NON-STANDARD CAR BODY ELEMENT JOINING PROCESS WITH SOLID SELF-PIERCING RIVET

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Summary

This paper outlines the riveting process using the piercing rivet. The possibilities of special and multipurpose rivet joining have been described. The special rivet is used for a specified thickness of material joined, and the universal rivet is used to join several material layers of various thickness. The piercing rivet enables joining the materials of different mechanical properties, featuring both high and low material strain hardening. The fastener is not being clinched, but interfered into materials being joined, and then properly locked in them. There have been presented the force characteristics, achieved for shear tested joints made up of special and universal piercing rivet. The joint strength depends significantly on mechanical properties of joined elements. When joining the sheets using standard and universal rivet, the energy consumption of the process has been similar in both cases. However, the different deformation energy absorption value has been observed during the strength test of these joints. Moreover, several selected real life implementations (automotive industry, steel plate joining) of this process have been presented in this paper.

Keywords: joining, strength of a joint, Solid SPR, assembly, motor-car body

1. Introduction

Current development of assembly technology based on the plastic processing extends the variety of material types, which can be joined together without thermal processing and predrilling [1, 2, 3, 4].

The capability of clinching of highly durable steel sheets, which are currently used in an automotive industry [5, 6, 7, 8], is being examined. Due to limited joining capabilities of redrawing joints for some material types, new joining methods for these materials are being researched, e.g. clinching joining along with heating of the material being joined [9].

The process development in the industry domain, which aims in reducing production costs, providing with high quality and reliability of manufactured goods along with reducing time to manufacture, enabled the new mechanical joining technology under pressure – self-pierce riveting [10, 11].

Nowadays, new technology solutions are extensively sought, e.g. by redrawing the material in form of flash.

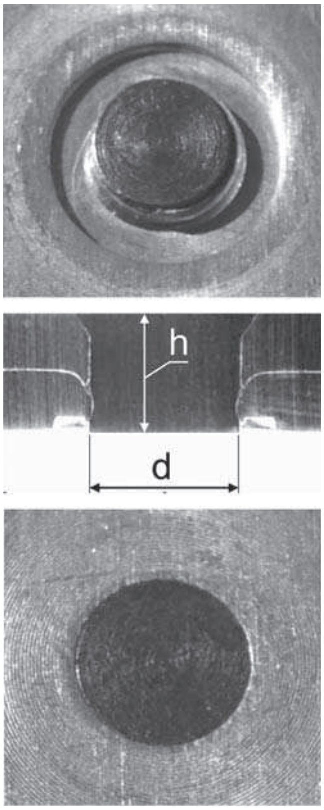
The flash is the result of redrawing joint forming and is achieved for the following joints: "clinching", self-pierce riveting with a self-piercing rivet (SPR) and clinched by oppressing with an additional solid rivet (ClinchRivet, "CR") [12].

One of recently invented and well developed methods for industrial purposes is a self-pierce riveting using the solid rivet (SolidSPR) [13].

When joining with the piercing rivet it is possible to join two or more material layers of low plasticity and achieving the plane surface on both sided without protruding flash (Fig. 1c).

a)

b)



c)

Fig. 1. Aluminum sheet plate joint using the SolidRivet self-pierce riveting: a) support side (die contact side) view, b) joint cross section, c) rivet head view.

However, the use of self-pierce riveting technology for a product of specified shape is justified by the capability of its adaptation that the tool access is guaranteed to achieve the tool adequate support rigidity and its retraction after the process. This technology may be used in the open design components. The exception is the joint made by driving the fastener [14, 15] or pierced frictionally [16]. The joining methods mentioned in the end feature high joint unevenness on the side where the fastener exits the elements being joined.

2. Joining technology characteristics

2.1. The fastener and tools

The fastener (rivet) is not being clinched, but interfered into materials being joined, and then properly locked in them.

Once pierced through the materials, the fastener preserves its original form and is not deformed. This determines its specific construction and strength requirements, i.e. the rivet stem diameter is almost the same as the head diameter (the rigidity is preserved and comparable pressure value on both sides of the rivet). The rivet material must feature a higher yield stress than the material being joined. The fastener may be made of steel, aluminum alloy, stainless steel or technical ceramics.

