



Parameters and Bead Geometry Relationship of Wire and Arc Additive Manufacturing for Aluminum Alloy ER5183

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Abstract. Wire and arc additive manufacturing (WAAM) is one of the most suitable additive manufacturing (AM) technologies for producing large volume metallic components. However, one of the challenges for the WAAM process is poor part accuracy, which is emphasized by the bead geometry. In addition, deposition process parameters are the controlling factor for bead geometry. Aluminum Alloy ER5183 is chosen as a material due to its being lightweight and widely used in engineering structures for the transport sector. Therefore, the objective of this study is to investigate the effect of WAAM parameters on the bead width and height of three layers ER5183 deposits. WAAM process was conducted with a gas tungsten arc welding (GTAW) system. The deposition parameters were arc current (120–180 A), travel speed (25–30 cm/m), and wire feed rate (50–100 cm/m). Results show that welding current was the main controlling factor of the bead width and height. The high arc current (180 A) increases bead width, and the low arc current (120 A) increases the bead height. A set of optimization parameters for the bead width and height was then proposed.

Keywords: Wire and arc additive manufacturing · Gas tungsten arc welding · Aluminum Alloy ER5183 · Parameters · Bead dimension

1 Introduction

Additive Manufacturing (AM) is a technique that promises to minimize the cost of components by reducing resource waste and time to market [1]. AM also improves design freedom, potentially leading to weight savings and reducing complex assemblies previously made of several subcomponents. The review shows that major methods of AM are additive powder processing by selective laser sintering (SLS), selective laser melting (SLM), and liquid binding by three-dimensional printing (3DP) [2]. However, some of the disadvantages of powder-bed fusion, especially in aluminum alloy powders, are oxide film on the surface of the metal powder, and a relatively low melting point of

aluminum makes it challenging to find a suitable binder [3]. Thus, selecting wire-based deposition such as wire and arc additive manufacturing (WAAM) can eliminate these advantages. In addition, the wire has advantages over powder as a feedstock due to its lower cost, lower oxide content, and higher deposition rate [4]. A WAAM system consists of a moving welding torch attached to a robotic arm, static worktable, wire feeder, and computer numerical control (CNC) to make the motion device and the welder linked and work synchronously. WAAM by gas metal arc welding (GMAW) has been reported more than gas tungsten arc welding (GTAW), especially in regards to aluminum alloy deposition [5, 6].

Deposition process parameters are the controlling factor for bead geometry (bead width, height, and penetration [7]). According to Horgar et al. [5], wire feed rate, travel speed, arc current, and voltage are the varying parameters. In contrast, arc mode, shielding gas, nozzle diameter, and filler wire size are the constant parameters.

This study aims to investigate the effect of WAAM parameters on the bead width and height of three layers of ER5183 deposits on the ER5083 base plate and propose an optimization of parameters for WAAM of ER5183 wire on the AA5083 base plate.

2 Experimental Method

WAAM process was conducted using OTC-400 robotic GTAW. Based on AWS A5.10 ASME SFA 5.10, ER5183 and ER5083 were used as the feedstock and base plate, respectively. The wire diameter was 1.2 mm, and the base plate size was $25 \times 150 \times 5$ mm (width \times length \times thickness). A new jig was designed and fabricated to hold the base plate. A preliminary experiment with a one (1) layer deposit was performed to determine a range of suitable variables for the parameters of arc current, travel speed, and wire feed rate. Following the selection of the variables, a design matrix based on Full Factorial was generated using Minitab software. Three (3) layers were deposited for every sample, with all layers started at the same origin (unidirectional). The bead width and height were measured with a vernier caliper and welding gauge, respectively. Then, the Pareto chart and main effects plot from the Minitab software were used in the analysis. All results were discussed accordingly, and finally, a set of optimization parameters for the bead width and height was then proposed.

