EUROPEAN UNION

GOVERNMENT OF ROMANIA

SERBIAN GOVERNMENT

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

WORKSHOP no.2 at ISIM Timişoara 26th of September 2014

“Ecologic Alloys for Soldering and Brazing. Brazing and Soldering Procedures”

Victor Verbitchi, Cristian Ciuca - NATIONAL RESEARCH AND DEVELOPMENT INSTITUTE FOR WELDING AND MATERIAL TESTING - ISIM TIMIŞOARA, ROMANIA

„Execution of brazing test samples of S235 steel sheets, with a new brass type”

CROSS
BORDER
COOPERATION

Romania-Serbia

Common borders. Common solutions.

EUROPEAN UNION

GOVERNMENT OF ROMANIA

SERBIAN GOVERNMENT

Structural Funds
2007-2013

ECOSOLDER

CONTENTS

The following brazing tests are presented:

1. ***Overlap-joint brazing test with the experimental ecological brass, elaborated in the Ecosolder project***
2. ***Overlap-joint brazing test with common available brass, for comparison***
3. ***Metallographic analysis***
4. ***Shear test***
5. ***Conclusions***

References

CROSS
BORDER
COOPERATION
Romania-Serbia
Common borders. Common solutions.

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

1. Overlap-joint brazing test with the experimental ecological brass, elaborated in the Ecosolder project

- *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.*

1.1. 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			

1.2. Filler materials

- *The filler alloy used in these experiments is an experimental batch of brass for brazing, having the symbolization CuZnSnSiMn. Its chemical composition is not exactly known. It may be subject of a patent application. 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.*

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	Remainder

- *The flux used in the brazing operations carried out in the present work and described here is borax.*

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

1.3. Execution of the brazing test. Fig.1.1. Oxygen-acetylene equipment for welding and brazing

CROSS
BORDER
COOPERATION
Romania-Serbia
Common borders. Common solutions.

