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Alternative Joining Methods in Car Body Production

Emil Spišák[1], Ľuboš Kaščák[2]
[1]Department of Technology and Materials, Technical University of Košice, Slovakia
[2]Department of Computer Support of Technology, Technical University of Košice, Slovakia

ABSTRACT
The optimization of a car body in terms of cost can be achieved by using different materials in various positions of the car in order to utilize specific properties of each different material. The paper deals with the methods of mechanical joining used in car body production as alternatives to the most used conventional resistance spot welding. Load-bearing capacities of the joints made by mechanical joining and resistance spot welding of various materials used in car body structures are compared. The mechanical joining is mainly used to join material with various thicknesses, mechanical properties, surface coatings, even ferrous or non-ferrous metals.
Keywords: *Mechanical joining, resistance spot welding, load-bearing capacity.*

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I. INTRODUCTION

The automotive industry meets the requirements for increased safety, the tightened regulations regarding environmental protection, as well as the requests of car drivers for more luxury features. The lightweight design of automobiles is one of the primary methods to realize reduction of energy and emission [1,2]. The car producers utilize the various combination of materials, such as steel sheets of drawing grade quality, advanced high-strength steel sheets or high-strength low alloy steel sheet [3]. There is a need to join different materials – materials of various thicknesses, qualities, surface treatments. Such practice in car body production opens new possibilities for designers in optimal utilization of properties of various materials, which can be combined into one construction. The cheapest materials can be situated in the common parts of pressing in car body, good-quality sheets can be situated in the critical places of deformation and high-strength sheets can be used in the exposed places due to demands of construction – deformation zones. These demands lead to research in the area of material joining with the emphasis mainly on load-bearing capacity of joints, quality of joints and corrosion resistance [4].

Resistance spot welding is the main joint mode in car body manufacturing but it is also a complex process containing the thermoelectricity, metallurgy and many other factors [5]. During the welding, a current with high intensity crosses through the assembly to be welded which are held between two electrodes with a predefined pressure [6,7]. Considering most of steel sheets are galvanized to improve life of car body, the wear of welding electrode decreases due to the lower electrical resistance and melting temperature of the coating layer. Therefore, alternative joining methods have attracted increasing interest and applications. There are many joining technologies that are alternatives to resistance spot welding such as spot friction stir welding, adhesive bonding or new joining solutions including the plastic forming cold processes – mechanical joining. The most used methods of mechanical joining in car body production are clinching and clinchriveting [8,9]. Clinching is an efficient joining method that enables to join two or more sheets without any additional elements such as rivets, bolts or nuts. In addition, clinching does not require a surface preparation e.g. drilling, cleaning and roughening of the surface and other types of surface preparations. Clinching is utilized in a wide range of applications and can be applied to different materials such as low carbon steel sheets, high-strength steel sheets, aluminium alloys, magnesium alloys. Clinchriveting is a single-step joining process which geometrically constrains two sheets by local deformation of the sheet metals using a punch and die, as well as the special rivet [4,10].

The paper describes mechanical joining methods used in car body production as alternatives to conventional joining methods such as resistance spot welding and laser welding or laser brazing.

II. MATERIALS USED IN CAR BODY CONSTRUCTION

The car body consists of a combination of several materials, which is a result of material and energy saving trends applied in car body production. The recent decade has witnessed considerable developments in advanced iron and steel technologies that car manufacturers frequently employ in new design solutions. The advances in the use of iron and steel significantly reduce the mass of ferrous materials, which are the dominant material (about 64%) of typical family vehicles. There are several ways of classifying automotive steels. The first is a metallurgical designation. Common designations include the following:

- low-strength steels (interstitial-free and mild steels),
- conventional HSS (carbonmanganese, bake hardenable, high-strength interstitial-free, and high-strength, low-alloy steels),
- newer types of AHSS (dual phase, transformation-induced plasticity, complex phase, and martensitic steels),
- additional higher strength steels for the automotive industry, such as ferritic-bainitic, twinning-induced plasticity, hot-formed, and post-forming heat-treated steels.

Recently, there has been a steady increase in the use of high-strength steels (HSS), many versions of which are referred to as high-strength, low-alloy (HSLA) steels. These materials and their associated advanced design and production techniques (as well as improved design and production of traditional steels) were used by the American Iron and Steel Institute (AISI) in Ultralight Steel Auto Body (ULSAB) series of studies and demonstration projects. In comparison with a conventional steel body, the ULSAB car body achieved a 19% mass reduction in a body structure that had superior strength and structural performance (including crashworthiness) as well as a reduced parts count and net manufacturing cost savings. Similar mass reductions and other advantages were reached for doors, decklids, hoods, and hatchbacks. Advanced steel materials and forming processes enable optimization of vehicle body structures and components. Various materials used in car body production are shown in Fig. 1a.

