EUROPEAN UNION

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Structural Funds
2007-2013

ECOSOLDER

Romania - Republic of Serbia
IPA Cross-border Cooperation Programme

Project: Promoting new ecologic filler alloys for soldering, based on the non-ferrous ore of the Romanian-Serbian cross-border area

Project Reference: MIS ETC Code 1409

CLOSING CONFERENCE 21st of November 2014

“Achievements of the ECOSOLDER Project. Recommended applications for ecological filler alloys”

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„Experiments on innovative processes for ecological filler alloys”.

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Experiments for the innovative processes:

1. ***Friction stir soldering (FSS)***
2. ***Laser soldering***
3. ***Electric soldering***
4. ***Brazing***
5. ***Weld-brazing***

Experiments with new alloys for soldering and brazing, produced by MMI Bor, are also presented .

1. Friction stir soldering (FSS)

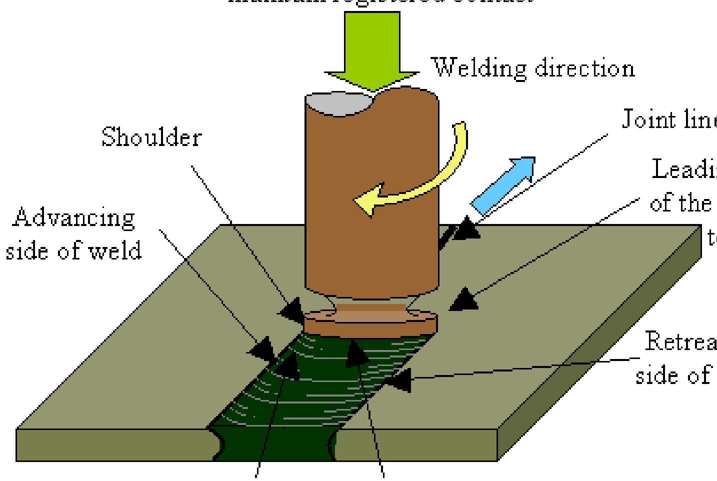


Fig. 1. Friction stir welding principle

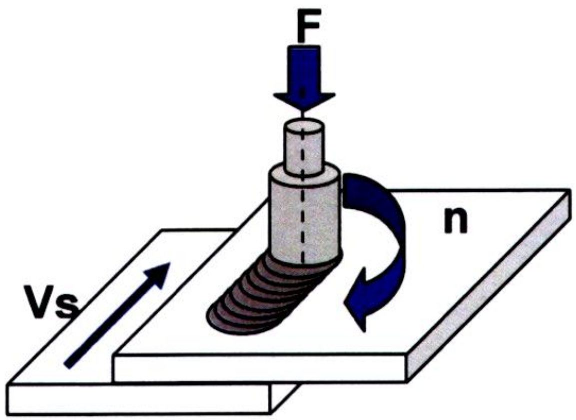


Fig. 2. Schematically presentation of the overlapped friction stir welding principle

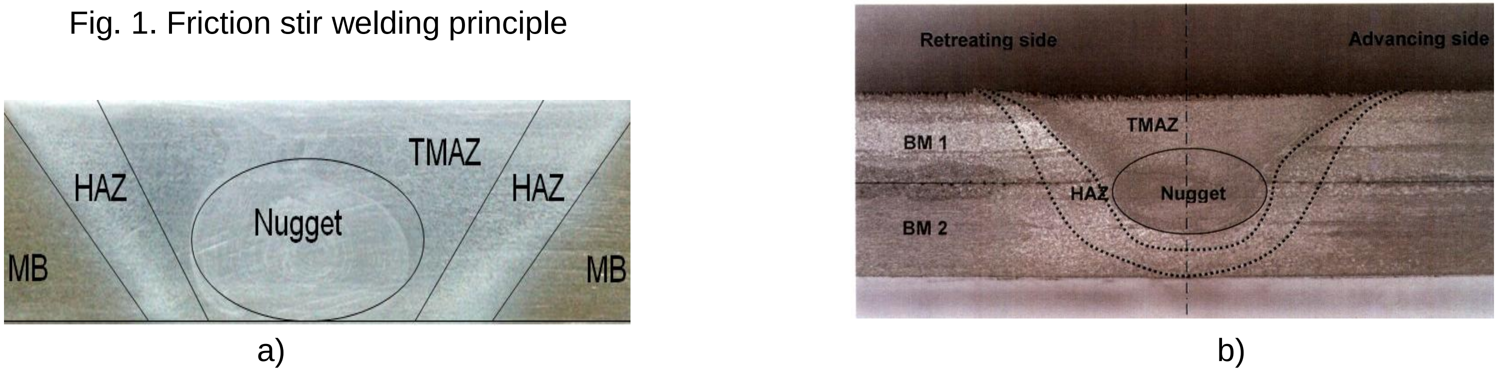
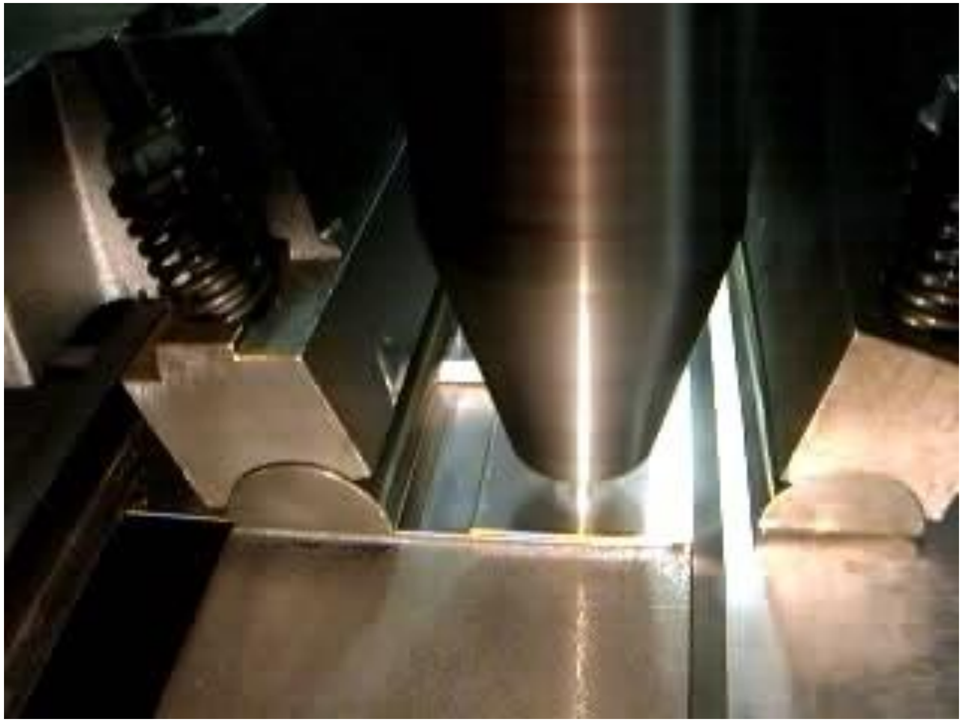


Fig. 3. Zones of welded joint

Friction stir welding principle



Friction stir welding equipment and tools

Fig. 4. Friction Stir Welding equipment

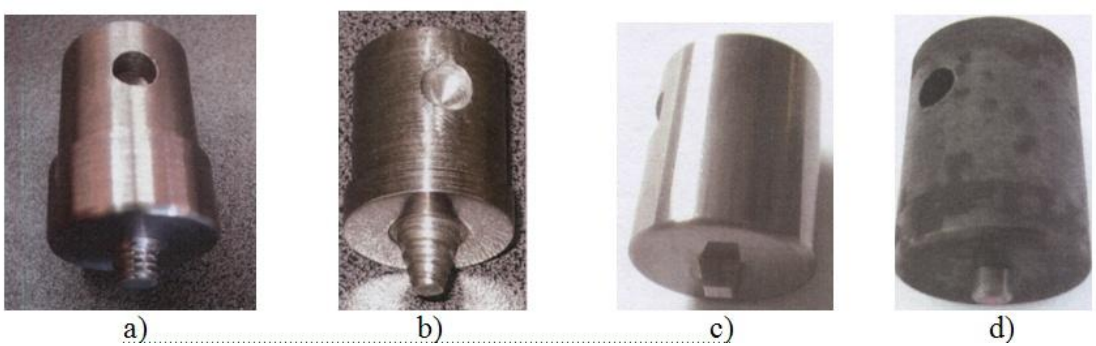


Fig. 5. Pin of the welding tool: a) threaded cylindrical; b) spiral conical shape; c) conical with four flat chamfers; d) smooth cylindrical

ISIM achievements in FSW field

Patent no A2007/00920

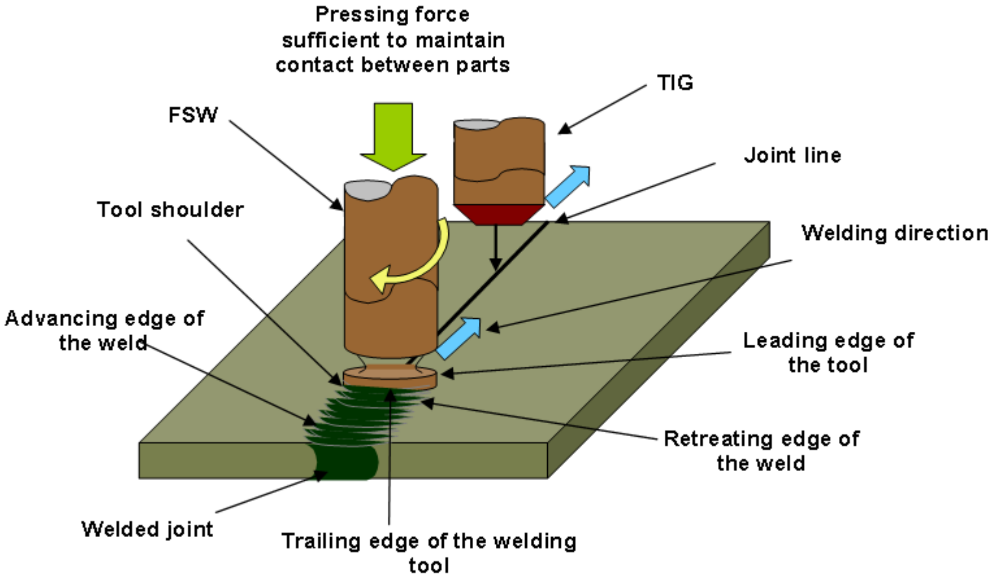


Fig. 6. FSW-TIG scheme

Device with FSW tool **TIG welding head**

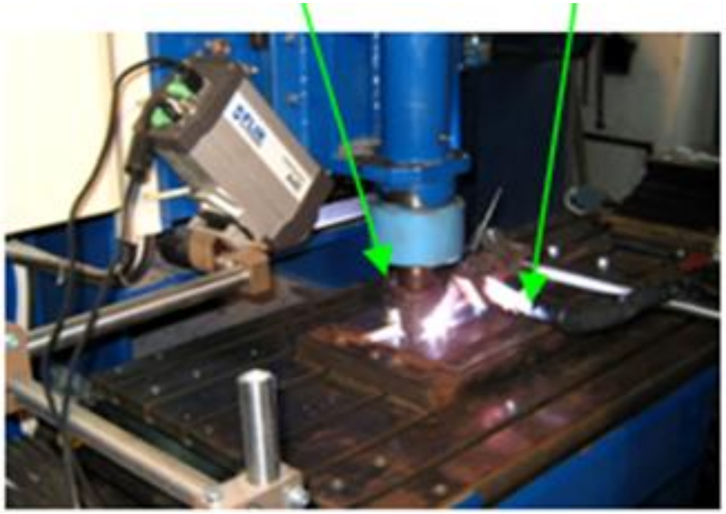


Fig. 7. FSW-TIG assembly

ISIM achievements in FSW field. Using infrared thermography at monitoring FSW process

