Developments in copper to copper micro-welding technologies

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Keywords

Joining technologies, airbag connection cables, resistance projection welding, copper wire

1. Introduction

Automotive electronic devices are gaining an increasing role in automobile industry. Safety systems, especially the production technologies of airbag connectors, are a priority [1, 2]. A significant proportion of parts used in automotive industry are composed of electric connecting components and safety systems attaining a prominent role - such as airbag connectors – as well as the electric devices of cars [6].

Producing of airbag connectors takes place at the facility of FCI Connectors Hungary Ltd. in Tatabánya, by manual, semiautomatic and automatic manufacturing equipment. The connection between wires and the electrical contacts in connectors – hereinafter referred to as the terminal – is most often created by the resistance projection welding procedure (Figure 1) [3, 7].

This paper describes the steps of the production technology of the airbag connection joints made by means of resistance projection welding, currently widely applied throughout the world. The compacting – as a resistance welding technique – is presented in detail followed by a description of the production technology of connectors made without compacting by means of resistance projection welding. Welded joints made by means of resistance projection welding techniques are compared through the application of destructive and non-destructive material testing methods.

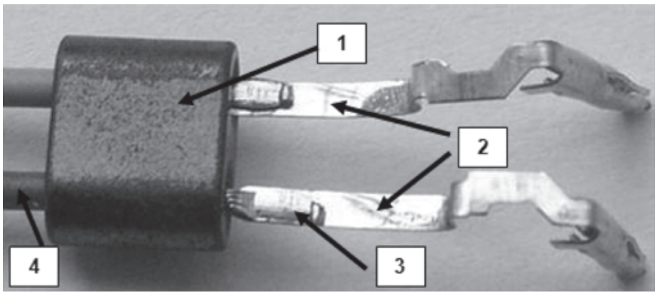

Figure 1. An airbag connector and their components: noise filtering ferrite (1), terminal (2), welded elementary joint (3), stranded wire (4)

After the assessment of the test results relevant to the welded joints made by resistance projection welding, a new laser beam micro-welding method, being both economically and technically beneficial, and having been developed by FCI Connectors Hungary Ltd. and the Budapest University of Technology and Economics, Department of Materials Science and Engineering, is presented. A detailed presentation of the devices needed for the laser beam micro-welding technique follows, along with the results of parameter optimization, performed by us. All test results of the joints made by the laser beam micro-welding method are compared with the test results of resistance projection welding techniques mentioned above.

2. Compacting and resistance projection welding

After that resistance projection welding is carried out, a welded joint can be produced by plastic deformation the joining zone, utilizing the heating effect of the current flowing through the work-piece – tin-coated and uncoated, stripped copper single strand and terminal. Compacting is a resistance welding technique. Cohesive hold is generated by the current led through or induced in the single strand of stranded copper wires [4, 5, 6].

Compacting and preparation steps preceding the operation:

- Cutting stranded wire to the desired size.
- Removing the insulation from the surface of the copper single strand.
- Forming the stranded copper filaments.
- Welding cycle.

See Figure 2 for details of the device and designation of the compacting equipment components.

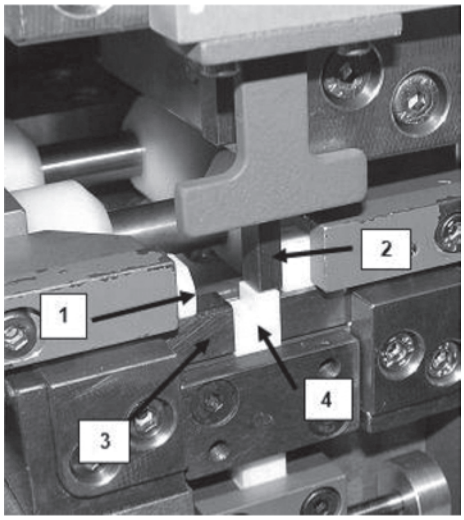

Figure 2. Compacting equipment: lateral ceramics (1), upper electrode (2), lower electrode (3)

Compacting has two essential goals: it prevents developing of hanging-out fibres when resistance projection welding is carried out, which would cause, later on, a short circuit in the connector, and it mitigates the temporary resistance occurring on the contact surfaces of fibres.

During compacting, the single strands are upset in blocks having a square cross-section. After upsetting, single strand are welded together by means of a machine especially developed for this purpose (Figure 2). Single strand are laterally supported by ceramics and are then welded together from the top and bottom by means of tungsten electrodes (type WL20). It can be seen in Figure 3 the pictures of deformed and welded single strand after the compacting operation.