Fig.1.2. The three delivery forms of the new filler alloy for brazing

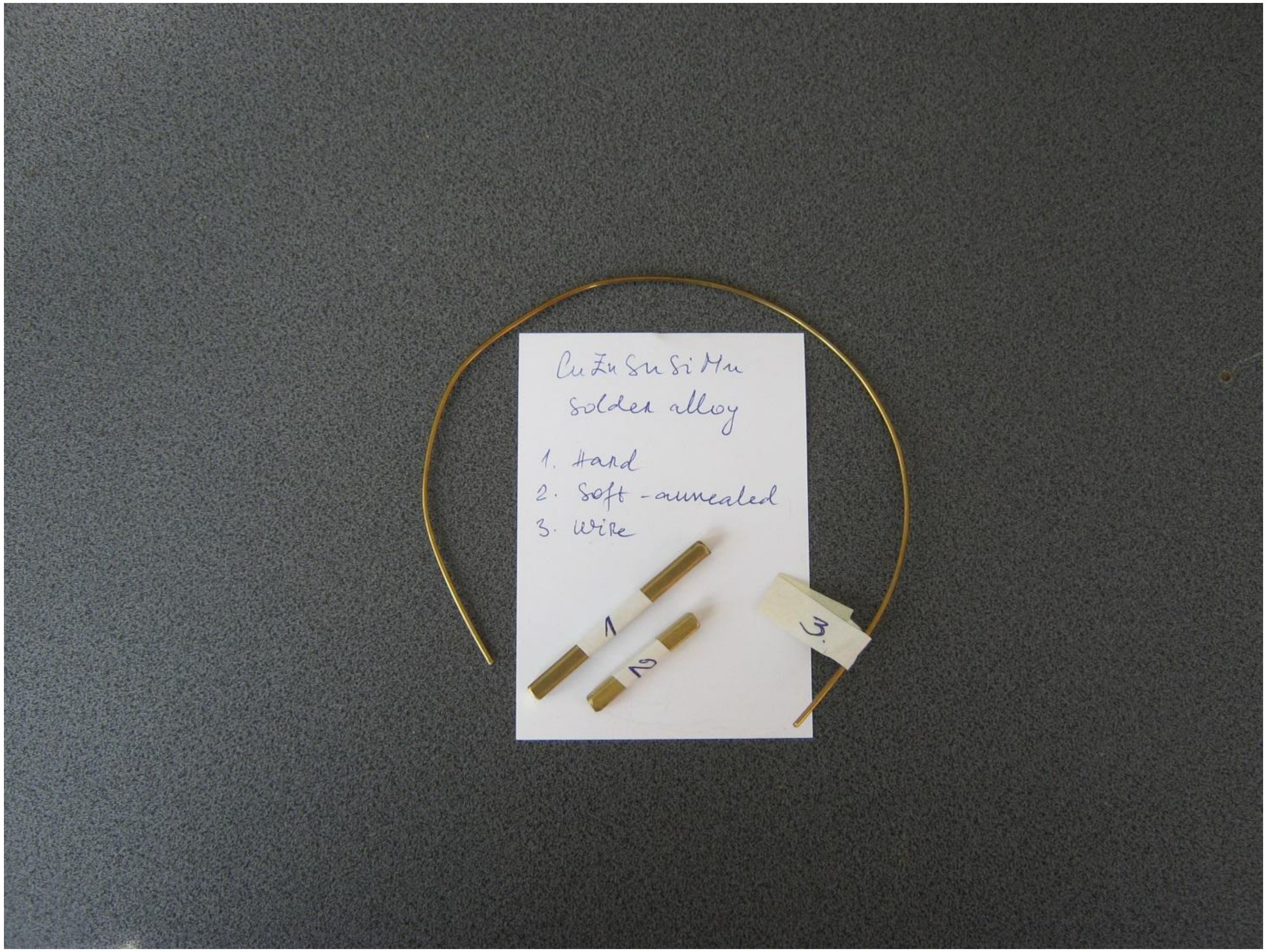


Fig.1.3. Heating the tip of the filler alloy wire, to prepare it for charging with flux

Fig.1.4. Heating one of the sheets and introducing the filler wire charged with flux

