

RESISTANCE SPOT WELDING ELECTRODE AND USE OF THE ELECTRODE

The present invention relates to a resistance spot welding electrode to be used
5 with high-strength metallic materials, such as aluminium, austenitic stainless
steels or carbon steels, in crash-relevant structural components.

Crash-relevant structural components of automotive industry, such as b-pillars,
are manufactured as a shell-construction of different dissimilar sheets and then
10 spot-welded together with resistance spot welding process. High-strength
press-hardening steel grades, such as 22MnB5, which is alloyed with boron
and a high carbon content of 0.22 – 0.25 weight %, are used for the outer shell
of the b-pillar. The result is high ultimate strength R_m of 1500 MPa, but a
decreased weldability. During crash tests it is noticed in spot-welds decreased
15 cross tensile forces and brittle failure behavior, which results in a non-
acceptable critical “zipper” behavior of the complete b-pillar. For the inner shell
of the b-pillar it is used ductile materials to absorb the crash energy and to
increase the passenger safety. Especially for resistance spot welding in
dissimilar combinations with high strength but also high carbon alloyed
20 materials the weld nuggets show a non-acceptable fracture behavior. For the
welder it is very difficult to influence the resulting spot weld quality. Reasons are
the physical background of Joule’s law (resistance heating) and the
circumstance that for resistance welding processes a metallurgical influence by
welding additives like different filler metals or a mixture of shielding gas is not
25 possible.

In relation to other welding procedures, such as beam welding processes, it is
rarely possible to adjust a controlled heat management or to create a deep
welding effect into the materials. Furthermore and crucial for the resistance
30 spot welding process, the used welding tools in kind of electrodes are carried
out with a rotationally symmetric, mostly circular contact area to the materials.
As a result also rotationally symmetric, mostly circular weld nuggets are shaped

between the weldable sheets. With such a rotationally symmetric weld nugget, a defined and targeted deviation of the force progression is not possible. State of the art welding nuggets with a rotationally symmetric shape have limitations in their tolerable loads under cross tensile direction and especially under
 5 peeling conditions. Additionally loadings for lap joints during crash like bending moments for transverse loads or shear stresses under axial loads lower the tolerable loads of a weld nugget in a further way.

For laser beam welding seam geometrics are the state of the art, but for
 10 resistance spot welding there is no solution for a defined force deflection. In resistance spot welding the electrode shafts and electrode caps are made of copper or copper alloys according to the standard DIN EN ISO 5182 to have a good current transmission with low resistance and low heat loss. At the transition points from copper to the metallic sheets, between the sheets and
 15 from the second sheet to copper, the current energy is changed to ohmic resistances. Because of that effect the transition resistance between the two sheets is by far the highest, the thermal energy is at this the highest, too. At the end the thermal energy at this point reaches the melting temperature of sheets and a spot weld nugget results.

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The standard DIN EN ISO 5821 manages the geometry for standard copper-alloyed electrode caps which are used for resistance spot welding.

The US patent publication 2008/0078749 relates to a resistance welding
 25 electrode body with a round weld face for contact with a workpiece, the face being provided with concentric rings of ridges or grooves extending radially from the center of the weld face. The features of the concentric rings penetrate surface oxides or other conductivity barriers.

30 The US patent publication 2011/0094999 describes a method for preparing a resistance spot welding electrode with a generally round cylindrical body with a cylinder axis in order to impart a visible image on a weldment. The electrode is

first shaped to create a generally flat or convex-shaped workpiece contacting surface. Then portions of the workpiece contacting surface are shaped with image-forming features in order to have protrusions and/or intrusions extending above or below adjacent regions of the workpiece contacting surface such that
5 the workpiece contacting surface imposes a visible reverse image in a weldment.

These US patent publications 2008/0078749 and 2011/0094999 will not utilize geometry for electrode caps in order to create a force deflection or to increase
10 power transmission or crash properties in material to be welded.

The US patent publication 2014/0319105 relates to a method for forming a resistance spot weld joint in a workpiece including a first steel substrate disposed in contact with a second steel substrate to define a faying interface
15 therebetween. The workpiece is disposed between welding electrodes which include an electrode holder and an electrode cap removably attached to the holder and having a central longitudinal axis. The cap includes a body having an end, and a welding surface that is substantially smooth and free from any grooves defined therein. The cap further includes a skirt portion extending away
20 from the body and configured to bear against the holder. The skirt portion has a first face that is substantially parallel to the axis and spaced apart from the surface. The body has a second face interconnecting the first face and the surface, and the body tapers from the first face to the surface. The US patent publication 2014/0319105 thus describes an electrode and a manner to form a
25 spot weld nugget.

