Comparative study of the joining technologies of vehicle bodywork sheets

Z Weltsch1

1John von Neumann University, Faculty of GAMF Engineering and Computer Science, Department of Materials Technology, Hungary, 10. Ízsáki road Kecskemét 6000.
weltsch.zoltan@gamf.uni-neumann.hu

Abstract. In the automotive industry lighter vehicles are needed with more fuel-efficient engines, due to reduced fleet consumption. Many development deals with new materials, but steel will remain probably the primary material for vehicle structures. Other materials, like new high-strength steel grades are finding their way into vehicle structures. Aluminium and magnesium with low-density and fiber-reinforced composites are increasing in demand in the vehicle industry. For the new materials new bonding technologies are needed. Bonding these new materials are the most important in this research.

1. Introduction

Many automotive designers and engineers have been particularly concerned about the “reduction of curb weight/curbside body weight” for the past three decades because vehicle weight reduction has been very important, as well as engine combustion improvement and friction reductions [1]. However, the efforts were unrewarding for the automobile industry. In the past two decades, the average curb weight of light-duty vehicles has risen by 20 % in European and 25 % in the US despite their best efforts [2, 3].

Fuel consumption can be reduced by a number of methods in motor vehicles, but the most commonly used method is lightweight construction. Lightweight construction immediately contributes to a reduction in consumption, and thus a reduction in the emission of pollutants. In addition to the vehicle body, the weight reduction of the transmission elements results in further secondary effects. Various studies have shown that a 100 kg weight reduction results in a reduction in CO₂ emissions between 5 and 12 g. As 40% of the total mass of vehicles is the body, this is one of the most important areas of weight reduction. If we make a change in the vehicle body, it works very effectively. As security for increasing acoustics demands are generally opposed to lightweight construction, they show the complexity and difficulty of the challenges inherent in it [2, 5].

The mass reduction of cars, automakers worldwide, are strategically implemented to achieve regulatory and market goals. Reducing the weight of a vehicle is mostly achieved by optimizing, reducing or reducing design, and by combining lower density materials with a greater weight and / or greater rigidity and weight ratios. New generations of automobiles are expected to contain an increasingly larger quantity and diversity of innovative material in their components (Figure 1.). The leading light weighting material candidates for vehicle body structures include advanced high strength steels, aluminium, magnesium, and plastic and polymer composites. Innovative combinations of these materials are available in product forms such as sheet, plate, moldings/castings, and extrusions.
Different composite body parts have a particular difficulty in choosing the right technologies, such as cutting technologies [2-4].

![Figure 1. New generations of automobile with several innovative materials [6].](image)

Thanks to the advanced materials, mixed materials are needed together to create cost effective solutions for them. Manufacturers are widely used in modern bonding technologies against conventional steel-steel welded joints. As supply chains are gradually evolving, more and more lightweight materials are becoming increasingly important in safety critical components, requiring extensive control over production quality.

Designing joining technologies is an extremely important engineering process that takes into account the materials used and their properties such as energy absorption, surface quality and shapability. In order for the latest materials to be properly connected, provide engineering features for different models. In order to establish such binding, it is necessary to examine the chemical and thermodynamic interaction of the adjacent components. [2].

In order to increase the confidence of car manufacturers, safety critical parts are often tested in both destructive and non-destructive ways. For the successful use of compound materials, life cycles such as end-of-life use should also be taken into account. These complex challenges can be solved in cooperation with research institutes, car manufacturers, suppliers and universities.

This paper investigates some of the popular methods for mixed material joining and identifies gaps and challenges and opportunities in their implementation for a mass-produced vehicle.

2. Experimental conditions

2.1. Applied materials and testing method

Two types of conventional DP and DC steels as DP600, DC01 with the basic mechanical properties, were applied in this study. The Figure 2. shows the geometric dimensions of the test specimens.
The Table 1. summarizes the chemical composition of the two different DC01 and DP600 sheets.

|        | Fe %  | C %   | Si %  | Mn %  | P %   | S %   | Cr %  | Mo %  | Ni %  | Al %  | Cu %  | Nb %  | Ti %  | W %   | Pb %  | N %   |
|--------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| **DC01** | 99.4  | 0.0291| 0.0091| 0.251 | 0.0063| 0.0091| 0.0394| 0.0238| 0.0579| 0.0513| 0.0085| 0.0019| 0.0186| 0.0065| 0.0182|
| **DP600** | 98.5  | 0.0873| 0.197 | 0.924 | 0.0124| 0.0026| 0.0305| 0.0029| 0.0333| 0.0479| 0.0077| 0.025  | 0.0027| 0.0205| 0.0075| 0.0101|

There are three combination of the investigated sheets for the experiments: DC01-DC01, DC01-DP600, DP600-DP600.

