Special issue of the 3rd International Conference on Computational and Experimental Science and Engineering (ICCESEN 2016)

Investigation of Tensile Properties of Aluminum 6082-T6 Alloys Joined by Cold Metal Transfer Method by Using Different Working Time

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In this study, Aluminium 6082-T6 plates having 1.0 mm thickness were joined by magnesium-based (AlMg5) wire in cold metal transfer technique. The specimens were prepared in butt joint form. Argon was used as shielding gas and joining operations were done at gas flow speed of 13 l/min. The joining operations were carried out during four different working times of 25, 30, 35, 40 and 45 seconds. Tensile properties of joints were determined and macro-structures of joints were investigated in order to evaluate the joinability of Aluminium 6082-T6 alloy by cold metal transfer technique. Finally, the micro-hardness values of specimens were measured.

DOI: 10.12693/APhysPolA.132.705

PACS/topics: 81.20.VJ, 81.70.BT

1. Introduction

Aluminium is used more than other metals due to such properties as lightness, good corrosion resistance, ductility, bondability and formability [1, 2]. Aluminium is remarkable for its low density and its ability to resist corrosion through the phenomenon of passivation. Aluminium and its alloys are vital to the aerospace industry and are important in transportation and structures, such as building facades and window frames. Aluminium alloys are classified in different series, depending on their composition ratios [2, 3–5]. The aluminium series 6082-T6 is preferred due to its good weldability, high corrosion resistance and good formability [3].

Joining of aluminium alloys by welding is hard due to the oxide layer on the top of joined parts. In addition, melting at low temperature and high heat conduction are the other disadvantages. Aluminium melts at 650 °C, but the Al_2O_3 layer covering it melts above 2000 °C. This requires high heat input [1, 2], which, in turn, causes changes of the internal structure and aging of aluminium and worsens the mechanical properties [4].

As the material becomes finer, the welding becomes more difficult, hot cracking and porosity increase, the heat input becomes higher and this light material loses its original properties [5]. As a result of various studies, cold metal transfer (CMT) joining method was developed by Fronius company in 2004, in order to join the aluminium/steel dissimilar materials. Such joining requires precise knowledge of the properties of each material. Until now, thermal joining of steel to aluminium had always been deemed practically unworkable. Attempts at solutions using conventional technologies are restricted to certain geometries and involve going to inordinate lengths in terms of the control technology.

With its unique CMT process, Fronius has now achieved spatter-free, high-strength joining of steel to aluminium, with all economic and practical advantages of classic MIG welding [6] and resistance spot welding [7, 8]. Thin-sheet welding (0.3 mm–0.8 mm) of aluminium sheets is also possible without difficulty [6]. The aim of this study is to show the joinability of Al 6082-T6 aluminium alloys by CMT method, as this will be of particular interest in the automotive sector, where it could spawn a whole range of previously undreamed innovations.

2. Materials and methods

Thermal joints used only to be accomplished with great technical difficulty, and did not go beyond the experimental stage. When steel is heat-intensively joined to aluminium, the joining zone attains great hardness and extremely low toughness. This is why all heat-intensive joining processes try to introduce as little heat into the seam as possible. The demand for minimised thermal input is met by CMT, a modified MIG process with controlled, almost current-free metal transfer in the dip-transfer arc. The aluminium filler metal and base metal fuse together, creating a melt which wets the galvanised steel material [6].

Unlike in a conventional pulsed arc, the droplet is not shed by a current impulse. Rather, it is a defined rearward motion of the welding wire which brings about controlled droplet detachment.

This rearward motion, coupled with a simultaneous lowering of the welding amperage, starts as soon as the power source detects a short circuit. After this, the welding wire runs forward again and the cycle begins all over again, at high frequency and with extreme precision. Both of which are fundamental preconditions for absolutely controlled metal transfer [6].

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Al 6082-T6 sheets with $200 \times 200 \times 1$ mm^3 size were joined by CMT method. The chemical compositions of materials used in experiments are given in Table I.

TABLE I

The chemical compositions of materials used in CMT operations.

