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# Thin-wall steel part fabrication using double-electrode GMAW-based additive manufacturing: deposition time and thermal cycles

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## Abstract

*The deposition time for generating the thin-wall component as well as the peak temperature of the substrate during the process was examined in the double electrode gas metal arc welding (DE-GMAW) based additive manufacturing (AM). The overall deposition time and the interlayer idle time of the manufacturing process reduced with the rising of the bypass current under the same interlayer temperature and the same deposition rate. The thermal cycling curves indicated that the peak temperature of the substrate was lower in the DE-GMAW base AM under the same circumstances. When depositing the thin-wall components, the DE-GMAW based AM may lower the heat input to the substrate and enhance the fabrication efficiency, compared with the GMAW based AM.*

## 1 Introduction

Additive manufacturing (AM) is a cutting-edge fabrication method that uses virtual solid models to create physical objects via a layer-by-layer deposition process. AM has been a focus of study throughout the globe [1] because of the significant savings it offers in manufacturing costs and materials. Recent years have seen a rise in the number of studies focusing on the use of additive manufacturing for the production of metallic functional goods [2]. Metal additive manufacturing (AM) methods primarily fall into one of three groups based on the kind of heat source used during the deposition process: laser, electron beam, or welding arc. Laser and electron beam based AM need a sizable initial investment and regular maintenance expenditures. In contrast, welding arc-based AM benefits from less complicated equipment and cheaper manufacturing costs [3]. Metal wire was used as the deposited raw material in most welding

arc based AM, making it a more hygienic method with less contamination difficulties than the powder process [4]. Gas metal arc welding (GMAW), gas tungsten arc welding (GTAW), and plasma arc welding (PAW) are some of the welding technologies used in additive manufacturing. The wire was introduced into the molten pool one at a time in GTAW and PAW-based AM, and an arc was struck between the tungsten and the base metal. However, the welding arc in GMAW based AM was struck Directly between the wire and the substrate. The wire will melt rapidly under the electric arc, resulting in a fast deposition rate in GMAW base AM. As a result, metal components for medium and large-scale structures are better fabricated with GMAW-based AM [5]. Recent years have seen a slew of research towards GMAW-based AM [6-10].

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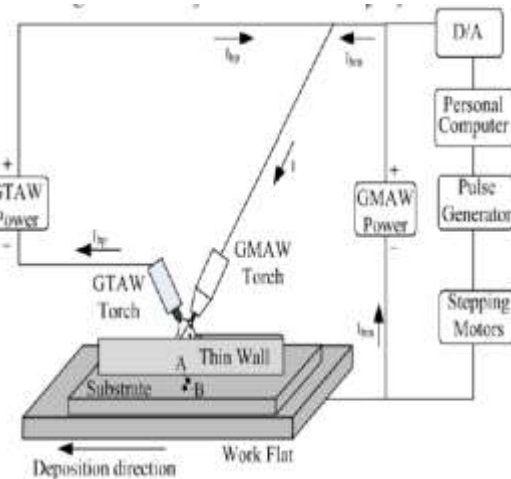
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However, heat buildup in the deposition is a typical issue that hinders the development and use of GMAW based AM in previous studies. Reducing the wire melting current, increasing the travel speed, or lengthening the duration between adjacent multilayers depositions are typical solutions. These factors will reduce the efficiency of this method of deposition. Double electrode gas metal arc welding (DE-GMAW) was suggested by Zhang et al. and refined by Li et al. to decrease the amount of heat introduced into the substrate through the bypass arc while maintaining the same deposition rate [11, 12]. Our prior work [13] brought it to the field of weld-based additive manufacturing. Researchers in this study looked at the influence of the bypass current on the deposition quality in multi-layer single-bead additive manufacturing using DE-GMAW. This work utilizes these measurements to analyze the thermal behavior of the DE-GMAW based AM process, including the impact of the bypass arc on deposition time and thermal cycles.

## 2 Experimental procedures

As can be seen in Fig. 1, the DE-GMAW provides the basis for the additive manufacturing system. Using a GTAW torch to create a second current loop for the wire melting current, DE-GMAW was born by doing so, the current in the base metal was isolated from the current needed to melt it and the heat required to melt it. Metal prices dropped. The GMAW power supply in this study was provided by a Panasonic YD-500FR welding machine operating in constant voltage mode, while the bypass arc power supply was provided by a Rilon WS-400 operating in constant current mode. Work flat motion control, GMAW and GTAW on/off control, relative process parameter modification, data collection and recording during heat cycles, and deposition may all be accomplished with the use of a computer. As can be seen in Fig. 1, the thin-wall component was manufactured by placing the work flat on the ground and keeping both welding flames in a fixed position during the whole process. Q235 low carbon steel plates measuring 250mm x 80mm x 9.5mm were used, and H08Mn2Si steel wire measuring 1.2mm in diameter was deposited as the consumable material. The tungsten electrode of the GTAW torch had a diameter of 3.2mm. The shielding gas for the GMAW

torch was a combination of Ar (95%) and CO<sub>2</sub> (5%), given at a constant flow rate of 15 L/min; the shielding gas for the GTAW torch was pure Ar, delivered at a flow rate of 8 L/min. Two welding torches were placed in an identical relative position to that described in Ref. [13].



