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# MODERN MECHANICAL JOINING METHODS UTILIZED IN CAR BODY PRODUCTION

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**Abstract:** Modern lightweight car bodies consist of sheets such as the aluminum alloys, or thin steel sheets in combination with aluminum alloy sheets. The aluminum alloy sheets could be difficult to join by conventional methods such as the resistance spot welding. Modern joining methods are being developed to overcome problems with the high thermal conductivity of aluminum or different thermal conductivities when joining two different materials. Modern mechanical joining methods overcome difficulties coupled with welding and also increase the efficiency and productivity of car body manufacture. Mechanical joining methods such as clinching, clinch-riveting and self-piercing riveting are going to be presented in this contribution.
**Keywords:** mechanical joining, joining by forming, clinching, clinch-riveting, self-piercing riveting, automotive industry.

## Introduction

Low weight of a car body and resulting better fuel economy are one of the main concerns in automotive industry. To achieve this, modern and also lighter materials must be used in car body production. Aluminum alloys or magnesium alloys are such materials, which offer considerable lower weight compared to steel (e.g. magnesium 75% lighter than steel). Materials such as aluminum alloys are difficult to weld generally, because of their high thermal conductivity. Another problem is joints which combine two or three different kinds of materials, because they have different thermal conductivities or melting points. The application of modern mechanical joining methods overcomes issues related to welding, because these processes do not require additional heat, but also issues with limited formability of modern high strength materials. Other advantages of mechanical joining are: high strength, easy maintenance, corrosion resistance, reliability at elevated or low temperatures, low processing and manufacturing costs. [1]

## Modern mechanical joining methods

The most used mechanical joining methods in terms of car body production are clinching, clinch-riveting and self-piercing riveting. [2] These joining processes are also classified as the joining by forming methods. Besides the automotive industry, they are also utilized in heating field, ventilation and air conditioning, or ship building industry. Mechanical joining refers to processes which manufacture permanent connections between two or more sheets by their controlled plastic deformation. Fasteners are additional parts which are needed for forming a connection with form or force relation between two or more sheet materials. Blind rivets are such fasteners. However, clinching joints do not require additional fasteners. [3] There are numerous advantages of mechanical joining technologies:

- No thermal structural transformation of joined materials
- No distortion, nor residual stresses induced by heat
- Variety of metallic and non-metallic materials or their combinations can be joined

- Different material thicknesses could be joined
- High economic efficiency, no pre- and post-treatment of workpieces
- Materials with surface coatings can be joined without damage to the coating
- Very good environmental behavior (no emissions or pollution)

Despite many advantages stated, mechanical joining methods have also disadvantages:

- Lower load-carrying capacity of some types of mechanical joints
- Poor level of standardization
- Geometrical unevenness due to nature of processes (local protrusion of joining area)

**Clinching (CL)**

Mechanical clinching consists in producing an interlock between two or more metal sheets by using a simple tool set consisting of punch and die. [4] Protrusion is formed by the material yielding and subsequent creating of a mechanical interlocking. Joining of more than two sheets is possible. High economic efficiency of this technology is due to joint forming without additional parts and high speed of a joint. Joint forming of the Clinching process is depicted in Fig. 1. Joint forming process is divided into four sub-stages.

