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Improving a Brazed Joint Structure, with a New Ecological Brass

VERBIȚCHI Victor[1,a*]; BOȚILĂ Lia[1,b]; CIUCĂ Cristian[1,c]; KOSTOV Ana[2,d]; MILOSAVLJEVIĆ Aleksandra[2,e]; TODOROVIĆ Radiša[2,f]

[1]National Research & Development Institute for Welding and Material Testing - ISIM; Address: 30, Blv. Mihai Viteazul, Postal Code 300222, Timisoara, Romania

[2]Mining and Metallurgy Institute – MMI; Address: 35, Zeleni Bulevar, Postal Code 19210, Bor, Serbia

[a]vverbitchi@isim.ro, [b]lbotila@isim.ro, [c]cciuca@isim.ro, [d]ana.kostov@irmbor.co.rs, [e]aleksandra.milosavljevic@irmbor.co.rs, [f]khurgan@ptt.rs

*Corresponding author: Victor Verbitchi, vverbitchi@isim.ro

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Abstract. In the frame of the Romania-Republic of Serbia IPA Cross-border Cooperation Programme, in the Project Ecosolder, the National Research & Development Institute for Welding and Material Testing - ISIM Timisoara, Romania, has elaborated a brazing procedure with a new ecological brass of the type B-Cu60ZnSnSiMn, elaborated by the Mining and Metallurgy Institute - MMI Bor, Serbia.

The brazing test was carried out according to the standard EN 13134:2000 related to the brazing procedure approval.

The applied process is oxygen-acetylene flame brazing of steel sheets, with the sizes of 87 mm x 80 mm, thickness of 1.0 mm and overlap 7 mm. Images of the execution of the brazing procedure are presented, with comments on every phase.

The appearance of the joint is adequate, by the visual examination.

By the metallographic analysis, the constituents of the deposited filler metal are dendritic solid solution, with fine particles of Sn, Si and Mn. No defects have been revealed. The values of the hardness are 91-133 HV1. The results of the specific shear test comply with the requirements. The technological, ecological, structural and mechanical characteristics of this filler alloy are adequate.

Some applications of brazing with the new ecological brass are recommended.

Introduction

In the frame of the Romania-Republic of Serbia IPA Cross-border Cooperation Programme, in the Project Ecosolder, ISIM Timisoara, Romania, has performed innovative studies and experiments on technological processes, in order to verify and extend the application possibilities of the ecological filler alloys for soldering, brazing and weld-brazing [1].

MMI Bor, Serbia, has carried out innovative studies and experiments concerning the elaboration of new ecological alloys for soldering and brazing, as required by the ROHS Directive 2002/95/EC for Restriction of Hazardous Substances and the WEEE Directive 2002/96/EC on Waste Electrical and Electronic Equipment [2].

The brazing tests were carried out according to the requirements of [3] and EN 13134:2000 [4] related to the brazing procedure approval. Important aspects of the standard EN ISO 13585:2012 [5] related to the qualification test of brazers and brazing operators have been also considered.

Base metal

The test of brazing was performed on sheets of steel grade S235, EN 10025, having the approximated sizes of 160 mm x 87 mm and 87 mm x 80 mm, thickness 1.0 mm, overlap 7 mm.

The S235 structural steel plates and sheets meet the European standard EN 10025-1: 2004 related to the general technical delivery conditions. These plates and sheets are produced of common carbon structural steel that can be used in a very broad range of fabrication processes.

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

Table 1. Chemical composition (%) of the steel S235, EN 10025-1

C	Si	Mn	Ni	S	P	Cr	N	Cu	Fe
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	Remain-der

Filler Alloy

The filler alloy used in these experiments is an experimental batch of brass for brazing, having the symbolization B-Cu60ZnSnSiMn, according to EN ISO 3677:1995. Its chemical composition may be subject of a patent application.

By the new experimental filler alloy, besides the contents of copper and zinc, one may remark the contents of tin, silicon and manganese. These elements contribute to improve the technological properties of the new filler alloy: melting, flowing, wetting and solidification.

In the table 2, the chemical composition of a common brass is given, available as filler alloy for brazing. For comparison, brazing tests have also been performed with this common type of brass, as described later in this paper.