Due to requirements to be satisfied, the piercing rivet may be used in the standard and universal version. This fastener's design differs from the conventional rivet, and includes: the head, stem, single or some notches on its perimeter and the cutting edge (Fig. 2a). The rivet length is determined by the highest total material thickness. If total thickness of joined sheets lowers, the rivet protrudes in its cutting edge zone. The conventional version of the fastener enables joining only specified total sheet thickness, whereas the universal rivet may be generally used to join materials of different thickness.

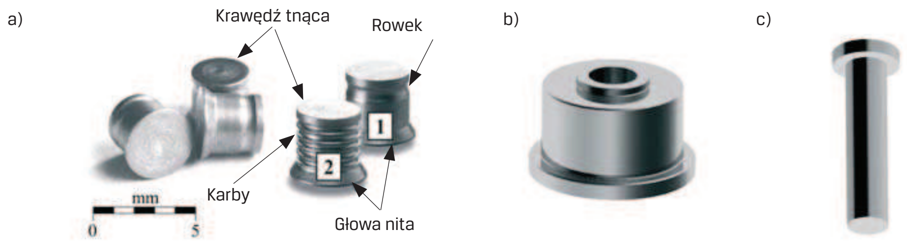


Fig. 2. The rivets and tools used for Solid SPR joints: a) rivets (1 - special rivet, 2 – universal rivet), b) and c) tools (die and punch).

Joining is made using tools of relatively simple design, i.e. the punch (Fig. 2c), which is guided inside the bushing (which acts also as a clamping device) and the die with a specified edge (Fig. 2b).

2.2. Joining process overview

When making the riveting joint forming using the Solid SPR (Fig. 3), the rivet acts as a cutting punch. The hole in the sheets joined is cut when the punch presses the rivet head (phase 1, 2, 3).

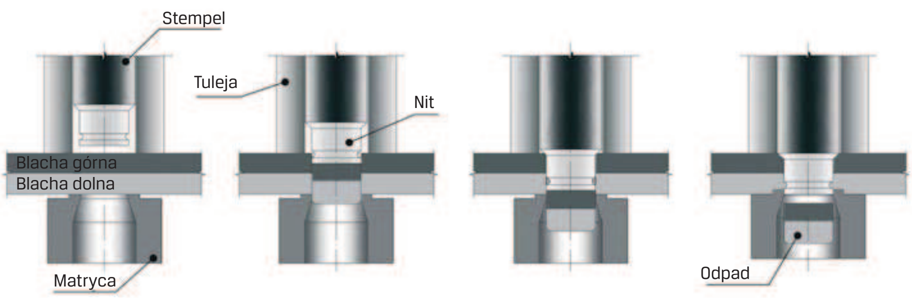


Fig. 3. The self-piercing riveting joint forming using the Solid SPR.

The scrap in form of a sheared blank is discharged by the opening made in the bottom die, which has no flat cutting edge. The opening is offset and its internal edge acts as a cutting edge. In the final phase (phase 4) the joined sheets are pressed in a way that the bottom sheet material fills in the groove on the rivet perimeter. Finally, this locks the rivet and the joint is made. The additional movement may be made by the bottom die or the clamping device with punch.

2.3. Technology advantages

This technology (self-pierce riveting with the solid self-piercing rivet) enables joining the following materials: the steel, aluminum, stainless steel. It is also possible to join coated and painted materials. This technology enables joining more than two sheets and of different thickness (Fig. 4).

The differences in total thickness of joined sheets may occur within a single product. In such a case, the universal rivet works effectively.

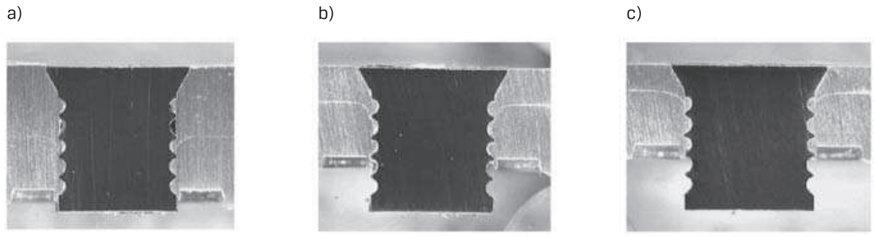


Fig. 4. The joint made up with universal rivet for various thickness of joined sheets: a) 2 mm+ 2 mm, b) 1.15 mm + 2 mm, c) 0.8 mm + 2 mm.