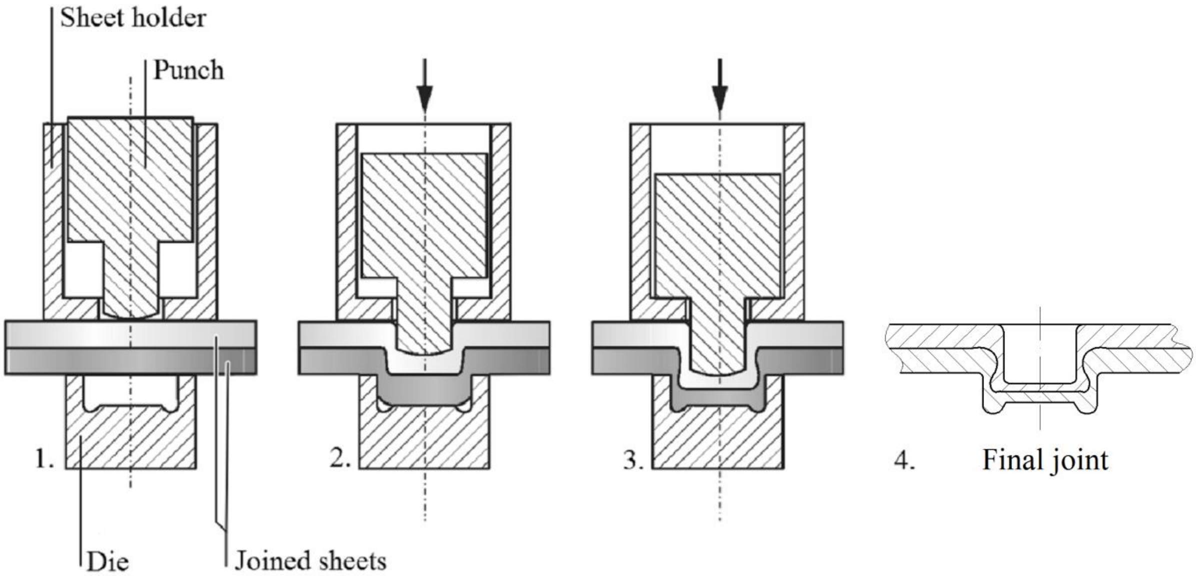


**Fig. 1 Mechanical joining by means of Clinching [3]**

In the first step, the sheet holder moves downwards in order to fix and clamp both joined materials. In the second step, the punch moves downwards and by its action both materials flow into the die cavity forming a protrusion. Upsetting of both joined sheets takes place in the third step. Thickness of both sheets is reduced by their upsetting. Material flows into the groove of die leading to formation of undercut between both sheets. In the last step, retraction of punch and sheet holder takes place after reaching the preset joining force or punch displacement. Step four4 in the Fig. 1 shows the final Clinching joint.

The die can be rigid (one part with specially formed cavity), or flexible. Flexible dies are composed of moving die blades clamped together by springs. Dies with flexible segments provide better material expansion in the lateral direction and better form- and force-closed permanent interlocking. Clinching technology could be divided into cutting and non-cutting joining. In cutting processes, punches with cutting edges partially cut material to enable the punch sided material to flow behind the die sided material forming an interlocking. Some examples of the Clinched joints are shown in Fig. 2.

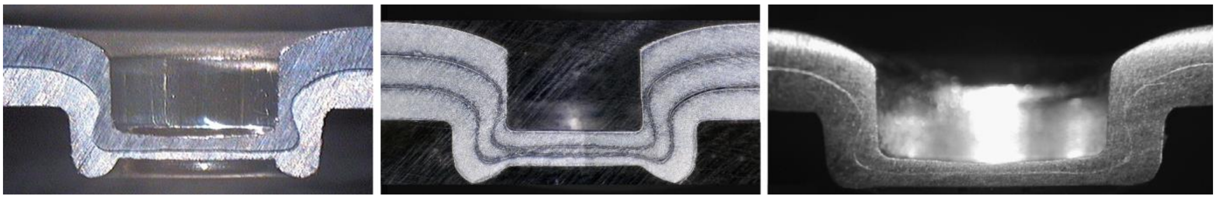

**Fig. 2 Metallographic sections of various Clinching joints**

## Self-piercing riveting (SPR)

Self-piercing riveting is a high-speed joining method for sheet materials. [5] In contrast to a regular solid rivet, for self-piercing riveting the cylindrical rivets are used. These special rivets expand while joint forming and form a force relation. Both work-pieces and rivets are partially deformed during the joining process. Self-piercing rivets are designed for punching only the set-head side of sheets and only deform the die side. Individual steps of joint forming during self-piercing riveting are shown in Fig. 3.

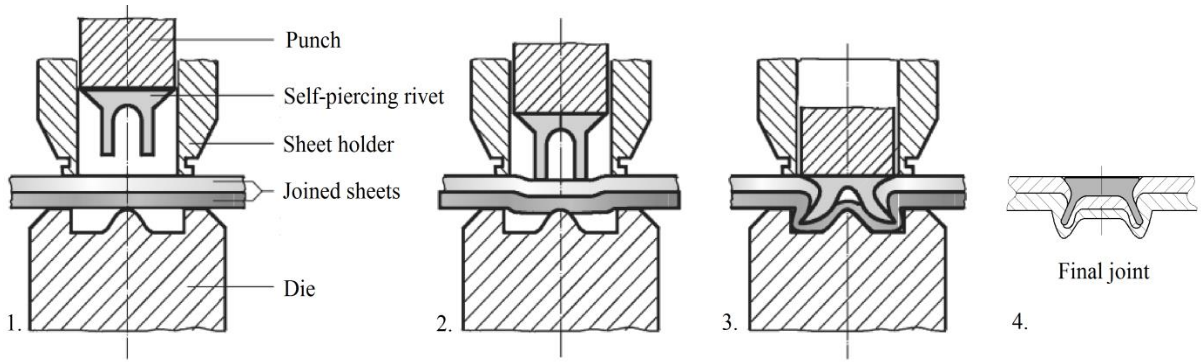


**Fig. 3 Mechanical joining by means of Self-piercing riveting [3]**

Sheets to be joined must be aligned with the punch and die in the first step. Clamping of both joined materials by sheet holder also takes place in this step. Self-piercing rivet is driven through the sheet holder in the second step. The cylindrical shape of die with a specially formed protrusion in the middle of the cavity causes the self-piercing rivet to expand and forms a form- and force-interlocking within the die-sided sheet material. This process takes place in the third step of self-piercing riveting. Punch and sheet holder retract and the joint is complete in the fourth step.

