Technological Applied Sciences
ISSN: 1308 7223 (NWSATAS)
ID: 2017.12.4.2A0124

Status : Original Study
Received: May 2017
Accepted: October 2017

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DOI	http://dx.doi.org/10.12739/NWSA.2017.12.4.2A0124	
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MECHANICAL PROPERTIES OF AA5754 SHEETS WELDED BY COLD METAL TRANSFER METHOD

ABSTRACT

Cold Metal Transfer (CMT) is a modified gas metal arc welding method. This method is different from conventional gas metal arc welding methods. In this process the heat input and the formation of spatter are reduced with the control of the wire movement and arc. So, CMT welding became indispensable in the welding of thin sheets. The importance of lightweight structures in vehicles is increasing day by day, so the use of thin sheet aluminum alloys such as AA5754 is becoming increasingly widespread. In present study, 2mm thick AA5754 sheets were joined with cold metal transfer welding using ER5356 (AlMg5) filler wire. The effect of heat input on the weld quality was investigated. Microstructural examinations were executed by optical microscope and SEM. Mechanical properties of joints were determined by tensile and bending tests. It was found that increasing heat input did not have a significant effect on tensile strength of AA5754-AA5754 joints, while it corrupted the bending strength.

Keywords: AA5754, ER5356, Cold Metal Transfer Welding, SEM, Welding

1. INTRODUCTION

Weight of vehicles which is dependend on the mass of used materials has a great importance for fuel consumption. Employment of thin sheet materials for lightweight vehicles in automotive industry is in demand for fuel save and reducing CO_2 emission [1 and 2]. Aluminum alloys which are available as sheet or cast products enables the weight reduction of car bodies [3]. The 5754 aluminum alloy of the 5XXX series has a wide range of applications in automotive industry. Some of them are inner trunk panels, fenders, heat shields, air cleaning covers [4]. Although thin sheet products of aluminium and its alloys are the most promissing material for automobile manufacturers, they exhibit some problems such as porosity, distortion and burning during the welding process. These problems can be minimized by welding methods with low heat input characteristic. For instance, Casalino et al. (2012) used laser-TIG hybrid welding for joining 3mm thick AA5754-H111 sheets and they reported that low arc current and medium laser power provided optimum penetration and reduced welding defects [5]. Laser welding of AA5754 was also studied by several researcher [6, 7, and 8]. However, laser welding has high initial investment cost and also requires high dimensional accuracy of components to be welded [9]. For this reason, modified arc welding techniques such as cold metal transfer (CMT) welding may be a cost effective solution for welding of aluminium thin sheets. The difference between the conventional arc welding methods and CMT lies behind the motion of wire. During the CMT process, the wire feed is not continuous, it is moved rearward by a mechanical oscillatory motor. Deposition of the

How to Cite:
Durmuş, H. and Çömez, N., (2017). Mechanical Properties of AA5754 Sheets Welded by Cold Metal Transfer Method, **Technological Applied Sciences (NWSATAS)**, 12(4):170-177, DOI:10.12739/NWSA.2017.12.4.2A0124.

molten material occurs by surface tension at a low heat input which is suitable for thin sheet materials [10 and 11]. Present study aimed to investigate the weldability of AA5754 thin sheets by CMT welding and the effect of welding parameters on weld quality.

2. RESEARCH SIGNIFICANCE

CMT welding method gains more importance day by day in automotive industry due to its superior abilities such as low heat input and stable arc characteristics. Thin sheets of AA5754 aluminum alloy are employed commonly in outer body parts of automobiles. Conventional arc welding methods can be applied successfully to AA5754 alloy. However CMT welding provides both spatter-free weld bead and low heat input which make sense in terms of aesthetic and strength concerns in welding of thin sheets. The significance of present study is the statement of findings about the weldability of AA5754 aluminum alloy with CMT method, tensile and bending strengths of joints.

3. EXPERIMENTAL METHOD

Cold metal transfer butt welding was applied to 2mm thick AA5754 aluminium alloy sheets using ER5356 (AlMg5) filler wire (Table 1). Welding parameters and heat input values are given in Table 2.

