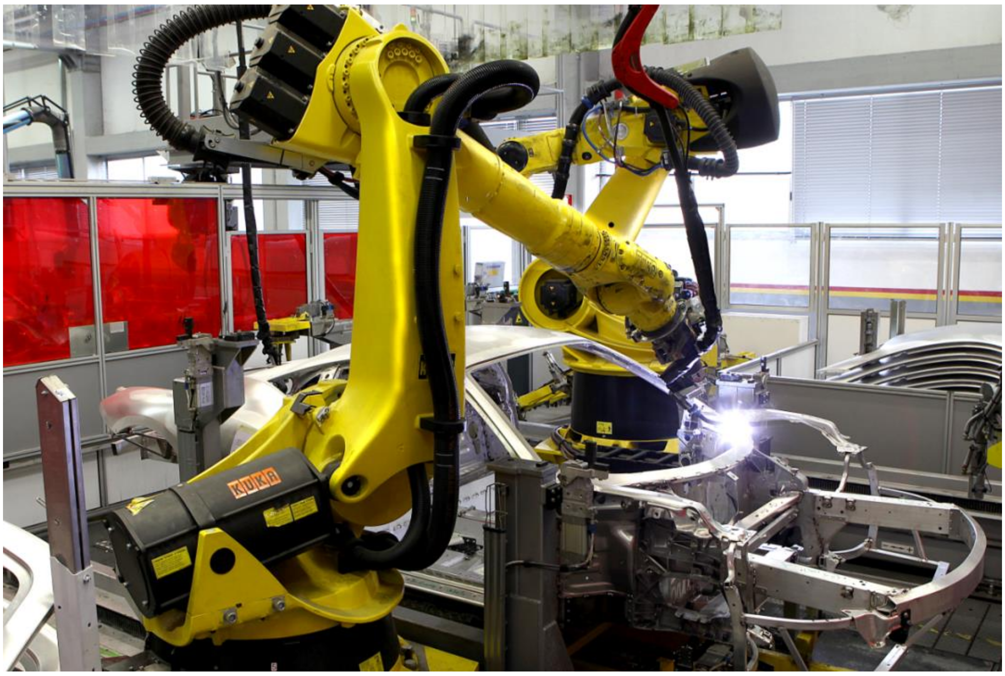


Modern automobile assembly line

(Source: BMW)

The technical feasibility of reliable and safe joints with highest process capability and optimum cost-efficiency is a prerequisite for the successful application of aluminium in automotive structures. The assembly tasks in automotive manufacturing range from the joining of individual aluminium components consisting of different alloys and product forms (stamped sheet parts, castings, machined extrusions, forgings, etc.) to multi-material joining of aluminium to steel, magnesium, plastic and composite components. Mixed material designs present additional complications since the selection of the applicable joining method is often restricted and secondary factors such as different thermal expansion coefficients or potential galvanic corrosion effects have to be taken into account. On the other hand, especially the availability of high quality, cost-efficient mixed material joining technologies is a most important requirement for the continuing implementation of innovative lightweight aluminum solutions in automotive constructions.

Apart from the demanding technical performance requirements on the assembled structure, it is most important to consider also the economic aspects of the assembly operation. The joining processes applied in automobile assembly have been optimised over many years for steel designs. In addition, automobile assembly lines are today highly automatized, i.e. in particular in the body shop, most assembly tasks are carried out by robots. The vast existing experience in steel joint design and engineering cannot be simply transferred to aluminium and other materials. Furthermore, it is only possible to apply the standard steel joining equipment as well as the extensive processing knowhow in limited cases. Consequently, substitution of steel parts by lighter aluminium components requires often the development and introduction of new, innovative joining solutions as well as significant investments in suitable assembly equipment and training. On the other hand, these new developments also offer the chance for new lightweight designs and cost-efficient manufacturing solutions.



