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# CMT Welding of Low Carbon Steel Thin Sheets

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**Abstract**. This paper addresses to the cold metal transfer MAG welding of low carbon steel thin sheets. The paper highlights the advantages of using CMT process for but joining of S235 carbon sheets by comparing the CMT with the conventional synergic pulse MAG welding. A lower weld bead area and heat affected zone is obtained by the continuous movement of the wire, digitally synchronised with the short-circuit of the arc. CMT welding can produce good welds even in unfavorable conditions, such as using thin plates and high diameter wire.

## 1. Introduction

Nowadays, after almost 80 years of industrial implementing, GMAW welding remains the most used welding technology up to date. Lighter materials are used to reduce the manufacturing costs and the overall weight of the welded structures (eg. automotive industry). Although numerous advantages can emerge from using thinner and lighter materials, welding of these structures is challenging, considering that a thinner material will be quickly overheated, thus resulting in major drawbacks residing in the welded strength and on the dimensional characteristics of the assembly. Laser technology is the best available technology for welding of similar and dissimilar materials [1, 2], especially as thin sheets, but the equipment is expensive and special preparation of materials are required (no gaps).

Conventional MIG welding, standard, synergetic or pulsed synergic, is used for joining thin sheets of low carbon steel in common industrial applications. An improved method for the MIG/MAG welding is obtained by adding a continuous movement of the wire synchronised with the arc short circuit. The process control commands the retraction of the wire (up to 90 time/sec) and allows a clear and precise detaching of the melted droplet [3,4]. Using this process control, Chen et al. [5] investigates the process stability and the deposition rate in the case of CMT welding of 3 mm mild steel workpiece. He reveals that welding frequency chance very little with welding parameters and has values between 80.1 and 90.1 Hz. The cold metal transfer welding – CMT is frequently used for welding of low carbon thin sheets, aluminium, or dissimilar joints [6, 7, 8]. Pickin et al. [9] have investigated the CMT cladding of thin aluminium alloy and determine that CMT process exhibits better control of the dilution and lower cracking susceptibility when welding with Al-2319 filler. In a complex study, R. Cao et al [10], successfully welded pure titanium with copper using ERCuNiAl copper wire as filler material. By using the CMT, a satisfying dual welding-brazing joint between Ti and Cu with sufficient strength and good mechanical behaviour could be obtained. In the recent years, the CMT process became increasingly attractive in research concerning welding and brazing of materials with low melting point or of dissimilar materials with high differences of physical and mechanical proprieties.

The objective of this study is to investigate the capabilities and advantages of the cold metal transfer process for welding of thin plates of carbon steel. The welds are analyzed from the geometrical and microstructural point of view and the mechanical behavior is also discussed.

## 2. Materials and methods

S235JR low carbon steel was used as base material for the experimental tests were with the nominal dimension of 100x100x1.2 mm and A5.18 wire of 1.2 mm diameter as filler material. S235JR steel possess good cold forming capabilities and is the most used structural steel for the construction industry. The 1.2 mm thick wire was chosen in order to highlight the advantages and versatility of the motion control system of the filler material.

The nominal composition of both materials is presented in table1.

**Table1.** Chemical composition of the base and filler material.

| *Specification* | *C* % | *Mn* % | *P* % | *S* % | *Si* % | *Cu* | *Cr* |
|---|---|---|---|---|---|---|---|
| S235JR | 0,17 | 1,28 | 0,03 | 0,04 | 0,04 | 0,45 | - |
| AWS A5.18/A5.18M - ER70S-6 | 0,07 | 1,7 | 0,016 | 0,011 | 0,85 | - | 0,013 |

The test specimens were clamped in a butt weld geometry using a special designed system. The specimens were positioned with a 0.4 mm gap. The experimental set-up is illustrated in figure 1.

The welding experiments were carried out using a CMT MIG-MAG power source made by FRONIUS (*TRANS PULSE SYNERGIC 5000*) equipped with a CMT PullMig welding torch manipulated by a Fronius programmable moving control unit as illustrated in figure 1.

The test plates were mechanically cleaned by steel wire brush, sand paper and degreased with isopropyl alcohol prior to welding.

