Agata Pawłowska

Replacement of Projection Welding with the Spot Welding Process Illustrated Using an Example of a VW Crafter Door Window Frame

Abstract: The process of projection welding is widely used in the automotive industry, e.g. when welding nuts or joining thin car body sheets. The article presents the possible replacement of projection resistance welding with two-sided spot resistance welding performed using an electrode having a smaller work area than that of electrodes used in projection welding. The comparative study involved the performance of technological tests involving both welding methods. Elements subjected to welding were front door frames of a Volkswagen Cratfer (i.e. a light commercial van) manufactured by the Volkswagen factory in Września, Poland. The joints obtained in the technological tests were subsequently subjected to visual and destructive tests.

Keywords: welded joints, projection welding, automotive industry, spot welding

DOI: *10.17729/ebis.2017.5/5*

Projection Welding in the Automotive Industry

Projection welding is the process of resistance welding in areas where technological projections are present. The above-named projections can be prepared on purpose or constitute parts of elements being joined, e.g. the cylindrical surface of a bar or filled projections in cases of bolts and nuts. The projection welding methods enables the joining of elements having diverse shapes and dimensions. As regards the joining of sheets, their thicknesses are restricted within the range of 0.5 mm to 3 mm, whereas diameters of welded studs are restricted within the range of 1 mm to 20 mm. The above-named technology is used in the automotive industry as well as in the production of household equipment, electrotechnical equipment etc. [1].

The nature of joints used in the automotive industry is responsible for the use of two types of projections. Massive (solid) projections are used to join nuts and bolts with sheets. Such projections do not constitute typical joints with the stirred material of both joined elements. The second type includes projections formed through the stamping of thin sheets, forming welds similar to those obtained in conventional spot resistance welding. As a result of applied force and heat induced by flowing current, the aforesaid projections undergo deformations, with an inseparable joint, being the mixture of both materials, formed in the area of contact between the projection and the sheet. Figure 1 presents examples of projections used in the automotive industry.

mgr inż. Agata Pawłowska, MSc Eng. - Volkswagen Poznań Ltd., Poznan University of Technology

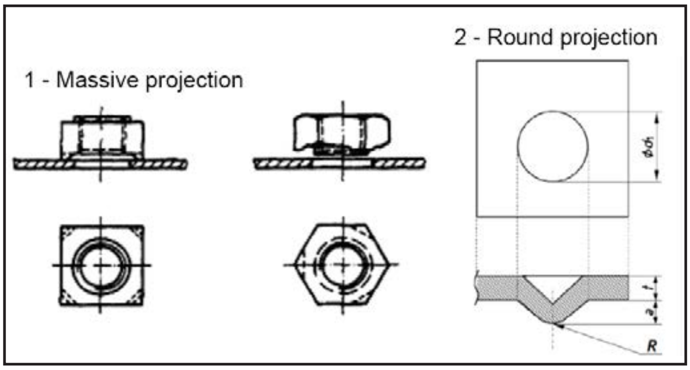

Fig. 1. Projections used in the automotive industry: 1 – massive projection used when joining the nuts with the sheet; 2 – round projection stamped in the sheet, used when joining sheets having thicknesses restricted within the range of 0.7 mm – 1.0 mm [2]

Fig. 2. Door window frame of a Crafter van

Projection Welding of the Window Frame in a Light Utility Van (VW Crafter)

Presently, the factory manufacturing light utility vans (VW Crafter) is equipped with one machine for the welding of nuts to the sheet in a process performed manually. In addition, the factory is provided with seven automated welding machines to join thin sheets. The example discussed in the article concern the projection welding of the front door window frame. Figure 2 presents the front door window frame in a VW Crafter utility van.

The process of welding is used for the joining of two 0.7 mm thick hot galvanised car body sheets. The zinc coating on both sides of joined sheets amounts to a minimum of 40 g/m². Welds are made on a 5 mm wide flange. The projection has a diameter of 2.5 mm. Figure 3 presents the schematic diagram of the projection welding of the window frame. Table 1 presents exemplary parameters of projection welding.

