INFLUENCE OF COOLING MODE ON THE ELECTRODE CAPS FROM ALLOY Cu-Cr-Zr OPERATING LIFE AT RESISTANCE SPOT WELDING

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Abstract

For production bearing welds at resistance spot welding there is very important value about number of welds made by electrodes at which is created regular welding spot higher than certain minimal value and thus also efficient bearing capacity. During welding there is with increasing number of welded spots simultaneously also wearing of electrode working area, changing of conditions for creation weld joints and thus also their quality. In consequence of electrical, mechanical, thermal and metallurgical loading there are changes in electrode working area geometry, changes in roughness and fouling of working areas, changes of mechanical and physical properties of electrode material. There is very important influence of the electrode working area surface temperature on the operating life. Within the scope of this paper there is description of new female electrode caps cooling system by liquid carbon dioxide. There is evaluated influence of cooling on the female electrode caps temperature course in the zone of its working area. On the basis of metallographic evaluation there is examining influence of electrode cap cooling mode on the change of its working area geometry and thermal affection. Upon the base of results from mechanical tests there is evaluated decrease of dimension and bearing capacity with increasing number of welded spots.

Keywords: Resistance Spot Welding, Alloy Cu-Cr-Zr, Electrode Cap, Cooling, Quality of Weld

1. INTRODUCTION

Resistance spot welding is still one the most applied technology at coining car-body parts. E.g. car-body of the automobile ŠKODA Octavia 3rd generation has 5085 spot welds. It´s possible to state that technological problems connected with spot welding of coated and uncoated sheets are nowadays almost all solved. As a basic topic is surely considered quality of spot welds i.e. creation of welds with sufficiently enough weld nugget and thus also sufficient bearing capacity. Quality of resistance spot welds and approach to their evaluation has its specifications. With increasing number of weld joints there is gradually wearing of electrodes working areas and there are changing conditions of creating weld joints and their quality. This is typical of welding sheets with different coating types – e.g. zinc or aluminium. Electrode working area is intensively influenced by melted metal from smelting coating thus electric and also mechanical properties of the electrode are changing. So there is mechanical damage of the electrode working area due to “gluing” on welded material and its subsequent separation. Metallurgically affected layer is on the electrode created already after welding several spots and conditions for electric current passage are changing. All mentioned phenomena surely have influence on the changing quality of welds. In praxis it is very important to know how many welds with required quality is possible to make without modification of electrode working area – thus electrodes operating life. Welds quality and electrodes operating life are mutually closely connected and to define electrodes operating life criterions also supposed to determine criterions about welds quality and vice-versa. From extensive researches it is obvious that electrodes operating life is greatly influenced by the thermal loading of their working areas. There is presumption that the higher electrode working areas cooling intensity, the higher operating life of electrodes. That is why this paper deals with the application of electrode caps cooling system by means of liquid carbon dioxide.

2. SYSTEM FOR COOLING ELECTRODE CAPS BY LIQUID CARBON DIOXIDE

The new system for cooling electrode caps was designed within the solving project no. TA03010492 (Applied multi-branch research and development progressive cooling methods at technological processes). Electrode caps are put on the electrode holder which enables inlet of the liquid carbon dioxide by the capillary tube. Scheme of electrode cap holder modification is shown in **Fig. 1**. Carbon dioxide is in liquid state taken by capillary tube through electrode cap holder body into the expansion chamber that is created in conical part of this holder and serves for gripping cap. Due to the expansion, liquid carbon dioxide changes on the mixture of gas and so-called dry ice which subsequently sublimates and removes heat from the environment. To make possible outflow of expanding carbon dioxide from the expansion area there are milled grooves on the surface of holder gripping part. Cooling intensity of the electrode cap working area is influenced by the way of dosing and amount of liquid carbon dioxide. Liquid carbon dioxide is into expansion area doses by control unit which opens and closes solenoids valves acc. to programmable time profile. In terms of experimental tests there were evaluated different methods for cooling electrode caps which were finally used at operating life tests:

- Convectional cooling by water with closed cooling circle;
- Combined cooling by water with closed cooling circle and with auxiliary cooling by liquid carbon dioxide at different dosing times;
- Convectional cooling by water with open cooling circle;
- Cooling by liquid carbon dioxide.

