The usage of aluminium for realization of current conductors

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Keywords

Current conductors, flexible conductors, COPAL, MIG welding, friction steer welding, etherogen joint, copper, aluminium, ultrasonic welding

1. Introduction

In the last period the explosion of prices for raw materials and especially for copper raised the question if aluminium may not represent an alternative for the realization of current conductors and in generally for the electrotehnically industry. The problem is now new, in the past where already existing some trends and where made tests to implement the usage of aluminium as current conductor. The topic of replacing copper with aluminium has two aspects: a technical and an economically one. The technical aspect refers mainly to the conductibility and the different specific weights of the two materials.

Aluminium is used nowadays as current conductor in the case of rigid conductors with an increased section, the main purpose being the reducing of weight. The electrical conductibility of aluminium is much more reduced than in the case of copper, normally being necessary a section of 1.5 greater, Tabble 1 [1], this disadvantage may be, in some cases neglected, if taken into consideration, the advantages regarding weight and costs.

Table 1. Physical properties of Al-Cu

Material	Copper	Aluminium
Relative electrical conductibility (Copper = 100)	100	62
Relative thermical conductibility (Copper = 100)	100	56
Thermical dilatation coefficient at 20ºC, $[k^{-1}]$	16.50	23.20
Density $[g/cm^3]$	8.95	2.70

One of the main disadvantages of aluminium is the oxide layer that forms on the surface of the material, layer who leads to the impossibility of joining by brazing and also to high values of the passing electrical resistances, in the case of using the joining by screws or clamps.

2. Aluminium conductors

2.1. Flexible conductors of aluminium slides

A flexible conductor made of aluminium is presented in Figure 1.

The base material for the aluminium slides is E-Al 99.5, the thickness of the slides is of 0.3mm, for the end connection being used E-AlMgSi 0.5. The flexible part of the conductors was joined with the rigid part by using MIG welding. The outside aspect of the joint realized by MIG welding is presented in Figure 2.

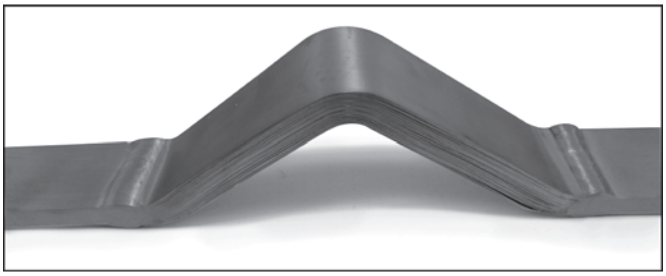

Figure 1. Flexible conductor (Al)

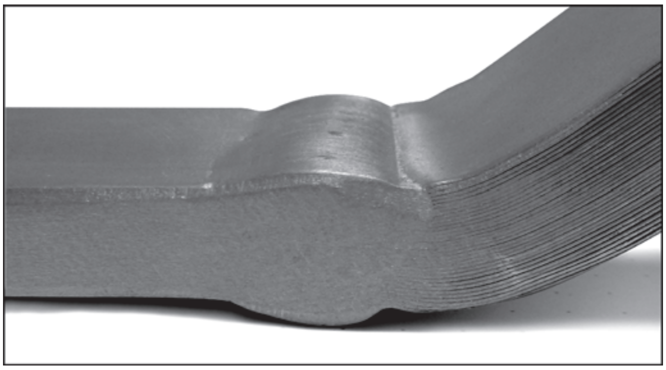

Figure 2. MIG welded joint

The MIG welded joint section, prepared for the metalographic analysis is presented in Figure 3.

