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Analysis of Materials for Resistance Spot Welding Electrodes

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The contribution deals with metallographic analyses of welding tip materials and workpieces used in production. Microstructures of most used alloys Cu for welding electrodes of resistance spot welding are evaluated. Alloys of CuCr Zr, CuCoBe and CuBe . Analyses of influence of alloying

elements and production technology of the alloys on final properties of electrode materials are presented. The effort of producers is the maximum lifetime of welding tips on which many factors have an influence during the welding process. Used welding mode, material properties of the tips, technology of their production, sort and surface treatment of welded materials and so on.

Analiza materijala elektrode za elektrootporno točkasto zavarivanje

Izvorno znanstveni članak

Ovaj rad se bavi metalografskom analizom materijala elektroda za elektrootporno točkasto zavarivanje koji se koriste u proizvodnji. Mikrostrukture najčešće korištenih legura Cu za izradu otpornih elektroda za točkasto zavarivanje su evaluirane. Analizirane su legure: CuCr1Zr, CuCoBe i CuBe₂. Analiza utjecaja legirajućih elemenata i tehnologije proizvodnje legura na konačna svojstva materijala elektroda je također predstavljena u radu.

1. Introduction

The most used method of car-body sheet welding is resistance spot welding. Even though it is a conventional technology of welding which has been used for a long time in practice, it is necessary to solve some problem tasks where a successful resolution will lead to satisfaction of customers and automobile producers [1].

The biggest problem which the automobile welding centers deal with is limited lifetime of welding tips during the welding process of surface modified sheets. During the welding of these sheets, the lifetime of welding tips is multiply lower in comparison with black sheets. Their lifetime decreases rapidly due to adhering the coatings with a low melting temperature on the contact surfaces of welding tips that cause the beginning of eutectics which have a negative influence on transition resistance during welding. That is why it is necessary to clean contact surface of tips periodically after a specified welding

cycle. The lifetime of welding tips is also considerably affected by material from production technology, their shape, cooling intensity and the conclusive influence used in welding parameters.

The alloys with higher content of Cu for production of the welding tips are used, which guarantee high electrical conductivity. These alloys are used for tip production: CuAl, CuZr, CuCrZr, CuCoBe, CuCoNiBe, CuBe₂, CuNiSi, CuNiSiCr, CuW and others.

2. Analysis of current case in production of materials for welding tips

Contact resistance depends on the surface condition, and it determines the heat generation and metallurgical reactions at the electrode-sheet interface. When welding galvanized steel sheets, the low contact resistance due to the high conductivity of zinc warrants a significantly high

welding current than welding bare steel. A more profound influence of free zinc at the electrode-sheet interface is on electrode wear. The alloying of copper with zinc to form brass increases the resistivity at the electrode face. This in turn raises the electrode temperature during welding. The face of an electrode is deformed through repeated heating and mechanical impacting at the interface, and the brass formed on the electrode face is often picked up by the sheets, leaving a golden-colored ring of indentation mark on the sheets. Therefore, the zinc coating promotes electrode wear [12].

Alloys of CuCr contain from 0,6 % up to 1,2 % Cr. They are used because of their high strength, corrosion resistance and electrical conductivity. These alloys could be hardened by ageing, which means a change of properties which occur at high temperature due to chrome precipitation from solid solution. The strength of hardened CuCr alloy is almost double in comparison with pure copper (220 MPa) and its conductivity is lower by only about 15 % than conductivity of Cu. These high-strength alloys keep their strength also at high temperatures (1000 °C). CuCr alloy is very good in cold formation. The alloy is used with advantage in production of electrodes for resistance spot welding, electrodes for seam welding, cable terminators, parts of braking systems and electrical and thermal conductor with higher strength [2]. Properties of CuCr alloys could be improved, except for Zr alloying, by arsenic alloying [3].