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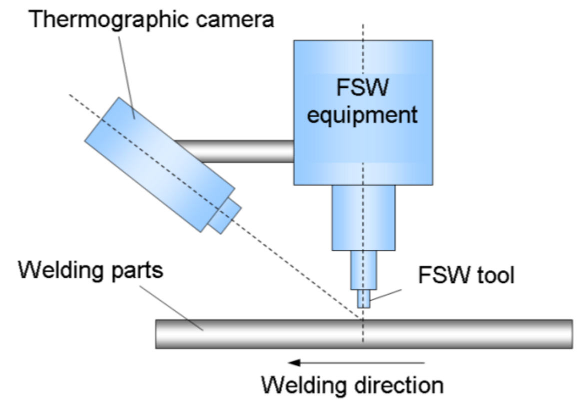

Fig. 8. Scheme of positioning for thermographic camera on FSW machine

Patent request no A/00531/11.07. 2012

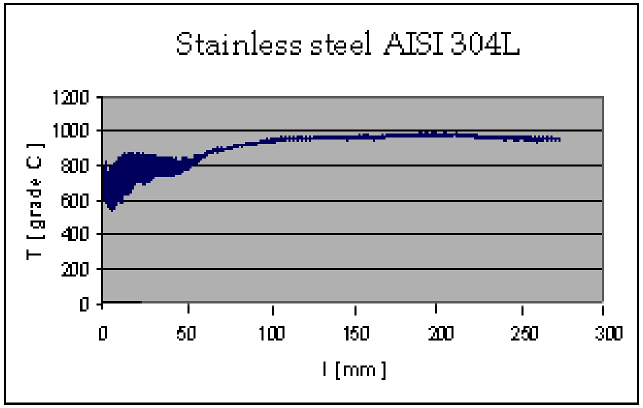

Fig. 9. Evolution of temperature – AISI 304L, monitoring by infrared thermographic camera

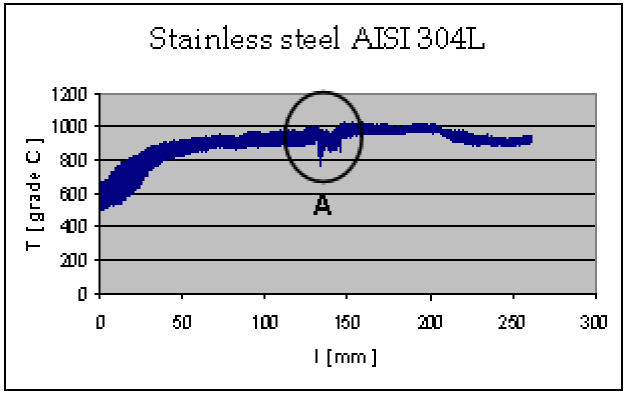

Fig. 10. Detection of defect by thermography

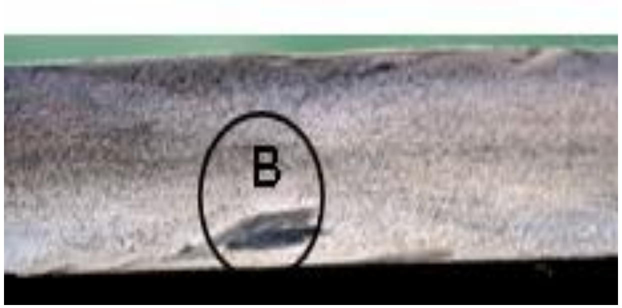

Fig. 11. Detection of defect in welded joint

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ISIM achievements in FSW field
Surfacing with functional layers

Patent request no A/01277/2010

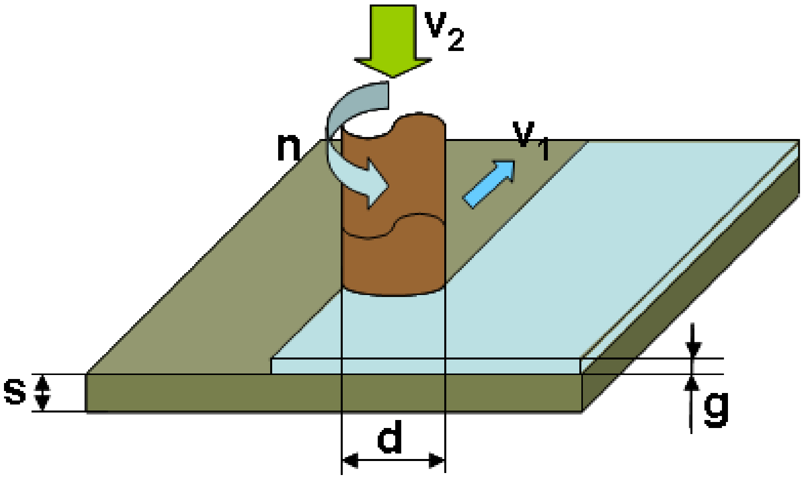

Fig. 12. Scheme of deposition procedures

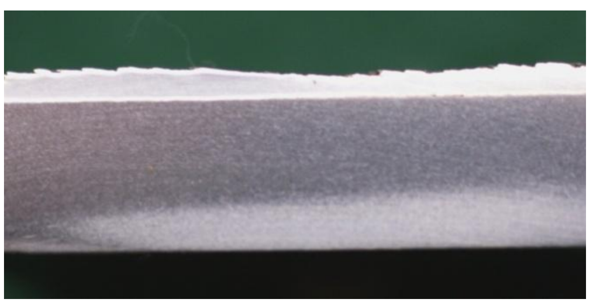
Fig. 14. Macroscopic aspect of deposition

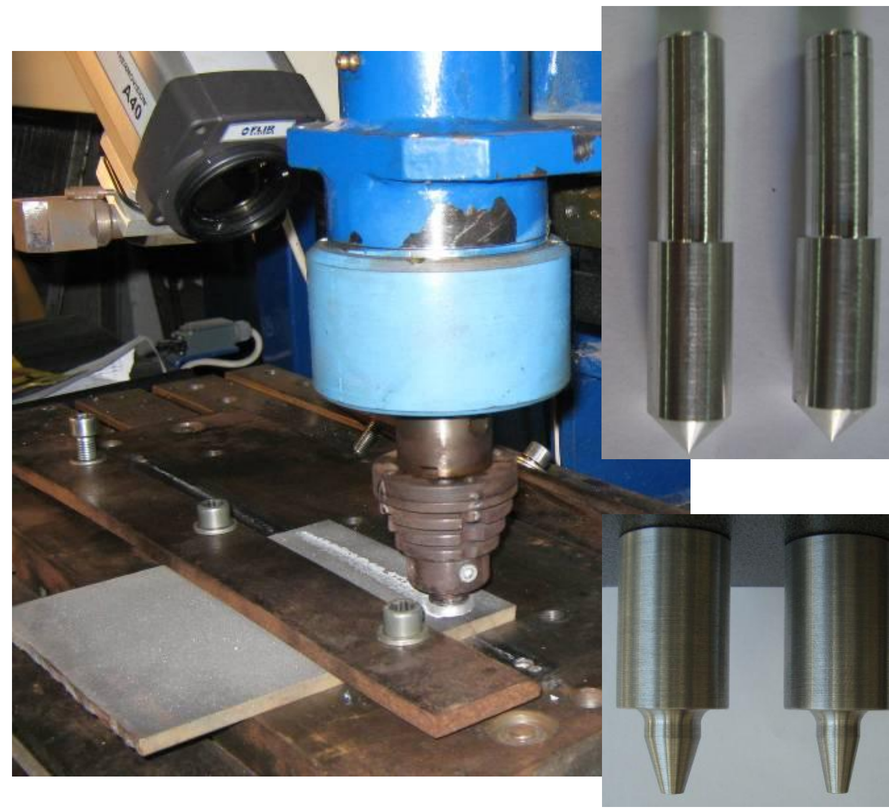

Fig. 13. Deposition of functional layers

FSS bonding preliminary experimental program
Innovative bonding process principle

- Total elimination of the tool tip (figure 15)
- Using a small tool tip (length l = max. 1 mm and 2-3 mm in diameter) when bonding sheets with thicknesses greater than 2 mm which will ensure a linear tool displacement motion (figure 16)

Fig. 15. Bonding (soldering) tool without the tip

Fig. 16. Bonding (soldering) tool with small tip

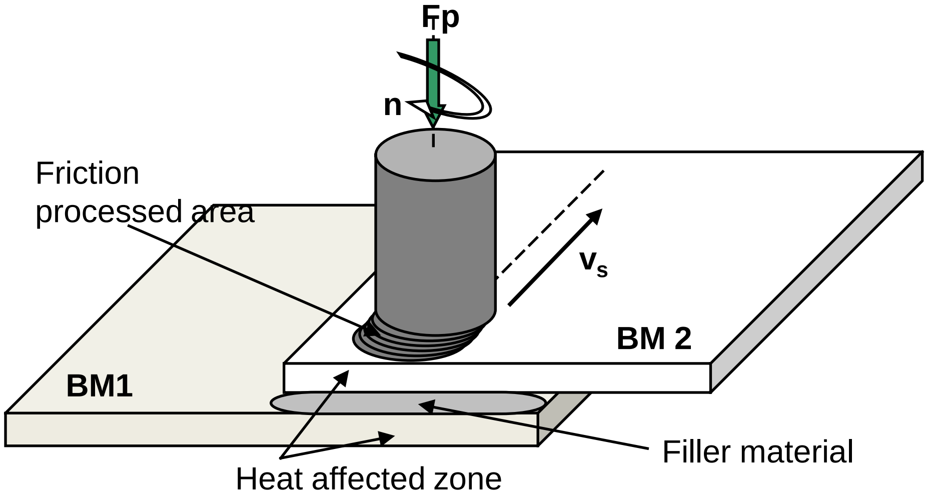

Fig. 17. Friction stir bonding principle

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FSS bonding preliminary experimental program - materials

Base materials used:

- aluminium EN AW 1200	- 1.5 and 2 mm thick;
- aluminium EN AW 5754	- 3 mm thick;
- copper Cu99	- 1,5 mm and 2 mm thick;
- brass Cu Zn39Pb2	- 1,0 mm thick;
- steel S235	- 2 mm thick;

Friction stir bonding tools (FSB):

- material	- sintered tungsten carbide – P20S;
- shoulder diameter	- Φ 20 mm;
- tools	- with conical smooth tip;
	- without tip;

Parameters of the bonding process:

- tool rotation:	- 750 ÷ 1450 rot/min;
- speed:	- 30 ÷ 100 mm/min;

Bonding materials:

- filler material	S-Sn97Cu3
- soldering flux for aluminium,	type ALUTIN;
- soldering flux for copper,	type ROSOL3.