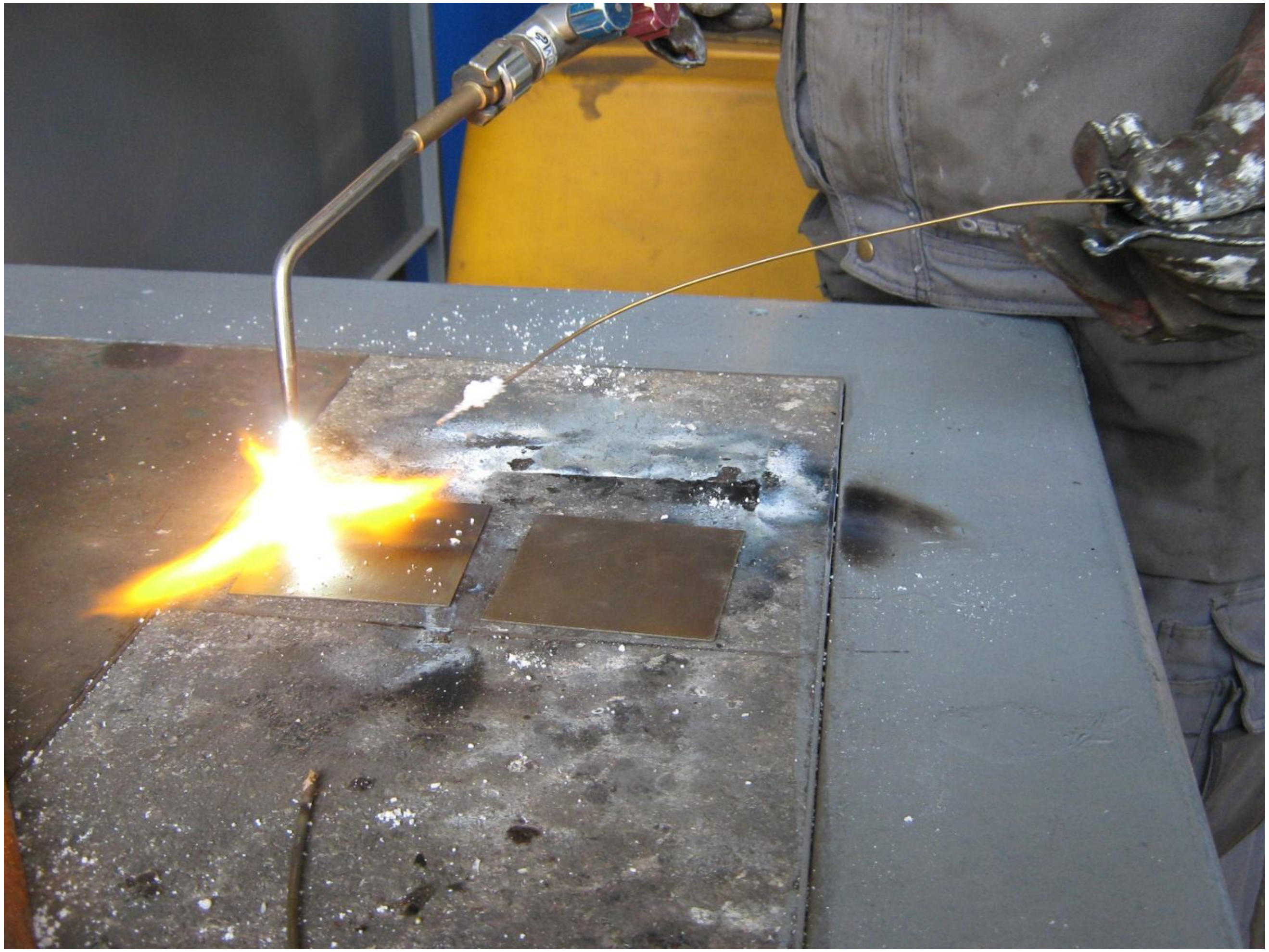


Fig.1.5. Depositing flux and filler alloy onto the second steel sheet

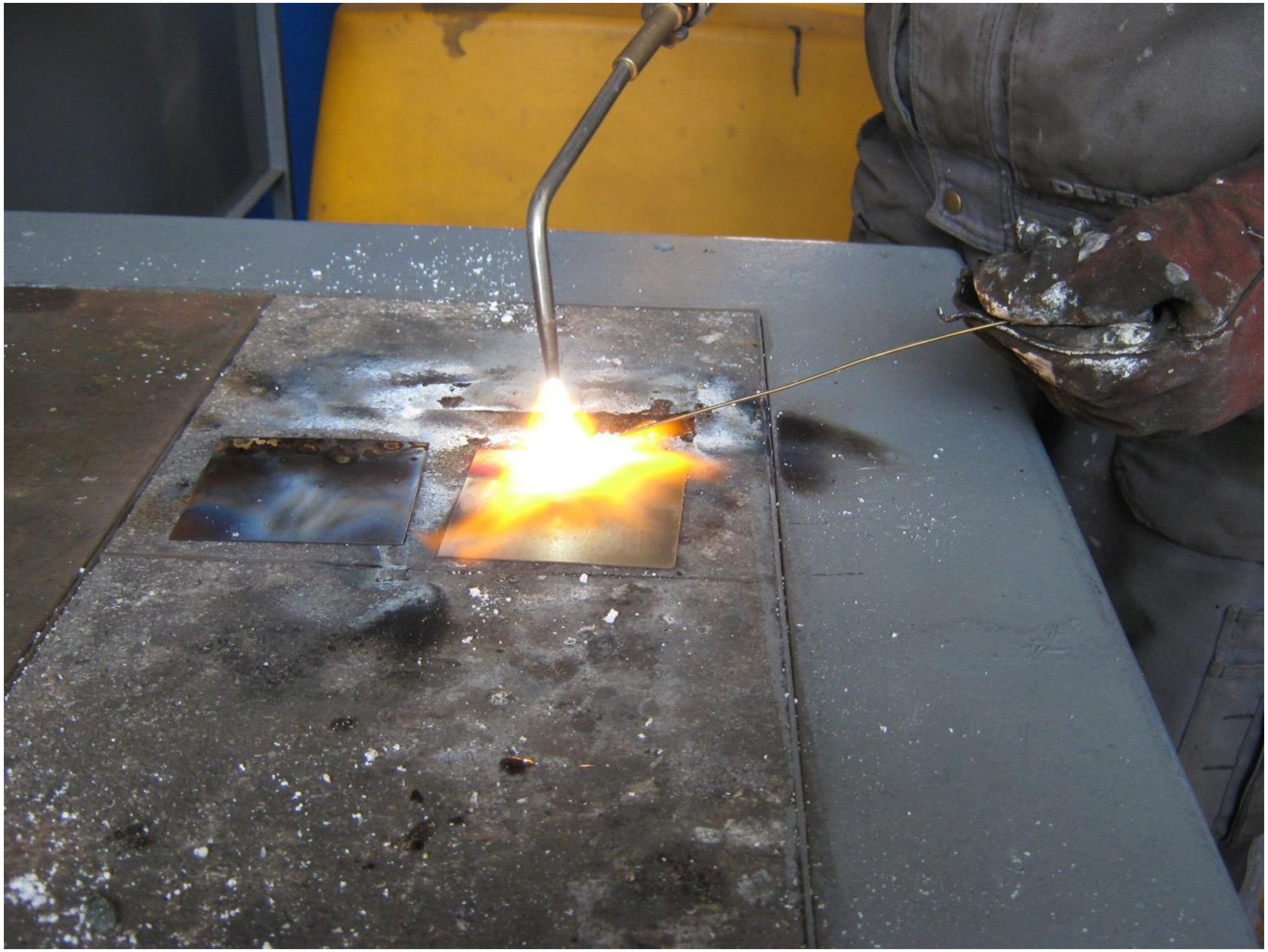


Fig.1.6 Execution of the brazed joint of the overlapped steel sheets

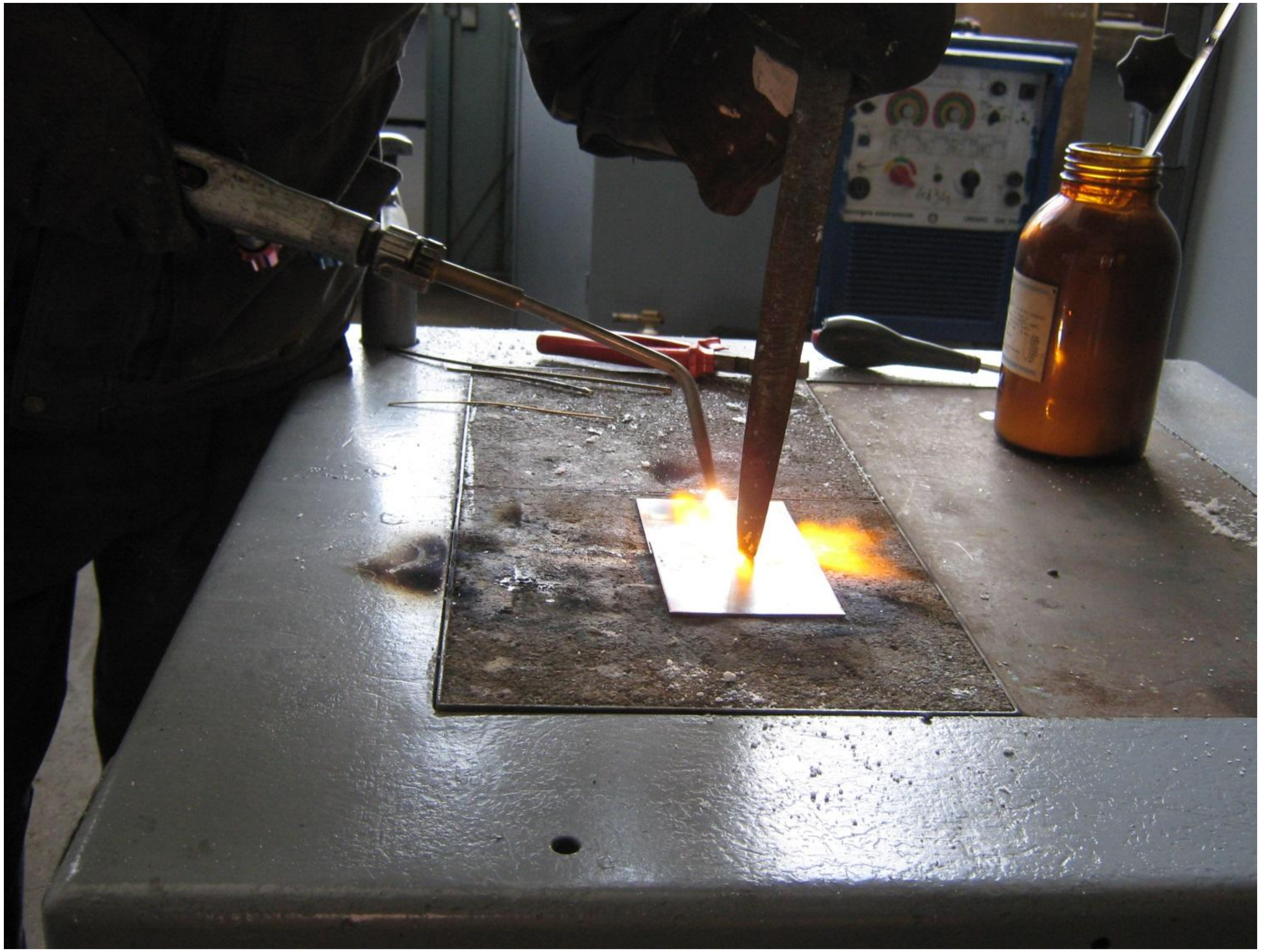


Fig.1.7-1.8. Top and bottom sides of the overlapped sheets joint of the brazing test sample

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

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.***

1.4. 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.***

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

2. Overlap-joint brazing test, with common available brass, for comparison

- *For comparison to the previously performed brazing tests, an overlap joint brazing test was carried out, using a common, commercially type of brass.*
- *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 160 mm, respectively thickness of 1.0 mm; overlap approx. 7 mm.*
- *The base metal consists of S235 steel sheets, according to EN 10025-1, presented by the previous brazing test.*

2.1. Filler materials

- ***The filler alloy used in these experiments is a common, commercially available type of brass for brazing, having the symbolization CuZn40, delivered as 3.25 mm diameter wire.***
- ***In the table 5, the chemical composition of a this type of common brass is given.***

Table 5. 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	59.71	max. 0.05	max. 0.1	Total 0.1	Remainder

- ***The flux used in the brazing operations carried out in the present work and described here is borax.***