Assembly of an aluminium car body

(Source: Ferrari)

Basically, material joining is based on three main principles:

- **Material coalescence** where the materials are held together by atomic or molecular binding forces. In this case, the atoms and/or molecules must be placed in close proximity to each other e.g. by processes without the presence of heat (solid state welding or diffusion), processes based on the mixing in a liquid state (like fusion welding) or processes with addition of a third, generally hardening, liquid substance (e.g. soldering or adhesive bonding).
- **Interlocking joints** are formed by the interlocking of two materials or by the anchoring of additional elements into or inside the corresponding materials (i.e. mechanical joints).
- **Frictional connections** which are the result of friction between the involved materials, enhanced by the application of an external force (e.g. the shrinking of a hub onto a shaft).

Today, different joining technologies are used for the fabrication of aluminium components and modules in automotive applications and the number of aluminum joining options continues to grow in response to specific design and assembly challenges, e.g.:

- Aluminium car bodies assembled using adhesives in conjunction with punctiform joints (e.g. self-piercing rivets) equal or exceed chassis stiffness requirements.
- Non-critical joints, such as hood and deck lid flanges, can be joined using inexpensive, readily automated clinching methods, often combined with adhesive bonding.
- Other newly developed mechanical joining techniques for structural and non-structural applications offer additional advantages regarding joint quality or process speed.
- Resistance spot welding is increasingly attractive because of new processes, material, and equipment developments that extend tip life, enhance weld quality, and reduce welding power demands.
- Arc welding is also enhanced due to advances in equipment, such as solid-state power supplies and better wire-feed devices.
- Laser beam and combined laser/arc welding methods provide automotive body designers with even greater assembly options for closures and structural components.
- Friction stir welding is making inroad into the field of automotive aluminium applications.
- Brazing of aluminium is largely confined to the production of heat transfer components. It may, however, well find future applications in other, structural applications.

In the following, the different joining technologies used for the assembly of aluminium parts for automotive applications (including joining of aluminium with other materials) will be described. Due to the large variety of possible solutions, no performance values can be quoted here, please refer to product suppliers for more detail information.

More details, in particular regarding fundamental metallurgical aspects, can be found on the freely-accessible aluMATTER website providing interactive e-learning resources for aluminium science and technology:

http://aluminium.matter.org.uk/content/html/eng/default.asp?catid=47&pageid=2144416963

Additional information on aluminium joining is offered by TALAT (Training in Aluminium Application Technologies), a comprehensive collection of training material for engineers and researchers in industries and universities:

http://www.alueurope.eu/talat/4000/4000.htm.

Much more information and other studies can also be found on the websites of the European Aluminium Association and the Aluminum Association:

http://www.alueurope.eu/applications/automotive/

http://www.drivealuminum.org/research-resources

Purpose

The intention of the present document is to provide information about the wide range of technologies applicable to join aluminium alloy components with other parts made from aluminium alloys or dissimilar materials, in particular for automotive applications. The list of the described joining methods is clearly not exhaustive, also keeping in mind the ongoing further developments. In addition, it should be kept in mind that the information provided about the different joining methods obviously can't be complete. If an actual application is envisaged, early contact with the supplier(s) of the respective processing equipment and auxiliary materials as well as your aluminium supplier is recommended.

The present document is not meant to be a guideline for design and engineering nor an actual manual for production purposes. Most of the described technologies are mature and proven in practical applications. However, there are also techniques still under development or in the qualification phase. For more detailed information, please contact the supplier(s) of the respective processing equipment and auxiliary materials as well as your aluminium supplier. The present document is also not an academic paper with specific references to the literature. Today, searching the internet offers the possibility to get additional competent and up-to-date information, including references to scientific and/or technical papers.

Acknowledgment

The work to develop this Aluminium Automotive Joining Manual is a joint effort between the European Aluminium Association and the Aluminum Association. The chapters have been reviewed by experts from member companies of both these associations.

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For additional information, please contact your aluminium supplier to be able to discuss details directly with the relevant experts.