FSS bonding preliminary experimental program. Establishing preliminary process parameters

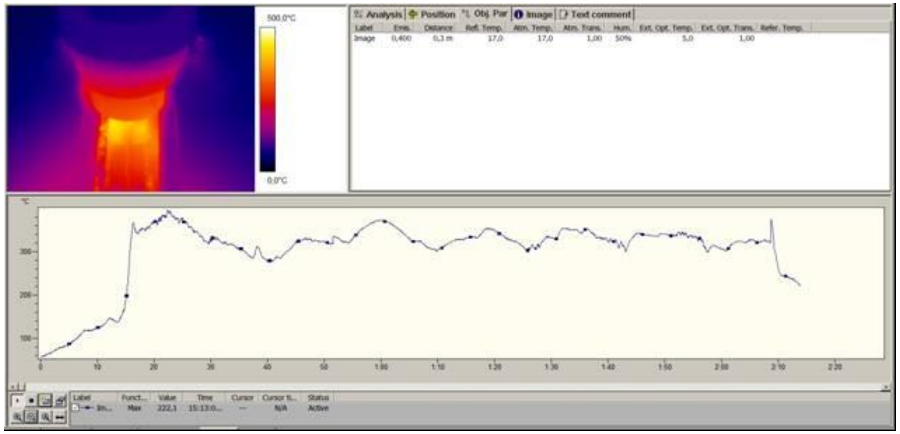

Fig. 18. Temperature of the processed surface for 3 mm EN AW 5754 (n=1450 rot/min; v=50 mm/min)

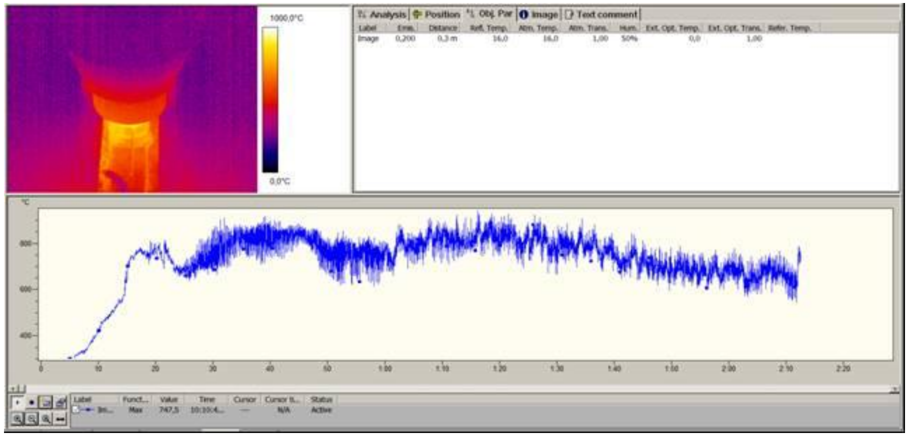

Fig. 19. Temperature of the processed surface for 2 mm Cu99 (n=900 rot/min; v=50, 100 mm/min)

For experimentations preliminary values have resulted:

- Bonding tool diameter
- Tool rotation
- Tool displacement speed

Temperatures:

- EN AW 1200 … 170-300˚C
- EN AW 5754 … 200-370˚C
- Copper alloys… 800-850˚C
- Steels … 800-950˚C

FSS bonding preliminary experimental program – Copper alloys

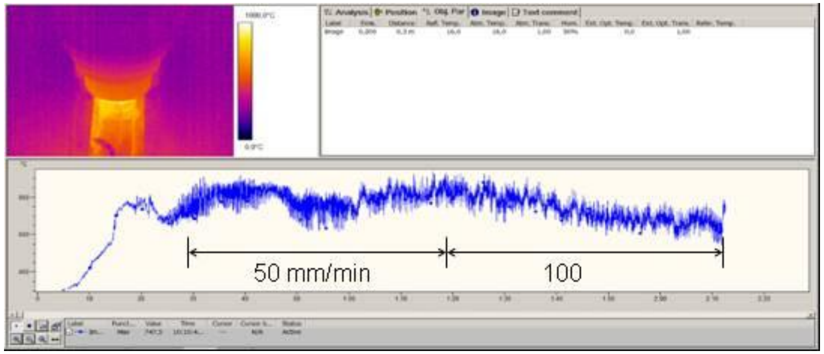

Fig. 20. FSS temperature evolution (Case I)

The samples failed in the bonded joints at different values of the force :
- at the start of the process after the tool moved approximately 20mm with a speed of 50mm/min – Fmax=2050N;
- after a tool displacement of 70mm with a speed of 50mm/min – Fmax=2300N;
- after a tool displacement of 40mm with a speed of 100mm/min – Fmax=3740N;
- after a tool displacement of. 70mm with a speed of 100mm/min – Fmax=5000N;

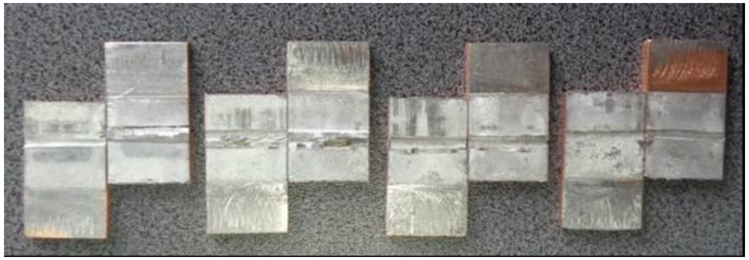

Fig. 21. Bonded joints aspect after shear tensile strength tests – Case I

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FSS bonding preliminary experimental program – Copper alloys

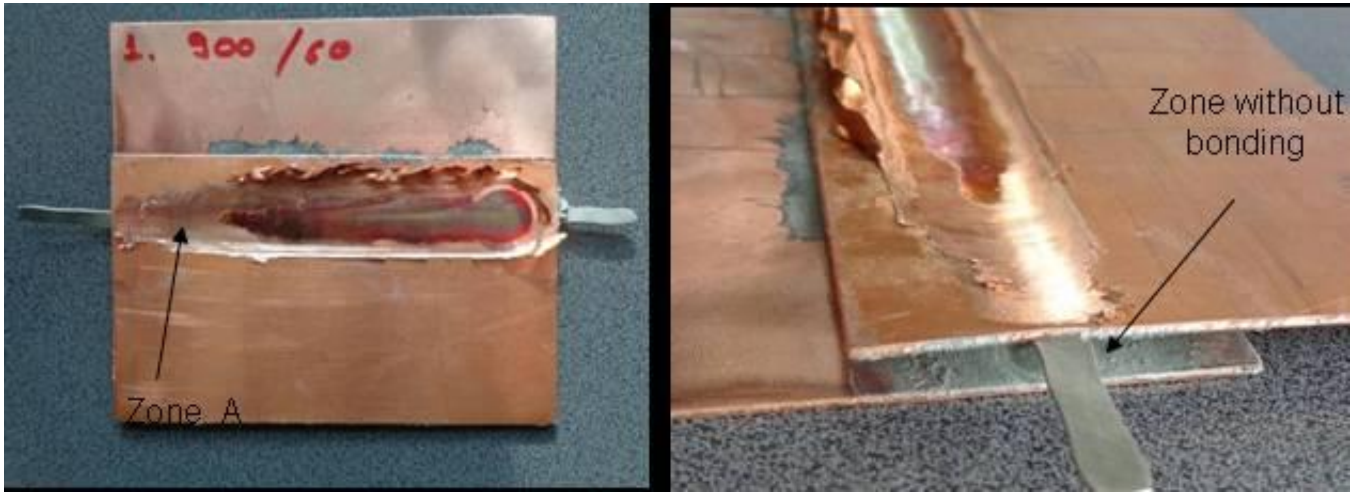


Fig. 22 Aspect of the processed area – Sample 1 (Case II)

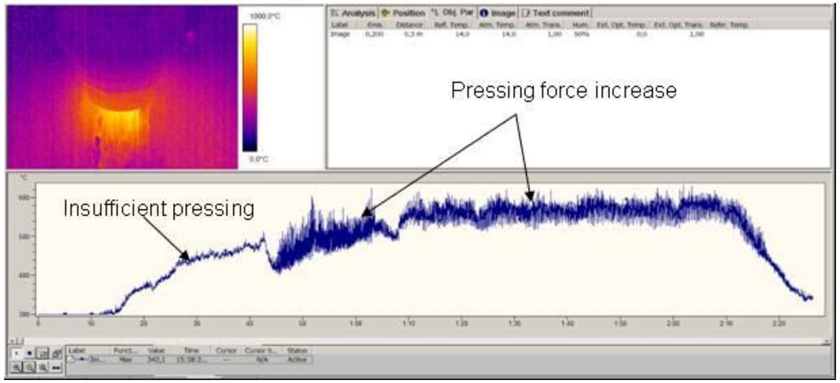


Fig. 23. Temperature evolution – Sample 1 (Case II)

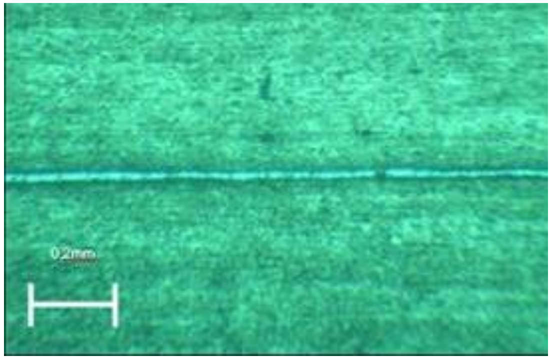


Fig. 24. Aspect of the cross section of the bonded joints (30x) (Sample 2 – Case II)

FSS bonding preliminary experimental program – Cu 99 – CuZn39Pb2

During this experiment FSB was tried on Cu99 – CuZn39Pb2. The following process parameters were used:

- Soldering tool without tip, shoulder diameter Ø20mm, made from sintered tungsten carbide
- Tool rotation, n = 1000 rot/min
- Tool displacement speed, v = 50 mm/min

Base materials:

- CuZn39Pb2 sheet with 1.5 mm thickness
- Cu99 sheet with 1.5 mm thickness

Filler materials:

- Flattened at 0.2 – 0.3 mm thickness – S-Sn97Cu3

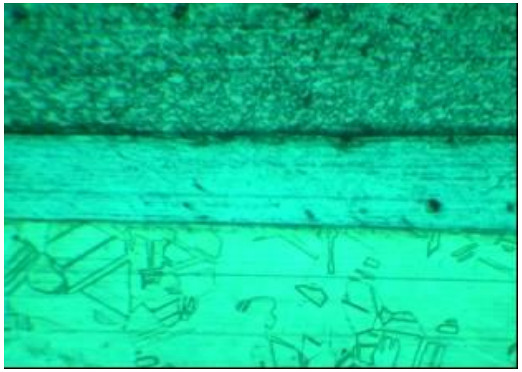


Fig. 25. Macroscopic aspect of the joint Cu99 with CuZnPb2

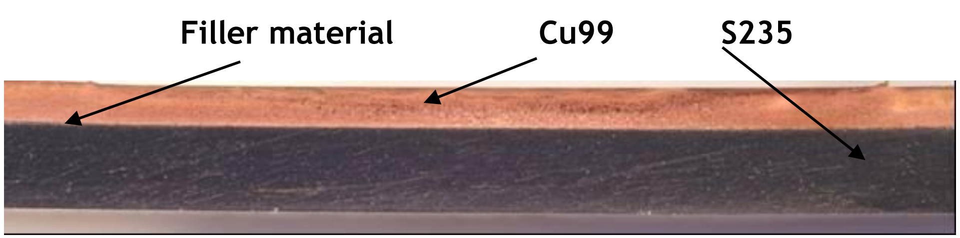
The filler material is equally distributed between the Cu99 and CuZnPb2 sheets. No major defects can be observed in the bond. At tensile test the sample failed at force values between: Fmax = 1700 – 2200N.