Table 1. Chemical compositions of AA5754 base metal and filler wire (wt.%)

Element	Mg	Si	Cr	Cu	Fe	Zn	Mn	Ti	Al
AA5754	3.14	0.22	-	-	0.35	-	-	-	Rest
ER5356	5	0.1	<0.07	<0.01	<0.2	<0.03	<0.1	<0.06	

Table 2. Welding parameters and heat input values

Sample	Current (A)	Voltage (V)	Welding speed (m/min)	Heat Input (J/mm)
55-A	103	13.3	1	73.97
55-B	114	14	1	86.18
55-C	87	11.6	0.5	108.99
55-D	119	14.5	0.7	133.11

Grinding and polishing processes were applied to cross-sections of welded specimens. Polished welded samples were etched with Keller solution. Clemex software and Nikon Eclipse LV150 optical microscope were used for microstructural investigations. The micro hardness measurements of the welded samples were carried out under 100 gf load with Future-Tech FM700 testing device. Tensile (DIN EN 895 standard) and bending (ASTM A381-96 (2001) standard) tests of welded specimens were carried out at room temperature with Shimadzu Autograph (250kN) tester. Tensile test and bending test were executed at the rates of 1mm/min and 3mm/min respectively.

4. FINDINGS AND DISCUSSION

4.1. Microstructural Investigations

Weld metal microstructures of 55-A and 55-C are given in Figure 1. On the 55-C specimen, pores which are 100-200µm size were observed both in the weld root and near the top surface of the weld seam. On the contrary, 55-A which was produced with minimum heat input has smaller pores which were located in the weld root rather than the top surface.

