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ANALYSIS OF THE ARC CURRENT OF CMT BRAZING PROCESS

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Abstract

The system with short circuiting metal transfer in comparison to common MIG/MAG process was introduced as CMT (Cold Metal Transfer) process by the Fronius company in 2004. The paper deals with the arc current analysis of the CMT process during MIG brazing of automotive components. The TPS 5000 CMT power source together with VR 7000 CMT wire feeder, Robacta Drive CMT welding torch and CuAl 5 Ni 2, Ø1 mm filler metal were used. In order to monitor the welding current, the galvanic separator WS 1.0, digital oscilloscope ETC M621 and IBM notebook with software applications ETC Scope M621 were engaged. A current waveform in the stage D at the time of 5s from the brazing process beginning within duration of 50 ms was closely analysed. The analysis revealed the total ratio of the arc burning to the total brazing time to be approximately 26%. The starting and ending phases of short-circuit were performed at decreased current (approximately 34 to 38 % of the current value during arc burning), which was very positive from the transient effect point of view, and could not be proclaimed for the conventional short-circuit droplet transfer modes.

Key words

CMT, brazing, short-circuit metal transfer, current analysis

INTRODUCTION

The modified MIG welding method based on the short-circuiting metal transfer process was introduced by the Fronius Company as Cold Metal Transfer (CMT) in 2004 (Schriel, 2005). This process incorporates an innovative wire feed system coupled with a high-speed digital control of arcing phase, providing a low thermal input and stable short circuit occurrence (Selvia, 2018). The CMT process behaviour can be characterized as “hot”, “cold”, “hot”, “cold”. This temperature alternation influencing directly the welding pool was possible by employing a brand new approach. It was the first time ever directly incorporated into the welding process control of the wire feed. The digital control circuit detects a short circuit phase and helps to detach a droplet in the phase of wetting the weld pool by retracting the wire. This wire movement is possible because of two wire drives: the front one and the rear one. The front feeding mechanism, Robacta Drive CMT, drives the wire forward and back approximately within the frequency of 70 Hz. It is equipped with an AC servomotor of high dynamics and it is transmission-free. It provides the exact wire movement and a constant contact pressure. The rear wire drive feeds the wire forward at the constant velocity. The both wire drives are digitally controlled. In order to ensure a smooth wire travel, so called wire buffer is situated between the wire drives.

As a result, reduction of residual stresses, lowered tendency to the formation of brittle intermetallic compounds as well as increase of the dimensional and shape accuracy of welded products was achieved. That is why the CMT process is widely used for joining the thin aluminium sheets (Feng, 2009), Al-Cu alloys (Cong, 2016), galvanised steel sheets with aluminium alloys (Cao, 2013), cladding (Lorenzin, 2009, Pickin, 2011, Ola, 2014), welding-brazing of magnesium to pure copper (Cao, 2014), etc. Moreover, the recent improvements in welding made it possible to employ Gas Metal Arc Welding (GMAW) or CMT combined with a positioning system as a CNC milling machine or a robot in Wire Arc Additive Manufacturing systems (Gonzáles, 2017).

This paper analyses in detail the key parameter of the CMT process – the arc current during the CMT brazing process of an automotive component.

MATERIALS AND METHODOLOGY OF EXPERIMENT

The measurements of an electrical proportion of the arc were carried out during the robotized MIG CMT brazing of a sun roof component for car industry. The equipment and process characteristics used are listed in Table 1. Since the MIG brazing process uses equipment for welding, the process parameters are presented in further text as welding parameters.