FSS bonding preliminary experimental program – Cu 99 – Steel S235

Experimentation conditions:

- Cu99 sheet with 1.5 mm thickness, placed on top.
- S235 sheet with 3 mm thickness
- Tool without tip and with shoulder diameter Ø20mm made from sintered tungsten carbide P20S.
- Tool rotation n = 1000 rot/min
- Tool displacement speed, v = 50 mm/min
- Filler material S-Sn97Cu3

Fmax ≈ 3500 N



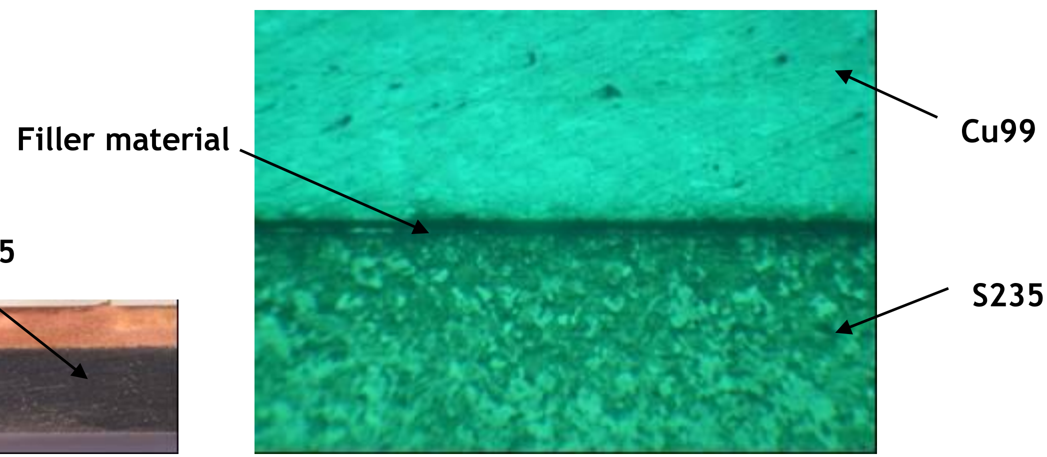


Fig. 26. Macroscopic aspect of samples extracted at 15 mm away from the start of the bonding process

FSS bonding preliminary experimental program – Steel S235

Experimentation conditions:

- S235 steel sheet with 3 mm thickness.
- Bonding tool without tip with shoulder diameter Ø20 mm made from sintered tungsten carbide P20S.
- Tool rotation n = 1000 rot/min
- Tool displacement speed, v = 50 mm/min

The sample processed at 30 mm from the start of the process failed at a force value Fmax = 2800 N with the process temperature at 580 – 600˚C.

The other two samples extracted at 75mm and 80 mm from the process start failed at a maximum force value of 5100 N with the process temperature at 650 – 700˚C and 4850 N when the temperature was 850˚C.

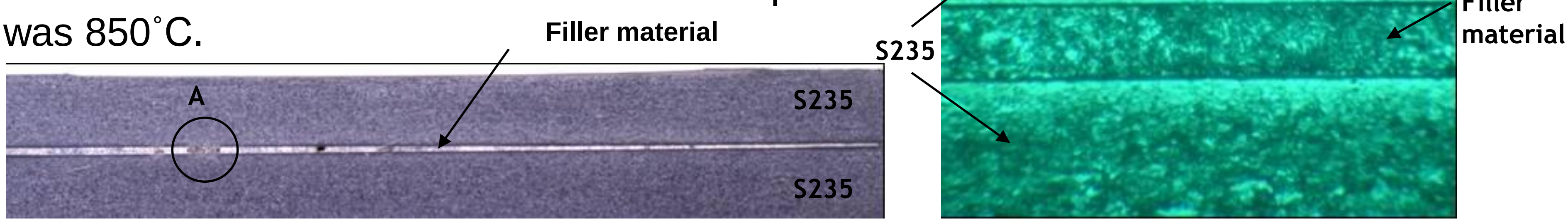


Fig. 27. Macroscopic aspect of samples extracted at 15 mm away from the start of the bonding process

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Conclusions

1)The performance, quality and extraordinary development potential of the friction stir welding (FSW) process are well known worldwide in the scientific and industrial fields.

2) Innovative technical developments based on FSW principle, made at ISIM Timisoara and latest results obtained consisted as a basis for initiating a new bonding method of materials by friction stir processing. The innovative bonding process / method corresponds to the project requirements by making an efficient symbiosis between ecological filler materials and ecological bonding processes.

3) The preliminary experimental program had as the main objective verification if the bonding process principle is viable.

4) Positive results were obtained at preliminary bonding samples of copper (Cu99), brass (CuZn39Pb2) and steel (S235). The bonding of aluminium alloys EN AW 1200 and EN AW 5754 was unsuccessful (probably due to the inadequate soldering flux and process parameters used).

2. Laser soldering

The soldering tests were executed with a laser welding equipment, presented in fig.1. This is an automated and programmable laser equipment, Nd:YAG type, with the following main characteristics: maximum average power Pmed Max= 120 W; pulse power Ppulse= 5 kW; pulse period Tpulse= 0.3…20.0 ms; pulse frequency fpulse= 0...300 pulses/s, spot diameter: 0.1mm (cutting) and 0.3mm (welding)

- PFO for micro-welding “remote”, superficial heat treatments, etc.

- micro-processing examples: welding special materials (Ta), molds repair, welding experiments for composite single-pulse welding applications, thin film deposition experiments, micro-drilling, micro-alloyed surfacing, making microsurfacing on Ti alloys.

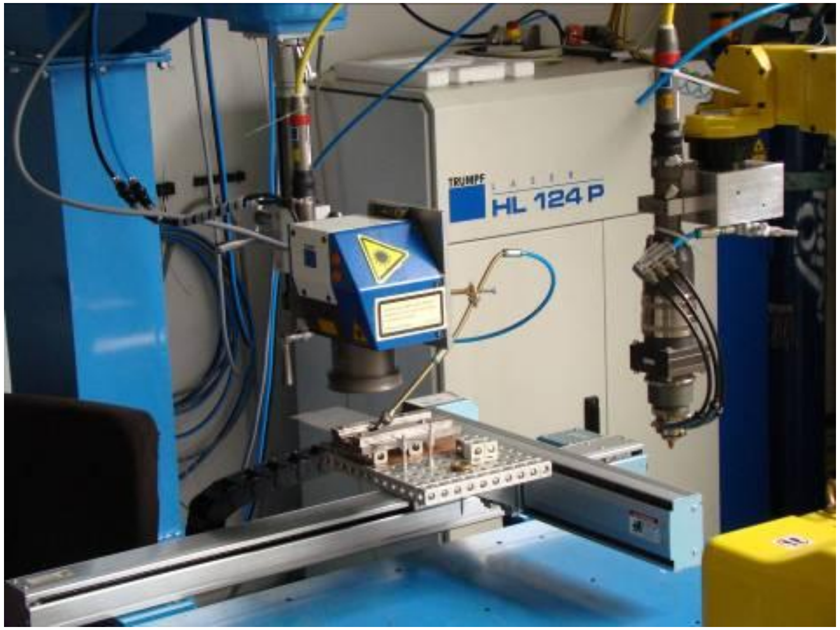

Fig. 1. Laser equipment type HL 124 P LCU

Base metal. Filler materials

Base metal

The preliminary test of laser soldering was performed on the mentioned printed circuit board, covered with the connection lines of electro-technical copper, of 0.2mm thickness.

Filler materials

This is an ecological filler alloy for soldering that contains tin as base element and copper as alloying elements.

The alloy must satisfy the following technical and technological requirements: a relatively low melting point, good melting properties, very good flow properties, good bonding, good mechanical strength, corrosion resistance, high electrical conductivity for electronic applications, relatively low cost.

The chemical composition of the used filler metals is presented in Table 1.

Table 1 Chemical composition % of alloy S-Sn96Ag3Cu1 (711), EN ISO 9453

Fe	Ni	Al	Cu	As	Pb	Zn	Ag	Sb	Bi	Cd	Au	In	Sn
max 0.02	max 0.01	max 0.001	0.3 – 0.7	max 0.03	max 0.1	max 0.001	2.8 – 3.2	max 0.1	max 0.01	max 0.002	max 0.05	max 0.1	Re-main-der

Laser soldering experiment

In fig.2, the laser soldering process is presented. Laser parameters are used for bonding: pulse frequency fp= 23...25 pulses/s; pulse period Tpulse= 0.3 ms; pulse peak power Ppulse= 1200…1400 W; upwards defocussing Δf≈ 8 mm; total soldering time ts= 3…8 s. This parameter combination is applied for the thin terminals of transistors and LEDs. The connection side of the printed circuit board with the soldered pads is in fig.3.

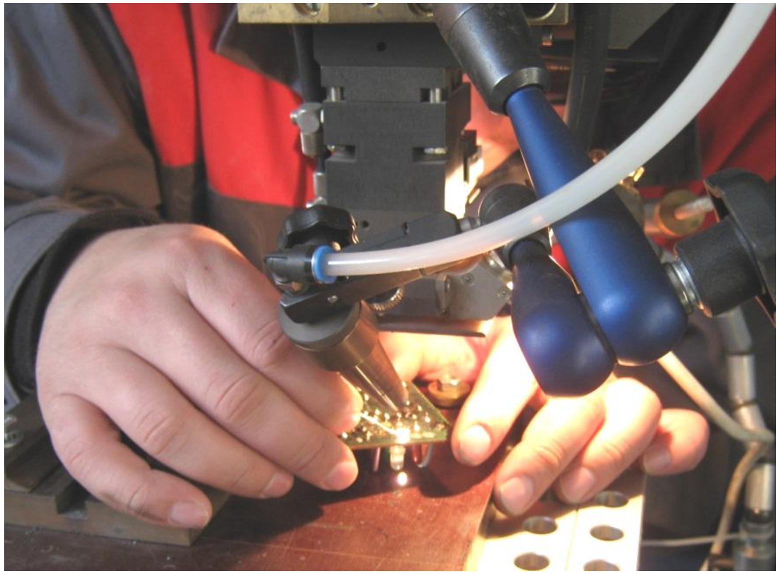

Fig. 2. Laser soldering on a pad of the electronic board.