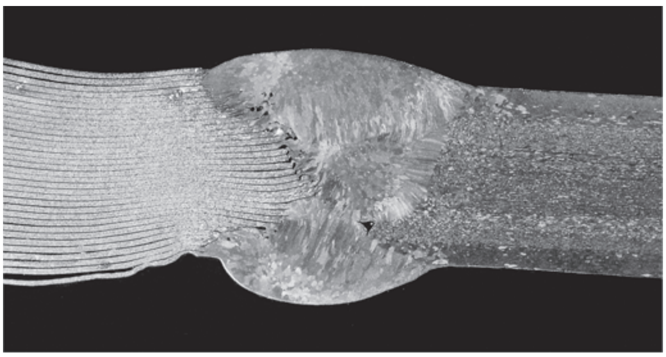

Figure 3. Microstructure of the transversal section of MIG welding

We remark the relatively low quality of the welded joint, one of the reasons being that the aluminium plates are free: they are not compacted as in the case of copper and do not constitute a solid mass of material. Even if the electric arc was directed during welding to the massive side, the aluminium slides are reaching the melting temperature much faster than the massive part, and due of this fact, especially

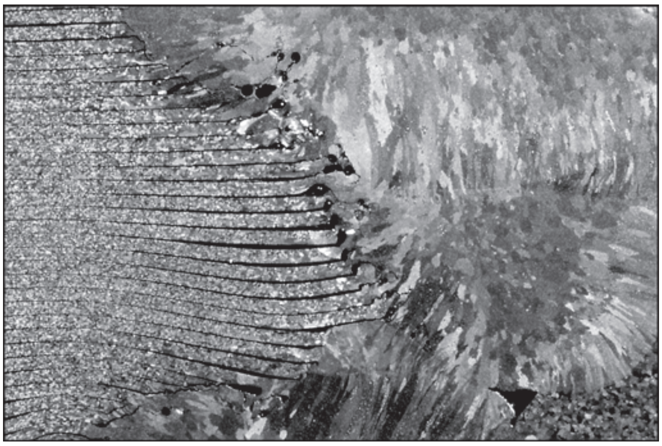

Figure 4. Macrostructure of the MIG welded joint (detail)

in the root layer certain slides are not melted properly (Figure 4).

2.2. Improving the electrical contact in the case of using aluminium. Passing electrical resistance

As mentioned, one of the major disadvantages in case of using aluminium is represented by the oxide layer that forms on the surface, layer that leads to high electrical passing resistances, in case of use joining with screws or clamps. A possibility to solve this inconvenient is the covering of the connective parts with copper or silver using the cladding process with cold gas.

Table 2. Comparation of the electrical pass resistance

Combination of base materials	Electrical pass resistance, [μΩ]
Cu+Cu	5.2
Cu+Al covered with cooper	7.3
Cu+Al covered with silver	7.3
Al+Al	28.2
Al+Cu	8.1

Table 2 presents a comparation between the electrical pass resistances of different combinations of materials Al + Cu with or without surfaces covered with copper or aluminium.

2.3. COPAL (Cooper-Aluminium)

A material through which the disadvantages of aluminium are avoided is COPAL.

COPAL is not an alloy but a bimetal produced through extrusion (Figure 5), being in fact a plating with copper of aluminium. This combines the advantages of lightweight alloys (reduced specific weight, easy processing specify through deforming) with those of copper, e.g. resistance to corrosion, possibility of brazing and galvanic coatings. The electric conductivity of COPAL is good, reaching, in case of high frequency current values, that of copper [3].

COPAL conductors may be mechanically processed without any problem, being also able to be brazed or galvanic covered, Figure 6.

In the Table 3 are presented several examples with the equivalence between the sizes of conductors realized from massive copper with those of COPAL.