2.2. Brazing process

- ***Brazing is a process that makes joints of various work-pieces, by means of heating them to more than 450ºC and applying a filler metal that has a melting temperature below that of the base metal. Filler metal flows into the joint by capillary attraction.***
- ***Brazing has several advantages [1-4]. Dissimilar metals can be joined. Assemblies can be brazed in a stress-free condition, and complex assemblies can be brazed in several steps by using filler metals with progressively lower melting temperatures. Materials of different thicknesses can be joined, as can cast and wrought metals. Nonmetals can be joined to metals when the nonmetal is coated. Metallurgical properties of base materials are not seriously disturbed, and brazed joints require little or no finishing.***

2.3. Brazing equipment

- ***The oxygen-acetylene equipment for welding and brazing of ISIM Timisoara, presented by the previous test, was also used by this brazing test.***
- ***Torch brazing is applied to join relatively small assemblies made from materials that do not oxidize at the brazing temperature or can be protected from oxidation with a flux. The most commonly used filler metals are the following: aluminum-silicon alloys, silver-base alloys, and copper-zinc alloys. Flux is required with these filler metals unless protective atmosphere is used. Self-fluxing copper-phosphorus alloys are also used. Torch brazing is done in air and is the most common brazing process.***
- ***Torch and machine brazing are generally used to make lap joints of parts with the thickness 0.254 mm – 6.35 mm. Joints can be brazed rapidly, but speed decreases as material thickness increases.***

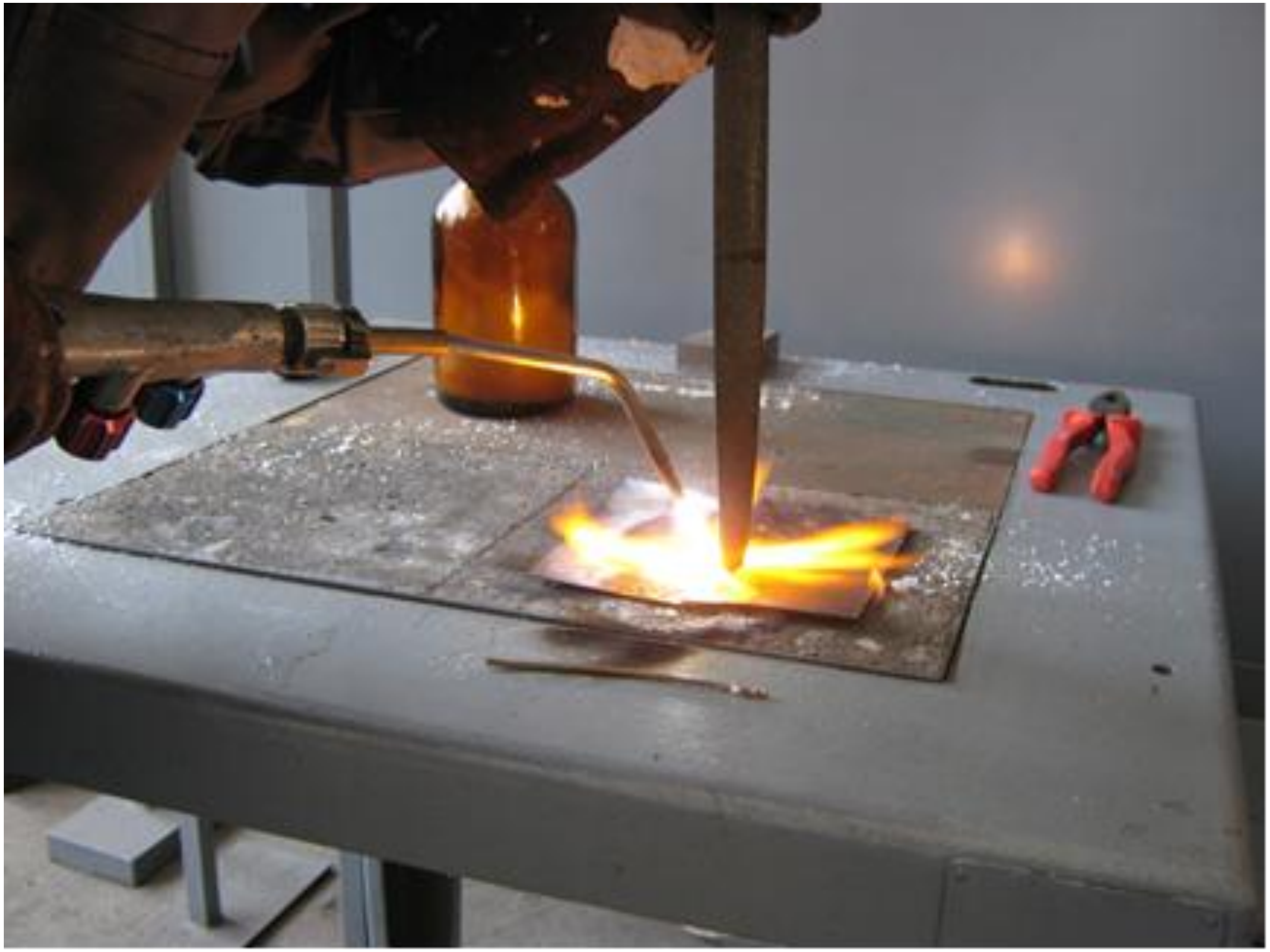
CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