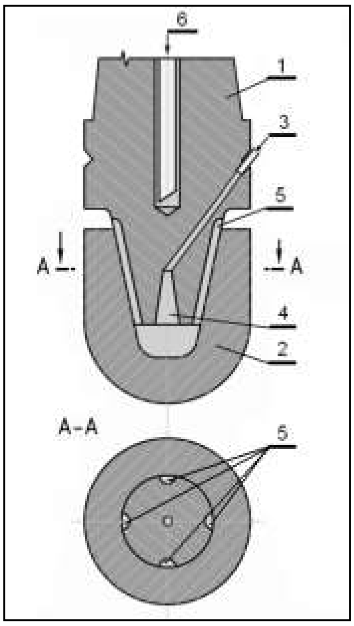


Fig. 1 Scheme of the electrode cap holder;
1 – electrode cap holder, 2 – electrode cap, 3 – inlet of liquid carbon dioxide, 4 – expansion chamber, 5 – holder for outlet of gaseous carbon dioxide, 6 – inlet of cooling water

Experimental tests were carried out on the welding workplace equipped with welding machine TECNA 6124 with built-in control system T 700 and with cooling unit Hyfra SVK 140/1. Welding parameters were recorded by measuring device MG3 Digital. Workplace was equipped with machine for dosing liquid CO_2 (machine from Co. Linde) which consists of pressure cylinder and control unit for valve on which are connected capillary tubes inletting liquid carbon dioxide into expansion chamber in the electrode cap holder.

3. CHARACTERICITICS OF USED MATERIALS

For experimental tests were used electrode caps from Co. Nippert marked as A – trode™ with target chemical composition 0.7% ÷ 1.2% Cr, 0.06% ÷ 0.15% Zr, 98.45% ÷ 99.04% Cu, other max. 0.2%. According to standard ISO 5821 has cap signification ISO 5821-F0-16-20-8-A2/2. Material of electrodes is made by patented casting system by Co. Outokumpu. Casting is realize without presence of oxygen and amount of alloying elements is optimized. The alloy should be resistance up to temperature 500 °C. Initial structure of material of electrode is in **Fig. 2**. Grains are markedly deformed in the direction of forming initial workpiece (rod) and moreover there is also influence from forming during production the final shape of rod. For etching of structure there was used etchant with compostion: 2 grams of potassium dichromate, 8 ml H_2SO_4, 4 ml saturated solution of NaCl in distilled water, 100 ml distilled water. Structure was evaluated in the middle part of cap working area. Vertical direction of image matches to the cap longitudinal axis. Original structure magnificence is 1000x. To carry out electrode caps operating life tests was chosen material commonly used in the Škoda Auto, Inc. Mladá Boleslav - HX 220 BD+Z 100 MCO. It is hot dip zinc galvanized sheet with thickness 0.7 mm with two-sided zinc coating in amount 100 $g \cdot m^{-2}$ with hardening effect at paint setting. Microstructure of sheet is in **Fig. 3** and is almost fully created by ferrite with rarely inclusions and carbides.