The combination of different materials, their thicknesses or surface treatment serves to achieve better material utilization. The tailored blanks allow the increasing use of high strength ductile steels. The bodies are assembled not only by means of resistance spot welding and adhesive bonding but also by means of mechanical joining – Fig. 1b.

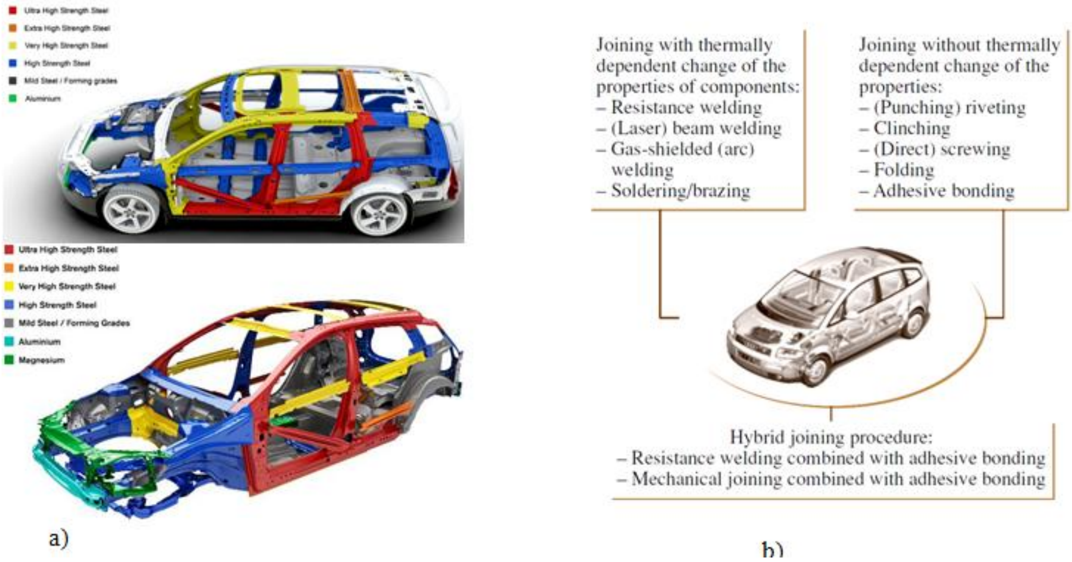

Figure 1: (a) materials used ibn car body and (b) typical joining methods in vehicle construction

Joining the advanced materials with special requirements or various combinations - joining steels, aluminium and magnesium alloys, by classic joining processes such as resistance spot welding is very difficult or sometimes even impossible. Therefore new joining methods including mechanical joining are used.

III. MECHANICAL JOINING METHODS

The application of mechanical joining save the assembly time as the additional efforts related to joined element pre-merging before other joining process such as laser welding. Due to the fact, that mechanical joining is cold process, it significantly decrease the energy cost.

Clinching is a joining method in which sheet metal parts are deformed locally without the use of any additional elements as shown in Fig. 2a. The technology allows joining of two or more metal sheets without any edge preparation as well as when the clinched joint has been made, there is no need for repainting the sheets or performing stress relieving treatments. Clinchriveting is a high-speed joining process that does not require pre-existing holes, therefore eradicating the need to align the joining materials. The punch impacts the rivet, piercing the top sheet, and partially piercing the bottom one. The die on the underside of the materials causes the rivet to flare under the force, creating a mechanical interlock - Fig. 2b.