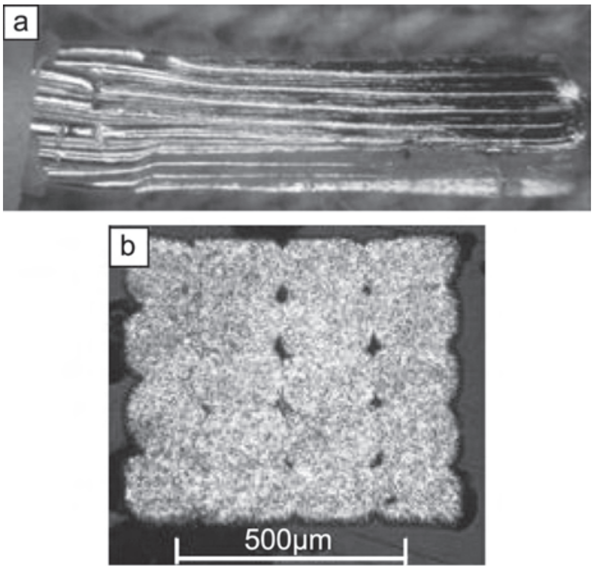

Figure 3. A single strand, after compacting:
a) macroscopic picture of copper wire after compacting,
b) cross section of copper wire after compacting

In the next steps the compacted product is fixed to the terminals by resistance projection welding (terminal: contact in the connector ensuring electric contact). In the course of the procedure the compacted wire on the terminal is welded by means of pressing and electric current. See Figure 4 for the metallographic picture of the connector produced by compacting and resistance projection welding.

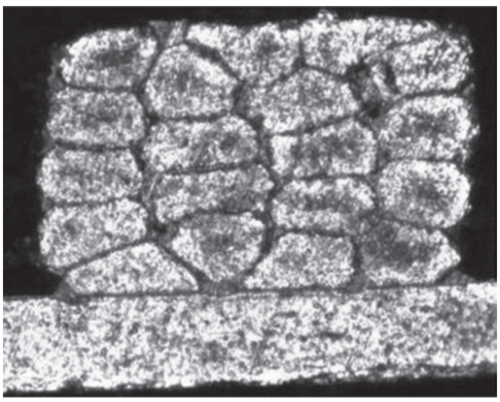

Figure 4. Compacting and resistance projection welded joint: cross-section (thickness of the terminal is 200 microns)

3. Resistance projection welding without compacting

For the compacting-less resistance projection welding procedure a new developed positioning and fixture device was used to assist making of the welded joints between the single strand of the cables and terminals. The advantage of this technique is that the compacting operation described above can be omitted from the manufacturing process. Upsetting and welding of single strand are carried out in a single step with the welding equipment applied.

To achieve the required deformation and the welded joint in one welding cycle several current-time impulses are applied. See Figure 5 for the model of the fixture-positioning device developed for the welding method without compacting, along with the designation of components thereof.

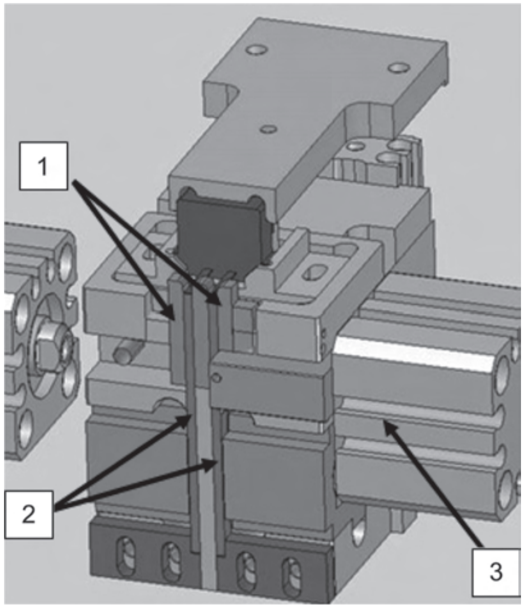

Figure 5. Positioning device and component names:
lateral ceramics (1), lower electrode (2), cylinder (3)

Applying the device shown in Figure 5, we could establish in experiments that we could produce, by means of welding without compacting, welding joints bearing mechanical properties identical with those of joints produced with compacting and welding. The first welding impulse served for heating and upsetting of single strand. The second and third impulses were intended to produce the welded joint between the single strand and the terminal. See Figure 6 for the metallographic picture of the connector produced with the usage of welding without compacting.

