SERVICE LIVE OF WELDING ELEKTRODES AT RESISTANCE WELDING OF ZINC COATED STEELS WITH NIT LAYER

KOLAŘÍKOVÁ Marie[1], FOREJTOVÁ Lucie[1], KOLAŘÍK Ladislav[1]

[1]*CTU - Czech Technical University of Prague, Faculty of Mechanical Engineering, Prague, Czech Republic, EU, marie.kolarikova@fs.cvut.cz*

Abstract

In the automotive industry, sheets are coated for protection against corrosion and oxidation during forming. This coating may deteriorate the weldability of steel sheets and shorten the life of welding electrodes. Currently, new tips of coatings are used, e.g. coatings based on Al-Si or NIT (New Inorganic Treatment). The contribution deals with the influence of the NIT layer on weldability and electrode lifetime. Electrode life tests were performed according to EN ISO 8166. Steels HX180BD coated HDG (Hot Dip Galvanized) and coated steel HDG + NIT was used as the base material. The results showed that the NIT layer does not particularly affect the service life of the electrodes. On the other hand, when welding HDG + NIT coated sheets, a longer service life (about 600 weld points) was achieved than welding of HDG-coated sheets.

Keywords: Resistance spot welding, HX180BD Z100 MCO, Zn coating, NIT layer, lifetime

1. INTRODUCTION

The most advantageous welding technology for steel sheets is resistance spot welding. There is a problem in the serial production of the bodywork with a smaller dimensional accuracy of the welded parts. Resistance spot welding allows compensate these inaccuracies. The solution is in welding devices and mid-frequency welding sources combined with a long life of the electrodes.

In the automotive industry, steel sheets (both high-strength and deep-drawing) are coated. Coatings improve the ductile properties (Zn-based coatings for cold-formed materials), protect steel sheets against oxidation during the forming process (Al-Si coatings for thermo-mechanically processed materials) and against corrosion. This increases the service life of the bodywork. But the surface treatments lead to complications in welding [1]. The development of coating properties is ongoing as well as the optimization of the welding process.

Decreasing the weight of the bodywork and increasing its stiffness leads to the use of high-strength steels. These steels have a high carbon content, often up to the very limit of weldability [2]. The problem of resistance spot welding is that materials with 0.2% carbon content may become hardened. [3] Alloying with aluminum will lead to consequent hardening of the material. To achieve the required joint quality, it is a trend to use welding parameters from hard welding mode [2].

Welding of sheets with zinc coating has a number of difficulties. The zinc in the coating diffuses into the working surface of the spot electrodes (material CuCrZr). The brass is formed. During the welding, continuously increase the content of zinc on the electrode surface. The resistance between the welded sheet and the electrode also increases. This reduces the welding current at the welding point. The welding quality is rapidly decreasing. The contact surfaces of the electrodes are deformed in the post-heating (**Figure 1**). The current density drops. There is a big problem with the diameter of the welding electrode. It is necessary to maintain the same diameter electrodes, which is gradually deformed [4]. Unless modified electrode, diameter may cause insufficient weld penetration (connected to the insufficient size of the weld lens), even when the dimension of the welding lens is satisfactory. The solution can be a gradual increase of the welding current (up to 30%), however at the expense of electrode service life [2].

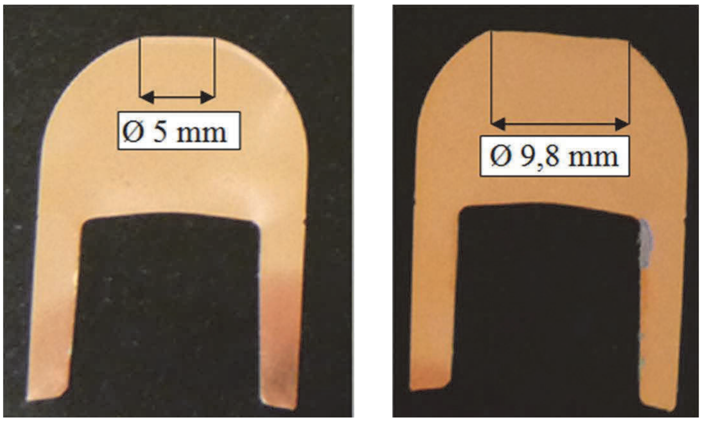

Figure 1 New electrode cap - left, worn electrode cap - right [2]

Another parameter influencing the welding quality and thus the life of the electrodes is the transition resistance. The size of the transition resistance affects the size of the welding force. The greater the welding force, the lower the transition resistance [3]. Further, the transition resistance is influenced by the conductivity of the joined metals, the roughness of the surface and its dirt.