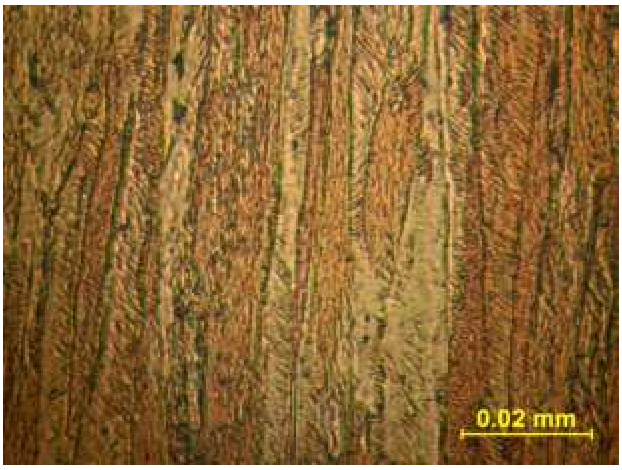


Fig. 2 Structure of electrode caps material

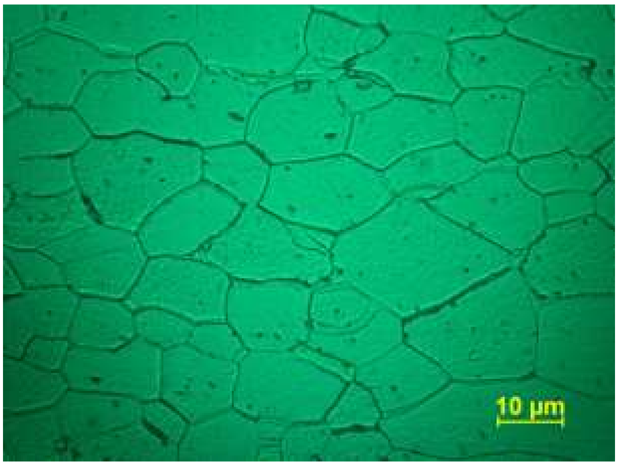


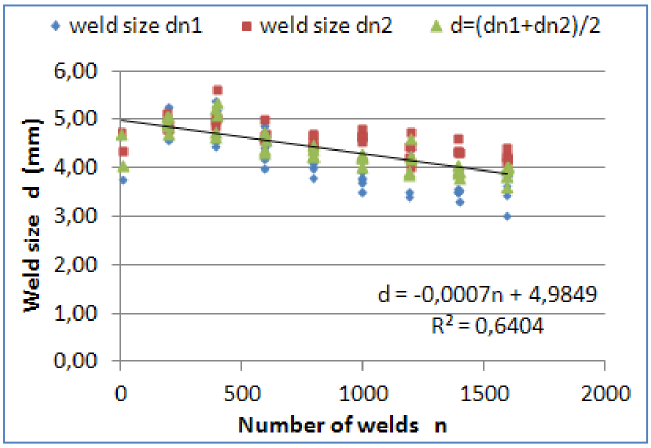
Fig. 3 Structure of sheet HX 220 BD+Z 100 MCO

4. DAMAGE OF ELECTRODE CAPS WORKING AREA AFTER THE OPERATING LIFE TEST

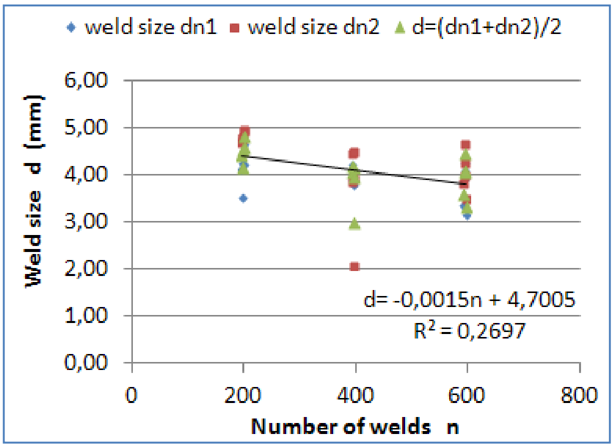
Operating life tests of electrodes were carried out acc. to ISO 8166 „Resistance welding - Procedure for the evaluation of the life of spot welding electrodes using constant machine settings“. Modification of electrode caps working area was done by its change into conical shape with vertex angle 120° and with diameter of bearing surface 4 mm. Cadence of welding was set to 30 welds per minute – typical of robotic spot welding. Tested sheets on which were realized welds between individual testing welds series had dimensions 500 x 400 mm. On sheet was made 12 rows per 16 welds. Welding was terminated after making 192 welds on sheet. For every 192 welds were carried out eight tested welds. These testing welds have to be made on the separated sheet. Regarding the purpose of tests there was modification of tests so that for evaluation of welds quality was in every testing welding series welded 5 samples for peel test acc. to ISO 10447 „Resistance welding - Peel and chisel testing of resistance spot and projection welds“ and three welds for shear test acc. to ISO 14273 „Specimen dimensions and procedure for shear testing resistance spot, seam and embossed projection welds“. Peel tests were carried out as mechanized acc. to standard ISO 14270 “Specimen dimensions and procedure for mechanized peel testing resistance spot, seam and embossed projection welds“. Electrode achieves the end of its operating time when welds have weld diameter determined by the peel test lower then 3,5 $\sqrt{t}$ (t thickness of sheet in mm) for three welds on the testing sample at five in sequence following welds. For the sheet of 0.7 mm is this value 2.9 mm. Regarding evolution in dimensions and shape of the weld nugget, tests were usually terminated early because the most important was mainly to determinate differences at various cooling methods of electrode caps and to determinate the tendency of dependences **weld dimensions – number of welds**.