**Fig. 4 Metallographic sections of various Self-piercing riveting joints**

The rivet has to have a high tensile strength and hardness to be able to pierce through both joined sheets. Also, the rivet must be deformable to form a proper joint without tearing or breaking of the joint or the rivet itself. High-strength materials may reduce the maximum thickness that could be joined. The properties of self-pierce riveted joints depend on the mechanical, thermal, chemical and electrical properties of joined sheets and the rivet. Some examples of the Self-piercing joints are shown in Fig. 4.

### Clinch-riveting (CR)

The joining process in the Clinch-riveting technology is similar to the Self-piercing riveting and Clinching. [6] Clinch-riveting is a cold forming process for joining two or more sheets by no piercing the sheets with a special rivet. The joint is formed by a rivet, whereas the rivet is anchored in the upper sheet material and upper sheet is anchored in the lower sheet. The principle of Clinch-riveting joining process is shown in Fig. 5.

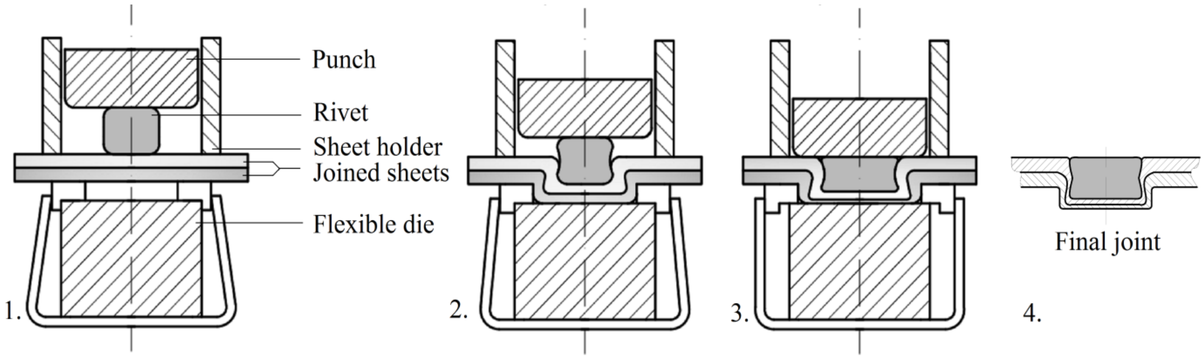


**Fig. 5 Mechanical joining by means of Clinch-riveting [1]**

In the first step, the punch, both joined sheets and the rivet must be aligned with die. The punch pushes the rivet to penetrate into the top sheet in the second step. Subsequently, die shape causes the rivet to flare within the lower sheet and forms a mechanical interlock between the both joined sheets. The Clinch-riveting joint is complete after retraction of the punch and sheet holder. This joining process requires the accessibility of both sides of the joint. Joint which were made by Clinch-riveting technology have different strength depending on the loading direction. Compared to regular Clinching, the rivet in the protrusion of the joint increases stiffness, thus the Clinch-riveting joints have higher load-carrying capacity. [1]

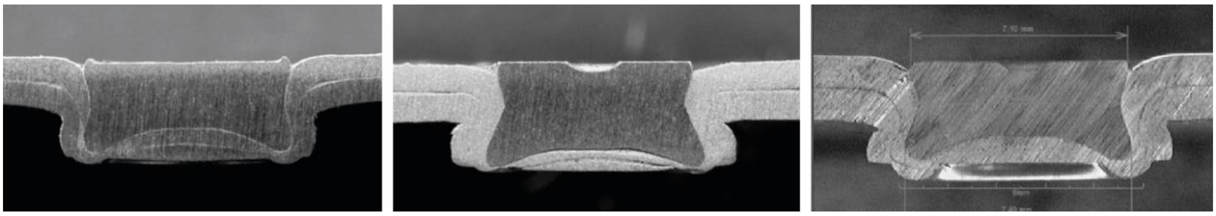

**Fig. 6 Metallographic sections of various Clinch-riveting joints**

### Mechanical joining examples

Many car body producers utilize modern mechanical joining processes when joining of individual car body parts. Such producers are: Volkswagen, Škoda, Audi, Porsche, Mercedes, BMW and others. Typical car body components joined by modern mechanical joining methods are shown in Fig. 7.