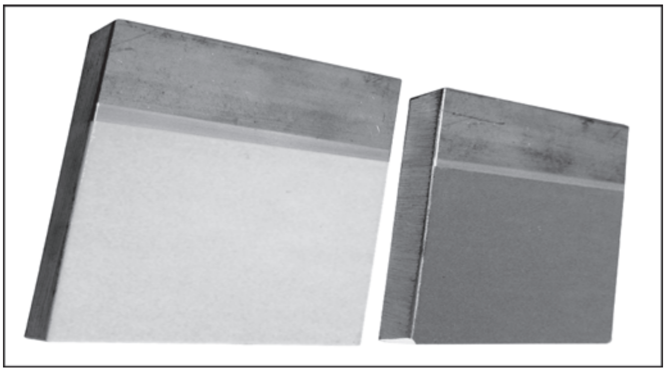

Figure 5. COPAL conductor

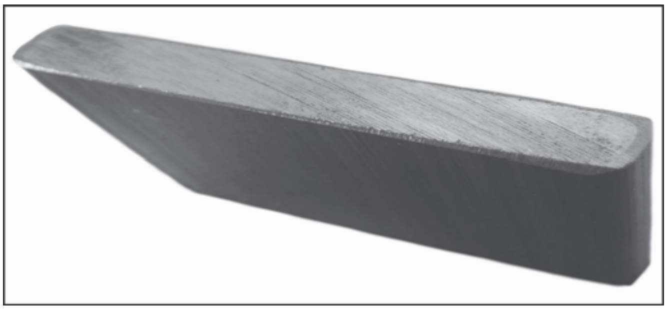

Figure 6. Electrical conductor realized from COPAL

Table 3. Characteristics of COPAL

Dimensions of copper conductor [mm]	Equivalent dimensions of COPAL at the same electrical charging [mm]	Reducing of weight compared to copper
12x5	20x5	32%
40x10	50x10	49%
100x10	120x10	42%

3. Etherogen joints Al-Cu

Between aluminium and copper exist, as we have shown, large differences between their physical properties. Although the two metals have a partial solubility in liquid state, between them intermediate hard phases will be formed. Therefore, it is preferable to avoid welding by melting these materials. In case welding of copper is done by WIG it is recommended to cover it in advance with a layer of Sn (50-60 mm) [4].

In case of aluminium electrical conductors, a major disadvantage is represented by the oxides layer formed on the surface, layer who causes the impossibility of brazing, and in case of using screws to an electrical resistance increase. In case of contacts under pressure, aluminium is deformed and flows slowly, at his surface being created almost instantaneously a layer of oxide.

3.1. FSW welding

The advantage of FSW welding regarding achieving of joints in solid phase are implementation for realizing dissimilar joints [5]. The technical literature signalizes a series of results obtained with materials having close or very little different properties, from the point of view of the nature of the materials and of their metallographic structure.

If for joint types as Al-Al and Cu-Cu, the applicability is extended, for etherogen joints Al-Cu, the experience is relatively reduced.

The outside aspect of an overlap welded joint realized by FSW of Al-Cu 3 + 3 mm is presented in figure 7 [6].

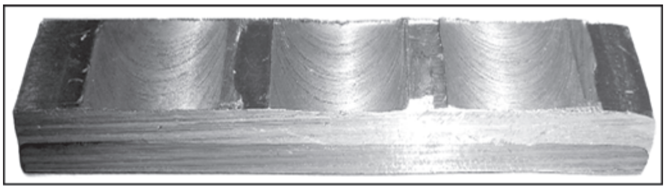

Figure 7. FSW joint Al-Cu 3+3mm

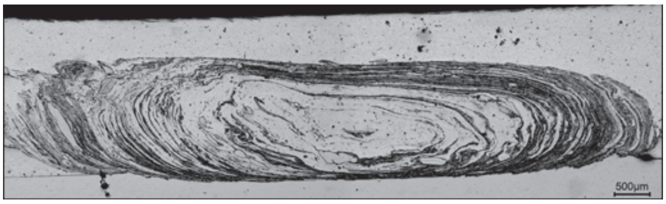

Figure 8. Metalographical analysis (12,5×) of a FSW joint Al+Cu 3+3mm

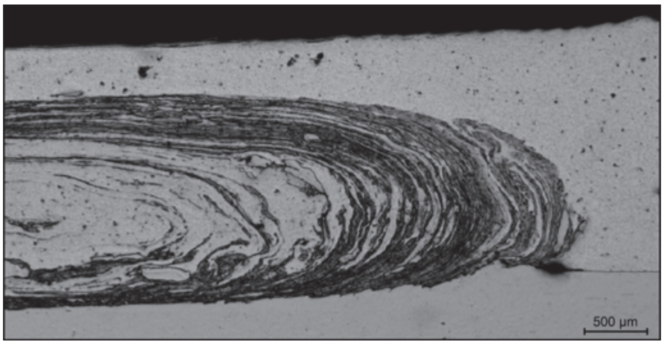

Figure 9. Microstructure of welded joint

In Figure 8 a metallographic analysis of the analysed probe are presented. The copper has dark colour and the colour of aluminium is light. The welded area, the joint is located in the greater part of the aluminium having a good connection with the copper part.

