Moving more with less CO2 - Bonding in the Automotive Industry

The motor car has been with us for more than 120 years. Initially it was expensive and exclusively for the wealthy, but gradually it became available to the masses. Now it is hard to imagine life without the motor car. It has transformed our way of life, our landscape, and our outlook. Worldwide it has provided mobility, pleasure and economic opportunity to millions of people, but its widespread use has damaged the environment. Now the big question is how sustainable is the motor car, and the way we use it?

Emissions from passenger cars account for around half of all CO2 emissions in the transport sector, and almost 12% of total CO2 emissions in the European Union.

For this reason the European Commission introduced a comprehensive strategy to reduce CO2 emissions from new cars and vans sold in the European Union, to ensure that the EU meets its greenhouse gas emission targets under the Kyoto Protocol and beyond.

To meet the targets requires some fundamental changes in the way cars are assembled, used, and – ultimately – disposed of. Adhesive bonding is one of beneficial factors in car production since it helps to reduce the vehicle's weight, and thus also the CO2 emission, of the finished car. Moreover, it has also proved to be the most energy efficient joining technique.

A lighter car emits less CO2. But modern cars also need to display ever more innovative and functional designs and continously improve the safety of the passengers.

In order to achieve these various goals, whilst also limiting the overall weight of the car, many different materials – such as aluminium, magnesium, steel, or fibre-reinforced plastics – need to be used. Joining all these different parts and materials to make a complete car can only be done with the help of adhesives, since traditional joining techniques like welding, riveting and clinching might damage the material and cannot be applied on all substrates.

Increasingly, vehicle manufacturers are using plastic in doors and other vehicle body parts, while most use plastic in bumpers. Tooling for plastic components generally costs less and requires less time to develop than that for steel components and therefore may be changed by designers at a lower cost, making it an attractive material for vehicle makers, despite its higher cost per kilogram. The relative low weight also contributes to higher fuel efficiency in cars.

Not only the car body, but many exterior and interior components, visible or hidden in a car, owe their functionality to state-of-the-art adhesive technologies.

Overall the energy spent per bonding application with adhesives is lower than the energy spent for conventional joining techniques like welding or clinching. A study, comparing the different joining technologies like spot welding, laser welding, clinching and bonding, found that adhesive bonding achieved the same, or even an increased strength of the joint with less energy spent.

Adhesive bonding increases the choice of material used and enables more innovative designs; both are important factors for the safety of the car.

For example, the windscreen provides structural strength to the car body and helps keep passengers inside the car if an accident should occur. As important as the windscreen quality is, so too is the quality and proper installation of the auto glass adhesive.

The use of adhesives in car production helps to improve the safety standards and allows modern design with innovative material. They help the car industry to meet their challenges of developing more environmentally friendly solutions for the future.

And what of the future?

Electric cars and also fuel cell cars are being promoted as part of a sustainable solution, but they still need fuel, and significant CO2 reduction would require electricity to be generated from non-fossil sources, However, electric vehicles may be important in reducing localised pollution. In any case such cars nedd als significant weight savings to increase their range.

Fuel cells represent the latest and, perhaps, the most rewarding of alternative energy technologies. The fuel cell is a power-generation system in which hydrogen is used as a fuel source. The hydrogen can be extracted from fractionated hydrocarbons (e.g., gasoline, methanol, propane) or natural gas with what is called a reformer. Hydrogen can also be produced from the electrolysis of water.

Tighter reliable, fail-safe sealing of the elecrical components is an absolute necessity in electric and fuel cell technology. The adhesive or sealant must be adaptable for high volume, mass production and have low assembly costs.

Whatever direction the motor vehicle industry takes in the coming decades, it is certain that adheisves and sealants will have an increasing part to play.