Table 2. Chemical composition (%) of brass B-Cu60Zn, EN 17672

Fe	Ni	Al	Cu	Pb	Sn	Others	Zn
max. 0.05	max. 0.3	max. 0.02	59 - 61	max. 0.05	max. 0.1	Total 0.1	Remainder

As presented in the fig.1, the experimental filler alloy was produced, in the following forms:

1. Hexagonal bar, size 5 mm, length 50 mm; elaborated as a hard alloy;
2. Hexagonal bar, size 5 mm, length 25 mm; elaborated as soft-annealed alloy;
3. Wire, diameter 1.5 mm, length approximately 300 mm; wiredrawn.

Flux

The flux used in the brazing operations carried out in the presented work and described here is borax. It is also known as sodium borate, sodium tetraborate or disodium tetraborate. It is an important compound of boron, a mineral and a salt of boric acid. Powdered borax is white, consisting of soft colorless crystals that dissolve easily in water. Borax is generally mentioned and used as sodium tetraborate decahydrate $Na_2B_4O_7 \cdot 10H_2O$. It is a very efficient cleaning substance.

Equipment

For the execution of the brazing test samples, the equipment for oxygen-acetylene welding, cutting and brazing was used, of the outfit of ISIM Timisoara.

Experimental brazing tests

Overlap joint brazing tests have been performed, as presented in the fig. 2, on grade S235 steel sheets. For comparison, common available brass B-Cu60Zn (test A) and the new type of brass B-Cu60ZnSnSiMn (test B), elaborated in the Ecosolder project, have been used.

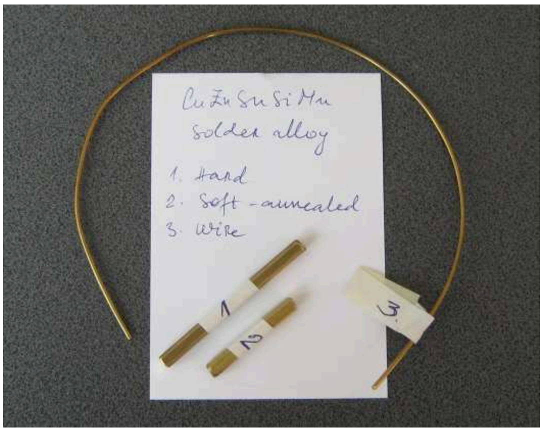


Fig. 1. The new ecological brass for brazing

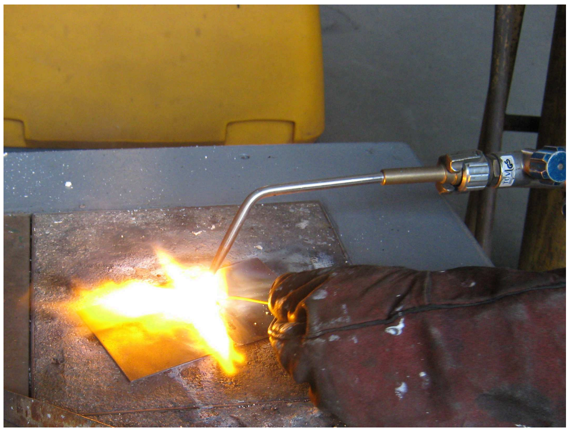


Fig. 2. Execution of the brazed overlap joint

In the first stage of the process, the tip of the filler alloy wire must be heated, to prepare it for charging with flux, so that the adequate quantity of flux gets on the tip of the filler wire.

The steel sheets need to be heated, as a second stage of the process, in order for the flux to melt and react with the oxide layer. The wire was previously charged with flux, by dipping it into the jar containing the flux. In the case the filler tip is not heated, the flux would not adhere onto the wire and the flux would be blown away from the brazing zone.

In the third phase, the filler wire charged with flux is introduced into the brazing zone. The flux melts and the etching of the base metal occurs. Then the filler wire melts gradually and drops are deposited upon the steel sheet. A horizontal position is favourable for the molten drops of filler alloy to flow uniformly onto the sheet, so an optimal shape of the joint would be obtained in the next phases of the process.