For redrawing joint technology an adverse material fracture may occur, which is a side and unwanted effect [2]. Then the different joining technique can be used, e.g. using the piercing rivet. The specialized rivet may be used for joining both hardened and soft materials and for various property combinations of joined layers (Fig. 5a, b).

Fig. 5. Joint combinations: 2 aluminum sheets and steel/aluminum sheet: a) EN AW-6181A (g1 = 1.5 mm)/EN AW-5754 (g2 = 2.5 mm), b) EN 10130 (2.0 mm)/EN AW-5754 (g2 = 2.0 mm).

3. Joint strength

3.1. The joint with a specialized and universal rivet

For shearing test of the solid self-piercing rivet joint, the sheet where the fastener head is anchored, is slightly deflected (Fig. 6). This phenomena occurs both for the joint made with specialized and universal rivet. Due to a joint loading, the additional single-action moment bending the sheet occurs on the side of conical head contact surface with the sheet.

The sheet merging area's deformation is forced by the tensile testing machine jaws acting on sheets. Due to a fact that the sheet material strength is lower than the rivet strength, loading the joint causes the sheet deformation until total separation (Fig. 7).

Fig. 6. The shear test of Solid SPR joint.

a) b) c)

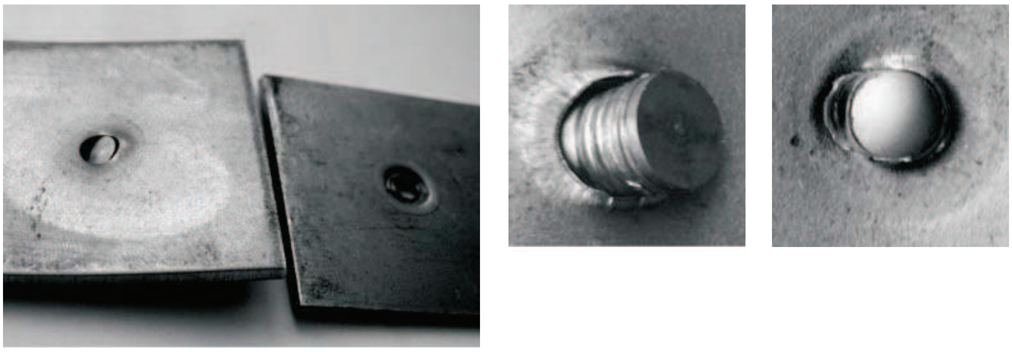


Fig. 7. The deformation of joint pieces: a) separated sheets, b), c) merge area after the shear test.

Depending on the rivet characteristics (specialized or universal), different force characteristics of joint loading are achieved (Fig. 8). For a universal rivet, the maximum shearing force (Fig. 8) increase by 7.4% comparing to a specialized rivet was observed. Increasing the maximum force from 4.87 kN to 5.23 kN is caused by necessity to shear more sheet material tabs.

Higher deformation effort is required for a total destruction (sheet separation) of joint with universal rivet than for a specialized rivet. These joints absorb the deformation energy in a different way, which is visible on the chart (Fig. 8) in form of different areas under force curve vs. displacement that forces the deformation.

In order to joint sheets of thickness 2 mm made of DC01 (low carbon steel for cold plastic working [17]), identical total force was required in both cases: 32 kN (blanking) + 2.5 kN (pressure). Thus the energy consumption of the joining process was identical, and the different deformation energy absorption value was achieved for these joints.