The welding machine used in the process (Düring) is provided with a servo-pneumatic electrode force system. The electrodes (welding

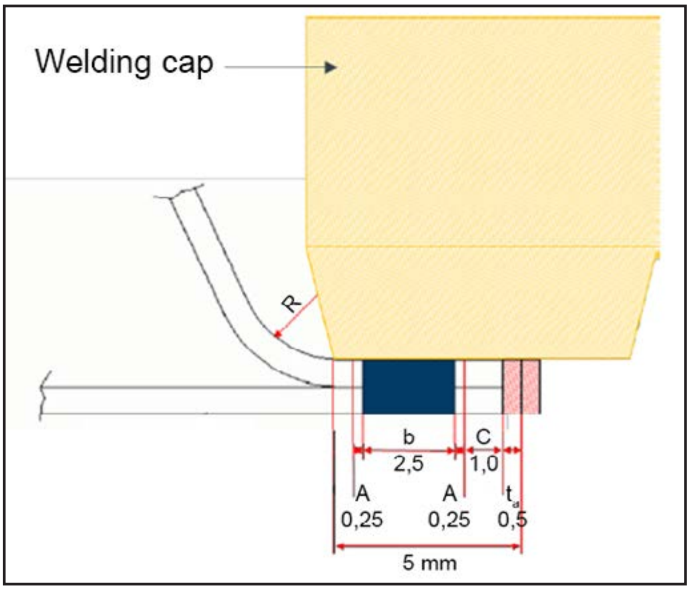

Fig. 3. Schematic diagram of the projection welding of the window frame: A – robot tolerance range assuming the invariable location of the projection, C – minimum distance between the projection and the edge of sheets, b – projection width, R – radius, ta – dimensional tolerance of the sheet

Table 1. Approximate parameters of projection welding

Electrode initial force [daN]	Welding current [kA]	Electrode force [daN]	Welding time [s]
0.2	8.4	190	0.35

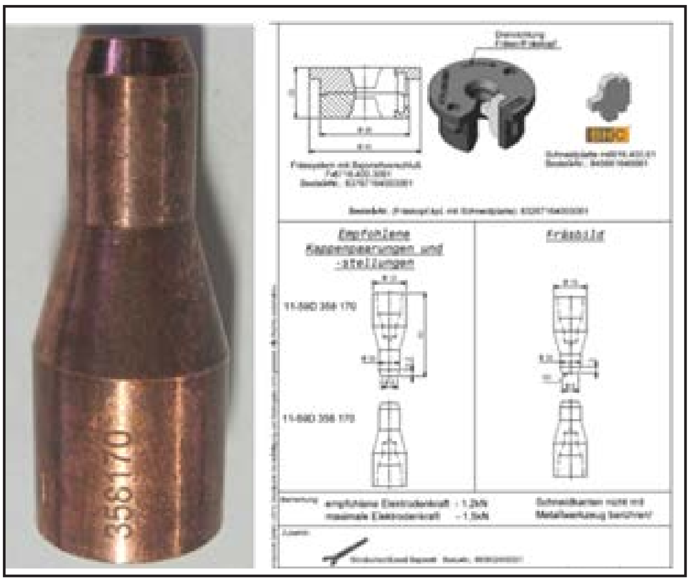

Fig. 4. Welding cap (electrode) for projection welding and milling head documentation

caps) used in the process are made of alloy produced by Le Bronze Powerode®. The welding caps (electrodes) are repaired using a milling head manufactured by Bräuer. Figure 4 presents the welding cap used in the process and the milling head used for repairs of welding caps. The diameter of the welding cap work surface amounts to 8 mm.