3 Results and Discussion

3.1 Selection of Parameters and Variables

Based on welding parameters and variables from the GTAW of ER5183, eight (8) samples were deposited in one (1) layer. Figure 1 shows an example of one (1) layer deposit built with 180 A arc current, 30 cm/m travel speed, and 100 cm/m wire feed rate. It has a poor start and weld crater at the end of the deposit. However, it can be considered as a good deposit from its straight and uniform bead with an oxide-free surface, no cracking, and no porosity on the bead's surface. Another good deposit from a lower level of arc current, travel speed, and wire feed rate was obtained from sample seven (7) built with 120 A, 25 cm/m travel speed, and 50 cm/m wire feed rate. Table 1 shows the selected parameters and their variables at low level and high level for the design of experiment (DOE).

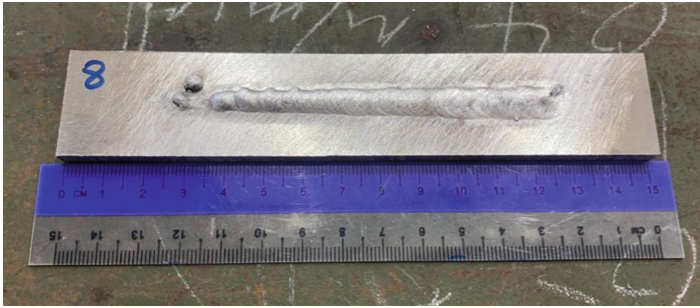


Fig. 1. Sample eight (8) of the preliminary experiment deposited with 180 A arc current, 30 cm/m travel speed, and 100 cm/m wire feed rate.

Table 1. Parameters and variables for WAAM process of ER5183 wire on AA5083 base plate using GTAW.

Parameter	Unit	Low level (-1)	High level (+1)
Arc current	A	120	180
Travel speed	cm/m	25	30
Wire feed rate	cm/m	50	100

3.2 Parameter and Bead Geometry Relationship

A design matrix was generated based on Table 1, and there were seven (7) sets of the experiment for the three (3) layer deposits. Bead width and height were measured and recorded for each sample. Pareto chart as in Fig. 2 suggested that welding current was the most significant factor affecting the bead width and height. Welding current is one of the factors in determining the total heat input besides voltage and travel speed [8]. Bead geometry plays a very important role in predicting the quality of weld as the cooling rate of the weld depends on the height and bead width.

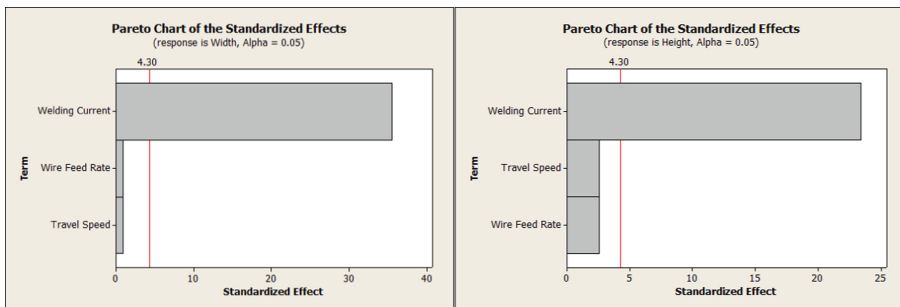


Fig. 2. Pareto charts of the standardized effects for bead width and height suggesting that welding current is the most significant factor.

3.3 Optimization of Parameter

Main effect plots were used to propose an optimization set of parameters for bead width and height. The optimization set of parameters proposed for bead width was when the three (3) layers deposit was built with 180 A, 30 cm/m travel, and 50 cm/m wire feed rate. The resulting bead width was 12.3 mm. On the other hand, to obtain a 3 mm bead height, the deposit was made with 120 A arc current, 30 cm/m travel speed, and 100 cm/m wire feed rate.

4 Conclusion

The preliminary experiment aided the parameters and their variables selection because the suitable set of parameters cannot be precisely determined from the literature review. The three (3) layers of deposition were a more accurate experiment to show the impact of WAAM deposition on the bead geometry (width and height). The arc current was the most significant factor affecting the bead width and height because arc current increases the total heat input during the WAAM process. In general, it can be concluded that high arc current (180 A) results in increased bead width, and low arc current (120 A) increases the bead height.

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