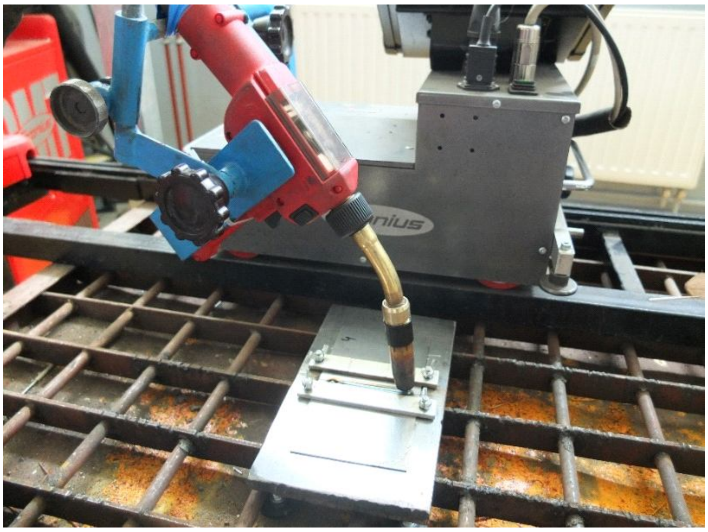

**Figure 1.** Experimental set-up used for the cold metal transfer MAG welding of low carbon steel thin sheets.

All the welding tests were performed using CORGON (82% argon and 18% carbon dioxide) as shielding gas, with a constant flow rate of 15 L/min. The tests were conducted in synergic mode and therefore the parameters interact with each other. From this reason, the tests were made by keeping a fixed value of welding parameters for pulse mode and respectively for CMT. The influence of the welding speed on the weld bead profile and the mechanical behavior of the joints has been assessed by gradually modifying the welding speed.

As summarized in table 1, the welding current was 60 A for conventional pulsed mode and 85 A for the CMT with very low variation during the welding process (+-1 %, indicated by the digital display of the power source).

**Table 2.** MAG welding process parameters and response factors.

| Sample | | Current [A] | Tension [V] | Welding speed [mm/min] | Weld area [$mm^2$] | Weld bead width [mm] | HAZ [mm] |
|---|---|---|---|---|---|---|---|
| Pulse Synergic | 1 | 60 | 18.3 | 600 | 6.92 | 4.5 | 1.55 |
| | 2 | 60 | 18.3 | 800 | 4.65 | 3.44 | 1.03 |
| | 3 | 60 | 18.3 | 1000 | 2.92 | 3.34 | 0.47 |
| CMT | 4 | 85 | 10.8 | 600 | 3.24 | 3.34 | 0.47 |
| | 5 | 85 | 10.8 | 800 | 2.85 | 3.00 | 0.77 |
| | 6 | 85 | 10.8 | 1000 | 1.50 | 2.20 | - |

## 3. Results and discussions

After the welding process the samples were prepared by extracting specimens for microstructure investigation and tensile testing. The cross-section specimen has been grinded, polished, and chemically etched in Nital reagent (3% $HNO_3$in ethanol). A Leica DM ILM inversed microscope was used for the macro and microstructural analyses of the welds.

In the figure 2 is illustrated the upper surface of the joints and the heat affected zone associated with sample 2 and sample 5, different magnitude of the HAZ being clearly visible.