2. MATERIALS

HX180BD steel sheet was used as the base material. The thickness of the sheet is 0.8 mm. The chemical composition is in **Table 1**. The mechanical properties are in **Table 2**. It is a material for cold forming with a minimum contract yield strength of Rp0.2 = 180 MPa, bake-hardening steel (requires an increase in the yield strength after heating over 170 ° C for 20 minutes), hot-dip zinc coated.

Table 1 The chemical composition of the base material HX180BD

Fe	C	Si	Mn	P	S	Al	Nb	Ti
99.7	0.003	0.04	0.17	0.008	0.006	0.032	0.007	0.0007

Table 2 Limit of tensile strength of base material HX180BD

Rm [MPa]	HDG coated sheet	308
	HDG + NIT coated sheet	324

Two types of surface treatment were used. HDG (Hot Dip Galvanized) and HDG + NIT (New Inorganic Treatment) (**Figure 2**). Chemical composition is in **Table 3**. Chemical composition of NIT coating is a hydrated salt formed by zinc (in the form of an oxide or hydroxide) in a sulphate compound - $ZnSO_4$. It is a thin layer on the zinc coating. NIT improves ductility (lower coefficient of friction), decreases the amount of oil during the forming (reduced sensitivity to used oil type) and decreases pollution of forming tools. [5]

Table 3 Average chemical composition of coatings [2]

	Zn	**Fe**	**P**	**Si**	**S**
HDG	72.95	23.16	1.21	0.24	0.05
HDG + NIT	85.15	10.58	1.44	0.15	0.05

Used electrode caps were type 39D 1978-1 from material A2/2 - CuCr1Zr with Ø16 mm. Chemical compound is Cu = 98.98 %, Cr = 0.9 %, Zr = 0.12 %.

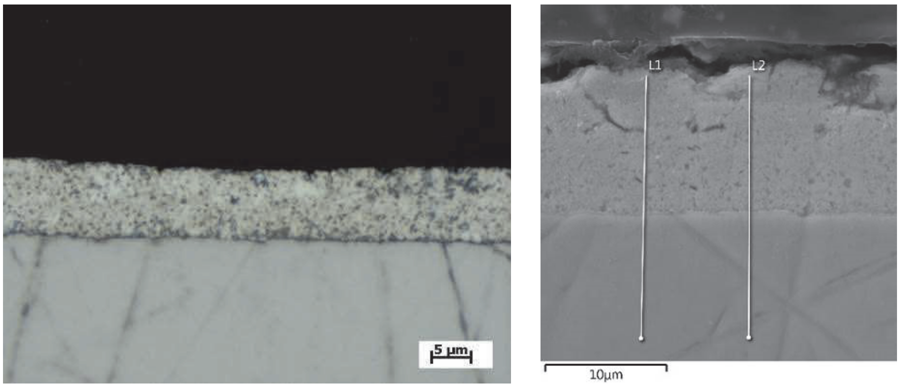

Figure 2 Coating HDG + NIT - optical microscope (right), electron microscope (left)