ANNEX I – Weight reduction

Due to new functions installed on the cars, the weight of vehicles is steadily increasing. The current average weight of a car in Europe is around 1.350 kg, producing around 180 g CO2, while in the USA it is 1.850 kg at 210g CO2. Crash resistant lightweight structures is one route to achieve better mileage and emissions, which has to be complemented by more efficient combustion engines, hybrids and/or e-drive, lower friction tyres, better aerodynamic shaping etc. The use of adhesives is enabling the development of new technologies in all these sectors with good resultd on weight reduction.

The inherent1 properties of bonded structures allow weight savings in the range of 15% when using high strength steel through reduced thickness without sacrificing crash performance and durability. With an assumed 350 kg steel car body the 52.5 kg reduced weight already saves 912 MJ necessary for the production of the bare steel and 1135 MJ for electogalvanized steel. Since welding of high strength steel reduces its strength, the welded joints will become the weakest area which reduces the durability of the structure. In contrast, adhesive bonding keeps the high strength properties of the steel unchanged, thus allowing thinner metals for the same strength and durability.

The savings for the lifetime of the car calculated with the data from the study of IFEU2 , amount to 27 GJ per 100kg or, in our case of 52.5 kg weight savings,14.2 GJ for a gas engine and with 13.1 GJ for a Diesel engine.

This means the adhesive technology allows for energy savings over the lifetime of the car of twice the energy necessary to produce the steel for the car body.

The savings of gas according to IFEU in the NEDC cycle is about 0.3 l/100 km and per 100 kg reduced weight. Assuming an average of 200,000 km and 15 years' use phase for a passenger car this results in gas savings of 315 l for its lifetime. The owner saves in the same period with a calculated gas price of 1.50 €/l 472 €. And that with a small amount of 800 g of adhesives.

For steel cars the use of structural adhesives will help to reduce the weight for a car by at least 15 %. The energy consumption for the production is reduced by 912 MJ and for the use phase by 14.2 GJ which sums up to more than 15 GJ. Compared to the energy of about 120 MJ required for the raw materials and production of 800 g adhesives itself this is a saving factor of 125. And the inherent energy in the adhesive can at the end of its life still be used for combustion. The difference between various adhesives is less than 20 %. Therefore the performance of the adhesive is the key for the savings and not its individual carbon footprint.

ANNEX II – Energy reduction during the entire lifecycle

The following calculations, show how adhesives can help to reduce the energy to produce a steel car with reduced weight.

Figure 1: Comparison of different joining technologies (Stephan, Henrik 2007)