*CMT*

*Conventional pulsed welding*

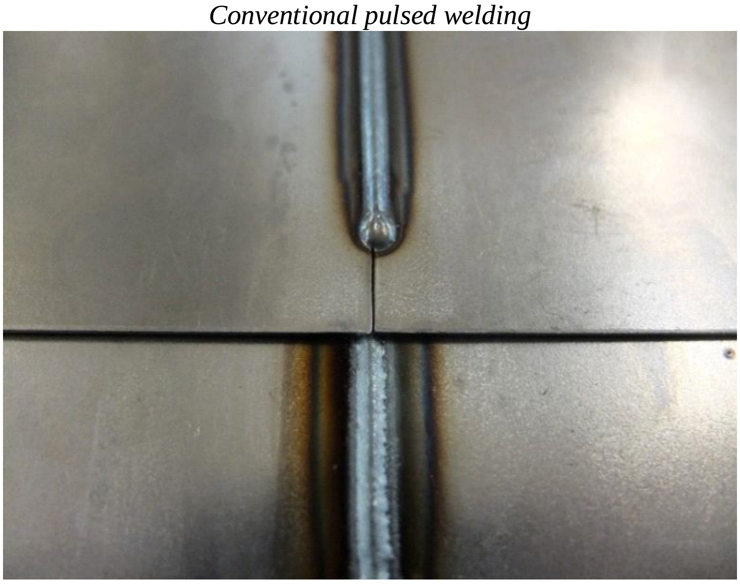

**Figure 2.** Upper side of the sample welded by synergic mode - pulse and CMT at 800 mm/min welding speed.

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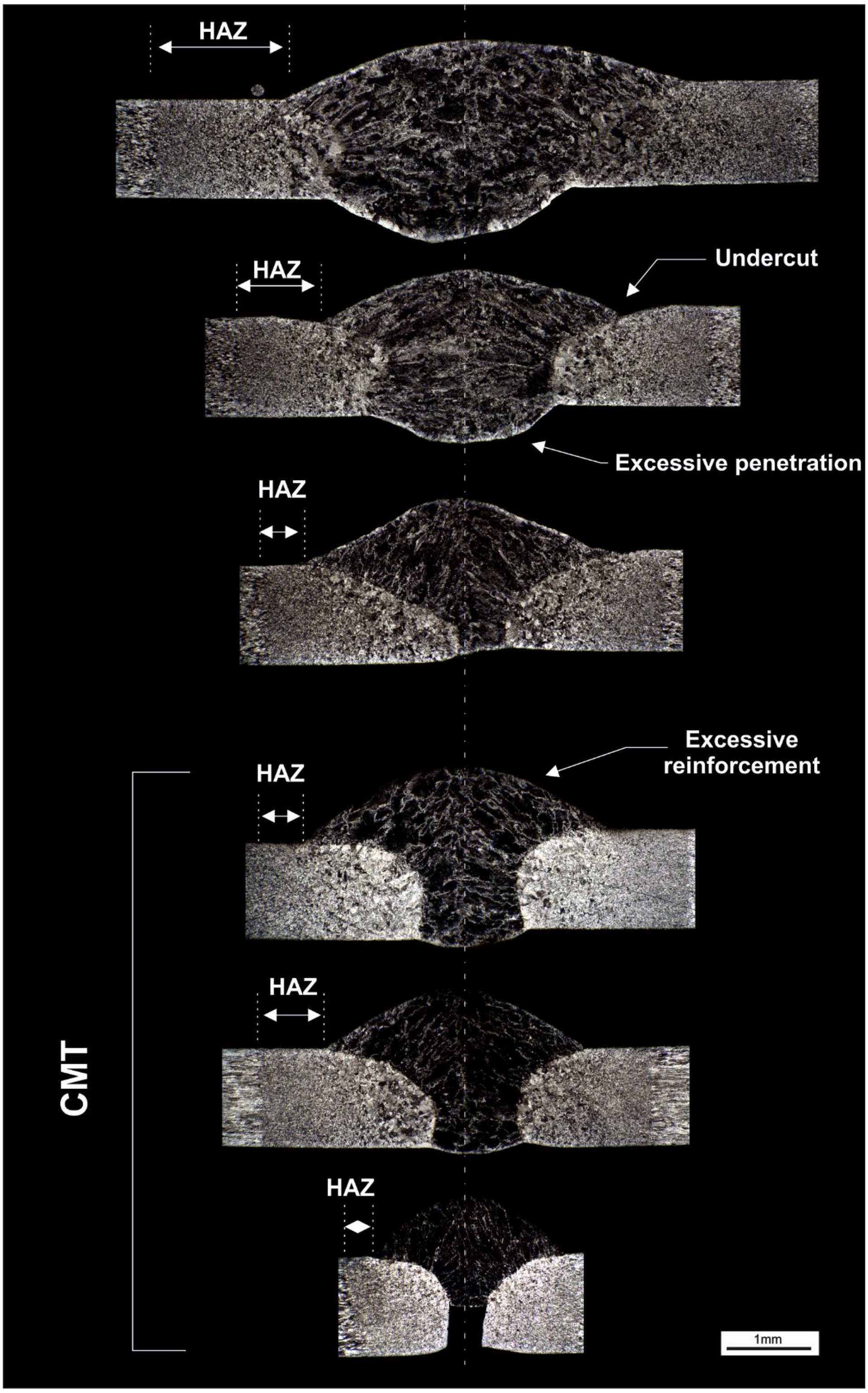


**Figure 3.** Cross-section profile of the samples 1 to 6 (A stitching picture software was used for composing the images).