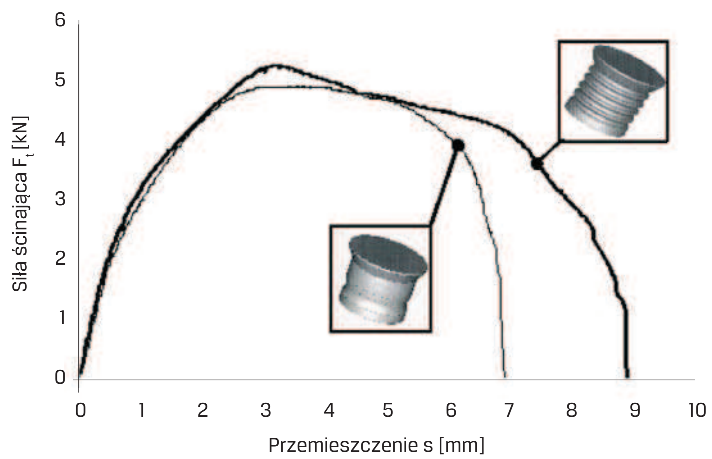


Fig. 8. The force characteristics for joint strain when shear testing of special and universal riveted joint (d = 4.00 mm, h = 3.95mm).

3.2. Shearing and tearing strength

The solid self-piercing rivet enables joining the materials of different mechanical properties (Tab. 1), featuring both high and low material strain hardening. Depending on joined material types, the specified joint strength parameters are achieved in joint shearing and tearing test (Fig. 9) [13]. For presented materials, the highest contribution of tearing strength vs. shearing strength features the joint made of H400LA (35% contribution), and the lowest the joint made of X6Cr17 (24% contribution). The joint location in the design should enable carrying the shearing loads in the highest level.

Table 1. The selected mechanical properties of rivet joint sheets.

Parameter	Material					
	Al 5556 A EN 18273	**H240LA EN** 10268	**H280LA EN** 10268	**H400LA EN** 10268	**X6Cr17 EN** 10088	**X5CrNi18-10** EN 10088
$R_{p0.2}$ [MPa]	125	305	320	430	260	230
R_m [MPa]	270	340	370	460	490	620
A_{80} [%]	24	28	24	18	20	55

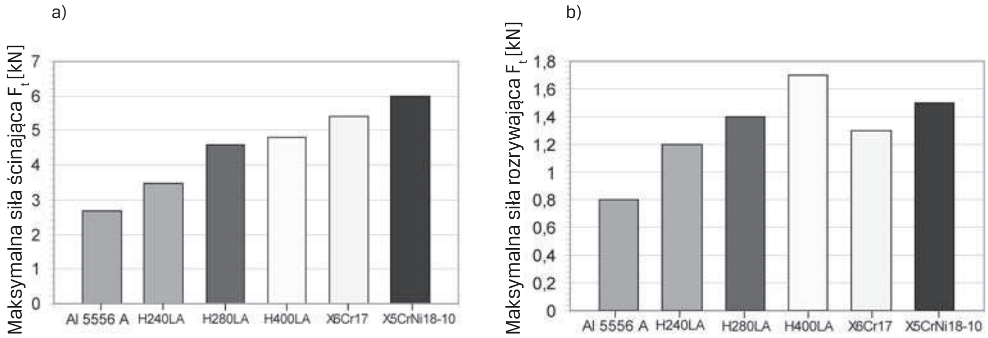


Fig. 9. The joint strength properties for selected materials of tested joined sheets (sheets thickness 1.5 mm + 1.5 mm, special rivet – d = 4.75 mm, h = 3 mm): a) for shearing and, b) for tearing.

When joining the sheets made of different materials and of identical thickness, i.e. 1.5 mm + 1.5 mm with identical rivet, the different joint strength is achieved. The higher the material limit strength, the higher the joint strength (Tab. 1). This trend is clearly visible on the bar charts (Fig. 9a, b) in the microalloyed steel sheet group with increased yield stress value [18].

4. Application examples

Joining the constructional elements using the solid self-piercing rivet during the assembly process can be considered as an additional, local hardening of a product, e.g. when joining thin steel sheets (Fig. 10).

Sometimes the car body designers require joining the sheets with an intermediate layer, which acts as a sealant or vibration damper. In many cases, the strength of a joint made using only a rivet is not satisfactory. If this is the case, the sheet joint is assisted by gluing (hybrid joints). The specialized substance or glue may be applied locally (Fig. 11a) or on entire contact surface of joined elements (Fig. 11b). In this case the river acts as a local merging and stabilizer supporting glued sheets in required position, until a final strength is achieved by the bonding agent.

Fig. 10. The reinforcing cross bar made of stainless steel (0H18N9) in the engine chamber of a sport car.