Material	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
Al 6082	0.88	0.43	0.08	0.47	0.71	0.03	0.04	0.03	rest
AlMg5 wire	–	–	–	0.1	5.1	0.1	–	0.09	rest

2.1. CMT process

Fronius A-460 type CMT device was used to prepare the joints. A magnesium-based 1 mm diameter AlMg5 welding wire was used in CMT operations. Butt joints were performed with 75 Ampere welding current and 12 l/min gas flow rate, by using 20° torch angle, under Argon shielding gas. The joining operations were carried out at six different operating speeds of 20, 25, 30, 35, 40 and 45 seconds. The weld current intensity, the gas flow rate and the torch angle were kept constant in CMT operations.

3. Results and discussion

3.1. Tensile tests results

The tensile tests were done according to EN 895 standard and fractured samples are shown in Fig. 1. The ultimate tensile stress value has increased with the increasing welding time up to 25 seconds where the highest value of 209 MPa was achieved, and then slowly decreased while the welding time increased, as shown in Fig. 2.

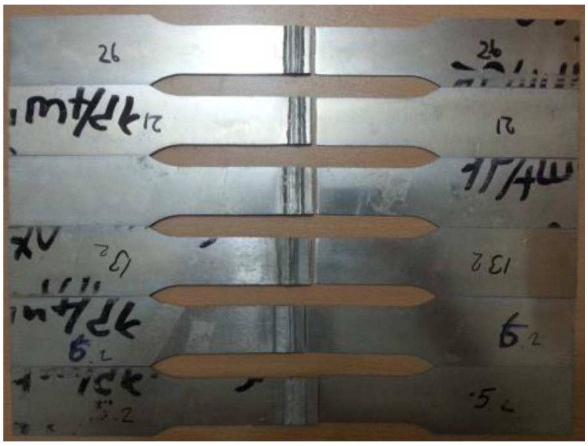

Fig. 1. The tensile test samples.

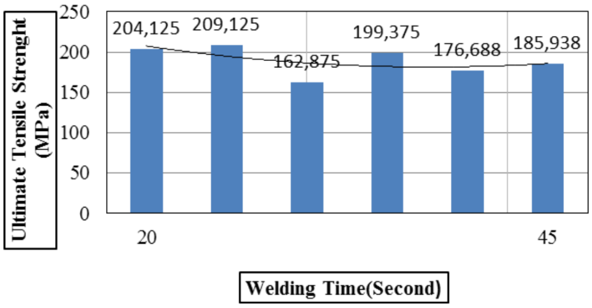

Fig. 2. The tensile test results.

3.2. Macro-structure appearances

The butt joined, cold metal transfer specimens were exposed to metallographic examination and etched by Keller solution, which contains 3 wt.% HNO_3, 2 wt.% HCl, 1 wt.% HF and 94 wt.% H_2O. The macro-structure appearances are seen in Fig 3a–f. It was seen that the macro-structure had changed, depending on the working times. The macro-structures obtained in this study are similar to those of Rakesh [3]. As the duration of the welding had increased, the expansion of the weld root was observed, which spread to the sides, up to a certain time. Figure 3b has the ideal root size, obtained using 25 seconds CMT time, where the highest ultimate tensile strength of 209 MPa was obtained.

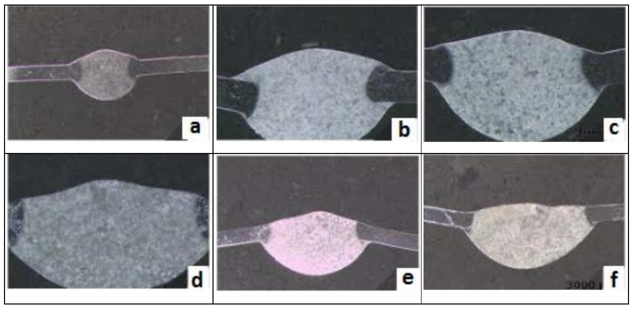

Fig. 3. The macro-structure of samples joined during (a) 20 s, (b) 25 s, (c) 30 s, (d) 35 s, (e) 40 s and (f) 45 s welding times in butt joint configuration.