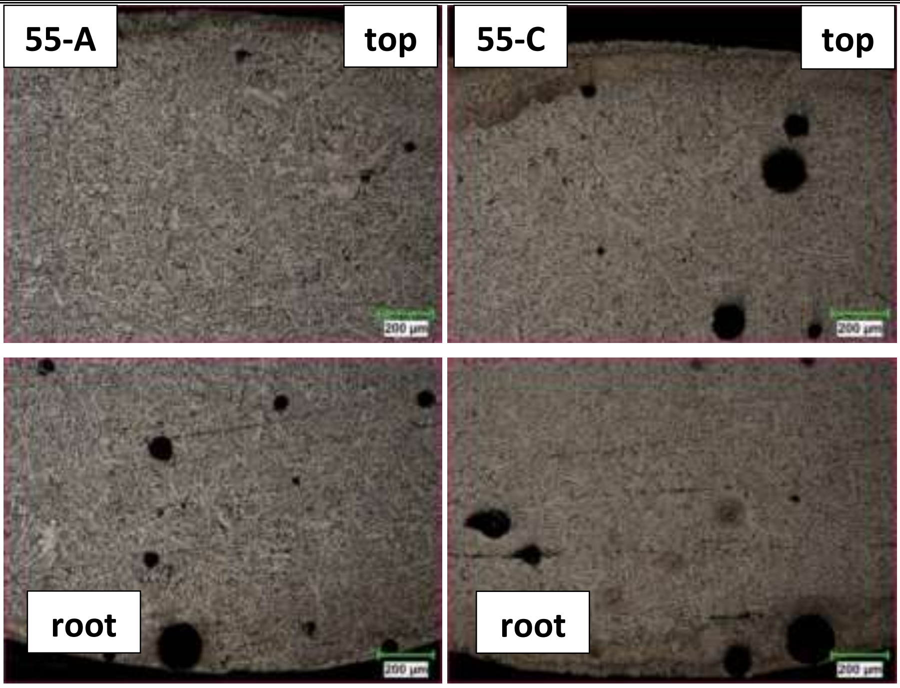

Figure 1. microstructures of weld roots and top surfaces of 55-A and 55-C

The pores in the weld metal of sample 55-A were found to be concentrated especially at the weld root. Because, the weld root was not covered with the protective gas. In the welded joint with higher heat input, since the solidification is completed for a longer time, the pores at the root of the weld metal can find the time to move towards the upper surface of the weld seam. If the heat input is low, the pores are trapped in the weld metal without the opportunity to rise to the surface of the weld seam. For instance, Yu et al. (2010) stated that due to the high solidification rates of laser welding, bubbles can not escape easily from the molten pool and they form porosity in weld metal [12]. Casalino et al. (2014) joined the 3 mm thick AA5754-H111 alloy sheets with the MIG/laser hybrid welding. They observed large number of macro and micro pores in the weld metal and stated that the pores over 200μm were formed due to laser key hole dynamics [13]. It has been observed that the pore size and amount remain at relatively low levels in this work because cold metal transfer welding provides low heat input. No pore formation over 200 μm was observed as it can be seen in Figure 1. Figure 2 shows the weld metal/base metal interface of samples 55-A, 55-B and 55-C. It was observed that increasing heat input led to a small amount of grain coarsening in HAZ of AA5754 base metal. Micro-scaled intermetallic compounds of AA5754 alloys can be seen in base metal as light colored dots.

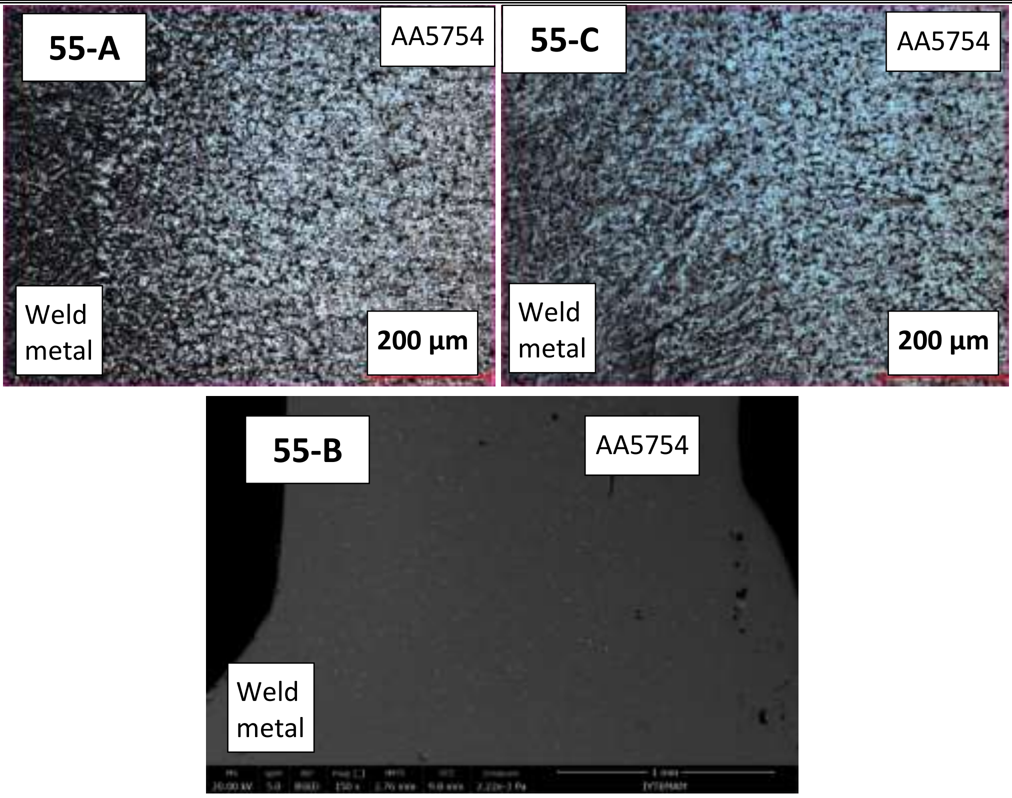

Figure 2. Weld metal/base metal interface of 55-A, 55-B and 55-C

4.2. Tensile and Bending Tests

Tensile strength of AA5754 base metal was found to be 237.1MPa. Joint efficieny (%) of CMT welded AA5754-AA5754 sheets was calculated and achieved minimum 97.52% and maximum 99.11%. Average tensile strength with standard deviation values are given in Table 3.