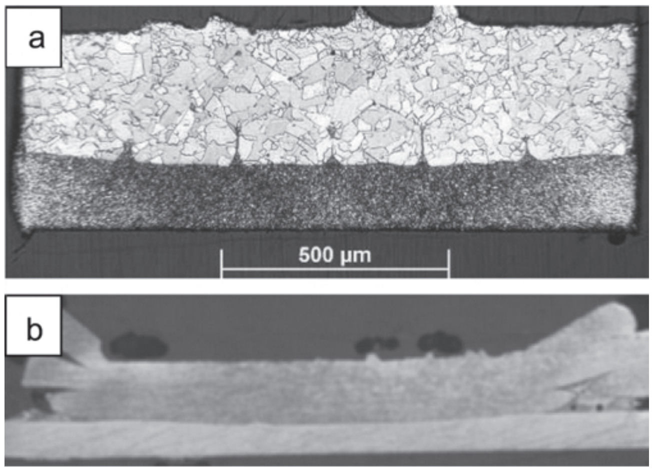

Figure 6. Macroscopic pictures of joints welded without compacting: cross-section (a) and longitudinal section (b) of the welded joint (thickness of the terminal is 200 µm)

4. Laser beam welding

Laser welding of copper is an intensively investigated topic as the literature shows [8-20]. Welded joints were performed between the terminals and the copper single strands by means of the laser beam welding technology. With a view to the quality requirements pertaining to the welded joints represented in the resistance projection welding, we developed a new laser beam welding procedure. In the course of laser beam micro-welding, after the insulation had been removed, we created welded joints by means of a specific fixture and positioning device between the contacting surfaces of copper single strand and the tinned copper terminal.

The mentioned fixture-positioning device ensured the relative positioning of the terminal and the single strand. High-purity copper was chosen as a base material for this device as it ensured appropriate heat-removal during welding; see Figure 7 for the model of the device.

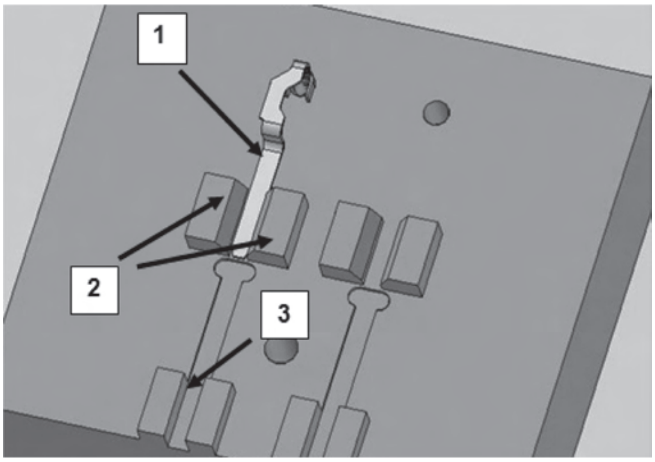

Figure 7. Fixture-positioning device with components: terminal (1), lateral support (2), wire positioning (3)

Laser beam welding experiments were performed using a TRUMPF TruLaser Station 5004 solid state laser equipment. The adjustable parameters of the welding equipment are indicated in Table 1.

Table 1. Parameters, adjustable on the laser beam welding equipment

Laser parameter	Unit
Impulse signal	–
Power	W
Pulse duration	ms
Frequency	Hz
Number of shots	–
Spot diameter	mm
Focus shifting	mm
Energy	J
Average capacity	W
Canting angle of the head	degree
Shielding gas pressure	bar

The laser welded joint between the terminal and the single strand was created avoiding destruction of the terminal. Spot diameter was selected depending on the aggregate diameter of the single strand.

The laser beam head and the single strand formed an angle of 90º. When the welded joint was made, partly of the energy generated by the laser beam was concentrated on the single strand, and partly on the surface of the terminal.

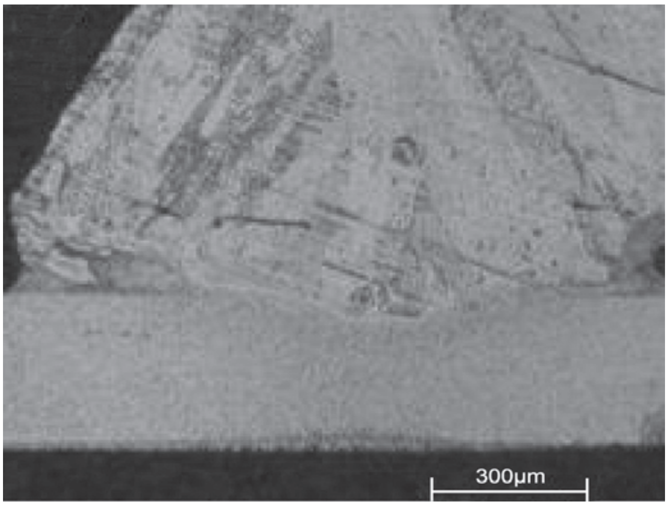

Figure 8. Laser beam welded joint: longitudinal section picture of the welded joint (b)

