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Study of laser welding of copper sheets

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ABSTRACT

Purpose: Purpose of this research is to study laser autogenous welding process of short seam beads and fillet welds of lap joints of oxygen-free copper sheets 1.0 [mm] thick. On the bases of results of quality assessment it was proved that high power diode laser (HPDL) welded lap joints of copper sheet provide mechanical properties on the level of parent material.

Design/methodology/approach: Short seam beads and fillet welds of lap joints of oxygen-free copper sheets 1,0 [mm] thick were tested, to establish the optimum parameters of high power diode laser autogenous welding process.

Findings: It was shown that there is very narrow range of optimum HPDL autogenous welding parameters of short seam beads and fillet welds of lap joints of oxygen-free copper sheets 1,0 [mm] parameters. It was proved that high power diode laser (HPDL) autogenous welded lap joints provide mechanical properties on the level of parent material.

Practical implications: It is possible to produce high quality short seam bead and fillet weld lap joints of oxygen-free copper sheets 1.0 [mm] thick. It was proved that high power diode laser (HPDL) autogenous welded lap joints provide mechanical properties on the level of parent material.

Originality/value: The optimum HPDL autogenous welding parameters of short seam beads and fillet welds of lap joints of oxygen-free copper sheets 1.0 [mm] parameters makes possible to produce high quality laser autogenous welded lap joints of copper sheets 1.0 [mm] thick.

Keywords: Autogenous welding; Lap joints; High Power Diode Laser; Copper sheet

1. Introduction

Forecast pertaining to the global economics development factors regard laser manufacturing techniques as the most promising and efficient ones for ensuring the development in world industries. Rapid development of industrial welding lasers contains the new high power diode lasers (HPDL), which provides extensive changes of development and significant extension of the surface engineering technology [1-9].

Copper and copper alloys offer a unique combination of material properties that makes them advantageous for many manufacturing environments [10-15]. Copper and its alloys constitute one of the major groups of commercial metals. They are widely used because of their excellent electrical and thermal conductivities, outstanding corrosion resistance, ease of fabrication, and good strength and fatigue resistance. Other useful characteristics include spark resistance, metal-to-metal wear resistance, low-permeability properties, and distinctive colour.

In manufacturing, copper thin sheet structures are often joined by welding processes like gas-tungsten arc welding (GTAW), gas-metal arc welding (GMAW), plasma arc welding friction welding, brazing and laser welding [10-15]. Laser welding technology provides high quality joints and high efficiency of welding. The paper presents results of study done in Welding Department of STU of laser lap joints HPDL laser welding of 1,0 [mm] thick oxygen-free copper (UNS C10100).

2. Experimental

The experiments were made on specimens made from the oxygen-free copper (UNS C10100) sheets 1,0 thick. The chemical composition, mechanical and physical properties of copper sheet are presented in Table 1.

Table 1.
Chemical composition and mechanical and physical properties of oxygen-free copper (UNS C10100)

Element	Cu	Sn	Pb	Fe	P	Sb	Bi	As	Ni	S
Composition [wt-%]	99,94	0,003	0,005	0,019	0,019	0,001	0,0001	0,001	0,001	0,003

Tensile strength [MPa]	Yield stress [MPa]	Rockwell hardness	Shear strength [MPa]	Elogation [%]
234	69	45	159	45

Density [g/cm^3]	Thermal conductivity at 20°C [W/m · K]	Electrical conductivity [MS/cm]	Thermal expansion at 20°C α [10^{-6}/C]	Young`s modulus [MPa]	Kirchhoff`s modulus [MPa]
8,94	339,2	0,497	17,1	117000	44130

The surface of copper sheets specimens was prepared to HPDL autogenous welding by mechanical and chemical cleaning. To establish HPDL optimal welding parameters providing high quality lap joints preliminary bead-on-plate (seam) welding tests were conducted on copper sheet 2,0 [mm] thick, Fig. 1. Bead-on-plate welds were remelted with no consumable addition at the range of HPDL power 1,8 – 2,2 [kW], and speed of welding 100 – 400 [mm/min]. Results of bead-on-plate tests allow to establish very narrow range of optimum HPDL welding parameters of lap joints of copper sheets 2,0 [mm] thick. The farther tests of welding the copper sheets 1,0 [mm] thick were conducted at laser power 2,2 [kW] and speed of welding 100 [mm/min]. A view of short seam beads of lap joints of copper sheets 1,0 [mm] thick were presented on Table 2, 4.