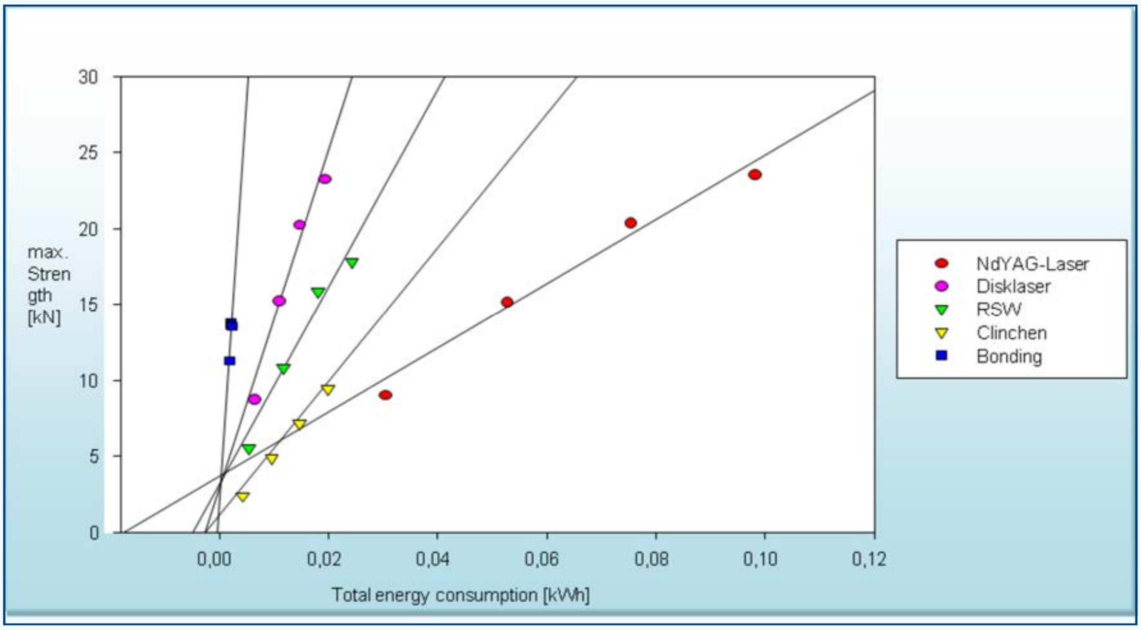


Figure 1 shows that the energy for 4 spot welds (RSW = resistance spot weld) at a length of 100 mm is 0.02 kwh or 0.072 MJ. The energy needed to achieve a similar strength for the joint with adhesive bonding is 0,003 kwh or 0.011 MJ. The basis for the comparison can be seen in the table 1 below.

Table 1: Comparison of different joining technologies (Stephan, Henrik 2007)

Base shear strength, relating to 1 RSW point			
	Joint equivalent	Energy consumption [kWh]	Shear strength [kN]
RSW	1 point	0,00546	5,5
NdYAG laser	13 mm	0,01072	5,5
Disklaser	13 mm	0,00285	5,5
Clinchen	3 points	0,01108	5,5
Bonding	0,05 cm³	0,00072	5,5
Base energy consumption, relating to 1 RSW point			
	Joint equivalent	Energy consumption [kWh]	Shear strength [kN]
RSW	1 point	0,005461	5,5000
NdYAG laser	9 mm	0,005461	4,3640
Disklaser	50 mm	0,005461	8,4700
Clinchen	2 points	0,005461	2,9698
Bonding	0,2 cm³	0,005461	31,2361

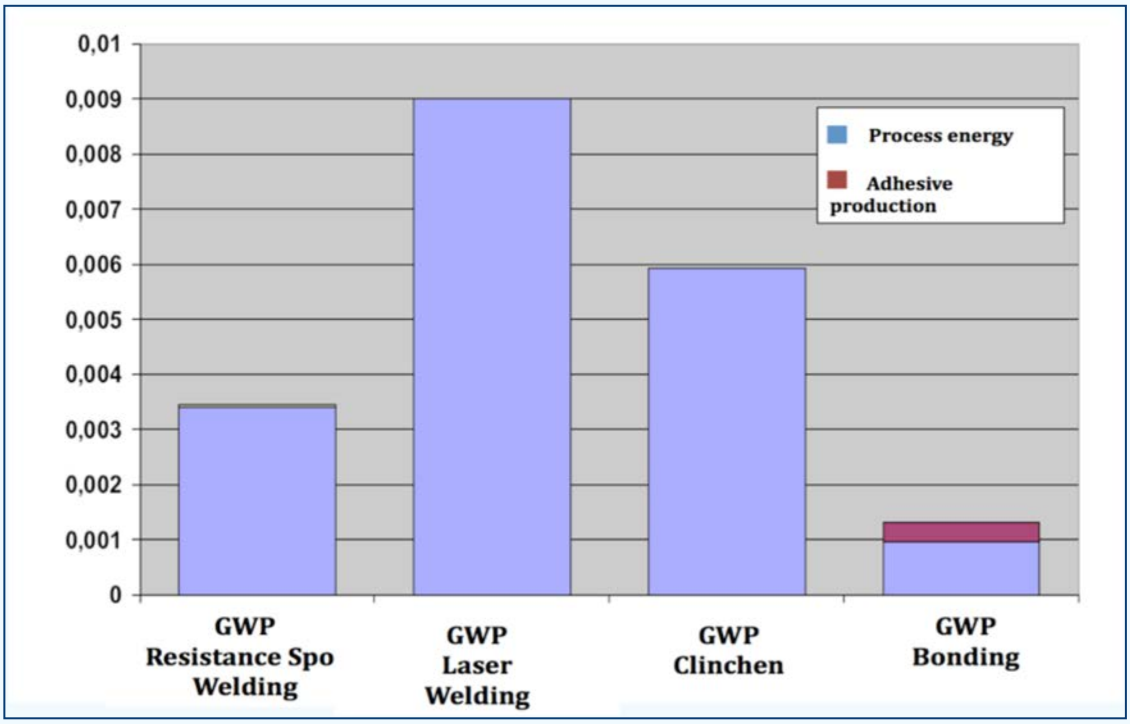
The energy required to weld the whole car body for an assumed joining length of 135 m is then calculated based on a number of 4500 spot welds. One spot requires 0.005 kwh and multiplied by 4500 it results in an energy consumption of 22.5 kwh or 81 MJ for the spot welding of the whole car body.