The KR patent application 2015/0125458 relates to a spot welding electrode for controlling pressure mark so that a conductor part is pressed to a welding part of a base material, flowing a current, and a nonconductor part is coupled with
30 the conductor part to be pressed around the welding part of the base material, while the conductor part is pressed to the welding part of the base material. The spot welding electrode in accordance to the present invention is used to

minimize depth of a pressure mark on a base material. The controlling of the KR patent application 2015/0125458 has an influence to the weld nugget in a sheet direction which is not optimal for the resistance spot welding.

- 5 The US patent publication 2015/0231729 relates to a method for spot welding a workpiece including a steel workpiece and an aluminium alloy workpiece. The workpieces overlap in order to provide a faying surface interface. Electrical current is passed between steel welding electrode and the aluminium alloy welding electrode so that the electrical current is at least initially passing
- 10 through the perimeter region in the aluminium alloy welding electrode so that the welding electrode has a greater current density in the steel workpiece than in the aluminium alloy workpiece. The method of the US patent publication 2015/0231729 is suitable only for a rotationally symmetric electrode shape.
- 15 The object of the present invention is to eliminate drawbacks of the prior art and to establish an improved resistance spot welding electrode to be used with high-strength metallic materials, such as aluminium, austenitic stainless steels or carbon steels, in different joined combinations. The resistance spot welding electrode of the invention will increase the power transmission of the welding
- 20 nugget by creating desired seam geometry and therefore influencing the direction of load and the load dissipation/bypass into uncritical areas of the component. The essential features of the invention are enlisted in the appended claims.
- 25 In resistance spot welding a welding electrode cap is made of copper or copper alloys according to the standard DIN EN ISO 5182 to have a good current transmission with low resistance and low heat loss. According to the present invention the welding electrode is advantageously for welding parts to be used in crash-relevant structural components of automotive industry. The welding
- 30 electrode cap made of copper or copper alloys is shaped in order to achieve by means of good power transmission between the materials to be welded a desired weld nugget for dissimilar welded lap joints. The welding electrode is

provided in that end which is during welding in contact with materials to be welded together, with a cap, having a non-axially symmetrical contact area. The cap is placed during welding in a position to the materials to be welded so that the weld nugget achieved from welding is non-axially symmetrical to the cross direction of the welded component, which cross direction is the most presumable crash direction of the welded component. The resulting weld nugget between the welded materials then deflects in a collision case crash energy into uncritical point in the welded structure or bypasses energy into uncritical component areas. Furthermore, the non-axially symmetrical shape creates a geometry-dependent resistance for the other spot-welded points against peeling forces to avoid “zipping” of the complete flange and therefore the complete component.

Instead of that force under crash takes effect into the longitudinal direction and results in a gradually fail of every spot weld in the structure of the prior art, according to the invention force under crash is deflected to the cross direction of the welded component and results to an uncritical crack outlet from one weld nugget over a small flange, and only local uncritical failure is caused for the function of the complete component.

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The non-axially symmetrical geometry of the welding electrode cap according to the invention is a special ratio of a width, a length and a distance between the opposite ends in the desired geometry in question. The desired geometry of the welding electrode cap can be essentially all geometries with a distinct power deflection. These kinds of shapes are modified or unmodified C, T, L or S shapes, modified or unmodified crescent, clamp or bracket shapes. Further, suitable shapes are a modified or unmodified combination of a classical point with a web, and modified or unmodified W or H shapes when the modified or unmodified W and H shapes are toppled in cross direction.

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During welding the welding electrode cap is oriented to the material to be welded so that a part of the non-axially symmetrical cap, which is essentially

parallel with the longest dimension of the welded structure, is positioned close to the opposite edge of the welded structure in the most presumable crash direction. It is also possible to position the part of the non-axially symmetrical cap which is essentially parallel with the longest dimension of the welded structure close to the first edge of the welded structure in the most presumable crash direction.

The dimension of the geometry used in the non-axially symmetrical resistance spot welding electrode cap according to the invention is also important for the possibility to absorb the first dynamic impact during a crash situation or to avoid undesirable peeling behavior of the other spot welds. Further, the circumferential dimension and the area dimension are also important parameters, such as the web width w of the cap and the web length l of the cap. The web width refers to an desired weld seam width in relation to the available flange dimensions of the component. The web length l refers to the distance between the level congruent to the one end of the cap and the point of the cap which is furthestmost from that level in transverse direction of the component flange.