In the next stage, flux and filler alloy are deposited onto the second steel sheet that was previously heated. The heated sheet of base metal is also favourable for the filler alloy to melt and flow uniformly on the base metal, in the brazing zone.

In the fifth stage of the process, the base metal sheets are overlapped and the upper sheet is pressed upon the other one, so that a good shape of the joint is achieved, having a uniform thickness of the deposited filler between the two sheets, without disturbances of the sheets.

A minimal gap between the two sheets must be achieved. This gap will be filled by the liquid filler alloy, during the brazing processes. The gap should not be much wider than the recommended size of 0.10...0.25 mm, in order to avoid the liquid metal to flow apart from the brazing zone. The base metal sheets are heated. The brazing time for each joining phase is t_b= 20... 30 s. It depends on the sizes of the sheets and 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, tilt, as well as other factors.

During the final stage, completion of the deposited filler alloy in the gap is performed, in order to achieve a uniform thickness of the layer between the two sheets of base metal.

The work temperature of the base metal is also an influence factor of the brazing time. 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. This temperature level corresponds to the melting temperature of the filler alloy. The colour of the sheet surface brings real time information about the execution of the brazing process. Light colours, as yellow (1050ºC) and white (1200ºC) show that too high temperature is reached and overheating must be avoided. The total cycle duration from the start of the heating until the joint is completed is in the range t_b= 2.5... 4.5 min, if unnecessary brakes are avoided, as recommended.

The properties of the new experimental and ecological filler alloy, regarding melting, flowing, wetting and solidification, have also been verified during the experiments. It has a good technological behaviour during these brazing tests. The new type of brass is recommended for brazing steel parts [2].

The test samples of the brazed joints, with the sampling plan of the specimens for both the metallographic analysis and shear test are presented in the fig. 3 and fig. 4.

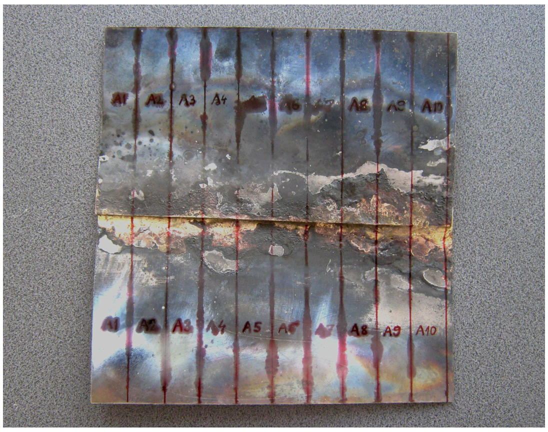


Fig. 3. Brazing joint test sample “A”

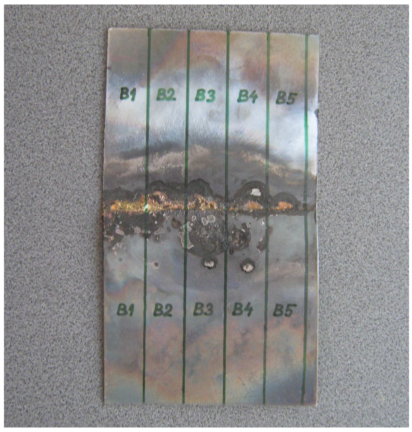


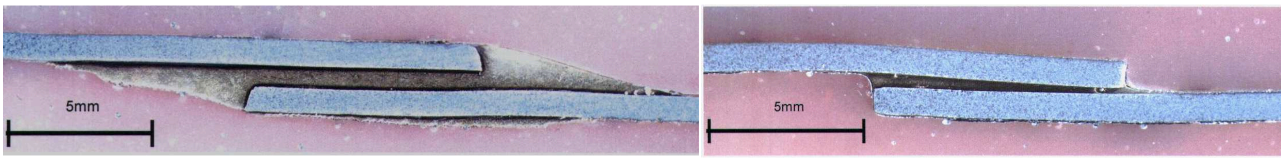
Fig. 4. Brazing joint test sample “B”

Non-destructive examination

Visual examination, according to EN 12799:2000 [6], of the brazed joints was applied. The imperfections are revealed and verified according to EN ISO 18279:2003 [7]. The brazed joints have adequate appearance, related to the class of these materials and to the applied joining process. They are well shaped and symmetrical related to the axis of the overlapped zone of the sheets. Thermally influenced areas of brazing are seen on the sheets. There are no defects in the deposited filler metal.