Table 1: MIG CMT brazing process characteristics

Power source	TPS 5000 CMT
Remote control unit	RCU 5000i
Cooling unit	FK 5000i
Wire feeder	VR 7000 CMT
Welding torch	Robacta Drive CMT
Filler metal	CuAl 5 Ni 2, Ø1 mm
Protective gas	Argon, I1 according to EN ISO 14175, gas flow 12l/min
Component thickness	0.8 mm
Tube thickness	Ø 10 mm, x 1.0 mm

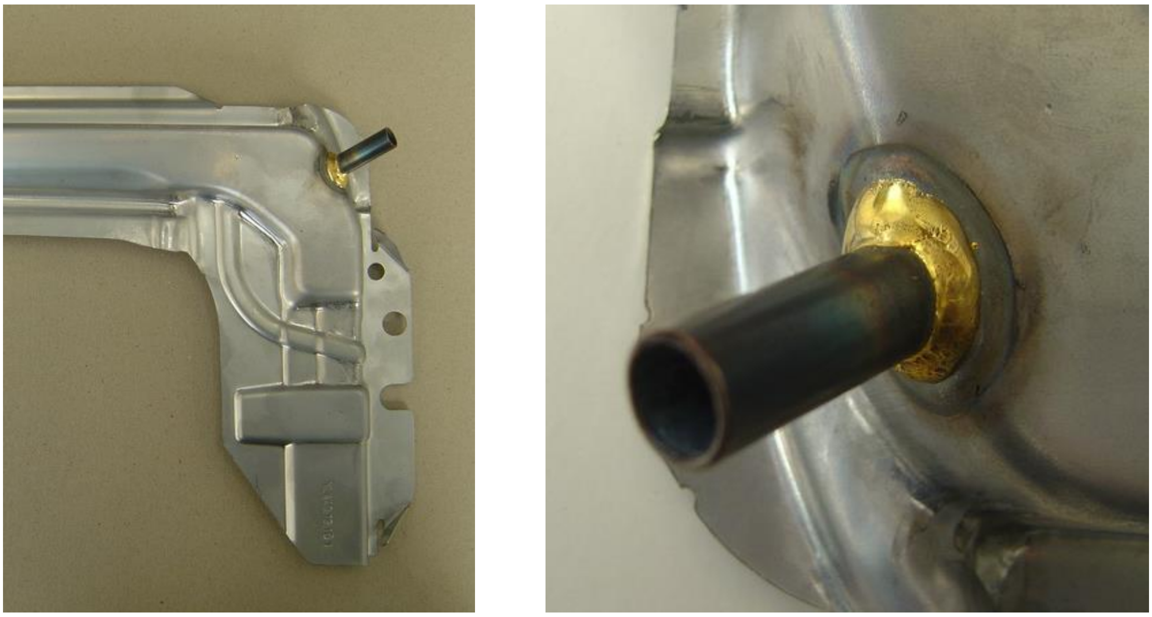

Fig. 1 *Left – view of roof window car component, right – the close-up of MIG CMT brazed joint*

MONITORING SYSTEM

The instantaneous current and voltage values were measured by the system consisting of a galvanic separator WS 1.0, A/D converter (digital oscilloscope ETC M621) and an IBM notebook with ETC Scope M621, Conversion v. 1.0 and MS Excel software application. The equipment is capable of processing power parameters of the common arc welding processes within the range of 0 to 1000 A and 0 to 1000 V, safely separating the power section and decreasing values to the level suitable for further processing. Welding processes can be monitored at the maximum sampling rate of 50 kHz and process parameters continuously being saved for further of-line processing.

The monitoring equipment was developed at the Department of Technological Engineering of the University of Žilina. The scanning procedure ran during the whole process of MIG brazing (about 7 s). Selected sampling frequency was 10 kHz. The output of the scanning procedure was a text file which was subsequently statistically processed. The brazing joint fabrication was robotized and the CMT welding torch track movement was divided into six stages (marked A to F- Table 2) with variable levels of the current load. The stage A represented the start of the arc. The higher current of 307 A was used in a very short time (about 0.2 s) for better arc ignition. The stages B, C and D denoted the periods of a brazing joint formation with decreasing the average value of current during brazing. The stage E represented the overlap of circumferential joint at its end. The stage F was the phase of the final (crater) current and designated the end of the brazing process. Time duration of particular stages and their current load are given in Table 2.