Hardening is in progress by increasing solubility of Cr in Cu with an increasing temperature. While a slow cooling process of CuCr alloy is in progress the structure is a two-phase one including chrome and alfa-phase of copper. Excellent mechanical properties are achieved by rapid cooling of CuCr alloy from annealing temperatures, which causes Cr kept with Cu in the oversaturated solid solution. So there is a regular distribution of precipitates in the matrix during the ageing process. Rapid cooling doesn't allow precipitation of Cr from a solid solution so the final structure is composition only of alfa-phase of Cu. The first pure Cu is solidifying, then the eutectic mixture alfa-phase of Cu and Cr. Eutectic mixture of alfa-phase Cu and Cr forms a lamellar structure in the interdendritic areas [2].

To improve the splintery workability of CuCr alloy, alloying elements are added such as Se, Te and Pb. Mechanical properties could be modified by addition of Ti (up to 0,5 %) and Be (up to 0,1 %) [3].

CuCr alloys are used for their high strength and electric-thermal characteristics. By addition of a small amount of alloying elements these alloys could be modified on the high-strength alloys or high-conductive alloys. For production of welding tips, it is necessary to find a compromise between the strength and conductivity which allow these alloys to be used also with hard modes of welding (high current – short time).

High-strength alloys consist of Be from 1,6 % to 2 % and approximately 0,5 % of Co. In order to achieve high strength it is possible to increase Be content up to 2,7 %. Alloys with high conductivity consist of 0,2 % to 0,7 % of Be and higher content of Ni and Co.

These alloys are used for the production of electronic connecting contacts, in electric devices as switches, inside the cases for magnetic switches, non-sparking applications, small sources, parts of injection forms for plastics and components of resistance welding. They are also suitable for production of casting because of good leaking.

High strength of CuBe alloys is achieved by ageing hardening or precipitation hardening. Hardening is in progress during precipitation of Be from oversaturated rigid solution of pure Cu. Precipitation is in progress during slow cooling of alloy, because a decreasing temperature causes a decreasing of solubility of Be in the alfa-phase of Cu. During rapid cooling of alloys from annealing temperature Be remains inside a rigid solution of Cu [2]. Consequently, inside the alloy precipitation comes in the progress hardening during 1 hour in a temperature of 200 to 450 °C. Tempering causes separation from the rigid solution.

During the first phase of precipitation, the homogeneous nucleuses of Guinier-Preston (G-P) areas occur. G-P areas are small precipitations inside the oversaturated solid solution of the alfa-phase of Cu. G-P zones do not have a purely defined own crystalline structure and these zones contain high concentration of Be atoms. Production of G-P zones is related to the changes of characteristics. In CuBe alloy, an increase of strength occurs. During the ageing process, some coherent metastable gamma double primary precipitates occur in the G-P zones. Subsequently, the primary gamma precipitates are separated. The strength of these alloys relates to the force of bonds which are in the border of the matrix and growing precipitation. Precipitation of balanced gamma phase decreases the strength characteristics of the alloy by reduction of metastable primary gamma precipitates [4].

3. Methodology of experiments

Welding tips and workpieces dedicated to production of welding tips were evaluated in the experiments. Samples for observation were from bar material and were taken off by a splintery process without a thermal impact. A metallographical analysis of examined samples was done on metallographical cuts with optical high microscope Olympus CX-31. A metallographical analysis was carried out on Cu alloys whose standard physical and chemical characteristics are presented in Table 1.

Table 1. Standard physical and chemical characteristics of welding tips and workpieces [2]

Tablica 1. Standardna fizikalna i kemijska svojstva materijala elektroda i obradaka.