From carried out experiments was made comparison of operating life tests results with classic cooling method of electrode caps by circulating cooling water in amount 6 $l \cdot min^{-1}$ (see position 6 in **Fig. 1**) and with cooling of electrode caps by liquid carbon dioxide in amount 0.5 g for every realized weld. Within the frame of carried out experiments was monitored also temperature course in the electrode cap working area with the purpose to evaluate influence of cooling intensity. Temperature of electrode working area was monitored by the thermocouple Chromel – Alumel (TFCY-010 and TFAL-010 from Co. Omega, diameter 0,25 mm) which was welded to the electrode cap conical part. Thermocouples were placed on the side of cap 2 mm from the working area (measured on the side of cone). Maximal temperature values at cooling by carbon dioxide were approx. lower by 50 up to 60 °C.

Results from operating life tests are shown in **Fig. 4**. Weld dimensions were measured after peel tests always in two directions perpendicular to each other (dimension dn1 and dn2). From the presented results is obvious that application of cooling by liquid carbon dioxide markedly increased operating life of caps. Totally there were performed 1600 welds with application cooling by liquid carbon dioxide in comparison to 600 welds for application classic cooling method by circulating water.



a)



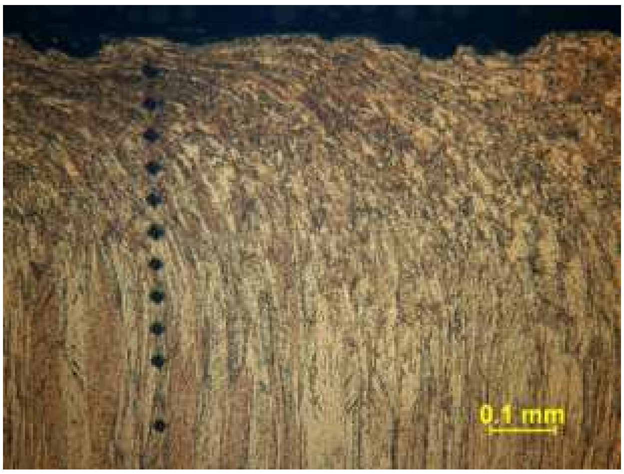
b)

Fig. 4 Results from evaluation operating life tests;
a) colling of caps by liquid carbon dioxide, b) cooling by water

4.1 Metallographic analysis of electrode caps

The higher damage of working area always took effect at upper electrode caps. After carrying out operating life tests were upper electrode caps cut in the longitudinal direction and from prepared samples were make metallographic scratch patterns. In the surface area was metallographic evaluation added by microhardness measurement. In **Fig. 5** is metallographic scratch pattern from the edge area (a) and middle part (b) of electrode cap working area from upper electrode with cooling by means of liquid carbon dioxide. On images are also evident dots from measurement microhardness. Before making metallographic images were samples repeatedly polished and again etched. Acc. to the change of fibers course it is possible to conclude about influence of deformation processes. In the area close to electrode axis is structure damage more important, in some areas it is possible to see also the change of structure character that probably results due to local increase of thermal loading.