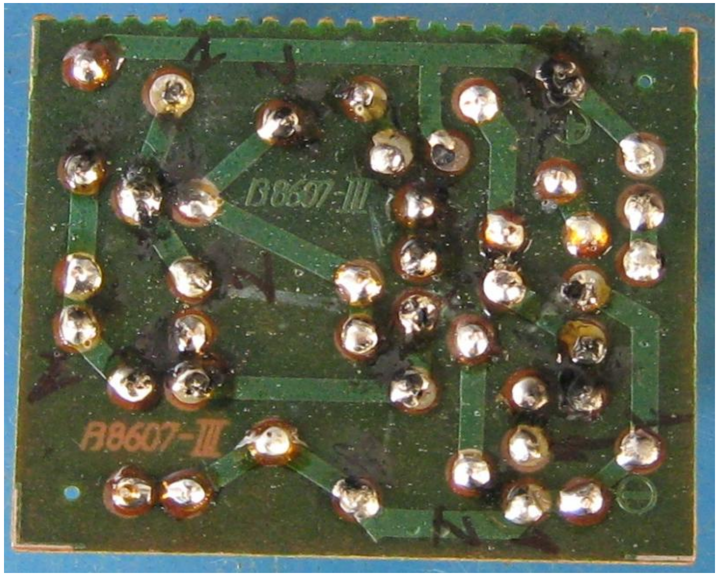

Fig. 3. Connection side with the soldered pads

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Conclusions

Visual examination, according to EN 12799:2000, of the soldered joints was applied.

The soldered joints have adequate appearance. They are well shaped, symmetrical around each terminal and they cover the hole of the board. In the deposited drops there are no defects, like: cracks, porosity, lack of metal, burnt cooper foil or isolating material, etc.

Macroscopic and microscopic analysis will be performed in another stage of the project.

As a result of this preliminary experiment, a combination of parameters was selected for other soldering tests, in the next stages of the project.

3. Electric soldering. Technical requirements

- ***Experiments are described, of electric bit soldering of the components on a printed circuit board with the sizes 100 mm x 25 mm of a voltage monitoring device for car accumulators.***
- ***This is a classical process aimed to special application of a new elaborated filler alloy for soldering.***
- ***The applied process is soldering based on electrical heating [1].***
- ***Verification of both its technological and ecological characteristics [2] are intended.***
- ***The filler alloy is elaborated in the frame of the Ecosolder project, by the Partner, the Mining and Metallurgy Institute of Bor, Serbia.***

Fig.1. Top side of the printed circuit board and the filler alloy

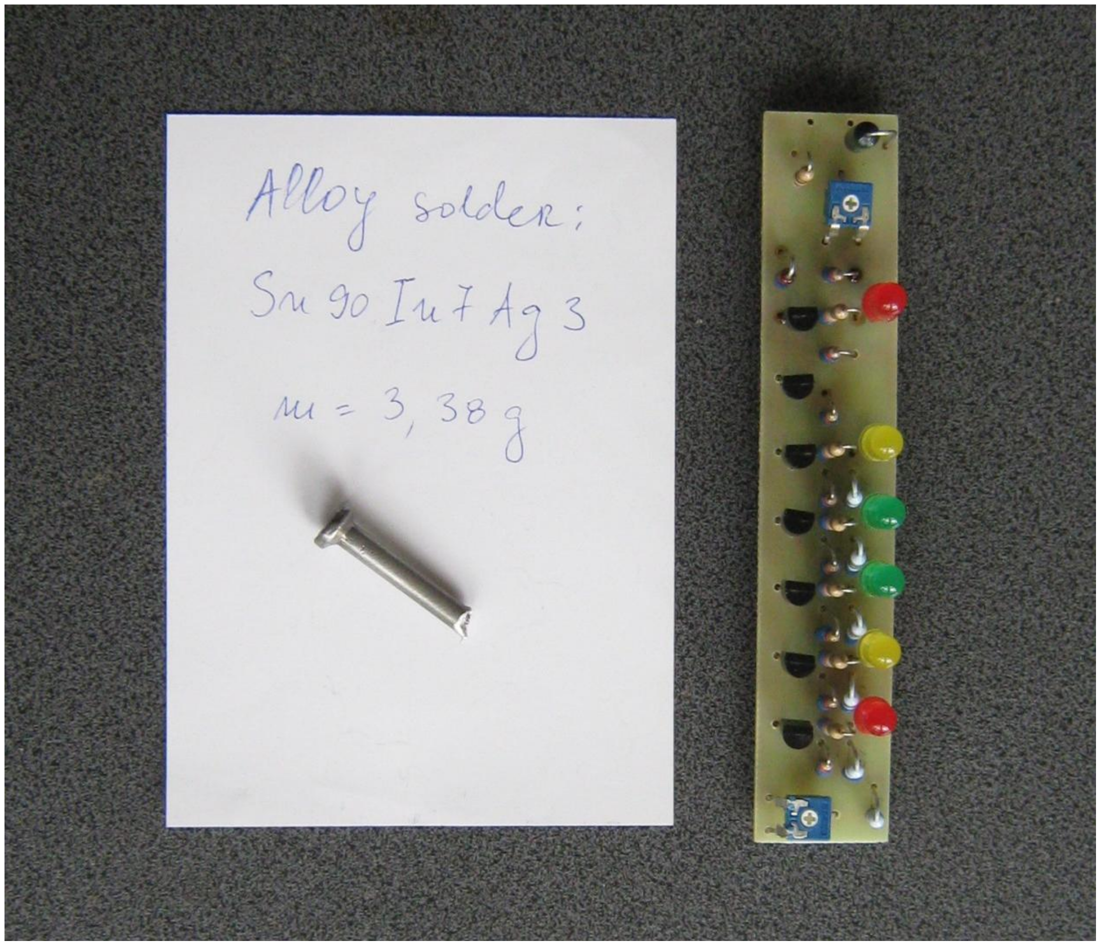
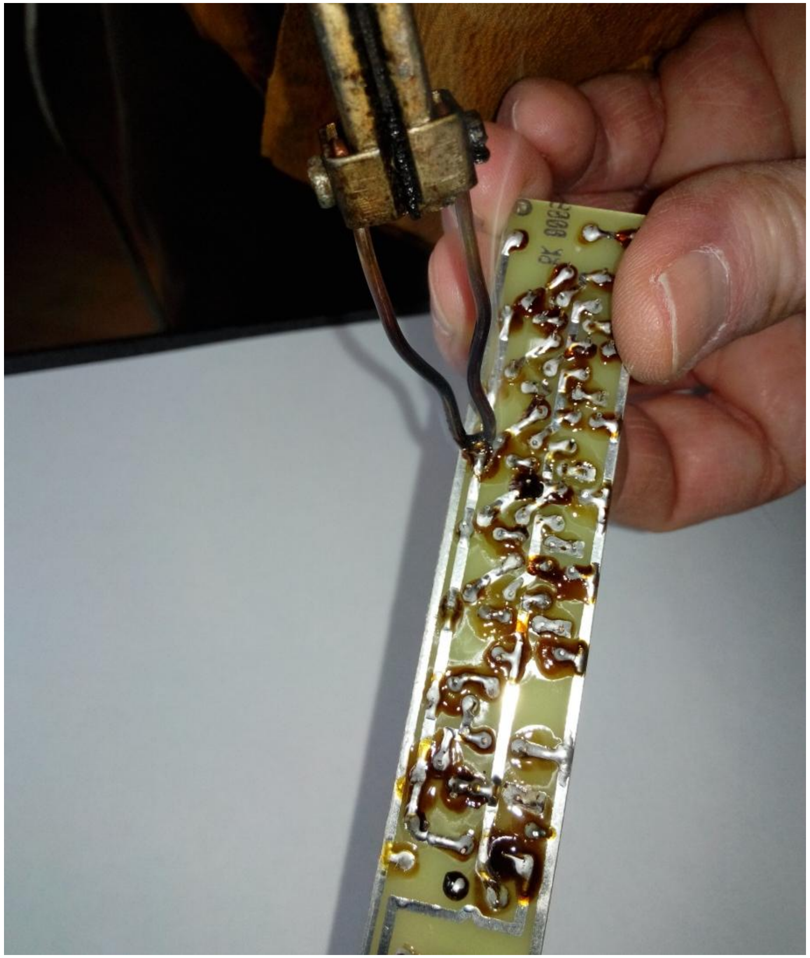


Fig.2-3. Application of solder drops on the pad of an electronic component terminal