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Table 2: The current amplitude at particular stages of brazing joint formation		
Stage	***Welding current [A]***	***Time [s]***
A	307.2	0.19
B	117.6	1.47
C	91.4	1.99
D	70.9	2.54
E	38.3	0.53
F	24.7	0.34
Total brazing time		7.06

RESULTS AND DISCUSSION

A current waveform in the stage D at the time of 5s from the brazing process beginning within duration of 50 ms was closely analysed. The current waveform of this stage is shown in Figure 2. Four typical time phases arising during every cycle were identified.

Phase A is the phase of arc burning (in this case, the maximum current level during this phase was 132 A). During the arc burning phase, the droplet is formed at the tip of the wire which remains there. During this phase, the wire is in reverse movement, i. e. backward from the welding pool. At the end of this phase, both, the arc burning and reverse movement of the wire, are stopped. At this moment, the wire starts moving towards the welding pool carrying one melted droplet at its tip. During this movement, the current decreases to the value of 45 A (phase B). The contact of droplet and welding pool occurs at the reduced current, thus preventing the significant transient effects.

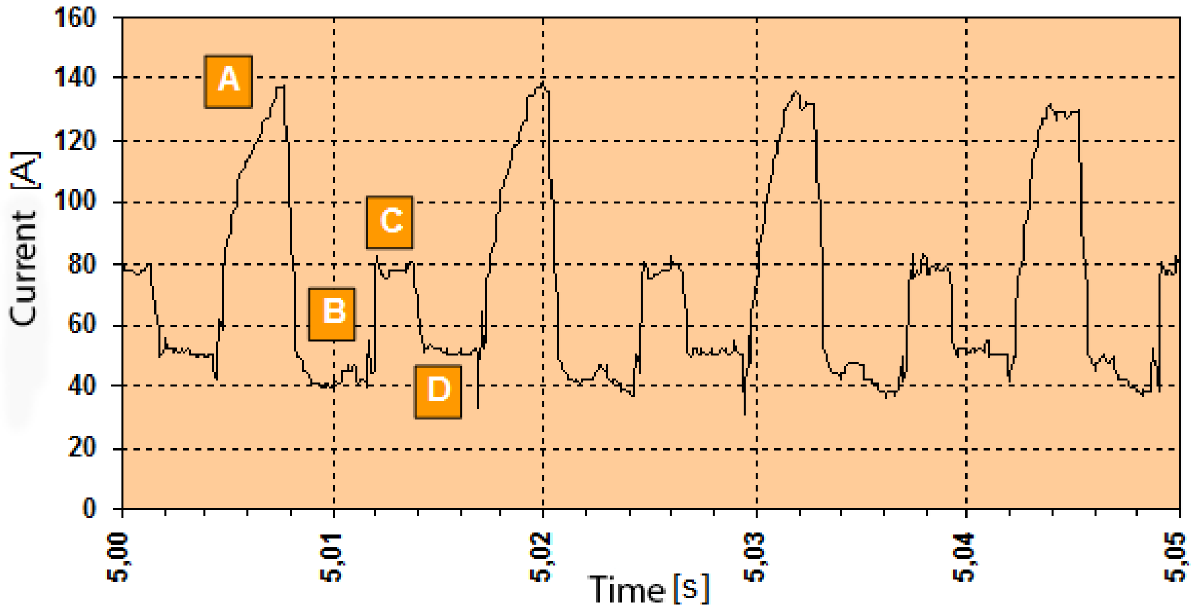

Fig. 2 *Current vs time dependence of CMT brazing process with particular phase designation*

A short-term welding current increase (2.7 ms) to the value of 78 A can be observed during the short circuit which could represent the resistance heat of droplet and welding pool. Simultaneously, at this phase (Phase C), the retracting movement backward from the welding pool starts again. This movement is dominant and helps the droplet “to fall” into the welding pool. The droplet separation itself proceeds again at decreased current in the phase D (the current value is approx. 51 A), which repeatedly reduces the problems with the arc transient effects. The described action repeats periodically. The period of one cycle “arc-short circuit” of the analysed time sequence of CMT brazing process is 12.4 ms, which represents the frequency of 80 Hz. This is also the frequency of wire retracting movement in electric arc. Average value of the current was 71 A. This value was simultaneously set on the control panel of the CMT power source. The analysis results of CMT brazing process coming from the current waveform in Figure 2 are shown in Table 3.