Table 3. Average tensile strength and joint efficiency values of AA5754-AA5754 joints

Sample	Tensile strength (MPa)	Joint efficiency (%)
55-A	231.29±6.02	97.55
55-B	234.99±2.5	99.11
55-C	231.21±5.71	97.52
55-D	234.32±2.32	98.83

σ-%ε curves of AA5754-AA5754 joints can be seen in Figure 3a. AA5754 aluminium alloys exhibit discontinuous deformation in the room temperature, which is called the influence of Portevin-Le Chatelier (PLC) [14]. In this study, the PLC effect was observed in the tensile curves of AA5754 joints. PLC effect can be seen in three different types depending on temperature and deformation rate. In this study, B-type PLC effect was observed in σ-%ε curves with irregular and small amplitude serrations which are seen at medium or high deformation velocities and are described as hopping bands (Figure 3a). All tensile specimens fractured at AA5754 base metal (Figure 4a). Fracture surface with fine dimples indicates the ductile characteristic of AA5754 (Figure 4b). Mindivan et al. (2015) joined the 2mm thick AA5754 plates with friction stir welding (1600rpm, 125mm/min). They obtained tensile strength values between 189.95-196.26 MPa and elongation values between 10.8-14.5%. They reported that tensile damage has occurred in the thermomechanically affected zone [15]. In this study, the average tensile strength values of joints varies from 231.21 to 234.99 MPa. The elongation of each tensile specimen is over 25%. Tensile strength values of AA5754-AA5754 joints were found to close to each other in despite of increasing heat input (Figure 3b), due to the non-heat treatable characteristic of AA5754 and working principle of CMT welding. As is known, mechanical properties of heat-treatable aluminium alloys are more sensetive to welding heat input. Because they experience overaging. Nevertheless, the irregular relationship between the heat input and tensile strength may occur from the formation or dissolution of Mg_2Al_3 phase. Leo et al. (2016)reported that, fast cooling rates cause the solute atoms may be trapped in Al matrix without precipitating particles.

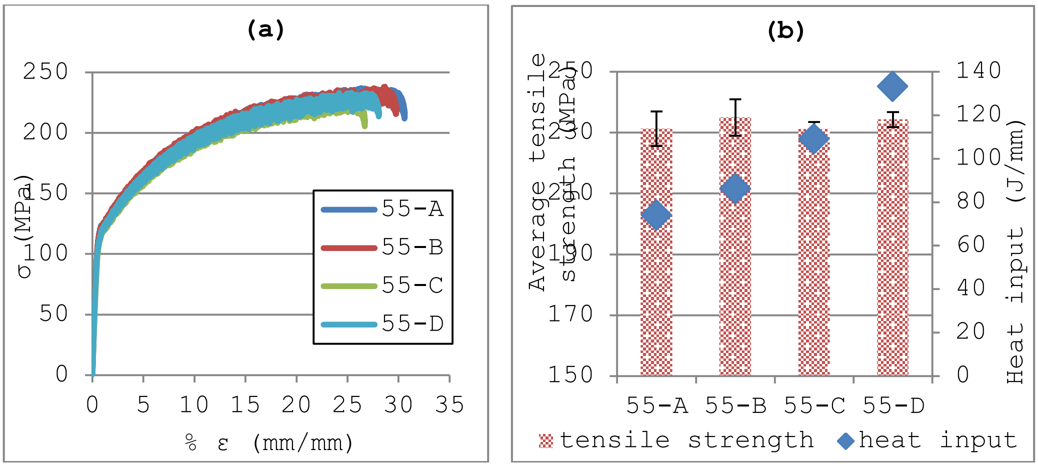

Figure 3. Tensile test results: a) σ-%ε curves, b) tensile strength-heat input relation