To establish HPDL autogenous welding parameters providing high quality fillet welds of lap joints of copper sheets 1,0 [mm] thick preliminary tests were conducted at the range of HPDL power 2,0 – 2,2 [kW], and speed of welding 300 – 500 [mm/min]. During the test the edge of upper sheet of lap joint was melted to achieve fillet weld. A view of fillet welds of lap joints of copper sheets 1,0 [mm] thick are presented on Table 3, 4.

Results of quality assessment of HPDL autogenous welded lap joints by tensile and bending tests, are given in Tables 5, 6.

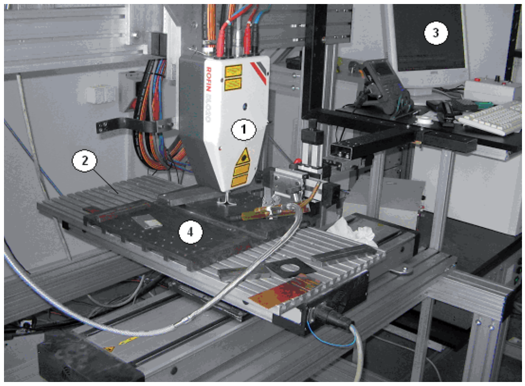
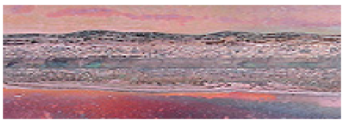
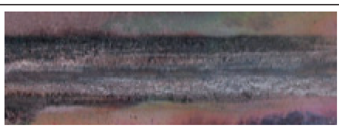
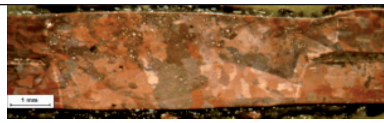


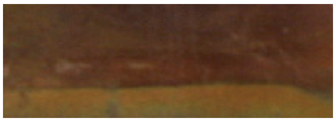
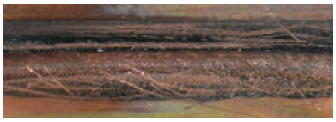
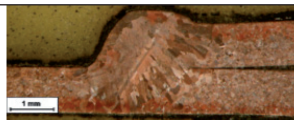
Fig. 1. A view of HPDL welding stand equipped with 1 – laser`s head, 2 – ISEL AUTMATION CNC table, 3 – computer control, 4 – steel plate

Table 2.
A view of short seam bead of lap joints of copper sheets 1,0 [mm] thick

Bead weld no.	A view of face of bead	A view of root of bead	A view of macrostructure
1			
2			
3			
4			

Remarks: welding parameters: welding speed – 100 [mm/min], laser beam power 2,2 [kW], Beads no. 1 and 3 were welded on austenitic backup, bead no. 4 was welded on argon backup

Table 3.
A view of fillet welds of lap joints on copper sheets 1,0 [mm] thick

Bead weld no.	Speed of welding [mm/min	A view of face of bead	A view of root of bead	A view of macrostructure
1	300			
2	500			
3	500			

Remarks: welding parameters: laser power 2,2 [kW], beads no. 1 and 2 were welded on austenitic backup, bead no. 3 was welded on argon backup

Table 4.
Influence of the HPDL autogenous welding parameters of lap joints of copper sheets 1,0 [mm] thick on the weld geometry

Bead weld no	Width of face [mm]	Depth of penetration [mm]	Cross – section area [mm^2]
1 (Table 2)	5,83	2,0	9,03
2 (Table 2)	5,66	2,0	8,67
3 (Table 2)	5,79	2,0	8,91
4 (Table 2)	6,21	2,0	10,04
1 (Table 3)	3,84	2,0	6,23
2 (Table 3)	3,34	1,42	3,6
3 (Table 3)	2,65	1,8	4,02

Table 5.
Results of static tensile test of lap joints of copper sheets 1,0 [mm] thick HPDL welded, Table 2, 3