Disadvantages of the Automated Projection Welding of Thin Sheets

The automated process of welding is characterised by very high repeatability. A welding machine mounted on an industrial robot makes 21 welds successively in the projection stamping area. The door is placed and fixed on an appropriately prepared work bench (using fixtures). The trajectory of robot movements is programmed with adopted accuracy ± 0.25 mm (0.02 mm according to the producer). As a result, the robot nearly always makes a weld at the same spot. Any deviations concerning the geometry and dimensions of an element being welded disturb the process of welding. The position, shape and dimensions of projections are important as they constitute current concentrators. If welding current does not flow through projection but through another area, resistance during welding is overly low and heat input to the material is insufficient to form the weld nugget. The projection welding technology does not offer possibilities of protecting against the above-named changes. The adjustment of welding programme, process parameters, trajectory and operating conditions of industrial robots do not provide a quick response to changes in dimensions of elements being joined. The above-named changes may result from press-shop operation disruptions caused by e.g. repairs, corrections as well as the wear of moulds and stamps.

Elements to be welded must be made and fixed so that during welding they are in contact with one another only in projection areas. The surface of these elements should be free from any irregularities, damage, jagged areas, roughness etc. All position fixing elements should be made of dielectric, i.e. non-conductive materials in order to prevent (during welding) the creation of additional current flow areas (so-called current shunting). [1]

The process of resistance welding can be divided into three phases:

1. phase of initial loading of a projection (cold squeeze of projection, before current flow),
2. phase of weld formation,
3. phase of cooling.

During the initial squeeze, the height of a projection decreases whereas the area of contact between sheets increases. Low forces trigger slight deformation, usually restricted to the range of elasticity, whereas the continued application of load leads to a plastic strain. In terms of projection welding it is important to apply force resulting in the projection height reduction. The hardening of the projection constitutes the initial welding force. It is assumed that the stabilisation of projection deformation and thereby of static resistance takes place after the projection height reduction by 25-35%. [1]

During the second phase, the flow of current triggers the plasticisation of the material, the projection deforms rapidly and fits the sheet. The dynamic resistance of the welding area decreases (in spite of a growth in the specific resistance of molten material) as a result of the increasingly larger area of contact between elements being welded. The weld nugget is formed along with the further flow of current. It is assumed that the phase of weld formation is three times longer than the initial squeezing of the projection. Once the preset welding time has elapsed, the weld nugget obtains its nominal size. During the cooling phase (that follows) the weld continues to be subjected to electrode force.

It is very important to appropriately design projections (in view of initial squeeze). Embossed projections used in the projection welding of sheets are spherical, longitudinal and ring-shaped. In terms of the possible adjustment of the welding programme during the welding of thin sheets, the most favourable are ring-shaped projections as they withstand greater forces than spherical ones.

The projection welding of the window frame is connected with certain inconveniences. The most favourable conditions when welding spherical projections are those which (after the initial squeeze) make it possible for the projection to reach 50-80% of its initial height, i.e. which provide a projection height reduction of 20-50%). Figure 5 presents the deformation of normalised projections (Iso 5821) in the function of force.

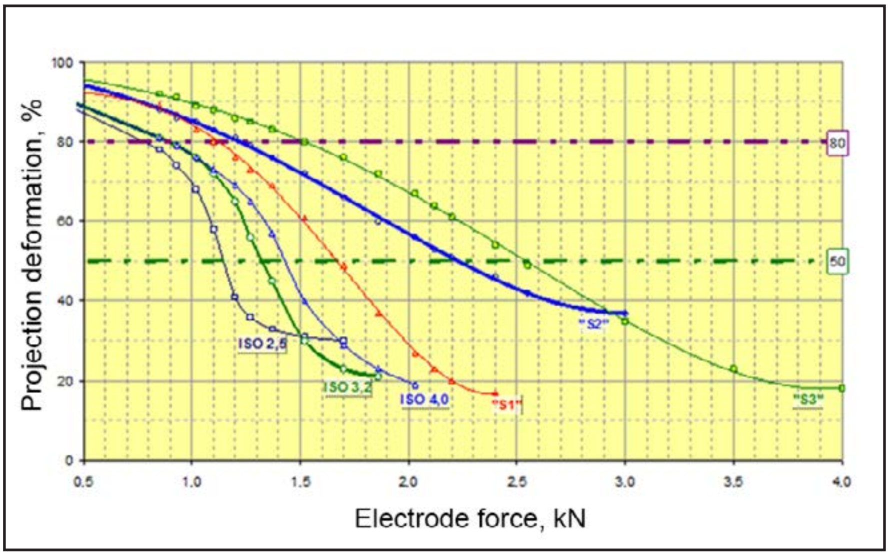

Fig. 5. Correlation between projection deformation and force [3]

Table 2. Approximate parameters of projection welding.