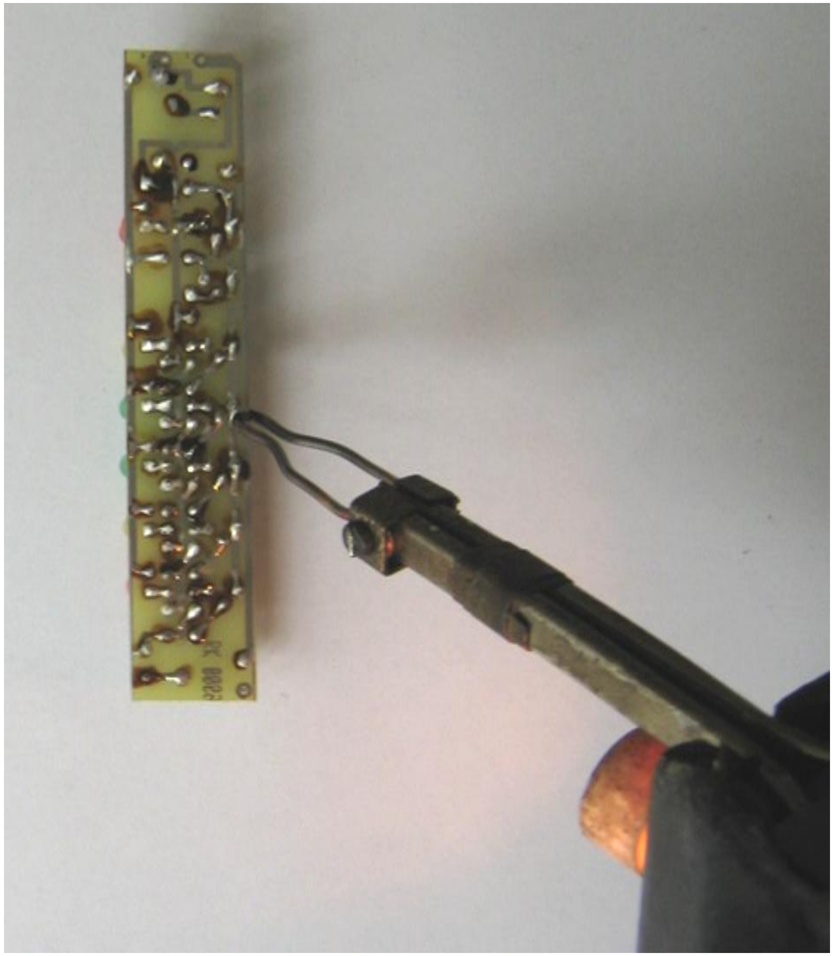
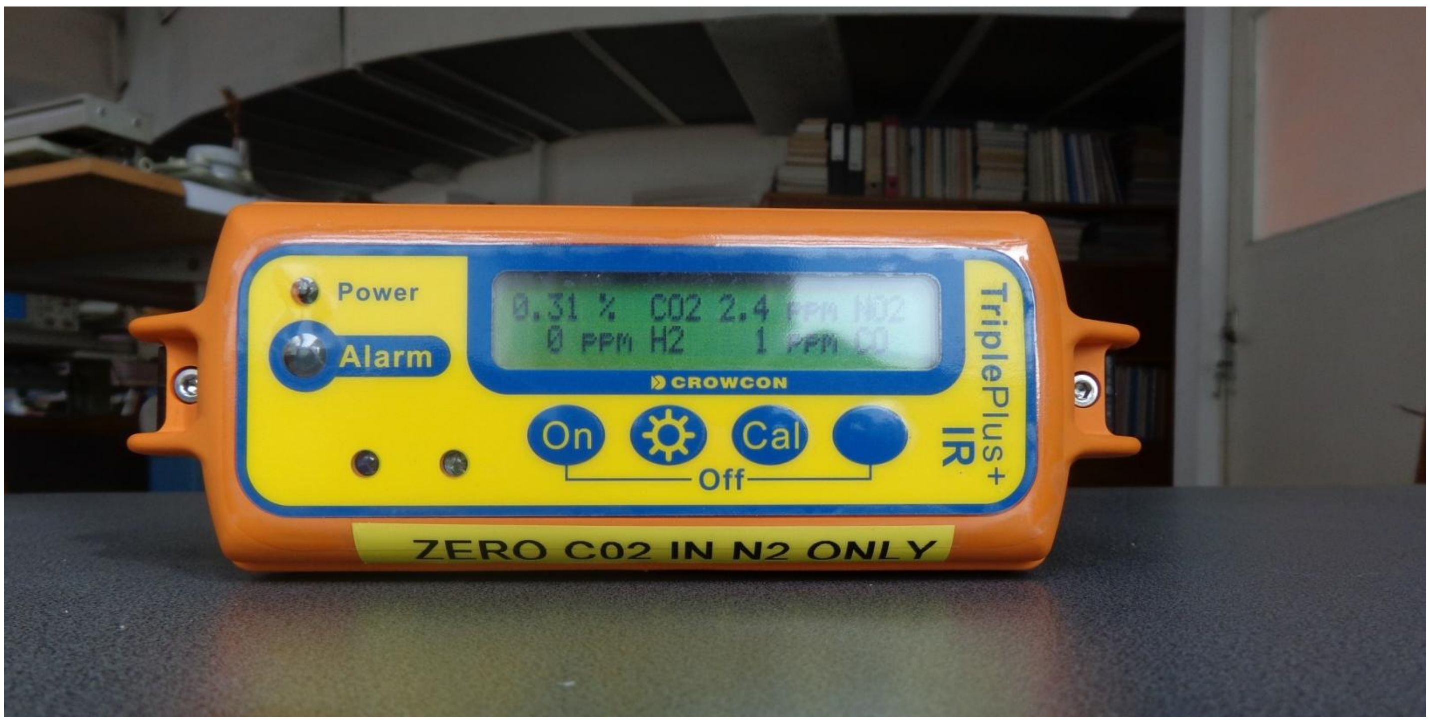


Fig.4. Bottom side with the soldered joints of the PCB

Fig.5. Soldering steel blades, with measuring gases and fumes concentration

Fig.6. Reference concentrations of gases, under clean air conditions

Fig.7. Exhaling of gases by burning, for comparison



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Ecological properties and work safety

- Due to its chemical composition, the soldering alloy S-Sn90In7Ag3 does not exhale any hazardous substances neither for the operating persons, nor for the environment.
- The colophon, used as flux in the soldering operation, may also get overheated and decompose in some volatile substances.
- The most efficient work safety measure for the occupational health is the local exhaust ventilation. In order to assure also the preservation of the environment, the toxic substances of the exhausted gases and fumes should be neutralized and filtered. Then, the filters must be treated in special installations, by authorized persons. The remains of the treated filters must be disposed of only in special locations for this purpose.

Visual examination

- *Visual examination, according to EN 12799:2000 [7], of the soldered joints was applied. The soldered joints have adequate appearance. They are well shaped, symmetrical around each terminal and they cover the holes of the board. There is no leakage of molten alloy through gaps of the holes, to the opposite side of the board. In the deposited drops there are no defects, like: cracks, porosity, lack of metal, lack of fusion, lack of adherence, additional metal, spatter, burnt cooper foil or burnt isolating material, etc.*
- *Tear-down test is recommended to verify the adhesion of he soldered joints to he copper pads of the electronic components terminals, according to the fabrication norm of the product.*

Conclusions

1. Special care should be taken with process times. A time interval ranging from 1.5 s to 4.2 s might be used, depending on the following factors: pad size, drop size, diameter of the soldering iron tip, power of the Iron, pre-set temperature of the supply station of the soldering iron, etc.
2. To long soldering times can also cause evaporation of certain substances of both the filler alloy and flux, that can affect the technology process.
3. The new experimental ecological filler alloy S-Sn90In7Ag3, elaborated in the frame of the Ecosolder project, has adequate properties regarding fusion, flowing, wetting and solidifying. The soldered joints executed with this new alloy have good appearance, form and sizes, as well as adequate mechanical characteristics.

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References

[1] L. Boțilă; V. Verbițchi et al.: Project ECOSOLDER. MIS Code 1409. „Promoting new ecological filler alloys for soldering, based on the non-ferrous ore of the Romanian-Serbian cross-border area”. Technical Report. Stages 1; 2; 3. ISIM Timisoara, Romania. 2013- 2014.

[2] A. Milosavljevic; A. Kostov; R. Todorovic et. al. (MMI Bor, Serbia): “New ecological filler alloy containing indium”. Presentation at the Workshop #1, organized by ISIM Timisoara, February 2014.

[3] EN 13599 - Copper plate, sheet and strip for electrical purposes

[4] EN ISO 3677:1995 Filler metal for soft soldering, brazing and braze welding - Designation (ISO 3677:1992).

[5] EN ISO 9453 : 2006 Soft solder alloys. Chemical compositions and forms. Compare.

[6] EN ISO 12224-1:1998 Solder wire, solid and flux cored - Specification and test methods - Part 1: Classification and performance requirements (ISO 12224-1:1997).

[7] EN 12799:2000 Brazing - Non-destructive examination of brazed joints (&

[8] ISO 5187:1985 Welding and allied processes - Assemblies made with soft solders and brazing filler metals - Mechanical test methods.

[9] EN 12797:2000 Brazing - Destructive tests of brazed joints (& A1:2003).

4. Brazing. Technical requirements

- *In this chapter, the execution of an experimental brazing test sample of steel sheets, thickness 1.0 mm is presented. The applied process is oxy-acetylene brazing [1-4]. The main specific aspect of brazing is heating the base metal over the melting point of the filler alloy, in order to melt indirectly the filler alloy.*
- *The brazing test sample is carried out according to the requirements of the EN 13134:2000 [7] related to the brazing procedure approval.*
- *Important aspects of the standard EN ISO 13585:2012 [8] related to the qualification test of brazers and brazing operators are also considered.*
- *Oxy-acetylene flame brazing is applied, of steel sheets with the sizes approximately 87 mm x 80 mm, respectively thickness of 1.0 mm; overlap approx. 7 mm.*

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Base metal

- ***In the table 1 the chemical composition of the steel S235 sheets is presented.***

Table 1 the chemical composition of the steel S235, EN 10025-1 [12]								
C	Si	Mn	Ni	S	P	Cr	N	Cu
max 0.22	max 0.05	max 0.6	max 0.3	max 0.05	max 0.04	max 0.3	max 0.012	max 0.3

- ***In the table 2 the mechanical characteristics of the steel S235 are shown.***

Table 2. Mechanical properties under T=20°C of the material S235, EN 10025-2 [13]								
Assort ment	Dimension	Direct.	σ_B	σ_T	δ_5	ψ	KCU	Heat treatment
-	mm	-	MPa	MPa	%	%	kJ / m^2	-
Sheet	2 - 3.9		360	235	20			

Filler materials

- ***The filler alloy used in these experiments is an experimental batch of brass for brazing, having the symbolization CuZnSnSiMn. This filler alloy is elaborated by the Mining and Metallurgy Institute of Bor, Serbia, as partner in the Ecosolder project.***
- ***For comparison, in the table 3 the chemical composition of a common brass is given, available as filler alloy for brazing.***
- ***The flux used in the brazing operations carried out in the present work and described here is borax.***

Table 3. Chemical composition % of grade CuZn30 (CW505L), EN 12166; ISO 426/1 [14]

Fe	Ni	Al	Cu	Pb	Sn	Others	Zn
max. 0.05	max. 0.3	max. 0.02	69.71	max. 0.05	max. 0.1	Total 0.1	Remain-der

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Fig.1. Oxygen-acetylene equipment for welding and brazing of ISIM Timisoara

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Fig.2. Depositing flux and filler alloy onto the second steel sheet