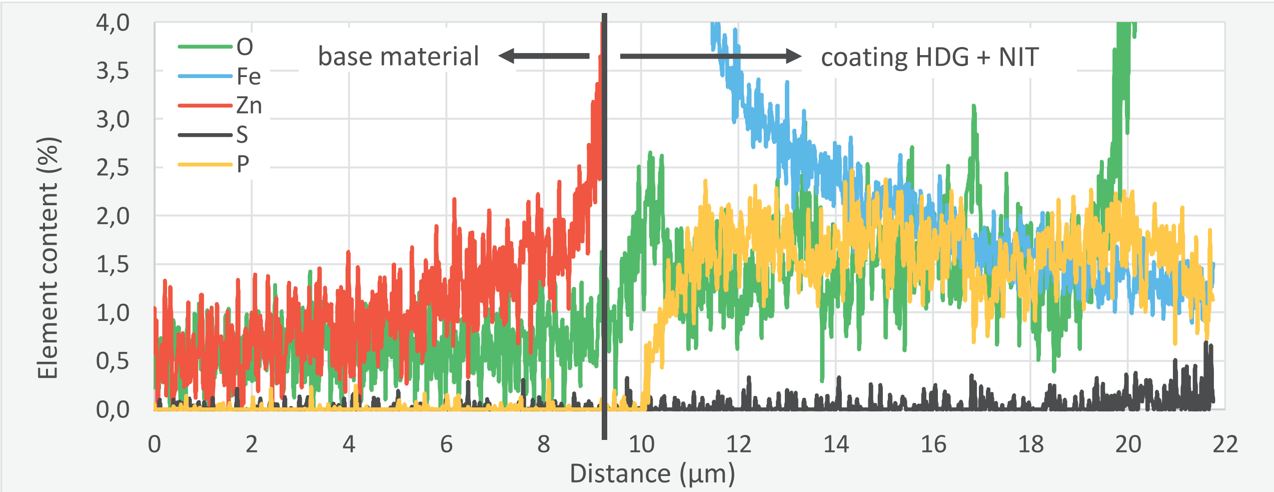

Figure 3 Detail of chemical composition of HDG + NIT coating and transition to base material

3. EXPERIMENT

The thickness of the coating on the optical microscope was measured. The results were verified on an electron microscope. The average thickness of the HDG coating is 10 µm; the HDG + NIT coating thickness is 12 µm.

A Tescan Mira 3 GMU scanning electron microscope was used for chemical analysis also. The results are shown in **Table 1**, **Table 3** and **Figure 3**. **Figure 3** shows an increased sulphur content in the coating.

The mechanical properties were measured on the LabTest 5.100SP1 (vertical design, speed control accuracy ± 0.5%, rated load 10 kN). The results are shown in **Table 2**. The strength limit for sheet with NIT is slightly increased compared to sheets without NIT (difference is about 5 %).

Tests of welding electrode service life have been performed. Two types of coatings were compared on the same base material. The methodology for the evaluation of electrode life is given in EN ISO 8166. The welds must be placed at least 10 mm from the edge of the sheet and the distance between the welds must be at least 30 mm. The dimensions of the test sheets must be chosen so that at least 192 welds are placed on the plate, for example at least 12 rows of 16 welds. The test sheet must be at least 470 mm long and at least 350 mm wide. The life of the electrodes is the number of acceptable spot welds that can be made between the need for electrode modification. The electrode reaches its service life when weld joints have a diameter of less than 3.5 t in three of the five consecutive welds (the diameter is determined by peeling test, t is the thickness of the sheet) [6]. Sheet thickness was 0.8 mm, so weld diameter should not be less than 3.13 mm. Electrode diameter should correspond to the formula: $d = 5\sqrt{t}$. The working diameter of the electrodes was 5 mm.

The resistance press Dalex PMS 11-4 was used to test the life of the electrodes. The welding parameters were as follows: welding time = 240 ms, welding current = 7 kA, electrode force = 2.4 kN, one pulse. First, 8 test samples (zero group) were welded for peeling test according to EN ISO 10447. By a digital sliding scale, the maximum and minimum diameter of each point weld ($d1$ and $d2$) were measured and the actual weld diameter $d = (d_1+d_2)/2$ was calculate. [7] Subsequently, the calculated median arithmetic mean.

The working diameter of the welding electrode (or replaceable caps) was monitored during the lifetime test. After each group of welds, another 8 test samples were welded for peeling test. Subsequently, the working surface of the upper and lower welding caps was measured.