Electrode initial force [daN]	Welding current [kA]	Electrode force [daN]	Welding time [s]
0.1	5.2	160	0.13

The use of spherical projections requires the programming of the welding process at low force. The lower the force used during welding, the higher the temperature (particularly in the contact area between the electrode and the material being welded). An increase in temperature during welding significantly affects the wear of welding caps and, consequently the cost of their repair and exchange.

Possible Applications of Spot Welding Using an Electrode Having a Very Small Working Area

The primary advantage of spot resistance welding if compared with projection welding is the reduced effect of part-related deviations (shifted or deformed projections etc.) on the quality of joints. The diameter of the working area of a welding cap used in the alternative method, i.e. spot resistance welding, amounts to 5 mm. Figure 6 presents the schematic diagram of the alternative process, i.e. the two-sided overlap spot welding of sheets in the front door window frame of a VW Crafter light utility van. The process is performed under the same conditions as those accompanying projection welding. The sheet does not contain projections. Table 2 presents exemplary parameters of spot resistance welding.

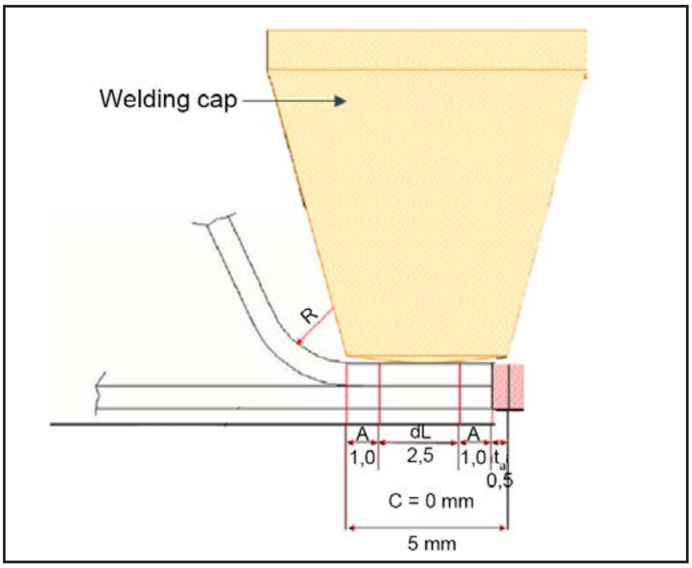

Fig. 6. Schematic diagram of (alternative) spot welding of the window frame A – robot tolerance range assuming the invariable location of the projection, C – minimum distance between the projection and the edge of sheets $C = 0$, dL – weld nugget diameter, R – radius, t_a – dimensional tolerance of the sheet

Similar to projection welding, the alternative process involved the use of welding caps manufactured by Le Bronze and a milling head produced by Bräuer (Fig. 7).

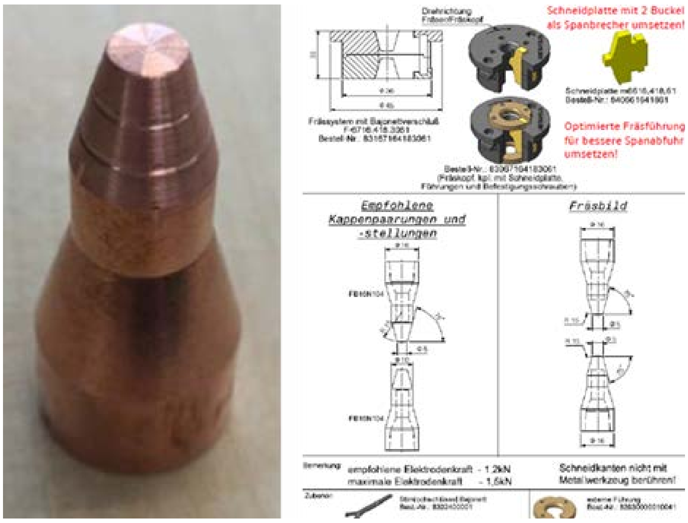

Fig. 7. Welding cap (electrode) for two-sided spot welding and milling head documentation