Alloy Standard / Slitina	Chemical composition / Sastav	Hardness HB / Tvrdoća HB	Electrical conductivity / električna vodljivost	Sample shape / oblik uzorka
CuCr1Zr DIN 2.1293	Cr 0,8 Zr 0,08 Cu residue	150	48	Welding Tip / Vrh elektrod
CuCoBe ASTM-No. (UNS): C17500	Co 2,4 – 2,7 Be 0,4 – 0,7 Ni max. 0,3 Fe max 0,1 Al max 0,1 Si max 0,2 Cu residue	270	43	bar workpiece / Šipkasti obradak
CuBe2 DIN 2.1247	Be =1,6 – 2 Ni + Co =0,4 Fe < 0,1 Cu residue	350	14	Welding Tip / Vrh elektrode

Observed workpieces and welding tips of standardized shapes and dimensions dedicated to resistance spot welding are mentioned at Figures 1, 2, 3.



Figure 1. Welding tips for metallographical analysis from CuCr1Zr material

Slika 1. Vrhovi elektrode za metalografsku analizu iz materijala CuCr1Zr.



Figure 2. Bar workpiece for production of CuCoBe welding tips (ø 16 mm × 300 mm)

Slika 2. Šipkasti obradak za izradu elektrode iz materijala CuCoBe (Ø16 mm x 300 mm).



Figure 3. Welding tips for metallographical analysis from CuBe2 material

Slika 3. Vrhovi elektrode za metalografsku analizu iz materijala CuBe2.

4. Results of metallographic analysis

At Figure 4, there is the microstructure of CuCr1Zr alloy with typical rectangular double boundaries of grains of rigid solution of alfa-phase of Cu.

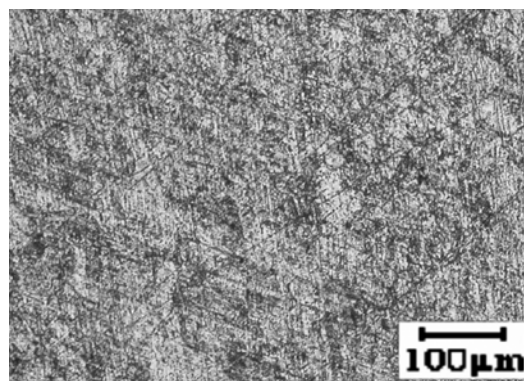


Figure 4. Microstructure of CuCr1Zr alloy

Slika 4. Mikrostruktura slitine CuCr1Zr

In the Cu matrix – see Figure 4 relatively massive Cu grains, separated on typical platy formation is shown. For visualization of a microstructure, the following etching was used: 1g of ammonium hydroxide NH_4OH + 2 g of ammonium persulphate $(\text{NH}_4)_2\text{S}_2\text{O}_8$ (2,4 %) in 100ml of distilled water.

The microstructure of thermal treated CuCoBe alloy is at Figure 5. Thermal treatment was carried out by dissolving annealing at 940 °C temperature and precipitation hardening at 480 °C temperature during 3 hours. In this way maximum hardness which is required for production of welding electrodes could be achieved. At homogeneous fine-grained alfa-phase of Cu it is possible to observe the regularly situated inclusions of CoBe compounds inside the whole matrix.

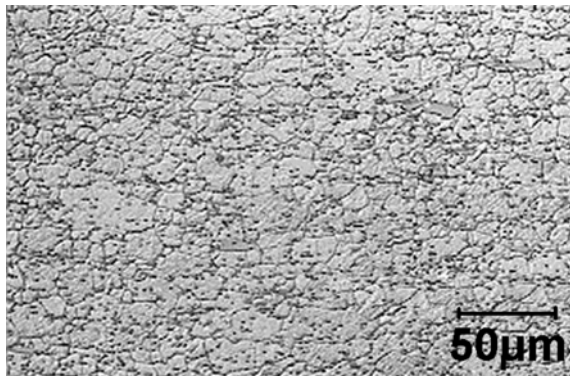


Figure 5. Microstructure of CuCoBe alloy

Slika 5. Mikrostruktura slitine CuCoBe.

For visualization of microstructure, the following etching was used: 1 g of KCN, 100 ml of distilled water.