The web width w should be not smaller than 1.5 mm and not greater than 5 mm, otherwise weld spatters appear before the weld nugget is formed completely. The preferred web width w is between 2.5 and 3.5 mm what avoids welding spatters with usual welding current 4 - 8.5 kA depending on the material or material combination on one side. On the other side a web width, which is too big, results in the same behavior as a traditional, rotational symmetry electrode cap with its limited power transmission and limited possibility for targeted load dissipation. Therefore one geometrical characteristic is the ratio of the web length l to the web width w , which ratio l/w is greater than 2.0, preferred between 2.5 and 4.0, but smaller than 6.0. The ratio guarantees, that a crack can bypass into the targeted uncritical component areas, for example to the longitudinal edge side of a flange. The upper limitation results from the frame condition to use typical flange width of

automotive structural components which are between 15 and 25 mm. The orientation of the web length, which can be termed also as “shank”, must be nearly vertical (75-90°) to the component longitudinal direction (for example the flange width). Moreover, in the geometrical transition zones a radius r can be defined. The lower limitation is equal to the web width to avoid local hot-spots which result in undesirable weld spatters. Further, a distance d is required when the cap is built up or combined with a traditional, axially symmetrical area and a non-axially symmetrical area. The distance d is a length into the longitudinal direction of the component and refers to the distance between the end of the axially symmetrical area and the beginning of dissipating element or part into the transverse side of the flange. It is necessary to dissipate the force, otherwise the traditional behavior can be determined in such a combination. Therefore, the distance d should be 2 times or more than the web width w .

The weld nugget achieved with the non-axially symmetrical welding electrode cap according to the invention has essentially the similar non-axially symmetrical shape. The non-axially symmetrical shape of the weld nugget causes in a collision case the force to defect to the cross direction in the welded structure.

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According to one embodiment of the invention it is also possible to combine on one metal sheet contact area a non-axially symmetrical electrode cap and on the other sheet metal contact area a prior art axially symmetrical cap. The resulting weld nugget fulfills the before mentioned requirements, what means that the resulting weld nugget is non-axially symmetrical.

One additional benefit of the present invention is that in the prior art it is not possible to combine a seam joining method with bonding, it works only with spot-welding what is called weldbonding. With the present invention it is now possible to create resistance welded seam by using at the same time adhesive materials for a combined joining way.

The resistance spot welding electrode with non-axially symmetrical welding electrode cap according to the invention is used for welding high strength materials, such as, carbon steels and stainless steels defined by yield strength more than 400MPa, and the carbon content is in the resulting dissimilar weld 5 nugget more than 0.15 weight %. Other limited weldable high strength materials, where the non-axially symmetrical welding electrode cap according to the invention can be used, are high strength aluminium alloys, such as 5xxx, 6xxx or 7xxx series.

10 The non-axially symmetrical welding electrode cap according to the invention can be in addition to B-pillar utilized in general for all crash-relevant parts in automotive industry, such as a door side impact member, A-pillar, crashbox bumper, reinforcement plates or a rocket rail. It is also possible to use the present invention in other solution fields than automotive industry, which uses 15 lap joints as a joining situation, such as driver's cabs of trucks, railway construction parts, battery packs for battery electric vehicles or hybrid and pressure resistance tanks, or white good applications like trammel, inner door of a dish washer.

20 The present invention is illustrated in more details referring to the following drawings where

Fig. 1 shows one preferred embodiment of the invention schematically seen from the top view,

Fig. 2 shows another preferred embodiment of the invention schematically seen 25 from the top view,

Fig. 3 shows still another preferred embodiment of the invention schematically seen from the top view,

Fig. 4 shows further another preferred embodiment of the invention schematically seen from the top view,

30 Fig. 5 shows one another preferred embodiment of the invention schematically seen from the top view.

Fig. 1 illustrates the end of a resistance spot welding electrode cap 1 which is during welding in contact with the materials to be welded and has a shape of a modified C letter rotated 180 degrees. The cap 1 is non-axially symmetrical in the vertical direction. In Fig. 1 it is illustrated for the cap 1 the web width w , the web length l and the radius r in the geometrical transition zone. The cap 1 is positioned to a welded component so that the longitudinal direction of the welded component is illustrated by an arrow 2.

Fig. 2 illustrates the end of a resistance spot welding electrode cap 6 which is during welding in contact with the materials to be welded and has a shape of an unmodified L letter rotated 180 degrees. The cap 6 is non-axially symmetrical in the vertical direction. In Fig. 2 it is illustrated for the cap 6 the web width w and the web length. The cap 6 is positioned to a welded component so that the longitudinal direction of the welded component is illustrated by an arrow 7.

Fig. 3 illustrates the end of a resistance spot welding electrode cap 11 which is during welding in contact with the materials to be welded and has a shape of an unmodified T letter. The cap 11 is non-axially symmetrical in the vertical direction. In Fig. 3 it is illustrated for the cap 11 the web width w and the web length. The cap 11 is positioned to a welded component so that the longitudinal direction of the welded component is illustrated by an arrow 12.

