Annals of DAAAM for 2011 & Proceedings of the 22nd International DAAAM Symposium, Volume 22, No. 1, ISSN 1726-9679
ISBN 978-3-901509-83-4, Editor B. Katalinic, Published by DAAAM International, Vienna, Austria, EU, 2011
Make Harmony between Technology and Nature, and Your Mind will Fly Free as a Bird
Annals & Proceedings of DAAAM International 2011

ELECTRON BEAM WELDING OF COPPER TO STAINLESS STEEL

TURNA, M[ilan]; SAHUL, M[iroslav]; ONDRUSKA, J[ozef] & LOKAJ, J[an]

Abstract: *The contribution deals with electron beam welding of dissimilar metals. Technically pure copper and austenitic non-stabilized CrNi stainless steel were selected as base materials. The welding was carried out in the horizontal position in vacuum. Especially, mechanical and physical properties of copper and austenitic stainless steel as well as Fe-Cu binary diagram were taken into consideration. Quality of welded joints was evaluated by optical microscopy, microhardness measurement across welded joint and EDX microanalysis. It can be stated, that produced welded joints without the presence of any imperfections.*

Key words: *electron beam welding, copper, stainless steel, quality control of welds*

1. INTRODUCTION

Electron beam welding (EBW) is characteristic by production of high depth to width ratio welds with narrow HAZ, low distortion, without presence of oxides. These joints can be produced at a high welding speed. EBW was successfully applied in welding dissimilar metals (Turna, 1989; Lippold, 2011). Welded joints of dissimilar metals, such as copper and stainless steels are utilized in various applications, for instance in aerospace applications, chemical, petrochemical, nuclear and electronics industries (Mai et al., 2004).

In the power-generation industries, the copper - steel material combinations have often been widely used due to high electrical conductivity and stiffness (Chengwu et al., 2009). Fusion welding of these metals brings many difficulties. This is due to their different physical, metallurgical and mechanical properties. Application of welding with concentrated energy source of mentioned combination of materials is the object of research carried out at many research institutions. *Chengwu et al.* dealt with welding of copper to low carbon steel with CO_2 laser. The main problem in laser welding is high reflexivity of CO_2 laser radiation from the surface of copper. The authors investigated the microstructure near the interface between Cu plate and the intermixing zone (Chengwu et al., 2009). *Kanaujia et al.* performed Nd:YAG laser welding of dissimilar metals AISI 304 stainless-steel and copper. In their study a statistical design of experiment was used to optimize selected welding parameters (Kanaujia et al., 2011).

The aim of this paper is the production of sound welded joints of dissimilar metals and evaluation of their quality.

2. EXPERIMENTAL

Austenitic non-stabilized stainless CrNi steel AISI 304 and technically pure copper were selected as welded materials. Design of welded component is given in Fig. 1. Outer diameter of stainless steel pipe is Ø 60 mm and inner diameter is Ø 56 mm.

Circumferential welds were produced in experiment. The electron beam welding was carried out in vacuum. Welded joints were made in pro-beam AG & Co. KGaA Company, Germany. Electron beam was deflected 100 μm towards to AISI 304 steel due to lower melting point of copper.

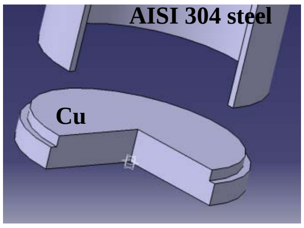

Fig. 1. Design of welded component

Universal Chamber EB Machine typ K7 was used for the production of welded joints. Welding parameters are listed in Tab. 1.

$I_{welding}$ [mA]	$I_{focusing}$ [mA]	v_{speed} [mm.s^{-1}]
33.75	515	25

Tab. 1. Welding parameters

Optical microscopy, microhardness measurements and EDX microanalysis were used for assessment of welded joints quality.

Cross-section of welded joint is given in Fig. 2. Cut was performed at the end of the weld. As could be seen in Fig. 2, the welded joint exhibits a slight concavity. The presence of undercut was also documented.

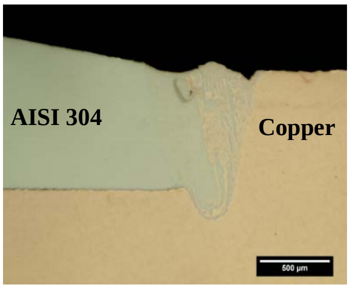

Fig. 2. Macrostructure of welded joint (polished)

ImageJ program was used for measurement of welded joint dimensions. The width of the weld at the surface of weld bead was approximately 1.268 mm and depth of penetration is 1.59 mm. As mentioned above, AISI 304 is non-stabilized austenitic CrNi stainless steel. The structure of AISI 304 is cold rolled (grains are elongated in the cold rolling direction). The structure consists of polyhedral grains of austenite. Structure of produced welded joint is given in Fig. 3.

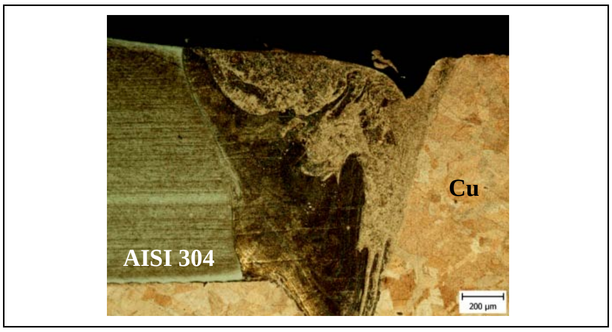

Fig. 3. Structure of welded joint (after etching)

In the further stage of quality control of welded joints, microhardness measurement through base material (AISI 304 steel) – Weld Metal (WM) - Cu interface was performed. Distance between individual indents was 150 µm. Loading used was 100 g, acting during 10 sec. Microhardness measured in copper averaged 67 HV0.1. The increase of microhardness from copper towards weld metal was recorded. Mentioned hardness increasing can be attributed to intermixing of welded materials in WM. On the other hand, measured values of microhardness in AISI 304 steel were higher than that measured in WM (Fig. 4.). That microhardness decrease could be associated with recrystallization, which occurred during welding.