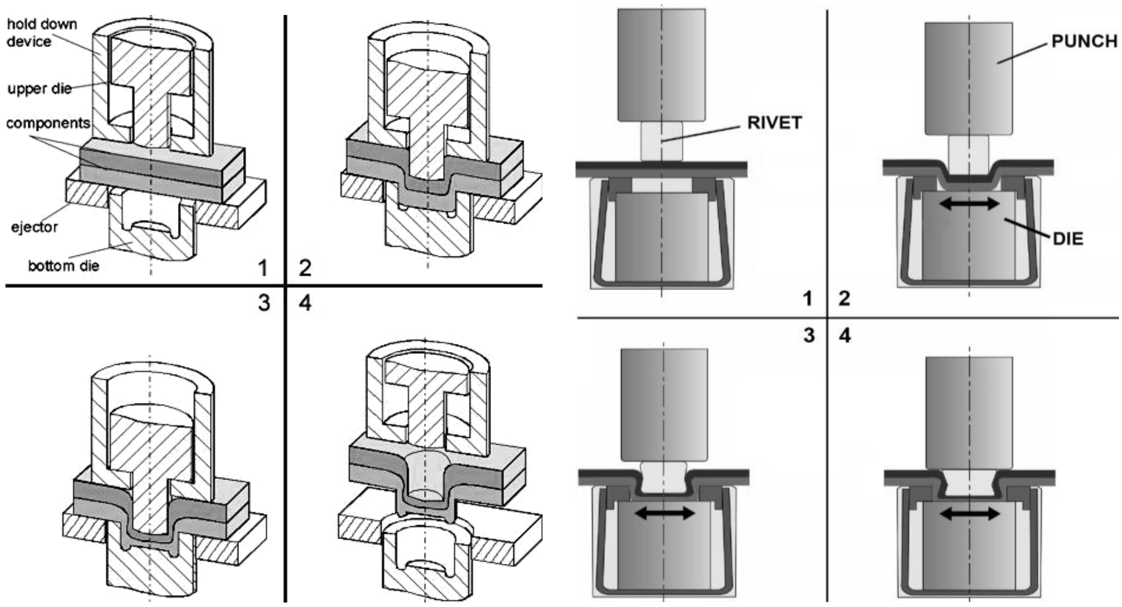

Figure 2: Principle of (a) clinching and (b) clinchriveting

Loaf-displacement curves of CR joints compared with the curves of resistance spot welded joints after tensile test are shown in Fig. 3. All observed samples of resistance spot welded joints had higher values of carrying capacities in comparison to CR joints. On average, the CR joints reached about 85 % (samples with H220PD steel) and about 60 % (samples with DX51D+Z steel) of carrying capacities of resistance spot welded joints. Joints made by clinch rivet method failed in the manner of a press-stud in combination with the mode of one edge of the joint fails.

When joining three H220PD steel sheets, the lowest total breaking force was achieved for the joint made by clinching – Fig. 4. Much bigger total breaking force was achieved for the resistance spot welded joints (curve: RSW), where the breaking force increase by about 40%. When looking at the shearing curves, the spot welded joint features the highest rigidity, this is the steepest curve in its initial forcing displacement range (Fig. 5). This second method was conventional riveting, which results in a loosening of the joint after quite small displacements.

Good effect was achieved for the clinchriveting joints. However, this solution requires more expensive tools and the rivet feeding header.

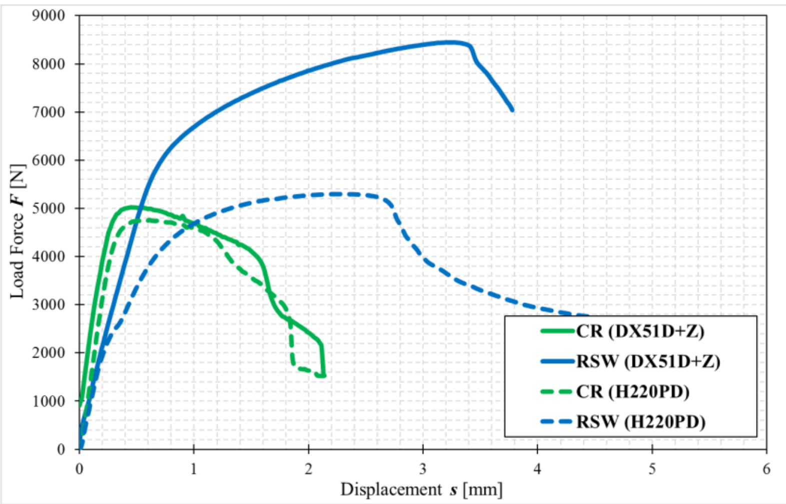

Figure 3: Load-displacement curves of clinchriveted joints and spot welded joints