Table 3: Results analysis of the controlled short-circuit CMT droplet transfer

Arc burning time	3.3 ms
Time of decreased current before short circuit	3.8 ms
Time of reduced current during short circuit	2.7 ms
Time of decreased current before end of short-circuit	2.6 ms
Period	12.4 ms
Short-circuit frequency	80 Hz
Ratio of the arc burning time to the total brazing time	26 %
Welding current during arc burning time	132 A
Welding current at time before short-circuit	45 A
Welding current at short-circuit	78 A
Welding current at time before end of short-circuit	51 A
Average welding current	70.9 A
Average welding voltage	13 V

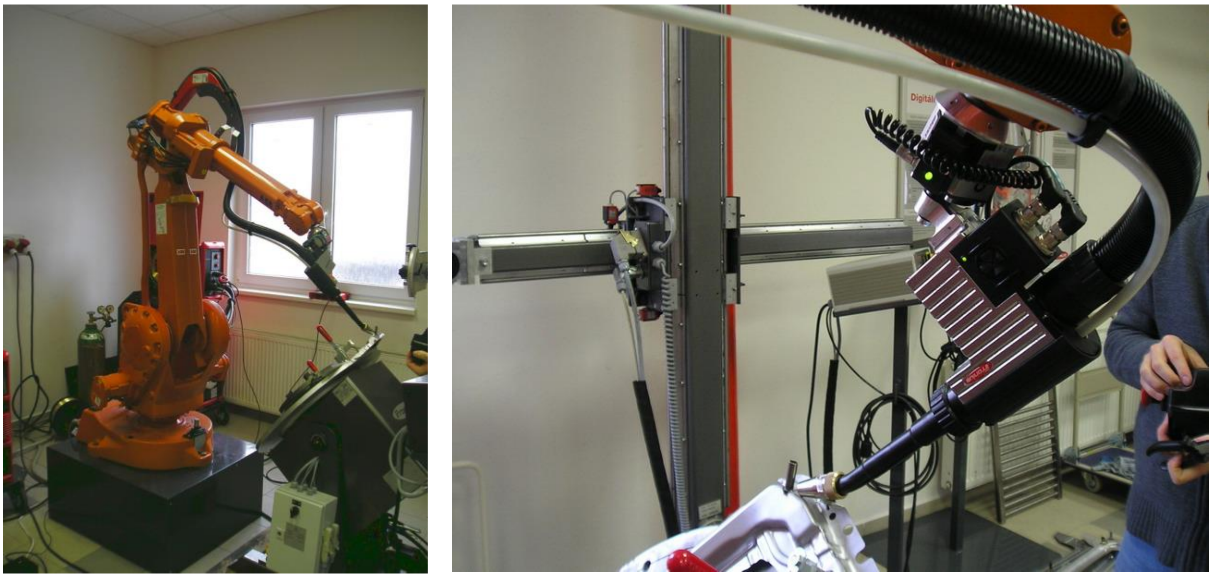

Fig. 3 *Left – a view of robotized workplace, right – the close-up of Robacta Drive CMT welding torch*

CONCLUSIONS

The total ratio of the arc burning to the total brazing time coming from the analyses is approximately 26%. The arc does not burn during the remaining time, or it burns with small intensity only, which cannot melt either the filler metal or intensively heat the parent material. As the producer proclaims, the CMT process is the “cold” process with low heat load of welded materials. The starting and ending phases of short-circuit are performed at decreased current (approximately 34 to 38 % of current value during arc burning), which is very positive from the transient effect point of view and cannot be recommended for the conventional short-circuit droplet transfer modes. It can be also confirmed that the CMT process can be declared as spatter-free.

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