At Figure 6 there is microstructure of CuCoBe alloy hardened by dissolving annealing at the temperature of 790 °C and consequential rolling during cooling. In this way, it is possible to increase hardness to about 35 % in comparison with material without thermal treatment and formation.



Figure 6. Microstructure of welding tip made by forming of CuCoBe

Slika 6. Mikrostruktura vrha elektrode iz materijala CuCoBe.

Prolonged grains of alfa-phase and inclusions of CoBe could be observed in microstructure. For visualization of a microstructure the following etching was used: 1 g of ammonium hydroxide NH_4OH + 2 g of ammonium persulphate $(\text{NH}_4)_2\text{S}_2\text{O}_8$ (2,4 %) in 100 ml of distilled water.

CuBe_2 alloy at Figure 7 has typical dendritic structure of alfa Cu with Be phases. Berilids could be observed on buffed and unetched samples. Berilids appear during solidification and they are typical with their elongated shape. Secondary berilids occur after solidification and they have a lamellar structure.

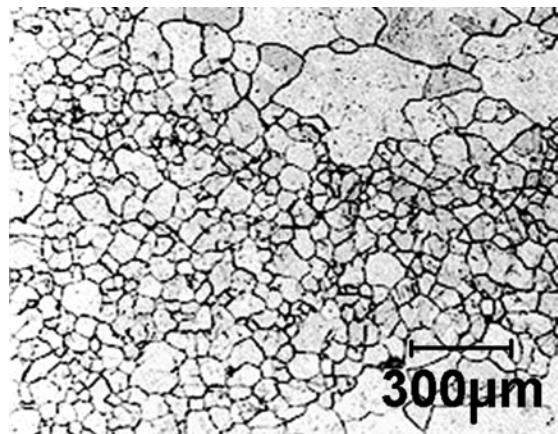


Figure 7. Microstructure of tip material after welding cycle

Slika 7. Mikrostruktura vrha elektrode nakon ciklusa zavarivanja.

Microstructure of the heat affected zone of the tip. Heat has a negative impact on the homogeneity of structure and especially on the size of grains. Nonhomogeneity of the structure was caused by insufficient tip cooling.

For visualization of microstructure, the following etching was used: 1 g of ammonium hydroxide NH_4OH + 2 g of ammonium persulphate $(\text{NH}_4)_2\text{S}_2\text{O}_8$ (2,4 %) in 100 ml of distilled water.

At Figure 8 is a microstructure of grain boundary of thermally unaffected material of CuBe_2 tips, formed and precipitately hardened. It contains rectangular double boundaries of grains of alfa Cu with diffused elements of Ni, Co or Ni and Co with Be_2 .

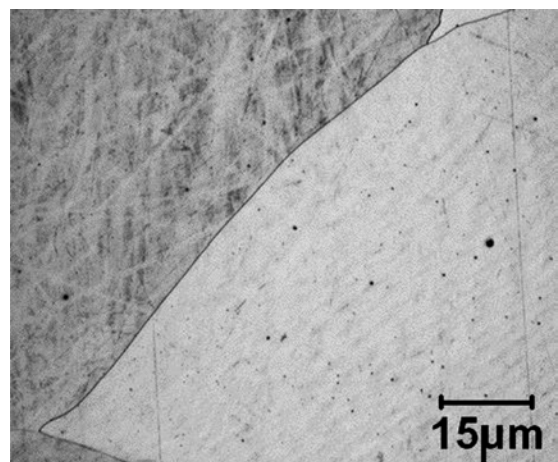


Figure 8. Microstructure of CuBe_2 alloy

Slika 8. Mikrostruktura slitine CuBe_2 .

For visualization of microstructure the following etching was used: 1 g of ammonium hydroxide NH_4OH + 2 g of ammonium persulphate $(\text{NH}_4)_2\text{S}_2\text{O}_8$ (2,4 %) in 100 ml of distilled water.

5. Conclusion

Consumption of welding tips in the production of car bodies in automotive industry reaches almost 50 000 pieces per month. There are several ways to reduce consumption.