4. DISCUSSION

The electrodes have reached their lifetime in the case of HDG coated sheets after 2005 spot welds, in the case of HDG + NIT coating after 2608 point welds. The diameter of the weld lens decreased with the increasing working diameter of the electrode (**Figure 4**).

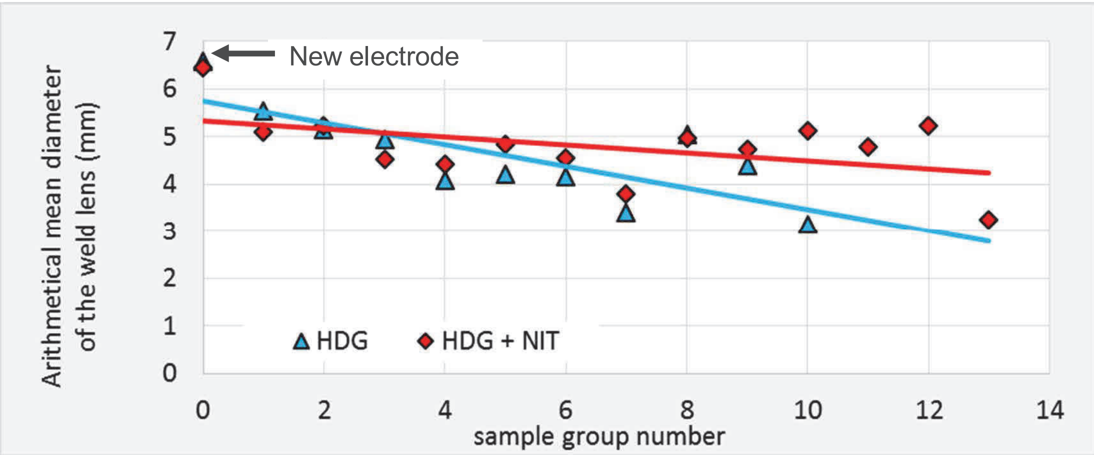

Figure 4 Arithmetical mean diameter of the weld lens

Figure 4 shows, that welding caps with HDG + NIT coating have reached longer life. At the beginning of the welding, the diameter of the weld lens was 6.5 mm for both sheets (the diameter of the welding cap was 5 mm). With the increasing number of welds the diameter decreased to a value of 3 mm. The reason was the zinc sticking on the welding caps. There it prevents the passage of electric current.

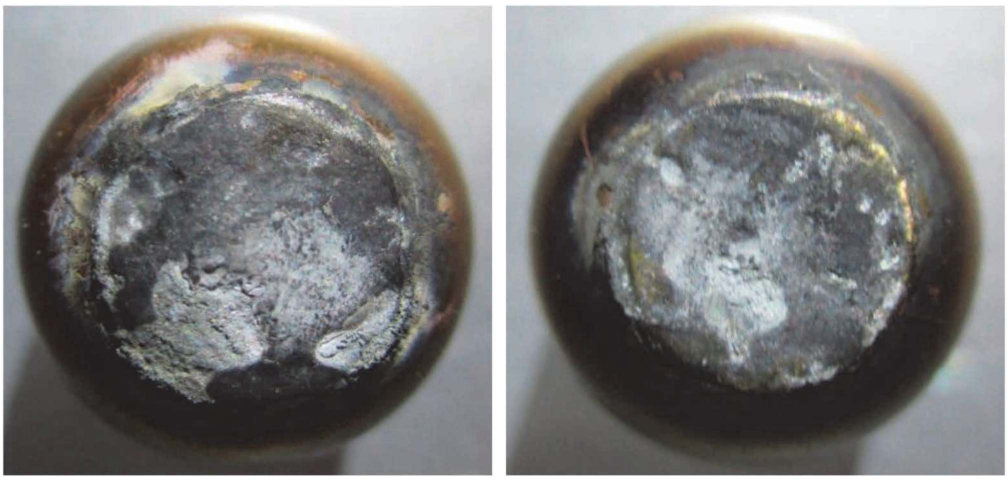

Figure 5 Zinc on work surface of welding electrode (left - upper cap, right - lower cap)

In **Figure 5** is the upper and lower weld cap at the end of service life (over 2608 welds) used for welding of sheets coated HDG + NIT. The lower weld cap (from the right) has a hollow, while the upper one is a salience. The reason is the stroke of the upper electrode. The lower electrode is immobile.