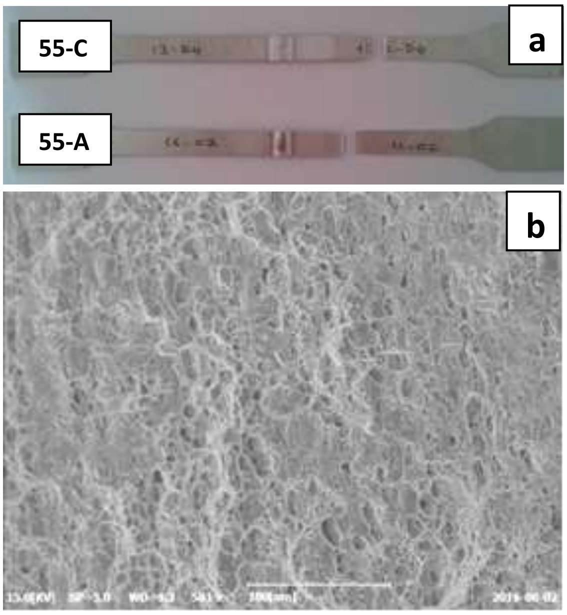

Figure 4. a) Fracture at AA5754 base metal, b) SEM image of fracture surface

Bending is an important forming property particularly in automotive applications [17]. Bending test results are given in Figure 5. It was remarked that increasing heat input decreased the bending force of AA5754-AA5754 joints. Sarkar et al. (2001) reported that, iron rich intermetallic particles in the microstructure of AA5754 deteriorate the bendability. They pointed out that cavities formed at these particles and led to the development of cracks on the tensile surface [16]. It was thought that, aluminium matrix and intermetallic particles have different mechanical properties and they do not give the same response to plastic deformation during the bending test. Increasing heat input may affect the size, shape, distribution of these intermetallic particles (Figure 2) and chemical composition gradient of weld zones (HAZ, partially melted zone, weld metal). Especially, the change in chemical composition of partially melted zone may increase the difference between the mechanical properties of aluminium matrix and particles.

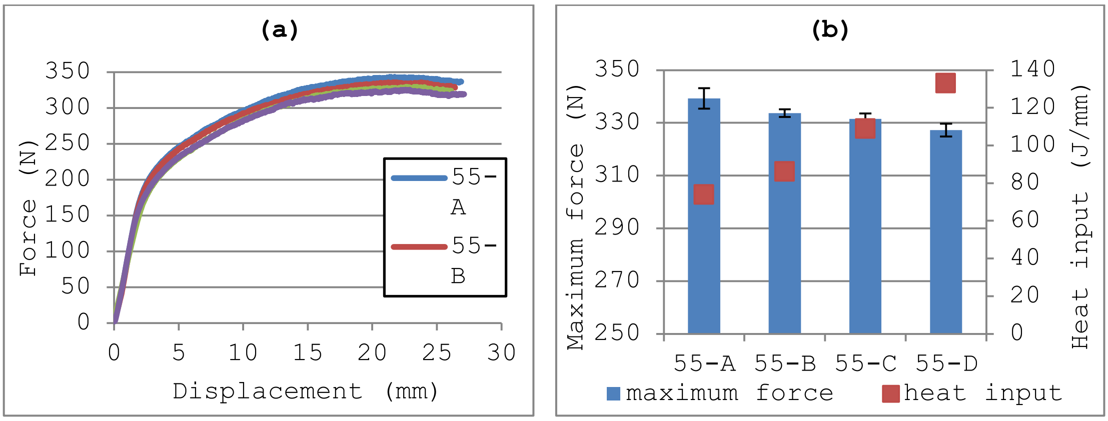

Figure 5. Bending test results: a) force-displacement curves, b) maximum bending force-heat input relation

5. CONCLUSIONS

Present study shows that CMT welding can be applied to AA5754 sheets successfully. The results can be summarized as follows:

- Heat input affects solidification rate and determines the amount and the location of pores in weld metal. It did not cause to a remarkable grain coarsening in base metal.
- PLC effect was observed in tensile curves of AA5754-AA5754 joints and ductile fracture occurred at base metal. Fine dimples were observed at the fracture surface.
- While bending strength of joints decreased with increasing heat input, tensile strength was not influenced significantly from heat input variation.

ACKNOWLEDGEMENT

The authors would like to thank to Manisa Celal Bayar University Coordination Department of Scientific Research Projects with the project number of CBU-BAP 2014-109.

NOTE

This work is presented at 05-08 September 2017, 2nd International Science Symposium (ISS2017) in Tbilisi-Georgia.

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