2.4. Execution of the brazing test sample

- *At the beginning, a brass layer has been deposited on each of the two steel sheets of base metal, in the zone of the intended overlapping.*
- *In the first phase of this process, the steel sheets were heated up to a temperature over the melting point of the flux. Then, the flux was poured on the sheets, so the reduction of the oxide layer occurs.*
- *In the second phase, the brass wire was charged with flux, by dipping it into the jar containing the flux.*
- *The third phase consists in heating the brass wire, covered with flux, in the oxygen-acetylene flame, so that drops of brass detach after one another and fall onto the steel sheet. The filler wire melts gradually and drops are depositing unto the steel sheet.*
- *The operation requires skill and accuracy.*

Fig.2.1. Base metal sheets with the deposited brass layers

Fig.2.2 Execution of the brazed joint of the overlapped sheets



CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

2.4. Execution of the brazing test sample (continued)

- ***A minimal gap between the two sheets must be achieved, to be filled by the liquid filler alloy, during the brazing processes. The gap should not be much thicker than the recommended size of 0.10...0.25 mm, in order to avoid the liquid metal to flow apart from the brazing zone,***
- ***In the same time, the base metal sheets are heated. The process must be very carefully conducted, in order to assure the filler alloy to melt and flow evenly over the base metal in the gap, especially in the case when the brazing position is not horizontal.***
- ***The temperature of the base metal (steel colour orange) is set on approximately 900- 940ºC, in order to melt the brass, but also to avoid overheating and evaporation of certain components of the brass (e.g., zinc, tin) or flux.***

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

2.4. Execution of the brazing test sample (continued)

- ***The brazing time for the joining phase is ts= 20... 30 s. It depends on the sizes of the sheets, but also on the parameters of the flame: flow rates of acetylene and oxygen, power, temperature, type of flame (reducing, neutral, oxidizing), length, height over the brazing zone, inclination, as well as other factors. The work temperature of the base metal is also an influence factor of the brazing time, because this brazing process is not automatically temperature-controlled.***
- ***All factors of influence on the melting, flowing, wetting and solidifying properties of the filler must be considered. The main parameters of the brazing process are adjusted manually, by the skill of the brazer. Automation of the process can also be applied, but it is quite difficult.***
- ***The total cycle duration of the brazing process is in the range ts= 2.5... 4.5 min.***

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

2.4. Execution of the brazing test sample (continued)

- ***The colour of the base metal sheet surface brings real time information about the execution of the brazing process, during the process itself. Light colours, as yellow (1050ºC) and white (1200ºC) show that too high temperature is reached and overheating must be avoided. Consequently, heat input must be reduced, by raising the torch flame from the sheet and placing it on another zone. Especially in the case of thin sheets, sudden movements are not allowed and constant travel speed must be maintained, in order to avoid fast cooling that can produce quenching of the steel sheets and brittle constituents in the structure.***
- ***The colours of the oxide layer of the sheets after the brazing process can bring information about how the brazing process was carried out. Thus, the process can be improved for the next time when it is applied.***

Fig.2.3. Pressure reducer of the oxygen cylinder with inlet and outlet pressure gauges

Fig.2.4. Pressure reducer of the acetylene cylinder with inlet and outlet pressure gauges

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

Fig.2.5. Addition of filler alloy and flux onto the bottom side of the joint

Fig.2.6. Final heating of the base metal sheets, for uniformity of thickness and width of the joint

Fig.2.7. Top and bottom sides of the overlapped brazed joint of the brazing test sample

2.5. 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.***
- ***A similar brazing procedure was used, as by the brazing test with the new ecological brass type 3, realized in the Ecosolder project, presented in the previous chapter.***
- ***The results of the visual examination is adequate for both brazing test samples.***

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

3. Metallographic analysis

3.1. Macroscopic metallographic analysis

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

- ***Joint imperfection of the type spheroidal blister of diameter 0.1-0.3 mm are revealed. This type of imperfections is accepted.***