The dependence of the diameter of the working area of the electrode on the sample group is in **Figures 6** and **7**. The graphs are not very different. In both cases, the diameter of the working area of the electrode increased by 1.5-2 mm after the welding of the first group of samples (208 welds) - see **Figures 6** and **7**. For the other two measurements, the diameter of the electrode increased by approximately 0.5 mm. For the remaining measurements, the increase was measured by about 0.15 mm. The enlargement of the work surfaces of the electrodes has slowed down. The graphs trend is very similar. The fundamental difference is only in the reached service life of the electrodes.

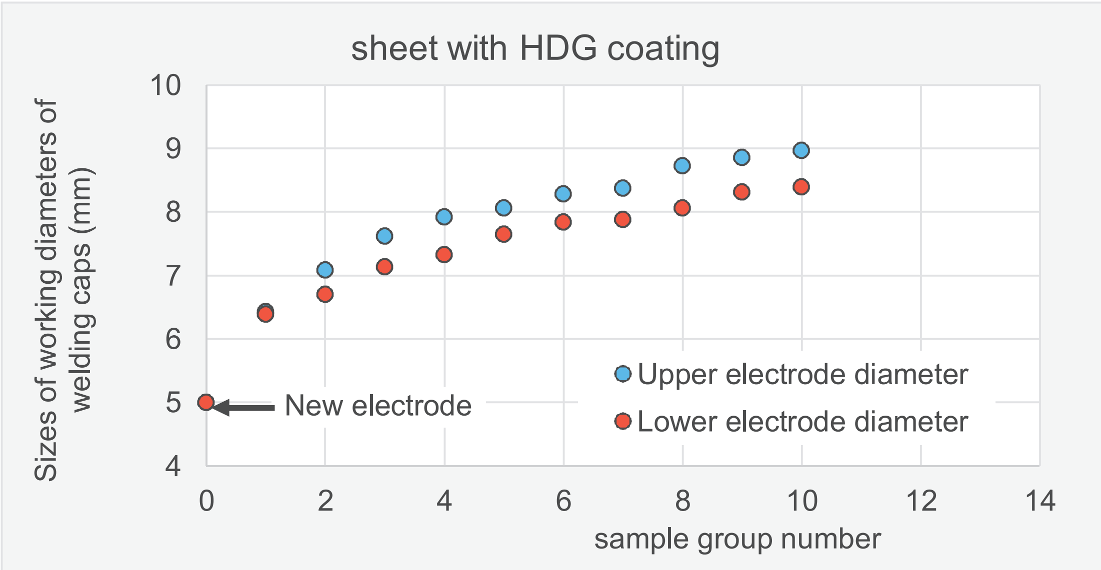

Figure 6 Changing the diameter of working area of welding caps used for welding HDG coated sheets