In Figure 9 we can observe the presence of copper particles dispersed and not arrant in the welded joint.

3.2. US welding

US welding has a lower applicability in the manufacture of copper conductors due to the restrictions of the maximum weldable section. Though, at some joints and of course in the case of serial production, US welding represent a good alternative both in terms of technical and economic operations for brazing or riveting. Kraus, as Manufacturer, applies this technology mainly to the plate-strand joints with maximum sections of 25 mm^2, or welding of US in line With Al + Cu (0.4 + 0.2 mm), Figures 10 and 11 [8].

4. Conclusion

From the above presented data, may be concluded that, in order to reduce the weight the use of bimetals as COPAL may recommend. The use of those products has comparable production costs with those of strands made of copper.

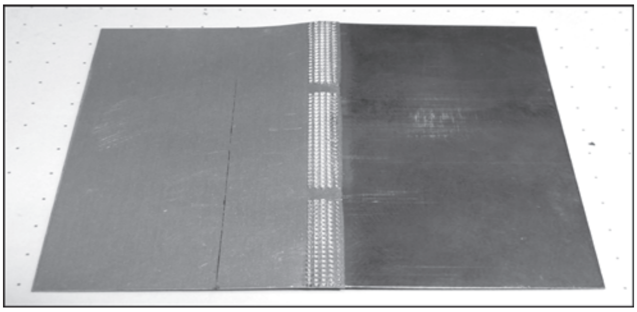

Figure 10. Eterogen joint Al+Cu (0.4+0.2mm) welded US in line

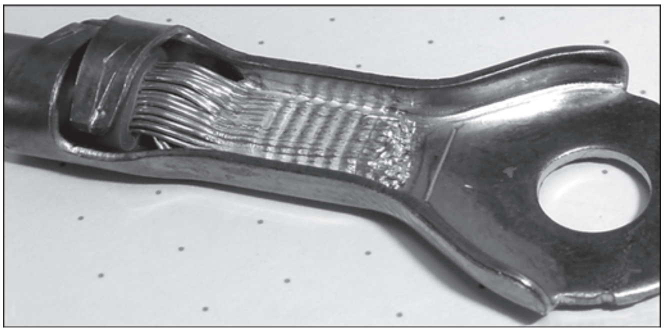

Figure 11. Eterogen joint Al+Cu of the type plate-strand, welded US

Tabel 4. Comparation between production costs [EURO].

	Copper strands	Copper slides	Aluminium slides
Material price	1	1.20	0.80
Cutting	1	2.00	2.00
Joining	1	0.50	1.20
Processing of grabbing parts	1	0.50	0.50
Further processing	1	0	0.50
Total	5	4.20	5.00

Bibliography

[1]. xxx: Kupfer in der Elektrotechnik - Deutsches Kupfer-Institut EV, 2000, Düsseldorf, Germany

[2]. xxx: Berolina Metallspritztechnik GmbH, Germany

[3]. Kirchberg, Ch.: Alu-Verbundschienen - Copal - Promet AG

[4]. Dehelean, D.: Sudarea prin topire, 1997, Editura Sudura Timisoara, Romania

[5]. Panaitescu, Ş.: Sudarea prin frecare cu element activ rotitor, 2009, Editura Sudura, Timişoara, Romania

[6]. xxx: SLV Berlin-Brandenburg -Verbindung Al+Cu (4+4mm) durch FSW Bericht 01/2011, Germany

[7]. xxx: SLV München - Schliffuntersuchung an FSW Schweißverbindung Al+Cu (4+4mm) Bericht 26.01.2011