3.3. Microhardness

The micro-hardness values were measured with 0.5 mm spacing, by applying 100 g load ($HV_{0.1}$) from base metal to weld zone at points, marked in Fig. 4. The hardness value of Al 6082-T6 base metal is in the range of 80–100 $HV_{0.1}$. Its value decreases to 60–80 $HV_{0.1}$ in heat affected zone (HAZ). However, the HAZ in CMT is very narrow with respect to traditional welding methods. Inside the joint zone (i.e. welding area) the hardness falls to approximately 60 $HV_{0.1}$ (Fig. 4b). The highest values were measured for 25 and 30 seconds CMT times, which were similar to the values found by Wan et al. [4] and Gungor et al. [5]. However, the vertical micro-hardness measurements in joint zone at nine points (Fig. 4c) show that there was not any hardness fluctuation and the mean value was measured as 60–70 $HV_{0.1}$ (Fig. 4d).

4. Conclusions

Argon shielding gas was used with five different working times in joining of Al 6082-T6 alloys by cold metal transfer method. The following conclusions were drawn from this study:

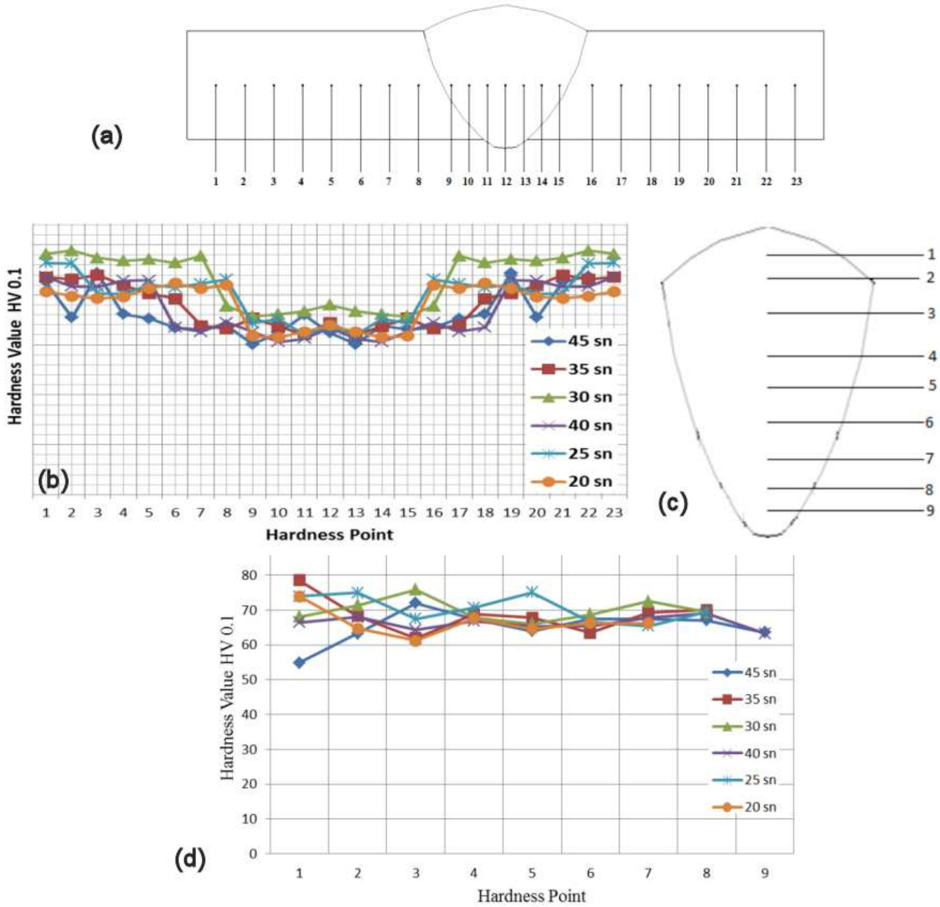

Fig. 4. (a) The hardness measurement points, (b) microhardness values, (c) vertical points in CMT weld zone, and (d) microhardness values in weld zone in vertical direction.

- The tensile strength increases up to 25 seconds of CMT time, when the highest tensile stress is reached and then decreases.
- The more heat is applied, the poorer the mechanical properties of the joint will be. Previously, good results could only be achieved by mechanical means or by bonding. Of much greater interest, however, is the ability to use heat to join materials with different properties.

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