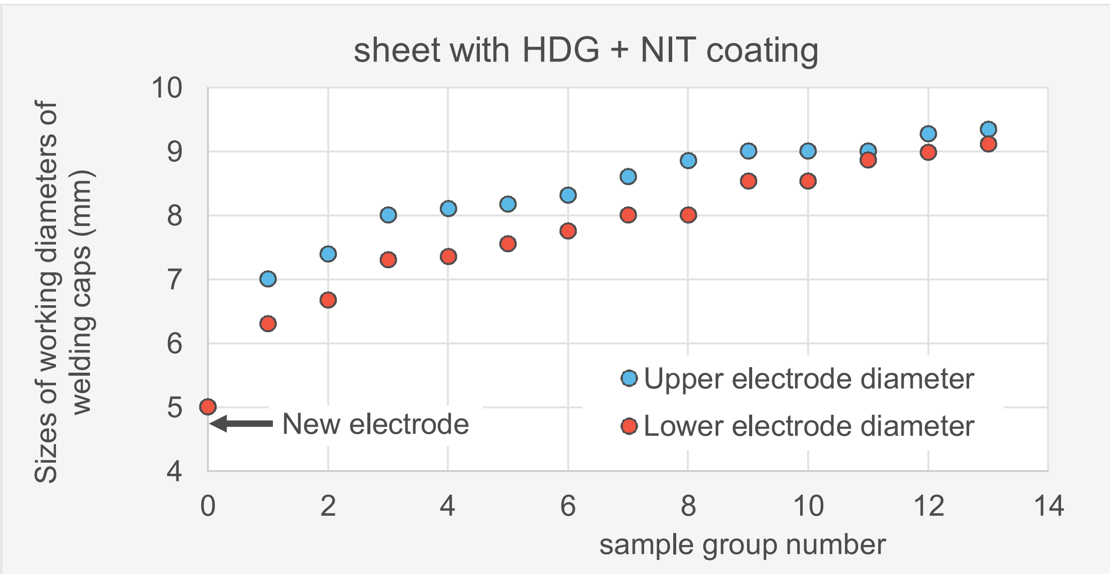

Figure 7 Changing the diameter of working area of welding caps used for welding HDG + NIT coated sheets

5. CONCLUSION

In the automotive industry, the properties of coated steel sheets are constantly evolving and improving. Just like welding parameters. The goal is a high-quality welding joint in terms of strength requirements and corrosion protection of the bodywork.

The appearance of welding lenses and their dimensions are dependent on the thickness of the sheets, used materials and the applied surface treatments.

The zinc coating negatively affects the welding process. Zinc adhering to the working surface of the electrode prevents the passage of the current through the welded sheets. With the increasing number of welds, the thickness of the zinc layer on the electrode increases. At the same time, the quality of welds decreases. Unfortunately, the zinc coating is irreplaceable surface treatment. Therefore, it will continue to be used in the automotive industry despite the negative impact of zinc on the welding process. The solution is milling of welding electrodes in working intervals.

It was assumed that the NIT layer would degrade the service life of the electrodes more than the HDG coating itself. This assumption has not been confirmed. Lifetime tests (in accordance with standard EN ISO 8166) have shown that the NIT surface layer does not impair the service life of the welding electrodes. In contrast, the electrodes used to weld HDG + NIT coated sheets have reached a longer service life (2608 spot welds) than the electrodes used for HDG-coated only (2005 spot welds).

It can be stated that 1000 - 1200 spot welds can be made without a joint with a weld lens value of less than 4 mm (condition with reserve: weld not less than 3.13 mm).

ACKNOWLEDGEMENTS

This research was been supported by the grant SGS16/217/OHK2/3T/12.

REFERENCES

[1] KASCAK, L., VINAS, J., MISICKO, R. Influence of welding current in resistance spot welding on the properties of Zn coated steel DX51D. *Songklanakarin Journal of Science and Technology*, 2016, vol. 38, no. 3, pp. 237-242.

[2] KOLARIKOVA, M., KOLARIK, L. The influence of resistance spot welding on weld joint quality and service life of elektrodes, In *METAL 2013 - 22nd International Conference on Metallurgy and Materials*. Ostrava: TANGER, 2013, pp. 589-594.

[3] LIPA, M. *Resistance welding*. Bratislava: Weldtech, 1995. 81p.

[4] KAARS, J., MAYR, P., KOPPE, K. Dynamic apparent transition resistance data in spot welding of aluminized 22MnB5. *Data in Brief,* 2016, vol. 8, no. 9, pp 1184-1189.

[5] ŠKODA, A.S. New Inorganic Treatment: Product and thickness measurements. *Corporate documents*, Mladá Boleslav.

[6] EN ISO 8166*: Resistance welding - Procedure for the evaluation of the life of spot welding electrodes using constant machine settings*. Praha: CNI, 2004. 16 p.

[7] EN ISO 10447: *Resistance welding - Peel and chisel testing of resistance spot and projection welds*. Praha: CNI, 2007. 13 p.