[8]. Kraus, R., Kraus, W.: GmbH Gegenüberstellung verschiedener flexibler Verbindungen, 2009, Bericht Siemens, Germany

Lecture presented in The 5th International Conference - Innovative technologies for joining advanced materials, 22-16-17.06.2011, Timisoara, Romania

NATIONAL R&D INSTITUTE FOR WELDING AND MATERIAL TESTING

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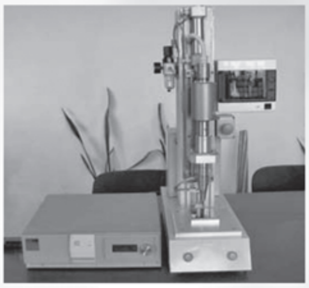
Ultrasonic Welding Laboratory

Research directions:

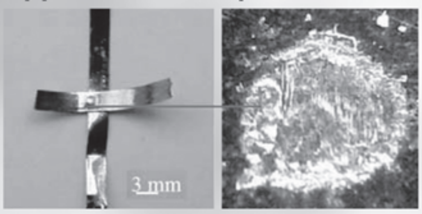
- Applied research for experimental development of new materials joining technologies for industrial applications
  - Ultrasonic welding of non-ferrous metallic materials: Cu, Al, CuZn37
  - Ultrasonic welding of thermoplastics materials: PC, ABS, PEHD
  - Ultrasonic welding of new materials, composites, with ”shape memory” and biocompatible: CuZnAl, NiTiCu, NiT6V
- Study of the interface phenomena, microstructure quality and metallurgical constituents in ultrasonic welding of metallic materials
- Conception, realisation and experiments of new ultrasonic joining equipments for plastics and metallic materials
- Conception and calibration of the mechanical resonator

Equipments

- **Ultrasonic equipment for metallic material joining,** 3000 W / 20 kHz
- **Ultrasonic equipment for plastic material joining, 2500** W / 20 kHz
- **Equipment for liquid media activation in sonochemistry,** 2000 W / 20kHz
- **Hybrid welding equipment, resistance and with ultrasounds,** 3000W /20kHz 36kVA / 220V
- **Testing equipment (sonometer) for electro-ultraacoustical systems – resonant frequency and acoustical impedance,** 100 Hz- 99kHz
- **Testing equipment (sonometer) for electro-ultraacoustical systems in working - resonant frequency,** 100-99kHz
- **Software for ultrasonic calibration, KRELL ENGINNERING.** Design and configuration of ultra-acoustical devices:
  - piezoceramic converters for liquid reaction media;
  - sonotrodes for plastics and metallic materials welding.

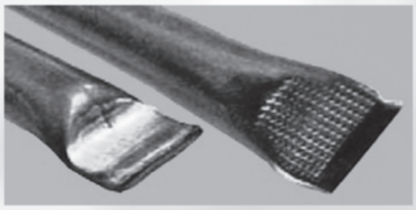


Application examples

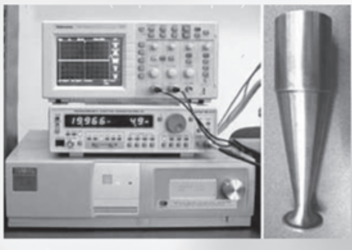


Welding bands of NiTiCu +NiTiCu (20μm +20μm)

Ultrasounds welding, 4 rivet joints, PC +6 % fiber in automotive micromotors

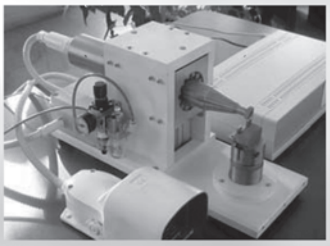


Copper pipe welds with ultrasoud (0,8mm + 0.8mm)



Conception and calibration of the mechanical resonator

Cavitational equipment, 500 W / 20 kHz



Ultrasonic welding equipement for textile materials

Services offer

- design and production of specialized US equipment
- design and production of sonotrodes
- technical development for US welding applications
- training of personnel
- consulting

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