Bead weld no	Break load [KN]	Tensile strengh [MPa]	Area of break
1, (Table 2)	4,011	100	HAZ
2, (Table 2)	4,059	103	HAZ
1, (Table 3)	3,225	80	Bead weld
2, (Table 3)	2,926	73	Bead weld

Remarks: R_m of parent material 248 [MPa]

Table 6.
Results of static bending test of lap joints of copper sheets 1,0 [mm] thick HPDL welded, Table 2, 3

Bead weld no.	Max bending angle [°]	Results of the transverse band test
1, (Table 2)	100	bead weld cracks
2, (Table 2)	90	bead weld cracks
3, (Table 3)	180	bead weld cracks
4, (Table 3)	180	no cracks

3. Summary

On the basis of the study of the technology of HPDL autogenous welding of lap joints of oxygen-free copper sheets 1,0 [mm] thick following conclusions are drown:

1. It is possible to produce high quality short seam bead and fillet weld lap joints of oxygen-free copper sheets 1,0 [mm] thick.
2. High quality short seam bead of lap joints are provided at the 100 [mm/min] speed of welding and 2,2 [kW] laser power.
3. High quality fillet welds of lap joints are provided at the 500 [mm/min] speed of welding and 2,2 [kW] laser power.

4. Tensile strengh of the fillet welds of lap joints is 25% lower than tensile strengh of the short seam bead of lap joints due to joint design. Tensile strength of the short seam bead of lap joints is 60% lower than tensile strengh of base material and tensile strengh of the fillet welds of lap joints is 70% lower than tensile strengh of base material due to strong structural changes in the area of weld metal and HAZ of joints.

References

[1] A. Klimpel, Surfacing and thermal spraying, Technologies, WNT, W-wa, 2000.

[2] T. Nacey, Diode laser offer welding advantages, Welding Journal, 6 (2001) 28 – 30.

[3] L. Lin, The advances and characteristics of high-power diode laser materials processing, Optics and Lasers Engineering, 34 (2000) 231 – 253.

[4] L.A. Dobrzanski, M. Bonek, E. Hajduczek, A. Klimpel, A. Lisiecki, Application of high power diode laser (HPDL) for alloying X40CrMoV5-1 steel surface layer by tungsten carbides, Journal of Materials Processing Technology, 155–156 (2004) 1956–1963.

[5] A. Klimpel, L.A. Dobrzanski, A. Lisiecki, D. Janicki, The study of the technology of laser and plasma surfacing of engine valves face made of X40CrSiMo10-2 steel using cobalt-based powders, Journal of Materials Processing Technology, 175 (2006) 251–256.

[6] L.A. Dobrzanski, M. Bonek, E. Hajduczek, A. Klimpel, Alloying the X40CrMoV5-1 steel surface layer with tungsten carbide by the use of a high power diode laser, Applied Surface Science, 247 (2005) 328–332.

[7] L.A. Dobrzanski, M. Bonek, E. Hajduczek, A. Klimpel, A. Lisiecki, Comparison of the structures of the hot-work tool steelslaser modified surface layers, Journal of Materials Processing Technology, 164–165 (2005) 1014–1024.

[8] M. Bonek, L.A. Dobrzanski, E. Hajduczek, A. Klimpel, Structure and properties of laser alloyed surface layers on the hot-work tool steel, Journal of Materials Processing Technology, 175 (2006) 45–54.

[9] A. Klimpel, L.A. Dobrzanski, A. Lisiecki, D. Janicki, The study of the technology of laser and plasma surfacing of engine valves face made of X40CrSiMo10-2 steel using cobalt-based powders, Journal of Materials Processing Technology, 175 (2006) 251–256.

[10] Welding Handbook. 8 edition, 3, Materials and applications – part 1, 163-215.

[11] http://www.key-to-nonferrous.com, Welding of Copper Alloys.

[12] http://www.key-to-nonferrous.com, Copper and copper Alloys.

[13] F. Curcio, G. Daurelio, F. Memola capece Minutolo, F. Caiazzo, On the welding of different materials by diode laser, Journal of Materials Processing Technology, (2006) 83 – 89.

[14] L. Brown, Joining copper and copper alloys, Weld. Met. Fabr., 1 (1995) 18-21.

[15] D.T. Peters, Copper alloys for industrial hardware, Advanced Materials & Processes, 150 (1996).