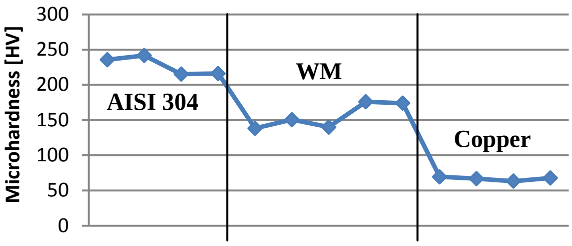

Fig. 4. Course of microhardness across welded joint

EDX microanalysis was used for more detailed study of welded joint with X-ray microanalyzer JEOL JXA - 840 A.

Measurements were assessed by KEVEX computer software. Area studied with EDX microanalysis is documented in Fig. 5. The courses of changes in concentration of Cr, Ni, Cu and Fe across the Cu - WM - AISI 304 steel interface are given in Figs. 6. to 9.

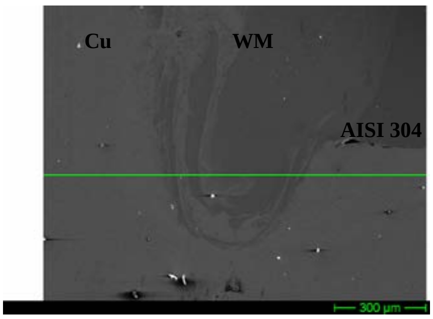

Fig. 5. Area studied by EDX microanalysis

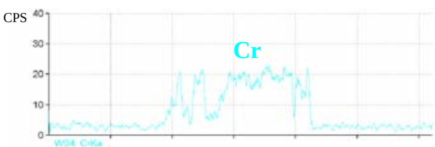

Fig. 6. The course of change in concentration of **Cr** across weld

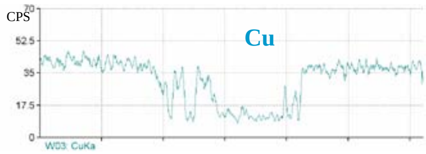

Fig. 7. The course of change in concentration of **Cu** across weld

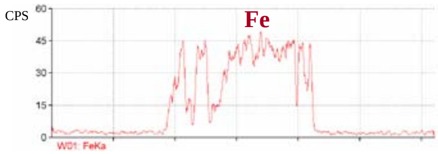

Fig. 8. The course of change in concentration of **Fe** across weld

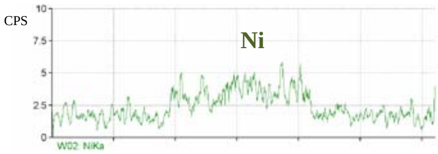

Fig. 9. The course of change in concentration of **Ni** across weld

3. CONCLUSION

The contribution solves the issue of welding dissimilar metals austenitic CrNi stainless steel and copper. As mentioned earlier, electron beam welding was proposed as the proper technology. The vacuum was important in the welding process to prevent the oxidation of both metals. Regarding to high reflexivity of laser radiation from the copper surface, electron beam welding was proposed instead of laser beam welding.

The steel was supplied in cold rolled condition. Microhardness measurement revealed decreasing of the steel hardness towards weld metal. It can be assumed, that recrystalization takes place. EDX microanalysis was carried out in order to study the weld joint interface more detailed. The increase of Cr, Ni, and Fe concentration in the weld metal was recorded. Liquation cracking is the problem of welding such combination of materials due to lower melting point of Cu. In this case they were not observed.

4. ACKNOWLEDGEMENT

The submitted work was prepared with the support of Grant agency VEGA, MŠVVŠ SR and SAV, project No. 1/0842/09.

5. REFERENCES

Kanaujia, K. K. et al. (2011). Optimization of Tensile Strength of AISI 304 Stainless Steel and Copper using Nd:YAG Laser Welding. *Proc. of the 5th International Conference on Advances in Mechanical Engineering (ICAME 2011),* June 06-08, 2011 S.V. National Institute of Technology, Surat – 395 007, Gujarat, India

Lippold, J. (2011). *Hot Cracking Phenomena in Welds III.* Springer-Verlag, ISBN 978-3-642-16864-2, Berlin

Mai, T. A.; Spowage, A. C. (2004). Characterisation of Dissimilar Joints in Laser Welding of Steel–Kovar, Copper–Steel and Copper–Aluminium. *Materials Science and Engineering: A*, Volume 374, Issues 1-2, June 2004, p. 224-233, ISSN 0921-5093

Turňa, M. (1989). *Špeciálne metódy zvárania (Special Welding Methods).* SNTL, ISBN 80-05-00097-9, Bratislava

Yao, Ch.; Xu, B.; Zhang, X.; Huang, J.; Fu, J. & Wu Y. (2009). Interface Microstructure and Mechanical Properties of Laser Welding Copper–Steel Dissimilar Joint. *Optics and Lasers in Engineering*, Volume 47, Issue 7-8, July 2009, p. 807-814, ISSN 0143-8166