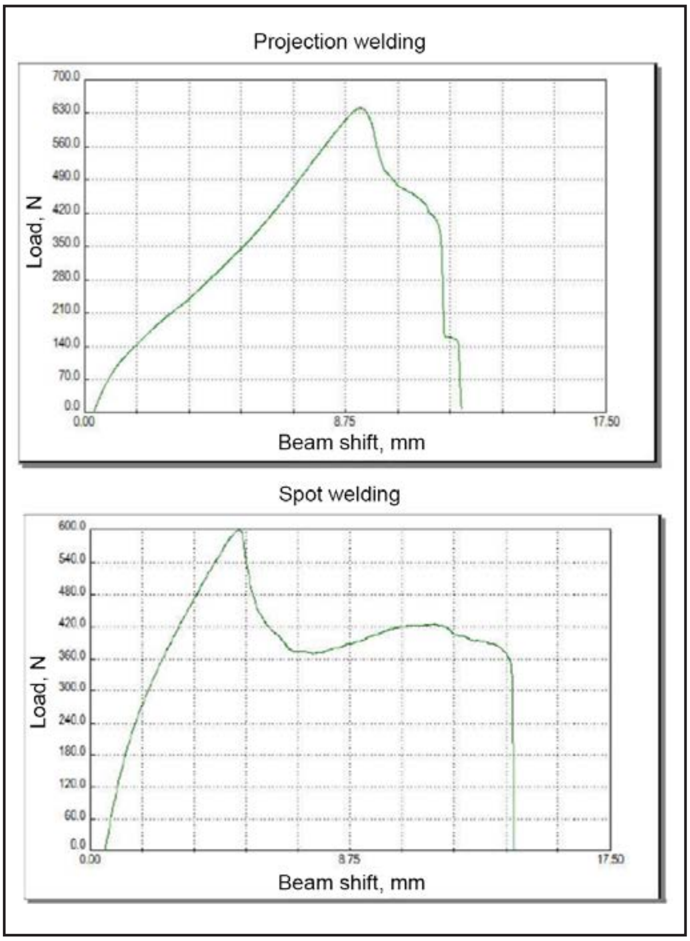

Fig. 8. Dependence of load in the function of the elongation of the projection and spot welded joints

The technological welding tests involved the use of elements subjected to welding during the production process. The lot of specimens was subjected to a destructive test aimed to determine the shear strength of the specimens. The joints were fixed in the jaws of a Quasar 100 testing machine and the test was performed in accordance with DIN EN ISO 14273 [4]. The second lot of the specimens was subjected to macroscopic observations. The specimens were also subjected to visual tests both before and after the application of varnish. All of the welds were assessed in accordance with DIN EN ISO 17677-1[5].

The results obtained in the tests revealed that, in terms of strength and quality, the spot welds did not differ from the joints obtained through projection welding. Figure 8 presents exemplary curves obtained in the static tensile test involving both weld types. The curves present the load transferred by the weld in the function of specimen elongation (beam shift). The projection welded joints transferred the maximum force of more than 630N at an elongation of 9mm. The two-sided spot welded joint transferred the maximum load of 600N at an elongation of more than 5mm.

In terms of the projection weld the maximum force occurred after approximately 10 seconds, whereas in terms of the spot weld – after 5 seconds.