According to the table one spot weld equals the amount of 0,05 cm³ of adhesives. This requires an amount of 0,00072 kwh. To replace 4500 spot welds with adhesive bonding, we would need 4500 * 0,00072 kwh = 3,24 kwh or 11,64 MJ. The volume of 0.05 cm3 adhesive corresponds to a bond length of 11.25 mm, an overlap length of 15 mm and an adhesive layer thickness of 0.3 mm. The volume of adhesive needed to bond 135 m joining length is calculated on the above assumptions to 600 cm3 or based on a specific weight of 1.33 to 800 g.

When compared to the energy necessary to produce the steel for a car body with 350 kg weight, which is in the range of 6.08 Gigajoule (GJ) for bare steel and 7.57 GJ for electro-galvanized steel this is almost a factor of 30 higher than the energy required for adhesive bonding.

In consideration of the entire life cycle, the ranking of the different compared joining technologies stays the same. In Figure 2 are the results of the Life Cycle Analysis shown for the impact category Global warming potential. Included here is the production of the adhesives. Regarding the amount of CO2 the required process energy for bonding in the automobile plant dominates over the production of the adhesives. All in all bonding can be seen as the best joining technology regarding the entire life cycle.

Figure 2: Comparison of joining technolgies over the Life cycle - Global warming potential in kg CO2 equivalents (HENRIK STEPHAN, 2007).



References:

1. STEPHAN, HENRIK (2007): Assessment procedure for joining technologies from the perspective of environmental protection, Phd-thesis, Scientific Journal Series Technical University, Darmstadt. ISBN: 3 – 932518 – 80 – 2; ISSN: 0721 – 5282.
2. Article in Adhesion (Bernd Burchardt, Jan Olaf Schulenburg, Martin Linnenbrink, New building blocks for lightweight structures, Adhesion, Adhesives & Sealants extra, 10/ 2009 p 22).
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4. Source: www.corusconstruction.com/en/sustainability/carbon_and_steel