ISIM TIMIŞOARA	Nr. raport: 41/PN110/1	Data:23.06.2014	Pag. 4/7

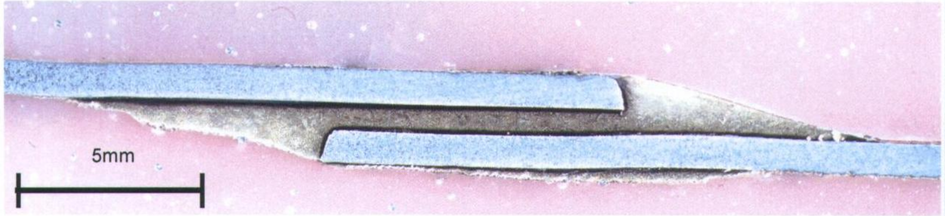


Fig. 3, A10- [Atac Nital 10%+E1]

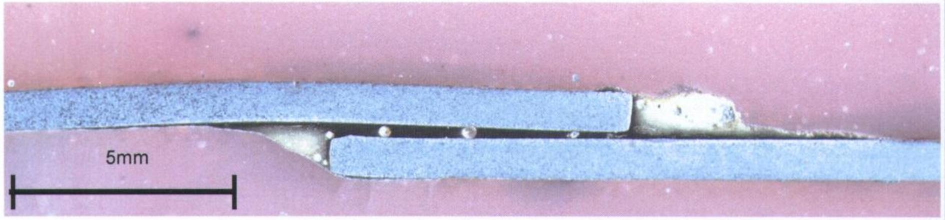


Fig. 4, B1- [Atac Nital 10%+E1]

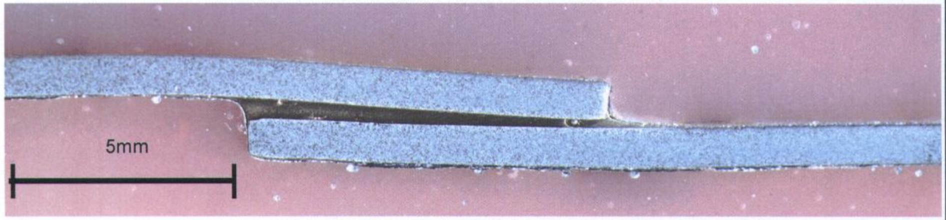


Fig. 5, B4- [Atac Nital 10%+E1]

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

3. Metallographic analysis

3.2. 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.***

ISIM TIMIŞOARA	Nr. raport: 41/PN110/1	Data:23.06.2014	Pag. 6/7

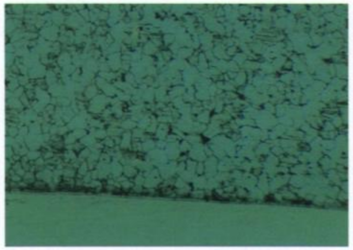


Fig.10, B1, ZIT [atac E1, 100X]

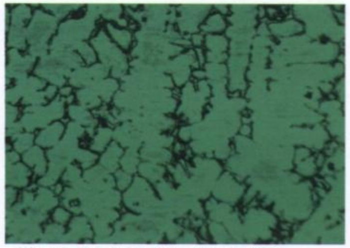


Fig.11, B1, MA [atac E1, 100X]

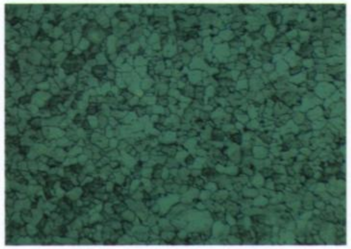


Fig.12, B4, MB [atac Nital 2%, 100X]

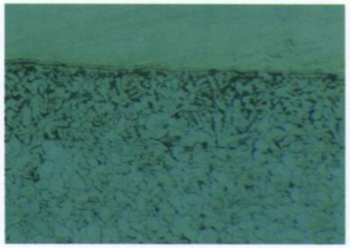


Fig.13, B4, ZIT [atac Nital 2%, 100X]

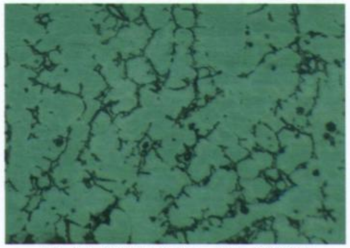


Fig.14, B4, MA [atac E1, 100X]

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

3.3. Vickers HV1 hardness test

- ***For the specimens A2, A5 and A10, the Vickers HV1 hardness are: 96-133 HV1 in the deposited filler alloy (MA), respectively 102-111 HV1 in the upper heat affected zone (ZITsuperior) and 102-119 HV1 in the heat affected zone beneath (ZITinferior), as well as 93-113 HV1 in the upper base metal (MBsuperior) and 99-131 HV1 in the base metal beneath (MBinferior). The result is adequate.***
- ***For the specimens B1 and B4, the ranges of Vickers HV1 hardness values are between 91-106 HV1 in the deposited filler alloy (MA), respectively 103-117 HV1 in the upper heat affected zone (ZITsuperior) and 100-106 HV1 in the heat affected zone beneath (ZITinferior), as well as 97-103 HV1 in the upper base metal (MBsuperior) and 99-110 HV1 in the base metal beneath (MBinferior). The elaborated type of brass has a lower hardness. The joint has a higher toughness. The result is adequate.***