Figure 3 shows the weld bead profile of samples welded by conventional synergic pulse (samples 1 to 3) and by cold metal transfer welding samples 4 to 6. In both welding mode, the current was kept as low as possible but enough to achieve welded joints at speeds between 600 and 1000 mm/min.

Excessive penetration, improper contour or undercut characterize the samples realized by synergic pulse and excess reinforcement or lack of penetration marks the samples realized by CMT. Although the defects are present, the results show that welding speed has a direct influence on the weld bead profile and on the heat affected zone and that CMT set-up can produce a better weld bead geometry in case of thin plates assembly. By synchronizing the wire feed motion with the short circuit of the arc (CMT) a lower amount of temperature in the welding process is induced, being obvious that a lower amount of filler material is used for construction of the welded joint.

An increasing of weld bead high is produced due to the lower amount of heat induced in the process that can allow a lower dilution and therefore a better formation of the reinforcement. The weld bead area is almost half in case of using the CMT as can be observed from figure 4.

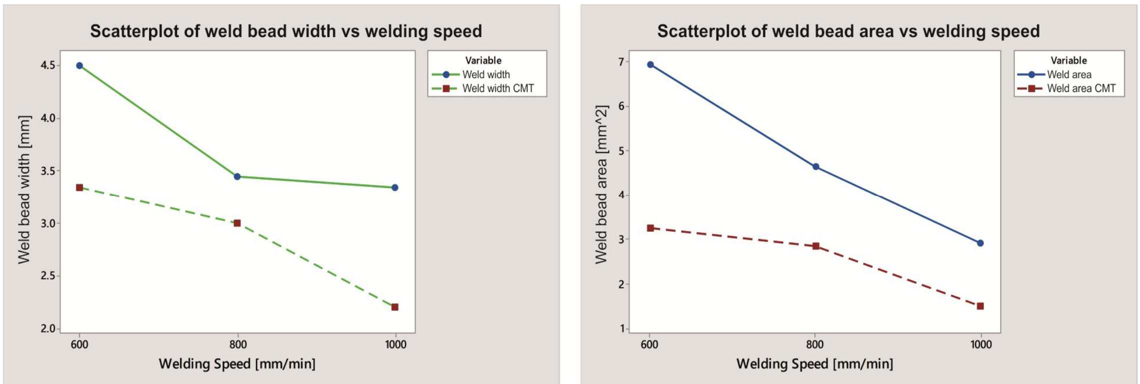


**Figure 4.** Influence of the welding speed on the weld bead area and width.

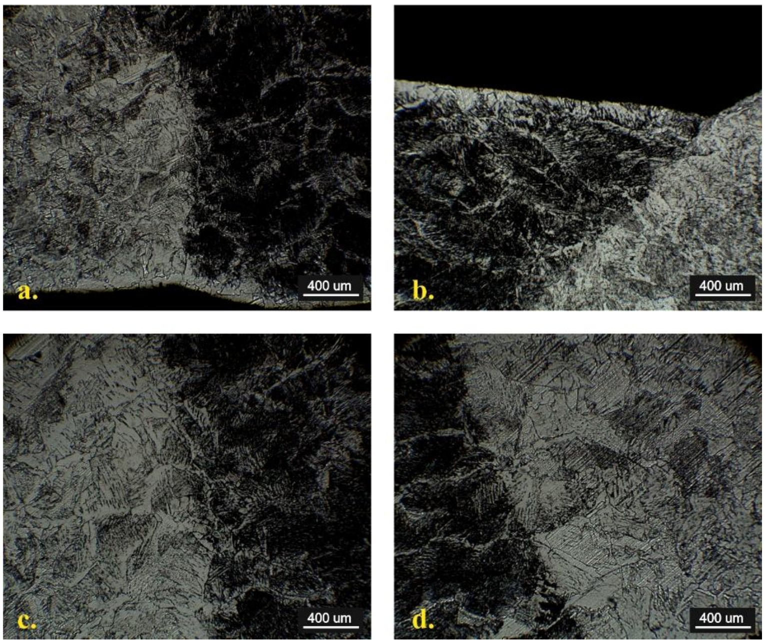


**Figure 5.** Microstructure of the sample 5.

The base material is characterized by a ferito-pearlitic microstructure with specific elongated grains formed due to the material rolling. The morphology of the base material changes near the welding bead to an oversized grain structures formed from pearlite and acicular ferrite (figure 5). The same microstructure characterizes the weld bead and the fusion zone.