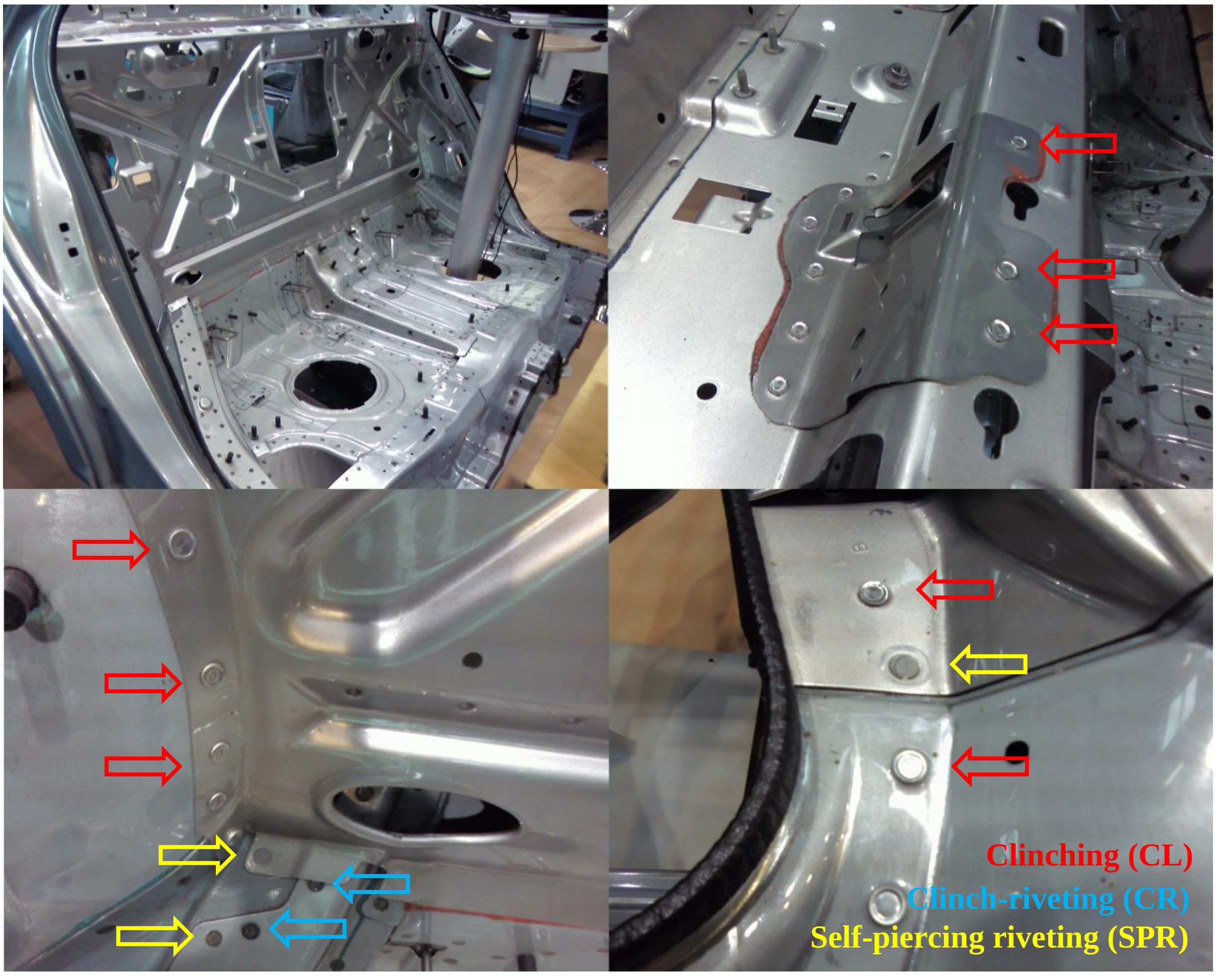


**Fig. 7 The application of modern mechanical joints in Mercedes Benz E body**

## Conclusion

Modern cars should have light bodies, resulting in better fuel consumption which also directly influences the level of pollution of environment. To fulfill this goal, light materials such as aluminum or magnesium must be used. Some of the light materials are difficult to join by conventional methods such as resistance spot welding. Modern mechanical joining methods overcome difficulties related to conventional technologies. Joining methods such as Clinching, Self-piercing riveting and Clinch-riveting were presented in this contribution in terms of advantages, general description, joint forming process, application and joint sections. Also, some examples of described mechanical joining methods were presented in the form of car body of the Mercedes Benz E type.

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