*The basic layout of a DE-GMAW based AM system is shown in Figure 1.*

The thermal behavior of DE-GMAW based AM and the deposition time are focal topics of this study. We've put up some focus groups based on prior studies to tests of depositing thin-walled components. Tab.1 shows the whole list of experimental settings. Each layer was deposited across a distance of 180 mm in Experiments 1–4, and the interposes temperature of the deposited components was maintained at 70, as determined by infrared temperature measurement at the geometric center of the top surface. Both the total deposition time and the interval time were recorded. In experiments 5 and 6, the interposes temperature was kept at 60 degrees Celsius, the deposited length of each layer was 150 millimeters, and data on the thermal cycling of the deposition process was obtained. Several thermocouples (K type) were placed at positions A and B on the substrate's top surface in order to analyze thermal cycling curves, as illustrated in Fig. 1. Point A was 15 mm from the center line of the components, and Point B was 30 mm out.

The experimental conditions for DE-GMAW based AM are shown in Table 1.

| No. | Wire feed speed<br>(m/min) | Bypass current<br>(A) | Arc voltage<br>(v) | Deposition velocity<br>(mm/s) | Total number of<br>layers |
|-----|----------------------------|-----------------------|--------------------|-------------------------------|---------------------------|
| 1   | 4.21                       | 0                     | 23                 | 5                             | 20                        |
| 2   | 4.21                       | 40                    | 23                 | 5                             | 20                        |
| 3   | 4.21                       | 80                    | 23                 | 5                             | 20                        |
| 4   | 4.21                       | 120                   | 23                 | 5                             | 20                        |
| 5   | 4.21                       | 0                     | 23                 | 5                             | 15                        |
| 6   | 4.21                       | 80                    | 23                 | 5                             | 15                        |

## 3 Results and discussion

### 3.1 Deposition time

Except for the initial layer, all subsequent layers in Exp 1-4 were deposited after the metal in the preceding layer cooled to 70. As a result, there was a pause in activity between each pair of layers. The downtime between each layer of material deposition, used for cooling purposes. Given a range of bypass currents, as seen in Fig. As the bypass current was increased, it was clear that the idle time between neighboring layers was reduced. The bypass arc reduced the heat input to the deposited component, explaining the phenomenon. More heat was removed from the DE-GMAW based AM due to the increased bypass current. The duration between consecutive depositions in each experiment was shortest between the first and second layer, became longer with each additional layer of deposition, then stabilized at a fixed value with very slight variations. The metal layer's temperature rapidly reduced due of its proximity to the relatively chilly substrate, which allowed for excellent heat dispersion. As the deposition height increased, heat diffusion conditions deteriorated, resulting in a longer period of time needed to cool the component to a stable temperature.

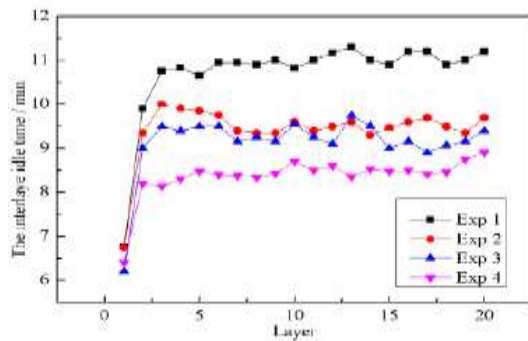


**Figure 2: The time gap between layers in Experiments 1-4.**

Tab.2 shows the sum of deposition time, the sum of interlayer downtime, and the mean of interlayer downtime. Time spent waiting between layers and

time spent actually depositing were both included into the overall deposition time. For all four experiments, the calculated actual deposition time was 12 minutes. As a result, the total time required to deposit was proportional to the downtime between each layer. Total interlayer idle time reduced when the bypass current was increased, as seen in Tab.2. With a bypass current of 120A, the total deposition may be reduced by as much as 21%. Due to the same wire feed speed, deposition velocity, and deposition length throughout all four experiments; it was hypothesized that the total volume of deposited metal would remain constant. The manufacturing efficiency drops as the overall deposition time rises. That is to say, when comparing AM processes that use the same circumstances but different deposition quality, the DE-GMAW based AM produced greater production efficiency. In Fig.3, when the bypass current increased, the deposition time of varying layer numbers decreased. When comparing DE-GMAW based AM to GMAW based AM at the same deposition rate, the DE-GMAW based AM significantly reduces the deposition time for higher layer numbers.