A partial grain refinement occurs at the interface of the weld bead with the base material and continues with a grain refinement with small grains of ferrite and pearlite formed due to the recrystallization process as presented in figure 6.

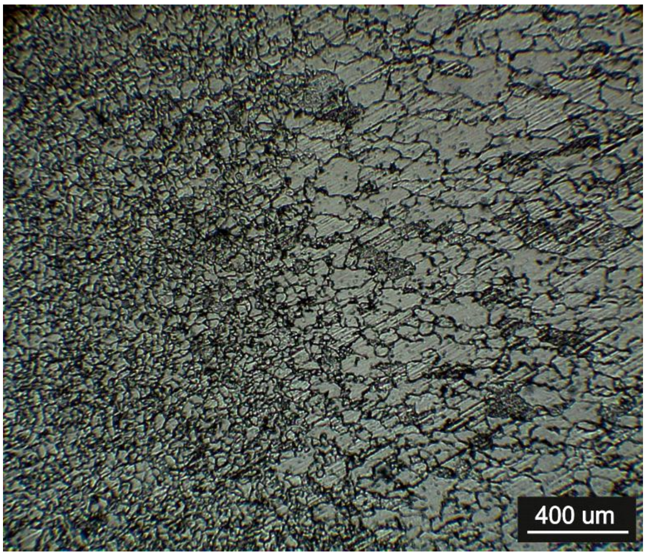


**Figure 6.** Microstructural change at the limit of the heat affected zone associated with sample 5.

**Table 3.** Results of the tensile tests of sample 5.

| No. | W to Fmax Nmm | W to break Nmm | ReH $M/mm^2$ | Rm $N/mm^2$ | Break | ε-F max % | ε-Break % |
|---|---|---|---|---|---|---|---|
| 1 | 33651,87 | 48907,07 | - | 492,50 | 1,00 | 31,07 | 41,84 |

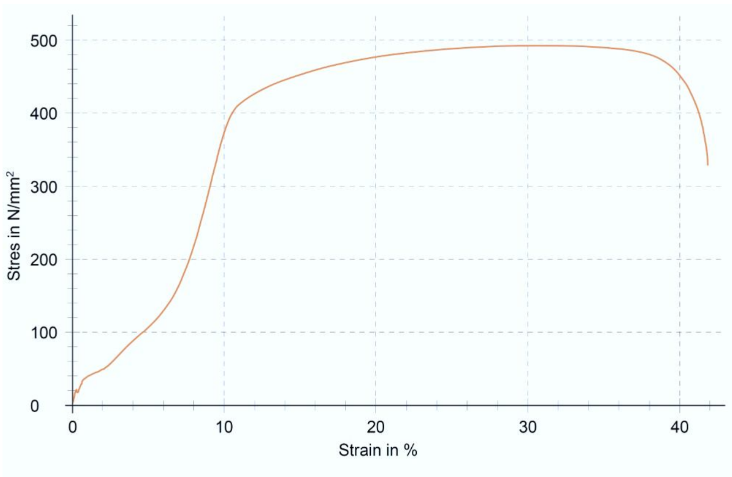


**Figure 7.** Tensile strength of sample 5 welded with CMT process.

Except the sample 6, all the welded samples present a good mechanical behavior as failure during the tensile test occurs far away from the weld bead or the heat affected zone. In the figure 7 is presented the strength – elongation curve acquired in the case of sample 5.

## 4. Conclusions

In this study, the CMT welding was used for welding of S235JR low carbon steel in butt geometry with a 0.4 mm gap. Compared with conventional synergic pulse welding the CMT technology can produce better results in term of heat affected zone and weld bead profile.

It was determined that an increased reinforcement of welds is favorized by the cold metal transfer process and must be controlled by reducing the wire speed. Increasing the welding speed will not reduce the reinforcement but will provide an improper penetration. Although the differences of weld bead geometry are major, the mechanical behavior of the analyzed specimens are almost similar. All the welding joints presents a superior tensile strength compared with the base material.

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