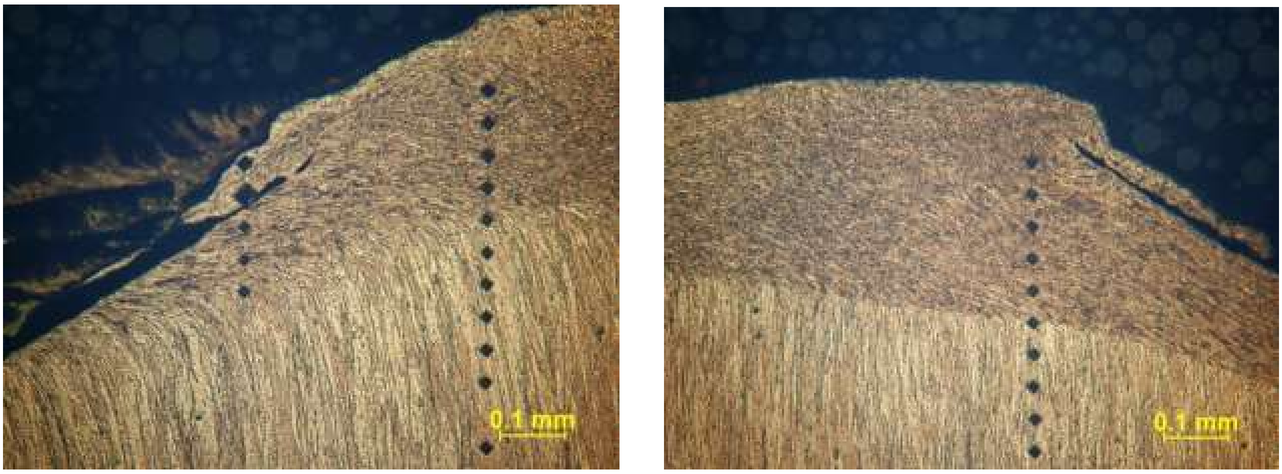
a)



b)

Fig. 5 Microstructure of electrode cap after production 1600 welds in its working area
(caps were cooled by means of liquid carbon dioxide);
a) edge of working area, b) area close to the cap axis

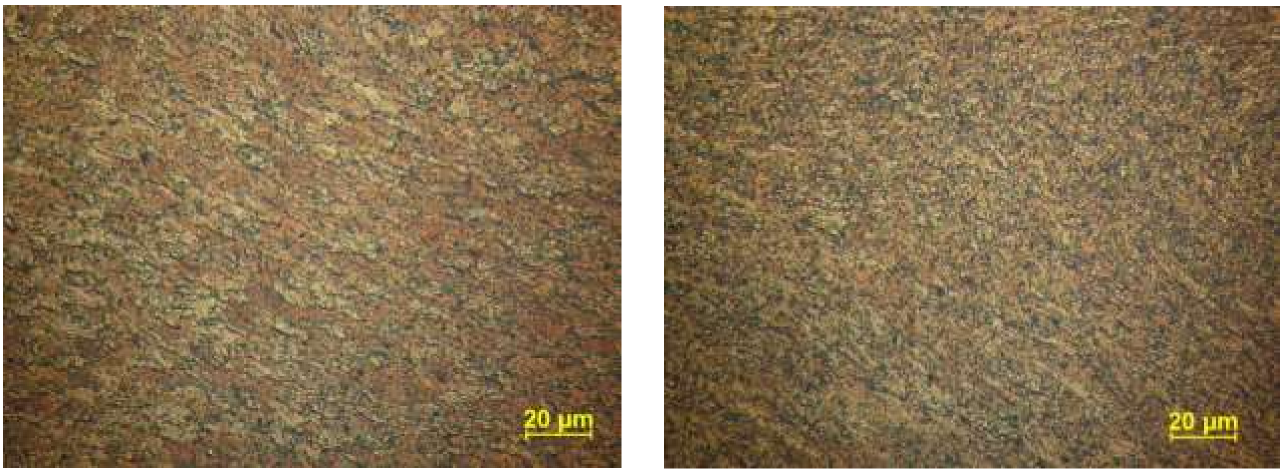
Microstructure of electrode cap which was cooled by means of water circulating through the holder body is shown in **Fig. 6**. Structure of cap material is changed in the direction from the electrode cap working area surface. Due to the higher thermal loading than in the previous case and also due to the mechanical loading there are evident markedly structure changes and material is extruded into burr.



a) b)

Fig. 6 Microstructure of electrode cap after production 600 welds in its working area (caps were cooled by means of water circulating through holder) on both sides of section; a) left edge, b) right edge

Character of the structure in the electrode cap affected zone in the area of measurement hardness acc. to **Fig. 6 a** is in **Fig. 7 a** – hardness measurement line corresponds with the left side of metallographic image. In **Fig. 7 b** is shown similar image that was made in the affected zone acc. to **Fig. 6 b** – hardness measurement line corresponds with the right side of metallographic image. Initial character of the structure with grains deformed in the longitudinal axis of the electrode cap is truly greatly changed due to the effect of both thermal and deformation processes.