Fig. 4 illustrates the end of a resistance spot welding electrode cap 16 which is during welding in contact with the materials to be welded and has a shape of an unmodified W letter rotated 90 degrees. The cap 16 is non-axially symmetrical in the vertical direction. In Fig. 4 it is illustrated for the cap 16 the web width w and the web length. The cap 16 is positioned to a welded component so that the longitudinal direction of the welded component is illustrated by an arrow 17.

In accordance with Fig. 5 the end of a resistance spot welding electrode cap 21 which is during welding in contact with the materials to be welded is a shape of a modified combination of a non-axially symmetrical area 22 and an axially

symmetrical area 23. The cap 21 is non-axially symmetrical in the vertical direction and, therefore, in order to achieve a desired weld nugget in accordance with the invention the cap 21 is positioned during welding in the transverse direction to the material to be welded. In Fig. 5 it is illustrated for the 5 cap 21 the web width w and the web length as well as the distance d between the traditional, prior art axially symmetrical area and the non-axially symmetrical area. The cap 21 is positioned to a welded component so that the longitudinal direction of the welded component is illustrated by an arrow 24.

CLAIMS

1 Resistance spot welding electrode for dissimilar welded lap joints in crash-relevant structural components of automotive industry made of high-strength
5 materials, **characterized** in that a resistance spot welding electrode is provided with a cap (1,6,11,16,21) having in that end of the electrode which is during welding in contact with materials to be welded together, a non-axially symmetrical contact area in order to achieve between materials a weld nugget with an essentially similar non-axially symmetrical shape.

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2. Resistance spot welding electrode according to the claim 1, **characterized** in that the resistance spot welding electrode is positioned so that a part of the non-axially symmetrical cap (1,6,11,16,21), which is essentially parallel with the longest dimension of the structure to be welded, is positioned close to the
15 opposite edge of the welded component in the cross direction.

3. Resistance spot welding electrode according to the claim 1, **characterized** in that the resistance spot welding electrode is positioned so that a part of the non-axially symmetrical cap (1,6,11,16,21), which is essentially parallel with the
20 longest dimension of the structure to be welded, is positioned close to the first edge of the welded component in the cross direction.

4. Resistance spot welding electrode according to any of the preceding claims, **characterized** in that the cap (1,6,11,16,21) has a web width (w) not smaller
25 than 1.5 mm and not greater than 5 mm, preferable between 2.5 mm and 3.5 mm.

5. Resistance spot welding electrode according to any of the preceding claims, **characterized** in that the ratio of the web length l to the web width w in the cap
30 (1,6,11,16,21) is bigger than 2.0, but smaller than 6.0, preferable between 2.5 and 4.0.

6. Resistance spot welding electrode according to any of the preceding claims, **characterized** in that the orientation of the web length is 75 - 90° to the component longitudinal direction (2,7,12,17,24).
- 5 7. Resistance spot welding electrode according to any of the preceding claims, **characterized** in that the cap (1,6,11,16,21) has a modified or unmodified C, T, L or S shape.
8. Resistance spot welding electrode according to any of the preceding claims 1
10 - 6, **characterized** in that the cap (1,6,11,16,21) has a modified or unmodified crescent, clamp or bracket shape.
9. Resistance spot welding electrode according to any of the preceding claims 1
- 6, **characterized** in that the cap (1,6,11,16,21) has a modified or unmodified
15 combination of a classical point with a web.
10. Resistance spot welding electrode according to any of the preceding claims
1 - 3, **characterized** in that the cap (1,6,11,16,21) has a modified or unmodified
W or H shape.
- 20 11. Use of a resistance spot welding electrode with a cap, having in that end of the electrode which is in contact with materials to be welded together a non-axially symmetrical contact area, for welding high strength materials, such as, carbon steels and stainless steels with yield strength more than 400MPa and
25 with the carbon content more than 0.15 weight % in the resulting dissimilar weld nugget.
12. Use of a resistance spot welding electrode with a cap, having in that end of the electrode which is in contact with materials to be welded together a non-
30 axially symmetrical contact area, for welding high strength aluminium alloys, such as 5xxx, 6xxx or 7xxx series.

13. Use of a resistance spot welding electrode with a cap, having in that end of the electrode which is in contact with materials to be welded together, a non-axially symmetrical contact area for welding crash-relevant parts in automotive industry, such as a door side impact member, A-pillar, B-pillar crashbox
5 bumper, reinforcement plates or a rocket rail.

14. Use of a resistance spot welding electrode with a cap, having in that end of the electrode which is in contact with materials to be welded together, a non-axially symmetrical contact area for welding crash-relevant parts in cabs of
10 trucks, railway construction parts, battery packs for battery electric vehicles or hybrid and pressure resistance tanks, or white good applications like trammel, inner door of a dish washer.