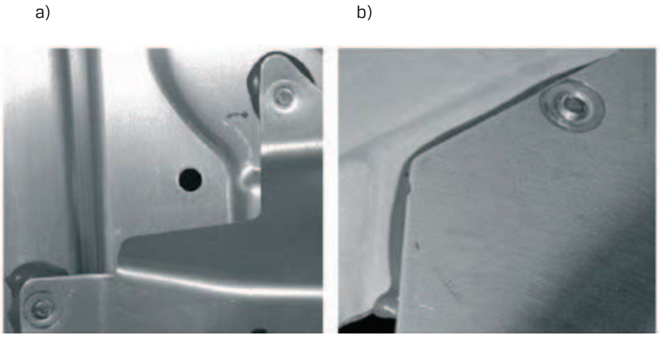


Fig. 11. The hybrid glue-rivet joint of car body pieces: a) with local gluing, b) the glue covers all contact area.

Proper selection of the "SolidSPR" rivet material enables joining the sheets with thin walled casting (Fig. 12). It is important that the element thickness and its material mechanical properties on the die side enable filling the fastener groove by final pressure of the die ridge.

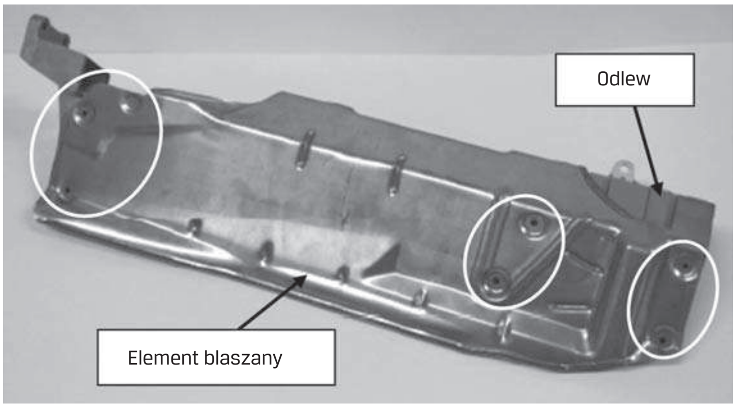


Fig. 12. Joining of galvanized steel sheet with an aluminum cast piece.

Proper selection of the universal rivet geometry, i.e. its length, enables joining materials of different thickness (Fig. 13). If thickness of joined sheets lowers, the rivet protrudes in its cutting edge zone above the outside surface of the sheet. The rivet length is determined by the highest total material thickness. Once pierced through the materials, the fastener preserves its original form and is not deformed for each material thickness.

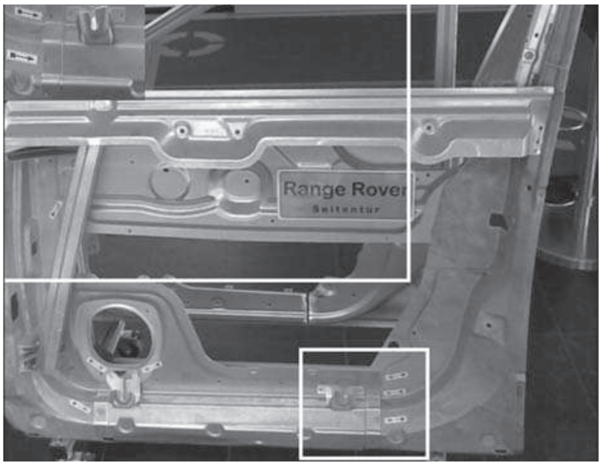


Fig. 13. Assembled car doors using the solid self-piercing rivet.

5. Summary

"SolidSPR" joining technology using solid self-piercing rivet extends the capability of sheet joining, and also thin walled casting elements. Making the solid self-piercing rivet joint in a combination with glue or sealant is not a problem. On the other hand, for spot welding it is difficult or even impossible. Despite the spot welding, this method has a significant disadvantage, namely increasing the car weight.

"SolidSPR" enables joining the steel and plastic elements, and also brittle materials.

The joint strength depends significantly on mechanical properties of joined elements.

When joining the sheets using standard and universal rivet, the energy consumption of the process is similar in both cases. However, the different deformation energy absorption value is achieved during the strength test of these joints.

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