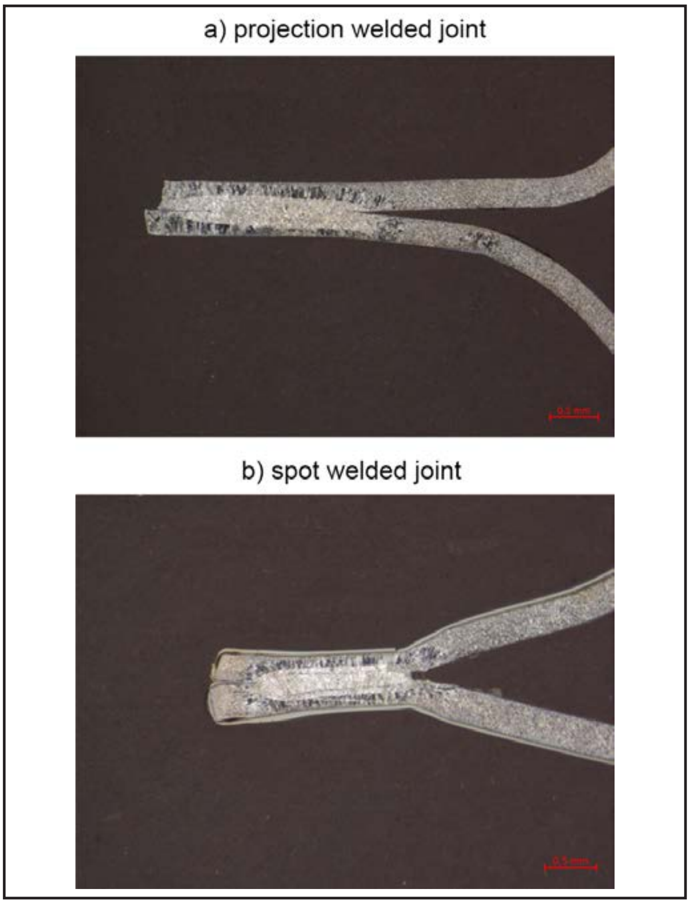

Fig. 9 Macrostructures of a) projection and b) spot welded joints

The metallographic specimens of the second lot were subjected to macroscopic analysis in accordance with internal guidelines developed by the Volkswagen concern and based on EU standards. In both cases, the weld nugget satisfied related requirements. The photographs present the (clearly visible) weld nugget and the heat affected zone (Fig. 9).

Because of the use of electrodes having a smaller diameter, two-sided spot welding enables the joining of very thin sheets and in poorly accessible areas (e.g. where the flange is narrow) as well as reduces the possibility of current shunting. This method is free from disadvantages characteristic of projection welding (e.g. projection quality tolerance).

Summary

Based on the technological welding tests and strength tests it can be stated that spot welding performed using a welding cap having a diameter of 5 mm poses an alternative to projection welding. Spot welding provides higher process repeatability as its course does not depend on the position, shape and dimensions of projections. Spot welded joints meet strength and quality-related requirements set for projection welds. The foregoing was confirmed by strength (static tensile test) and metallographic tests. The use of higher forces than those applied in projection welding reduces the consumption of electrodes.

Both welding technologies can be performed using the same robots and welding machines. It is only necessary to adjust a welding programme and electrode repair frequency. The replacement of projection welding with two-sided spot welding requires the use of differently shaped welding caps and a milling head.

References

[1] Papkala H.: *Zgrzewanie oporowe metali*. Wydawnictwo i Handel Książkami „KaBe” s.c., Krosno, 2003

[2] DIN EN 28167: *Buckel zum Widerstandsschweißen*

[3] Study by SLV Duisburg – Schweißtechnische Lehr- und Versuchsanstalten

[4] EN ISO 14273 *Widerstandsschweißen - Zerstörende Prüfung von Schweißverbindungen - Probenmaße und Verfahren für die Scherzugprüfung an Widerstandspunkt-, Rollennaht- und Buckelschweißungen mit geprägten Buckeln*

[5] DIN EN ISO 17677-1 *Resistance welding - Vocabulary - Part 1: Spot, projection and seam welding*