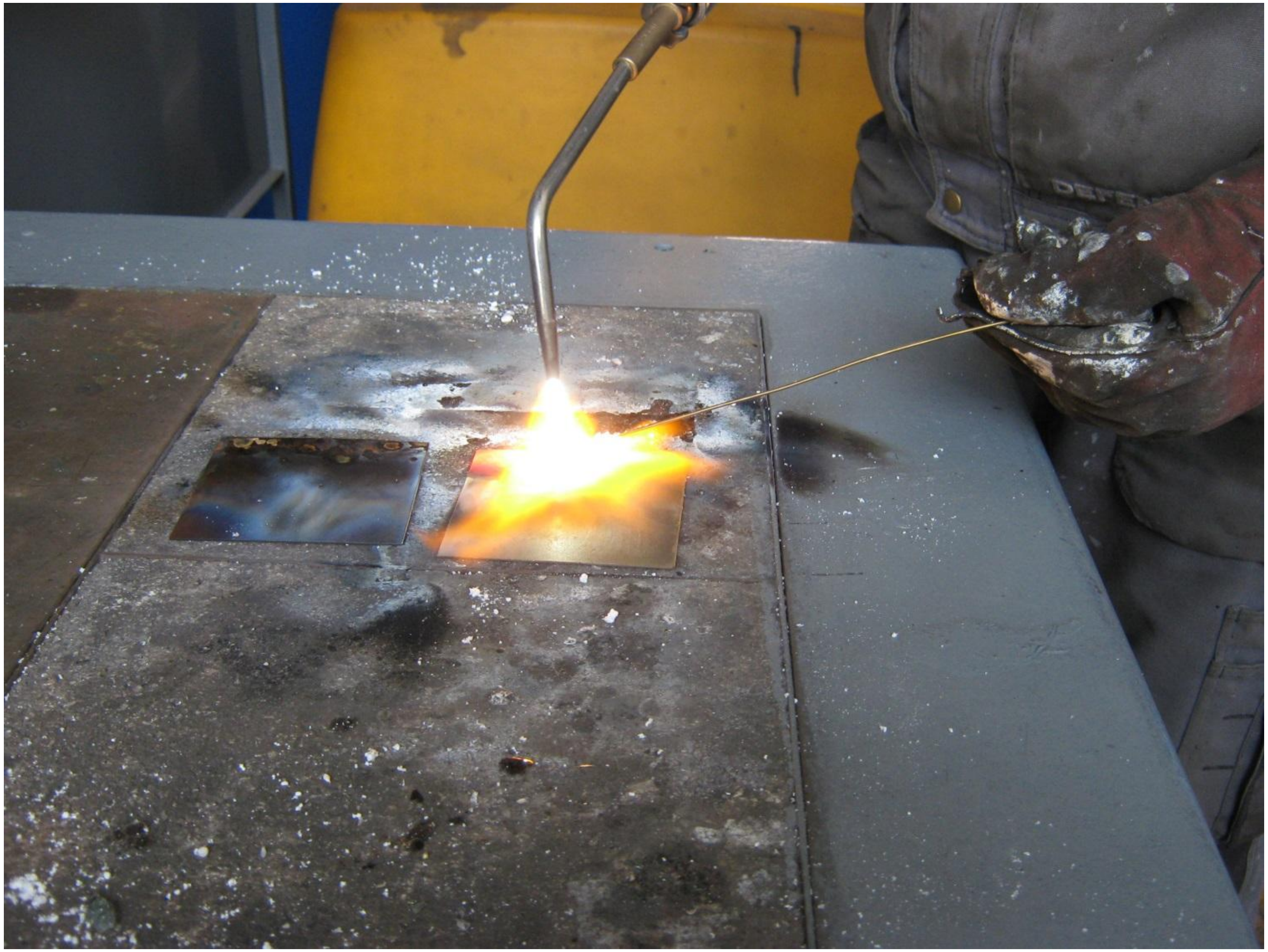

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Fig.3. Execution of the brazed joint of the overlapped steel sheets

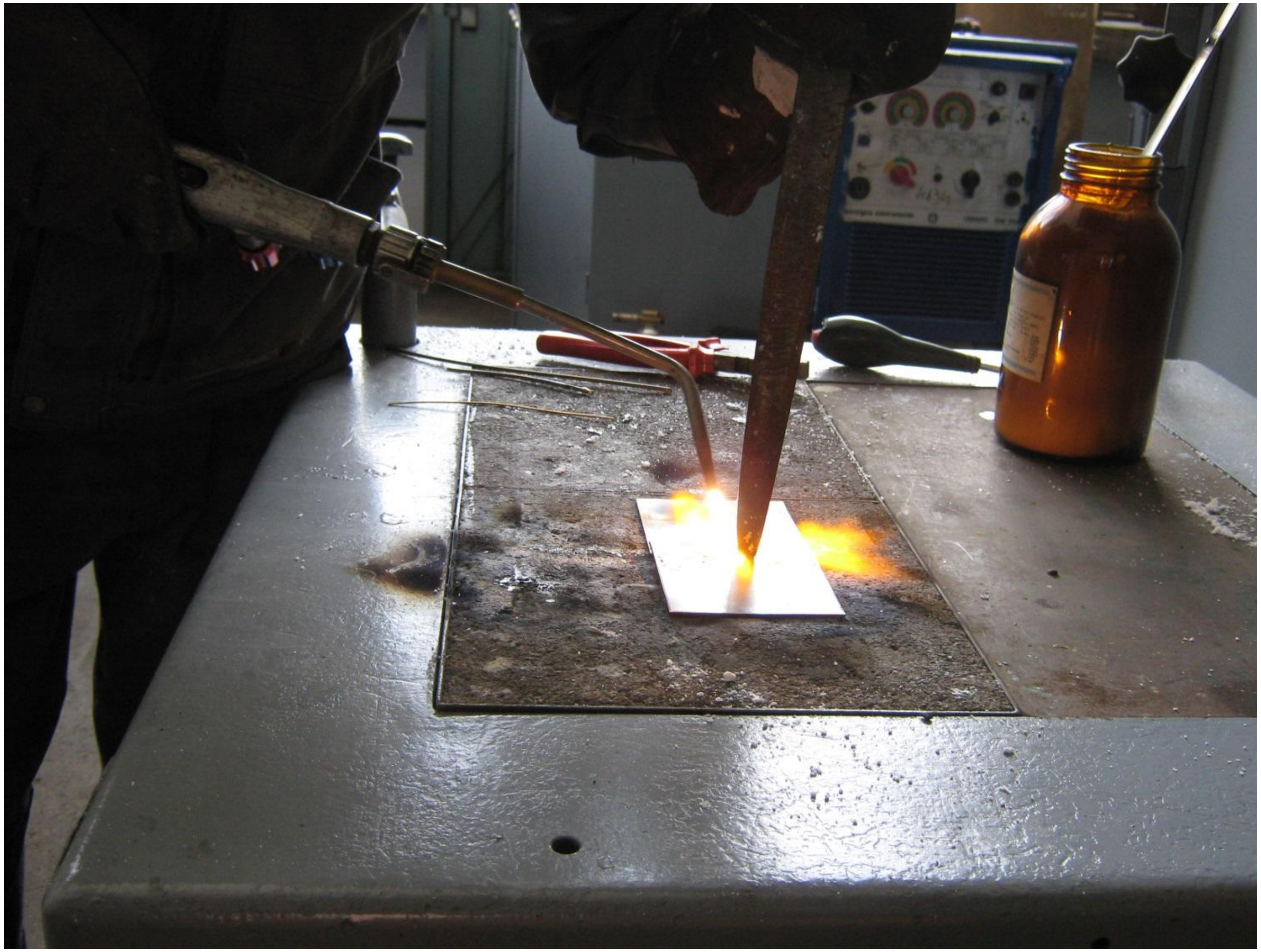

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Fig.4. Brazing of steel sheets, with monitoring the concentration of gases and fumes

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Fig.5. Reference levels of gases and fumes, under shop conditions

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Fig.6. Measurement level of exhaled gases during brazing

Ecological properties and work safety

- ***Due to its chemical composition, the experimental brazing alloy CuZnSnSiMn does not exhale any hazardous substances neither for the operating persons, nor for the environment.***
- ***Borax, used as flux in the brazing operation is not acute toxic [3]. But it may get overheated and decompose in some volatile substances.***
- ***The most efficient work safety measure for the occupational health is the local exhaust ventilation. In order to assure also the preservation of the environment, the toxic substances of the exhausted gases and fumes should be neutralized and filtered. Then, the filters must be treated in special installations, by authorized persons.***

Non-destructive examination

- ***Visual examination, according to EN 12799:2000 [17], of the brazed joints was applied. The brazed joints have adequate appearance. They are well shaped, symmetrical related to the axis of the overlapped zone of the sheets. There is some leakage of molten alloy apart from the joint on the top side of the test sample, respectively smaller leakage on the opposite side of the assembly.***
- ***In the deposited filler metal there are no defects, like: cracks, porosity, lack of metal, lack of fusion, lack of adherence, additional metal, spatter, burnt steel sheet, etc.***

Fig.7. Macroscopic metallographic analysis

- ***Macroscopic examination according to SR EN 12797 and SR EN ISO 18279 has been carried out.***

- ***The cross section of the brazed joint is presented in the fig.7. The appearance is adequate and no unaccepted imperfections are detected.***

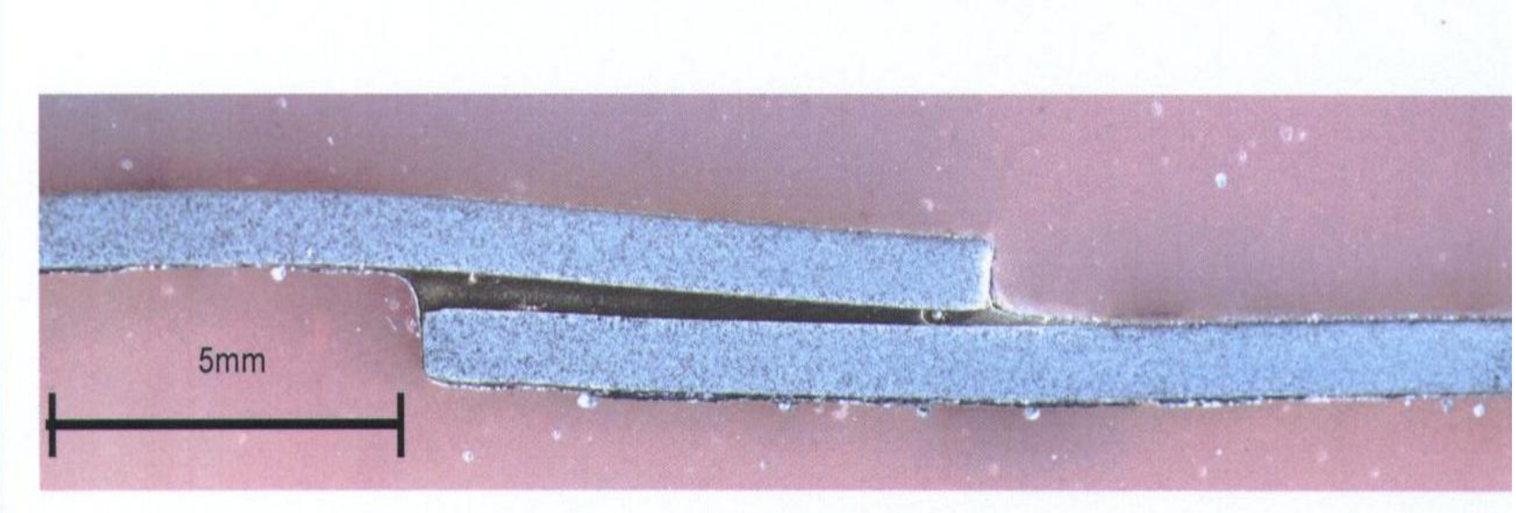

Fig.8. Microscopic metallographic analysis

- ***Microscopic metallographic examination according to SR EN 12797 and SR 5000-97 has been carried out.***
- ***The constituents of the deposited filler metal are α dendritic solid solution with fine particles of Sn, Si and Mn.***
- ***No defects are revealed in the deposited filler metal.***