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

4. Shear test

- ***The specimens A1, A3, A4, A6, A7, A8, A9 are allocated to the shear test, for the brazing test with common brass.***
- ***Related to the brazing test sample with the experimental brass elaborated in the Ecosolder project, the specimens B2, B3, B5 are allocated to the shear test. The series A and B of the specimens must be compared.***
- ***The shear test according to SR EN ISO 25239-4,5:2012 was carried out for this brazed test sample, in order to assess the maximal force and the ultimate strength of the joint. The results are presented in the test report in the annex.***

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

4. Shear test (continued)

- ***By the shear test of the specimens A1...A9, from the brazed joint made with the common type of brass, the maximal force is Fmax= 4000- 4400 N, respectively the ultimate strength is Rm= 274- 304 MPa. The values of the ultimate strength are proportional to the maximal force. All the specimens have broken in the base metal.***
- ***Thus, the ultimate strength of the joint is higher than the ultimate strength of the base metal. All specimens have been without imperfections, by the shear test. The result is adequate.***

4. Shear test (continued)

- *In the case of the specimens B2, B3 and B5, from the brazed joint made with the type of brass elaborated in the Ecosolder project, the maximal force is Fmax= 4320- 4440 N, respectively the ultimate strength is Rm= 296- 304 MPa. The values of the ultimate strength are proportional to the maximal force. All the specimens have broken in the base metal.*
- *By consequence, the ultimate strength of the joint is higher than the ultimate strength of the base metal. All specimens have been without imperfections, by the shear test. The result is adequate. The brass type elaborated in the Ecosolder project is adequate.*

5. Conclusions

1. The preparation of the base metal sheets before the brazing operations, as well as placing and fixing the sheets are very important.
2. High quality finishing of the overlapping zone can allow both good flowing and wetting of the flux and filler metal.
3. The base metal sheets must have a correct position, in order to assure the adequate fusion, flowing, wetting and solidification of both the flux and filler alloy, onto the overlapped zone, depending on the location of the gap, related to the tip of the brass wire, charged with flux.
4. 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: flow rates of acetylene and oxygen, power, temperature, type of flame (reducing, neutral, oxidizing), length, height over the brazing zone, inclination, as well as other factors.

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

5. Conclusions (continued)

5. To long brazing times can also cause evaporation of certain substances of both the filler alloy and flux that can affect the technology process.
6. 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, leaking, wetting and solidifying. The brazed joints executed with this new alloy have good appearance, form and sizes, as well as adequate mechanical characteristics.
7. The brass type CuZnSnSiMn has a good behaviour during the brazing process. The results of the visual examination, metallografic analysis and shear test of the brazed joint are adequate. The results of the tests performed with the elaborated type of brass are similar or better than the results the common brass.

5. Conclusions (continued)

8. 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.

Based on the behaviour during the brazing test and the results of the visual examination, metallografic analysis and shear test, the brass type CuZnSnSiMn, elaborated in the Ecosolder project, is adequate.

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

References

[1] Groover, Mikell P. (2007). Fundamentals Of Modern Manufacturing: Materials Processes, And Systems (2nd ed.). John Wiley & Sons. ISBN 978-81-265-1266-9.

[2] P.M. Roberts, "Industrial Brazing Practice", CRC Press, Boca Raton, Florida, 2004.

[3] *** Brazing. en.wikipedia.org/wiki/Brazing

[4] *** The Oxy-Acetylene Handbook, Union Carbide Corp.

[5] 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.

[6] A. Kostov; R. Todorovic; A. Milosavljevic et. al. (MMI Bor, Serbia): “New ecological solder CuZnSnSiMn”. Leaflet presented at the Workshop #1, organized by ISIM Timisoara, February 2014.

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

[8] EN ISO 13585:2012 - Brazing - Qualification test of brazers and brazing operators.

[9] EN 14324:2004 - Brazing - Guidance on the application of brazed joints.

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

References (continued)

[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).

CROSS BORDER COOPERATION
Romania-Serbia
Common borders. Common solutions.

CONTACT PERSON

- ***Name: Dr. Eng. Victor Verbițchi***
- ***Phone: +40256-491828-143***
- ***Mobile: +40728-576630***
- ***Fax: +40256-492797***
- ***E-mail: vverbitchi@isim.ro***
- ***Web: www.isim.ro***

Thank you for your attention !