Metallographic analysis

Macroscopic analysis. Macroscopic examination according to SR EN 12797 [8] and SR EN ISO 18279 [7] was carried out. In the fig. 5, cross sections are presented of the specimens, made by both the common (A) and the new (B) brass types. The appearance is good. Brazing metal excess is observed, as an accepted imperfection, at the specimen A10, caused by an exceeded care to avoid the lack of deposited metal. The result is adequate.



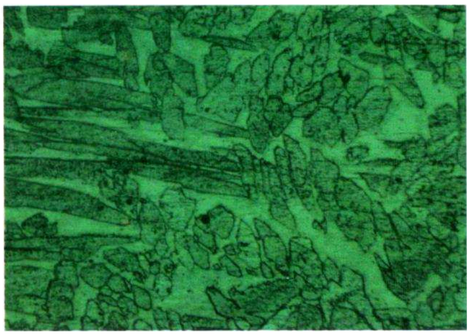
a. Specimen A10, made by common (A) brass b. Specimen B4, made by new (B) brass

Fig. 5. Cross sections of the brazed joints [Etching Nital 10%+E1]

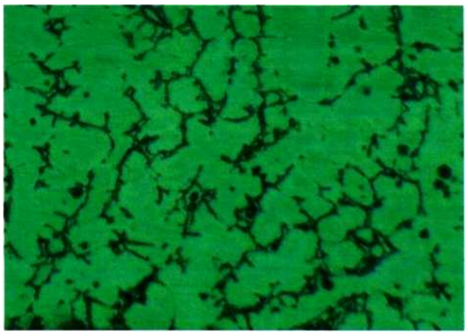
By the specimen B4, the report mentions good appearance of the brazed joint, respectively imperfections of the type spheroidal blister, having the diameter d = 0.1- 0.3 mm, that are accepted. It is a consequence of the fast cooling of the molten brass. A technical solution to avoid this consists in gradually cooling the brazed joint, by setting apart slowly the flame. The result is adequate.

Microscopic analysis. The metallographic microscopic analysis, according to SR EN 12797 [8] and the specific standards for the analysis method, has been performed in the base metal (BM), heat affected zone (HAZ) and deposited brass (DB).

In the fig. 6, the structure of the brazed joint of the specimen A2, respectively specimen B4 are shown. In the DB, the following structural constituents have been revealed: solid solution rich in copper and particles of oxides (brass A), respectively dendritic alpha solid solution with fine particles of tin, silicon and manganese (brass B). No defects are revealed. The results are adequate for both A and B series of specimens, related respectively to both types of brass.



a. Specimen A2, made by common brass (A)



b. Specimen B4, made by new brass (B)

Fig. 6. Structure of the brazed joint, DB [Etching E1, 100 X]

Hardness test

The hardness test, according to SR EN 12797 [8] and the specific standards of the test method, has assessed values in the range 91 - 133 HV1. The distribution of the hardness is shown in the fig.7. The hardness is uniform in all areas: the base metal, heat affected zone and deposited brass. The values of the hardness and their uniform distribution show that the joints have no brittle constituents. The result is adequate.

Shear test

By the shear test according to ISO 5187:1985 [9] and EN ISO 25239 - 4; 5:2012 [10], matched for this case of brazed overlap joint, the ultimate strength is higher than R_m= 274 - 304 MPa, as presented in the fig. 8. All the specimens have broken in the base metal; this is adequate. The results comply with the requirements for both A and B types of brass.