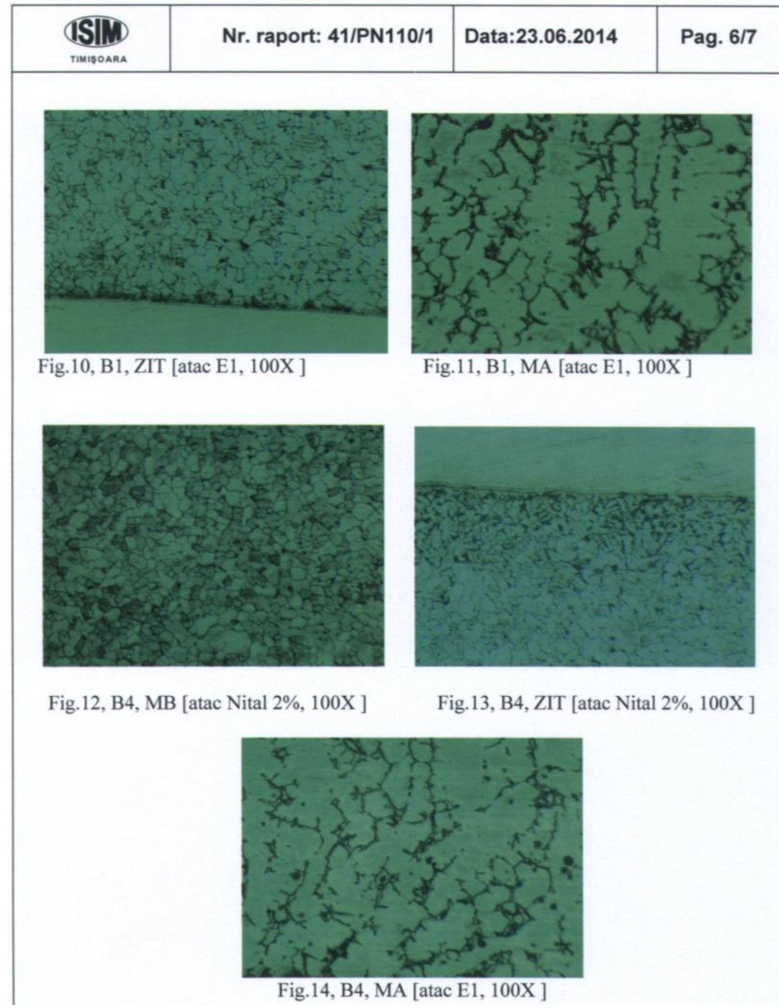

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Fig.10, B1, ZIT [atac E1, 100X]

Fig.11, B1, MA [atac E1, 100X]

Fig.12, B4, MB [atac Nital 2%, 100X]

Fig.13, B4, ZIT [atac Nital 2%, 100X]

Fig.14, B4, MA [atac E1, 100X]

Conclusions

1. Special care should be taken with process times. A time interval ranging from 2.5 min to 4.5 min might be used, depending on the parameters of the flame.
2. The new experimental ecological filler alloy CuZnSnSiMn, of the class of brass filler alloys, elaborated in the frame of the Ecosolder project, has adequate properties regarding fusion, flowing, wetting and solidifying. The brazed joints executed with this new alloy have good appearance, form and sizes, as well as adequate mechanical characteristics.
3. The ecological properties of the new brass elaborated in this project are adequate, as it produces no hazardous substances, at the work place. Local exhaust ventilation should be applied for evaporated components of the flux, as it is the most efficient work safety measure for the occupational health and environment protection.

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[7] EN 13134:2000 - Brazing - Procedure approval.

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[10] EN ISO 3677:1995 - Filler metal for soft soldering, brazing and braze welding - Designation (ISO 3677:1992).

[11] EN ISO 17672:2010. Brazing. Filler metals.

[12] EN 10025-1:2004 - Hot rolled products of structural steels — Part 1: General technical delivery conditions.

[13] EN 10025-2:2004 - Hot rolled products of structural steels - Part 2: Technical delivery conditions for non-alloy structural steels.

[14] ISO 426-1:1983. Wrought copper-zinc alloys - Chemical composition and forms of wrought products - Part 1: Non-leaded and special copper-zinc alloys

[15] NSSM 3 - Norme specifice de securitate a muncii pentru fabricarea, stocarea, transportul si utilizarea oxigenului si azotului.

[16] NSSM 4 - Norme pentru fabricarea, transportul si depozitarea acetilenei.

[17] EN 12799:2000- Brazing - Non-destructive examination of brazed joints (& A1:2003)

[18] ISO 5187:1985 - Welding and allied processes - Assemblies made with soft solders and brazing filler metals - Mechanical test methods.

[19] EN 12797:2000 Brazing - Destructive tests of brazed joints (& A1:2003).

5. Weld-brazing. Base metals

- ***Weld-brazing tests were performed on a beam of aluminium EN AW 1200, according to EN 573 [2], having a rectangular profile, with the sizes 40 mm x 20mm. Various products of aluminium and aluminium alloys are available for this purpose [3-5].***
- ***In this beam, holes with the diameter of 8 mm were drilled. Hooks made of 8 mm diameter wire of titanium TiGr.1, according to ISO 5832-2 [6] are inserted into these holes and dissimilar joints are performed between the aluminium beam and the titanium hooks. Other grades of titanium wire or bars can be also applied [7].***
- ***This is the original geometry of a frame used for placing various metal parts to be coated with a protective and decorating layer by an electro-chemical process.***
- ***In the fig.1 and fig.2, the work-piece prepared for the joining test is illustrated.***

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Chemical composition and mechanical characteristics of the aluminium part

Table 1. Chemical composition of Aluminium EN AW 1200, EN 573 [2]							
Weight%	Si +Fe	Cu	Mn	Al	Zn	Ti	Others
Aluminium EN AW 1200	Max. 1.0	Max. 0.05	Max. 0.05	Max. 99.0	Max. 0.10	Max. 0.05	0.05 (each), 0.15 (total)

Table 2. Mechanical characteristics of Aluminium EN AW 1200, EN 573 [2]				
		Rp.02	Rm	E
Metal/Alloy	Condition/Temper	MPa	>MPa	GPa
Aluminium EN AW 1200	O / Anealed	25	90	69
Aluminium EN AW 1200	Hx4 / Strain Hardened material supply	100	120	69

Chemical composition and mechanical characteristics of titanium TiGr1

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Table 3. Chemical composition of Titanium, ISO 5832-2 [6]

No.	Element	TiGr.1	TiGr.2	TiGr.3	TiGr.4
1	Nitrogen, max.	0.03	0.03	0.05	0.05
2	Carbon, max.	0.10	0.10	0.10	0.10
3	Hydrogen, max.	0.0125	0.0125	0.0125	0.0125
4	Iron, max.	0.20	0.30	0.30	0.50
5	Oxygen, max.	0.18	0.25	0.35	0.40
6	Titanium	Balance	Balance	Balance	Balance

Table 4. Mechanical characteristics of Titanium, ISO 5832-2 [6]

TiGr.	UltimateTensile Strength, min.,ksi (Mpa)	Yield Strength, min. (2% offset)ksi (Mpa)	% Elongation (2 in. gage length), min.,%
1	35 (240)	25 (170)	24
2	50 (345)	40 (275)	20
3	65 (450)	55 (380)	18
4	80 (550)	70 (483)	15

Filler Alloys

Table 5. Chemical composition % of AlMg5, EN ISO 18273 [9]										
Fe	Si	Mn	Cr	Ti	Cu	Be	Mg	Zn	Others	Al
Max. 0.4	Max. 0.25	0.6-1.0	0.05-0.20	0.05-0.20	Max. 0.10	Max. 0.0003	5.0-5.5	Max. 0.20	Each 0.05; Total 0.15	Remainder

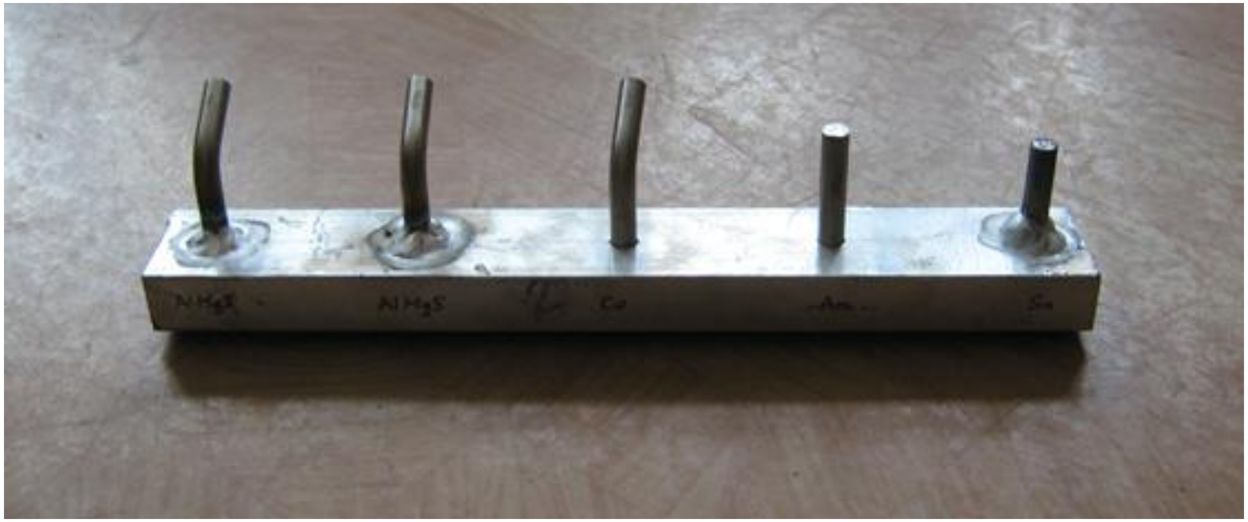
Table 6. Chemical composition % of copper filler alloy, wire [10 - 13]										
ISO 17672 Designation	EN 1044 Designation	Ag	Cu	Zn	P	Cd	Pb	Sn	Melting temperature, ºC	Working tempe-rature, ºC
CuP281	CP104	5.0	93.0	-	6.0	-	-	-	645-815	710

Table 7. Chemical composition % of grade CuZn30 (CW505L), EN 12166; ISO 426/1 [14,15]							
Fe	Ni	Al	Cu	Pb	Sn	Others	Zn
max. 0.05	max. 0.3	max. 0.02	69.71	max. 0.05	max. 0.1	Total 0.1	Remainder

- **Fig.1. Weld-brazing process of the second upper joint, with a 1.6 mm AlMg5 rod**

Fig.2. Weld-brazing parameters by the second upper joint

Fig.3-4. Weld-brazed assembly of the aluminium beam with the titanium hooks.



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Non-destructive examination

- Visual examination of the weld-brazed joints was applied according to SR EN ISO 17637: 2003. "Non-destructive testing of welds. Visual testing of fusion-welded joints" [20] and
- EN 12799:2000 Brazing - Non-destructive examination of brazed joints (& A1:2003) [21].
- The visual examination was based on the following criteria: stability of the welding parameters, width of the weld bead at the top surface (measured value), penetration (total/partial), clear burned-edges (yes/no), general shape of the bead at the top surface (convex / plan / concave), and spatter (many/few/none).
- By the visual examination, no defects were detected.

Conclusions

1. The precise machining preparation of the beam hole for the joint, as well as finishing the hook surface, can allow a weld-brazing process with higher velocities and lower heat input, while keeping a proper penetration of both titanium hook and aluminium beam.
2. A single weld-brazed joint at the bottom of the hook is requested in the specification of the frame with hooks. Another weld-brazed joint on the upper side of the beam improves the mechanical strength and corrosion withstand of the hook-beam assembly.
3. Surface finishing of the parts has an important influence on avoiding the porosity of the weld-brazed joints. With improved surface preparation, this phenomenon did not occur.

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Thank you for you attention !