Table 2. Parameters for laser beam welding defined by way of experiments

Laser parameter	Value
Pulse signal	–
Power	2800 W
Pulse duration	21 ms
Frequency	5 Hz
Number of shots	1
Spot diameter	1.1 mm
Focus displacement	150 mm
Energy	58.8 J
Average power	2.2 W
Head position	0º
Shielding gas pressure	2 bar

For assuring the joint protection, we applied laterally fed argon shielding gas of 2 bar pressure. See Figure 8 for the metallographic pictures of the connector produced with laser beam welding technique. The parameters applied to create the laser beam welded joints are included in Table 2.

5. Examinations

The joints produced with the techniques described in the foregoing were inspected by means of pull-out force testing. The results of the implemented pull-out force tests are indicated below, in Table 3.

The laser welded joints were also examined by peel test. See Figure 9 for the stereomicroscopic pictures of welded joints produced with different welding methods after peel test.

Table 3. Comparison of pull-out force testing results

Welding technique	Pull-out force, [N]				
Compacting / resistance projection welding	105.7	109.8	104.2	107.6	110.4
Resistance projection welding	107.1	109.4	112.3	106.7	107.5
Laser beam welding	110.2	108.9	107.6	110.9	112.4

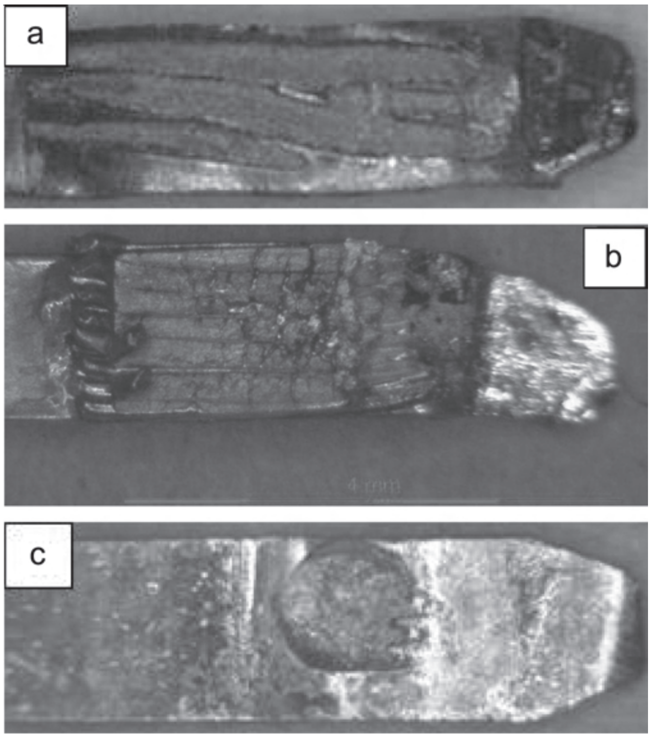

Figure 9. Macroscopic pictures of welded joints produced with different welding methods after peel test: compacting and resistance projection welding (a), resistance projection welding (b), laser beam welding (c)

It is obvious, based on the images in Fig. 9 that in the case of welded joints made with resistance projection welding without compacting and laser beam welding we did not manage to detach the single strand, participating in the connection, from the surface of the terminal. The break occurred at a point farther from the joint, in the single strand.

6. Conclusions

It was performed a comparison of mechanical and material testing results of the welded connectors produced by resistance welding and by the laser beam welding developed by us as presented in this paper.

According to the results of the pull-out force test and peel test we could establish that each connector produced with resistance projection welding and laser beam welding broke when exposed to a breaking strength exceeding 105 N, and this break occurred in the single strand at a point farther from the welded area.

We controlled the layout of the single strand and the welded joints created between the terminal and the single strand by metallographic investigation.

It was produced welded joints between terminals and copper single strand by means of the laser beam welding developed by us with the following parameters: 2800 W capacity, 21 ms pulse duration, 1.1 mm spot diameter, 58.8 J pulse energy, and 2 bar shielding gas pressure.

The investigated mechanical properties of the joints produced with the laser beam welding were practically identical with the characteristics of the joints produced by resistance projection welding.

Acknowledgements

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14-16 Oct.	2nd IPC International Personnel Certification Conference	Rio de Janeiro Brazil	http://www.abende.org.br
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