Development in the production of welding tips is constantly evolving. Alloys with high conductivity together with hardness are being observed. These enable their usage in application of hard modes of resistance spot welding. One of the innovations is a special alloy dedicated to welding tips of AEG SVS Schweiss Technik company, namely "AEG Wirbalit NIB". It is an alloy whose electrical conductivity corresponds to the alloy CuCrZr, that is 48 MS/m and its hardness corresponds to the alloy CuCoBe, i.e. 270 HB.

Experimental tests carried out in our laboratories confirmed the positive influence of Be as an alloying element in conventional alloys of CuCr which caused the increasing lifetime of the welding electrode tips without significant negative influence on their electrical conductivity. A positive influence on their total electrode lifetime is onto 0,7 % when high electrical conductivity is guaranteed.

The possibility of increasing the strength characteristics without the support of alloying elements comes only in a limited range by choice of suitable technology of production where it is possible to use mainly the hardening effect of formation.

The way of increasing the lifetime of welding tips is a combination of alloying elements in the copper alloys, a method of their production as well as geometric design.

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REFERENCES

- [1] LIPA, M.: *Odporové zvaranie*. 1. vyd.. Bratislava: Weldtech, (1995), 265.
- [2] ÁBEL, M.; VIŇÁŠ, J.: *Hodnotenie vplyvu zvaracích parametrov na životnosť zvaracích špičiek*. In: *Acta Mechanica Slovaca*. roč. 10, č. 4-a Povrchové inžinierstvo, Košice: Viena, (2006), 7-12.
- [3] CHVOJKA J.: *Neželezné kovy a jejich slitiny*, SNTI Praha, (1971), 240.
- [4] ISO 5182: *Resistance welding -- Materials for electrodes and ancillary equipment*.
- [5] ÁBEL, M.; EVIN, E.: *Analýza vplyvu stupňa deformácie na životnosť zvaracích elektród pre odporové zvaranie*. In: *Strojné inžinierstvo 2006 : Zborník príspevkov*, Bratislava: STU, (2006), 514-520.
- [6] VURAL, M.; AKKUS, A.: *On the resistance spot weldability of galvanized interstitial free steel sheets with austenitic stainless steel sheets*. *Journal of Materials Processing Technology* 153-154 (2004), 1-6.
- [7] MARASHI, P.; POURANVARI, M.; AMIRABDOLLAHIAN, S.; ABEDI, A.; GOODARZI, M.: *Microstructure and failure behavior of dissimilar resistance spot welds between low carbon galvanized and austenitic stainless steels*. *Materials Science and Engineering A* 480 (2008), 175-180.
- [8] b1 AŠKOVITŠ, P.; SUKUBOVÁ, I.; DURCOVÁ, J.; KASAI A, M.: *Rozvoj procesov zvarania na zvarané konštrukcie*, In.: *Zvaranie 2001*, Tatranská Lomnica, (2001), 166 - 170.
- [9] KAŠČÁK, Ľ.; SPIŠÁK, E.: *Resistance spot welding of three steel sheets for automotive industry*. In: *PRO-TECH-MA '07 : Progressive Technologies and Materials : International scientific conference*, Rzeszów - Bezmiechowa, Poland, Rzeszów : Politechnika Rzeszowska, (2007), 49-54.
- [10] MORAVEC, J.: *Simulation of Temperature-metallurgical parameters Influence on Dimensions and Shape of Temperature Field*. In: *Junior-Euromat*, Lausanne (CH), září 2006.
- [11] MORAVEC, J.; NEUMANN, H.: *Comparison of the Distribution of Residual Stresses in Welding of Fe Al and High-Alloy Steel Plate*. In: *Zvaranie 2007*, Tatranská Lomnica (2007), 212-217.
- [12] ZHANG, H.; SENKARA, J.: *Resistance welding – Fundamentals and Applications*. Taylor & Francis Group, New York, 2006.