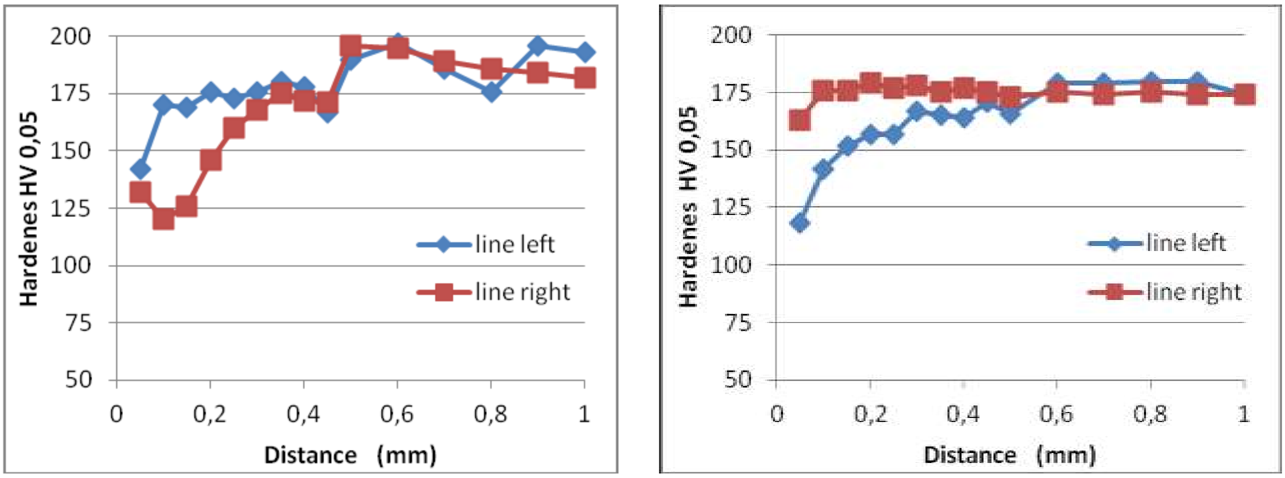


a) b)

Fig. 7 Microstructure of electrode cap cooled by water circulating through the holder in the working area on both sides of section in the markedly affected zone after production 600 welds

Results from microhardness measurement in area acc. to **Fig. 5** are shown in **Fig. 8 a**. Affection of hardness due to the thermal loading of electrode caps working area achieves c. to 0.45 mm from working surface.

Burrs on the working surface edge were not created and decrease of hardness in the area around cap axis in more expressive. For this sample was also carried out hardness measurement directly in the burr area (totally in five places). Results from microhardness measurement in electrode caps working area in lines acc. to **Fig. 6** is then shown in **Fig. 8 b.** Thickness of the affected zone is comparable with the previous case.



a) b)

Fig. 8 Dependence of microhardness in the electrode cap working area;
a) cooling by means of liquid carbon dioxide, b) cooling by means of water circulating through holder

CONCLUSION

Carried out tests of electrode caps operating life under different cooling modes proved fact that cooling of electrode caps by liquid carbon dioxide leads to the great improvement in electrodes operating life. At cooling of electrode caps by water circulating in the caps holder is in the working area of caps created thin continuous layer of heat affected material with markedly changed structure. Such material is due to the higher thermal loading "extruded" toward edge of the working area and wearing of electrode cap working area is proceed faster. On the basis of carried out control procedures about heat affection of electrode caps material it is possible to predict that in these areas temperature achieves value about 550 °C. This continuous layer was not created at cooling of electrode caps by liquid carbon dioxide and wearing process was lower. Influence of the different electrode caps wearing process is proved also by different results from operating life tests which were evaluated on the basis of testing welds mechanical tests.

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