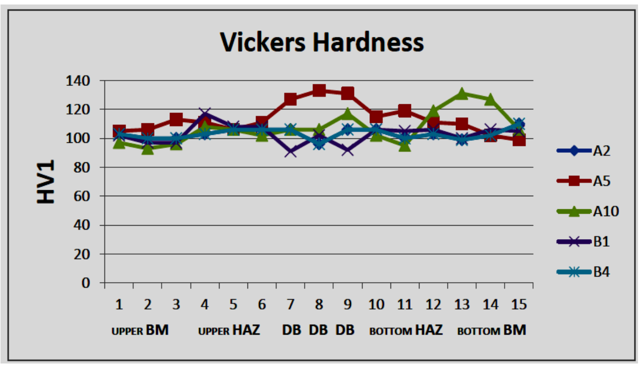


Fig. 7. Hardness distribution of the joints

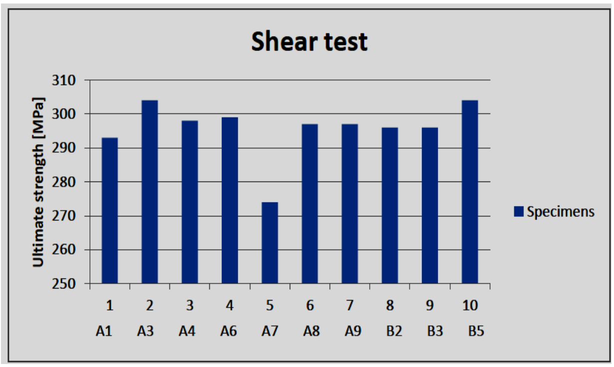


Fig. 8. Ultimate strength by the shear test

Conclusions

Preparation of the base metal sheets before the brazing operations is very important. High quality finishing of the overlapping zone allows good wetting of the base metal.

The base metal must have correct position, for proper conditions of the brazing process.

A positioning jig for the base metal sheets is important for the precise positioning of the parts to be joined. This jig should be designed and built to firmly hold the components, as to avoid disturbing movements during the brazing process.

The temperature of the base metal must be kept at 900 - 940ºC (steel colour orange), in order to melt the brass, but to avoid overheating and evaporation of certain components of brass or flux.

The new brass B-Cu60ZnSnSiMn, has adequate technological behaviour, regarding fusion, flowing, wetting and solidification. The brazed joints executed with this new alloy have also good appearance, form and sizes, as well as adequate mechanical characteristics.

The structures of the brazed joint are in accordance with their mechanical characteristics.

The ecological properties of the new brass are adequate, as it exhales no lead, cadmium or other hazardous substances. Local exhaust ventilation must be applied for common fume and gases caused by the process, as it is the most efficient measure for the occupational health.

Compared to the common brass B-Cu60Zn, the technological behaviour and the test results of the new ecological brass B-Cu60ZnSnSiMn, elaborated in the Ecosolder project, are adequate.

As brazing applications of the new brass, the following should be recommended: mining and oil equipment, electro-technical devices, refrigerating technique, manufacturing tools and others.

Acknowledgement

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References

[1] L. Boţilă; V. Verbiţchi; R. Cojocaru; C. Ciucă et al. (National Research & Development Institute for Welding and Material Testing – ISIM Timisoara, Romania): 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 4-6. Romania-Republic of Serbia IPA Cross-Border Cooperation Programme. ISIM Timisoara, Romania. (2013- 2014).

[2] A. Milosavljević, R. Todorović, A. Kostov, L. Todorović (Mining and Metallurgy Institute Bor, Serbia): “Special brass solder for steel parts hard soldering”, (2013). http://www.irmbor.co.rs/ images/projekti/ecosolder/database/mmiBor/document_03.pdf.

[3] P.M. Roberts, "Industrial Brazing Practice", CRC Press, Boca Raton, Florida, 2004. www.asminternational.org

[4] EN 13134:2000 – “Brazing - Procedure approval”.

[5] EN ISO 13585:2012 – “Brazing - Qualification test of brazers and brazing operators”.

[6] EN 12799:2000- Brazing – “Non-destructive examination of brazed joints (& A1:2003)”.

[7] SR EN ISO 18279:2003 – “Brazing – Imperfections in brazed joints”.

[8] SR EN 12797:2000 – “Brazing - Destructive tests of brazed joints (& A1:2003)”.

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

[10] EN ISO 25239-4 and 5:2012 – “Friction stir welding -- Aluminium -- Part 4: Specification and qualification of welding procedures. Part 5: Quality and inspection requirements”.