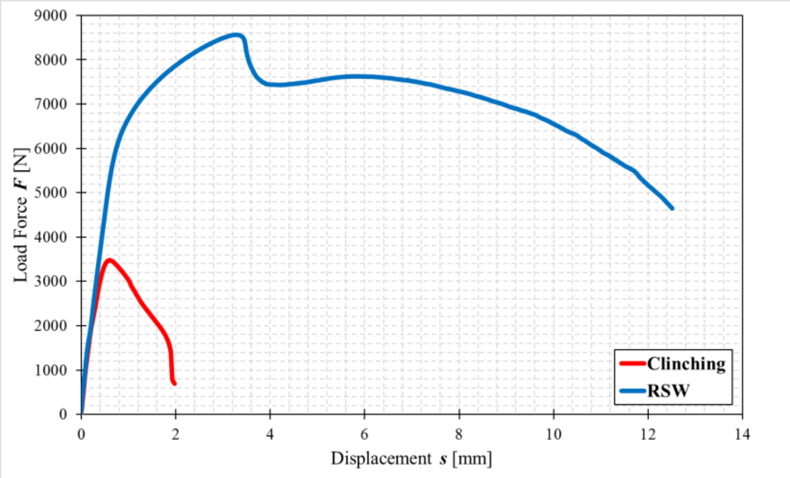

Figure 4: Load-displacement curves of clinched and spot welded joints

In the case of joining materials such as DX51D+Z, DC06 and H220PD, similar relations between the maximum shear force and the joining method can be observed (Fig. 6). The highest values of Fmax were measure in resistances spot welded joints, then clinchriveted joints and the last ones were double clinched and clinched joints. The most significant differences in maximum shear force were observed in samples with DX51D+Z materials.

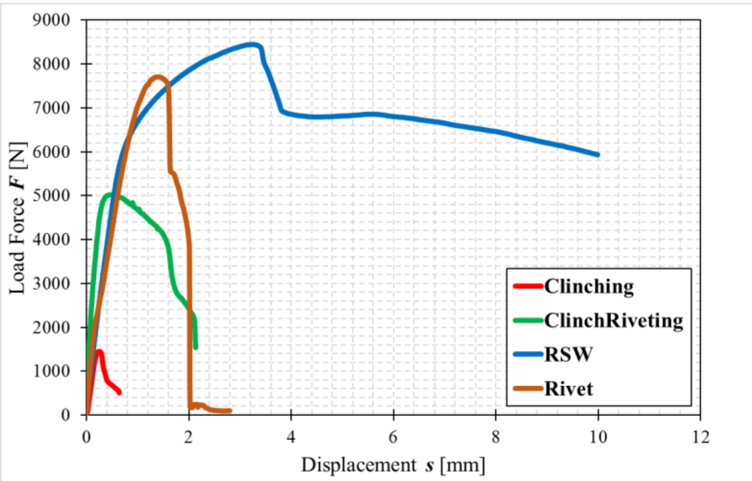

Figure 5: Load-displacement curves of the joints made with various joining methods

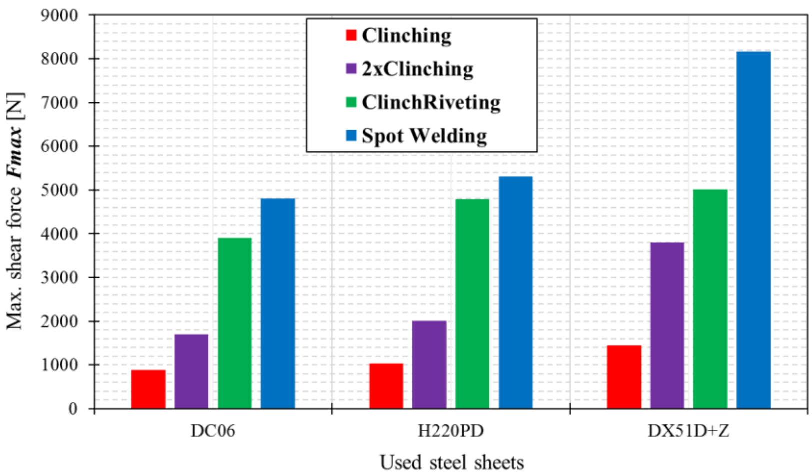

Figure 6: The comparison of shearing force of joining methods

IV. CONCLUSION

The increasing use of coated, lightweight and high-strength materials has led the automotive industry to re-examine traditional methods of component assembly. Conventional materials are in the limit of use, despite of the continual increasing of their technological application. It is necessary to develop and evaluate new material combinations and progressive technologies of their processing to withstand demanding conditions together with the economical demanding. The question is not only how to make the parts of car body, but also how to join them together in functional and safety construction.

The results of experiments showed possibility of mechanical joining such as clinching and clinchriveting to be an alternative method to resistance spot welding when joining the car body steel sheets. The joints formed by method of clinching as well as clinchriveting do not reach the values of load-bearing capacity of resistance spot welded joints, however. Their utilizing in automotive industry is for their advantages such as low energy consumption during joining, retained corrosion resistance of joined galvanized materials, or the possibility to combine different materials in terms of quality, thicknesses, as well as ferrous and non-ferrous metals.

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