The plates are overlaid by 20 mm were coupled to the various joining modes. After this shear stress has been investigated by mechanical tensile test to determine the breaking force of the bonds.

2.2. *Adhesive bonding technologies*

Prior to gluing, the adhesive surfaces were thoroughly cleaned and then, as described in the catalog, the adhesive was allowed to bind.

TEROSON EP 5055 is a 2-component high-strength epoxy-based structural bonding adhesive with excellent corrosion protection properties for bonding metal (coated and uncoated) e.g. steel, aluminium or sheet moulding compounds. It is ideal for roof and panel bonding. The product exhibits excellent corrosion prevention and spot-weldable properties.

2.3. *Brazing technology*

The MIG brazing technology was carried out with a Migatronic Flex 3000 DUO in pulse mode with 5.0 purity argon gas and CuSi3Mn1 brazing materials wire 1.2 mm thick. The used fix current - voltage parsers are: current: I = 95 A, voltage: U = 19.4 V. The brazed bond was formed along the overlapping (Figure 3.)
2.4. **Welding technologies**

For spot welding were used SIŁA Schweissmaschinen NKLP 26. The machine in pulse and in traditional operation, with several parameter settings. The maximum current at which the machine can weld 14 kA. Figure 4. shows an example of a spot welded bond, the microscopic image shows the cross section of welded DP600-DP600 plates with the enriched martensit texture.

For the CO₂ arc welding used a Migatronic Sigma 300 C Pulse. It is also suitable for conventional and pulse welding, and I used only the conventional welding method. The used current and voltage parameters are: current: I = 98 A, voltage: U = 18.8 V.

2.5. **Riveting technology**

Clinching is a common joining technology that does not require consumables or pre-drilled holes. It is performed in a single step where stacked, ductile materials are pressed into a die with a punch. The punch forces the materials down and radially out into the die which creates a strong mechanical bond.

For the TOX Clinching use a CEC 008.100 type squeamish press with hydropneumatic cylinder. The Figure 5. shows the cross section of the investigated type of Clinching.
3. Results and discussions

Figure 6 shows the result of the shear test of the various joints. The DC01-DC01 specimen result shows that the welding of the MAG welding and the MIG welding line resulted in a more uniform stress distribution, thus providing these two technologies with the highest bonding force. At spot welding, the material is torn apart around the point due to increased stress. The bond strength of the TOX clinching technology could be closer to the bonding force of a larger bonding diameter or using thicker disks as the thickness of the neck and the area to be absorbed would increase.

In DC01-DP600 there was no significant change in DC01-DC01 for tensile forces, which means that the strength of the DC01 plate determined the maximum breakage value. This also means that the strength of the bonds formed is determined by the strength of the sheet in the vicinity of the bond.

Compared to this, the DP600-DP600 has a significant change in tensile forces. Except for clinch binding, there is a significant increase in tensile force for each type of joint. Observing the tensile specimens, it seemed clear that in these cases the sheet was not the weak point, but the lost bond in every case. Thus, in the case of plate pairing, the particular types of bonds are comparable.
If we introduce a specific index number, then we can refer to the measurement results on a unit surface. This is shown in the Table 2.

**Table 2. Proportionate tensile force**

| Joint surface (mm²) | Proportionate tensile force (N/mm²) |
|---------------------|-----------------------------------|
| Chlinch             | 28,27 84,1                        |
| Spot welding        | 19,63 495,6                       |
| MAG welding         | 80 159,5                          |
| MIG brazing         | 100 100,7                         |
| Adhesive            | 400 30,4                          |

The results shown in Table 2 are graphically shown in Figure 7. It can be seen that the spot of welded bonding can provide the best bond strength on the surface. From this point of view, the adhesive bond will remain below the same type of bond.

**Figure 7.** Proportionate tensile strength of different joining technology.

4. Conclusion

In this article, the joining technology of different vehicle body plates has been matched, depending on the tensile forces formed by the joining. This alone can not be used to classify bindings in all respects, but in this article the goal to get a comprehensive view of the evolved binding forces. Based on the results, the following conclusions may be drawn:

In the case of base-strength steel, all bonding types, with the exception of clinch, could provide the bond strength for low-strength steel.
In the case of matching the high and the base strength steel, the properties of low strength steel mechanics determine the bond strength. In the case of cohesion bonds significant structural changes are taking place on the boundaries.

When using high strength steel, the bond strength is determined by the bonding environment. Considering a specific bonding surface, there are significant differences between the various joining pairs. We can achieve the smallest specific bond strength with spot welding, but in this form the adhesive bond is the weakest.

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