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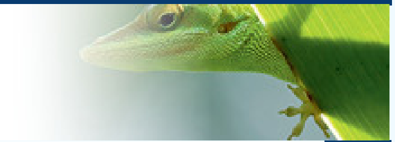
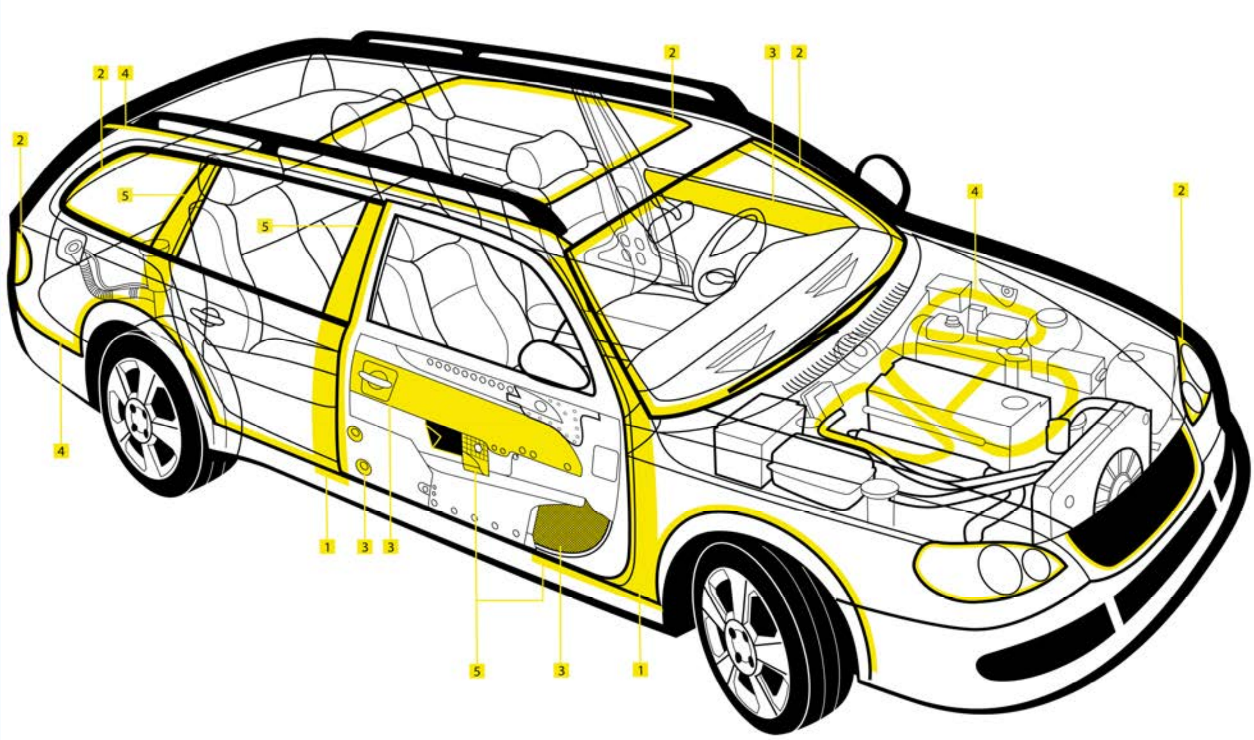
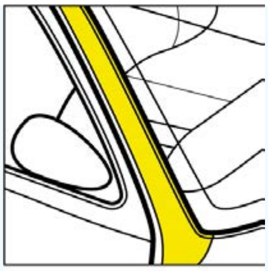
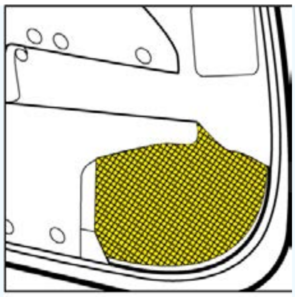




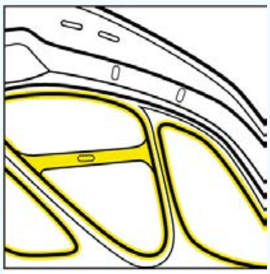


1.
Structural reinforcement of cavities

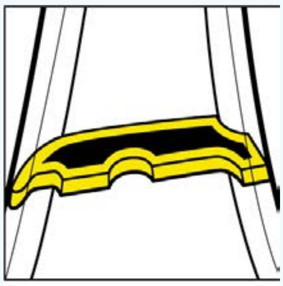
2.
Direct glazing with and exterior bonding



3.
Interior bonding



4.
Structural bonding and sealing



5.
Sound damping

"**Sika car**" Images courtesy of Sika Services AG.

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