Deposition times for all four experiments are shown here.

| Experiment | Total deposition time<br>(min) | Total interlayer idle time<br>(min) | Mean interlayer idle time<br>(min) |
|------------|--------------------------------|-------------------------------------|------------------------------------|
| 1          | 226.39                         | 214.39                              | 10.72                              |
| 2          | 200.43                         | 188.43                              | 9.42                               |
| 3          | 194.52                         | 182.52                              | 9.13                               |
| 4          | 179.22                         | 167.22                              | 8.36                               |

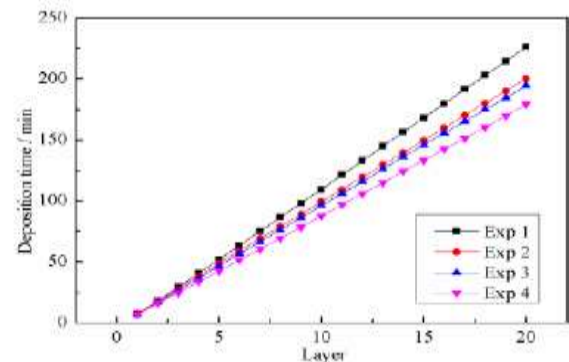
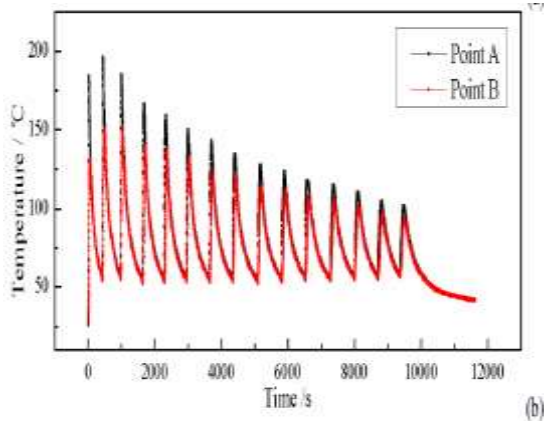
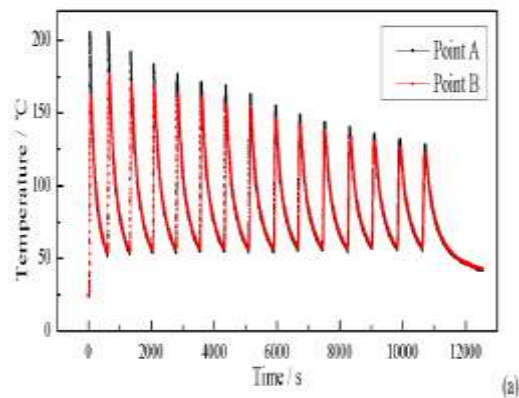


**Figure 3. The deposition time with different layer numbers in Exp 1-4.**

### 3.2 Thermal cycling

Experiments 5 and 6 have collected data on the effects of heat cycling at several settings on the

substrate. Figure 4 depicted the normal temperature cycles, and the distinguishing features of the curves were clear. The thermal cycling curves for locations A and B on the substrate are simply presented here. Welding arc as a metaphoreach experiment included 15 separate applications of heat to the components. As a result, under these circumstances, the substrate's points experienced thermal cycling with 15 peaks. As the number of layers increased, the distance between the heat source and the locations on the substrate increased. This resulted in a progressive decrease in the locations' peak temperatures. The temperature at point A on the substrate was 55 degrees Fahrenheit, while the temperature between layers was maintained at 60 degrees. The peak temperature was lower and location B was farther from the center of the component than location A. The thermal cycle cooling curves were much in sync between the two locations.



**Experiments 5 and 6 show thermal cycles at Points A and B (Figure 4). Both (a) Exp. 5 and (b) Exp.**

As can be observed in Fig. 5, the thermal cycles of the substrate sites were noticeably affected by the bypass arc. The spots on the substrate all had similar thermal cycling curves, with one notable

exception. Because it was the hottest point. So, just the end outcome of point A was shown. Experiment 5's peak temperature for each layer of deposition was greater than Experiment 6's peak temperature with bypass current. This indicates that for a given deposition rate, the heat input during GMAW-based AM is greater than that during DE-GMAW-based AM when using an appropriate bypass current. Total deposition time and interval idle time across all tests were consistent with what was described in Section 3.1.

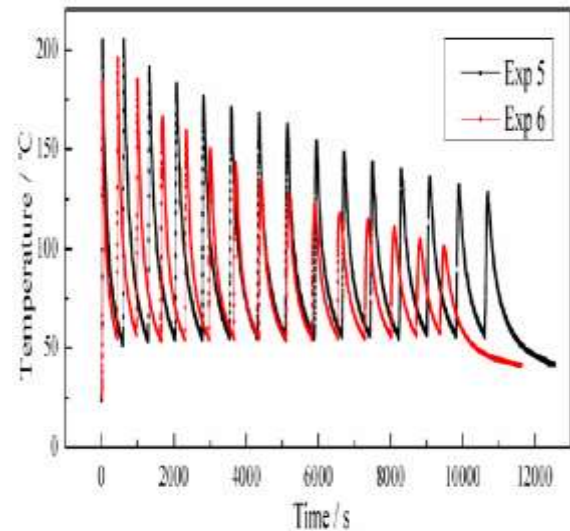


**Figure 5. Comparison of thermal cycles of Point A in Exp 5 and Exp 6.**

## 4 Conclusions

By increasing the bypass current during DE-GMAW based AM at a constant deposition rate, the overall deposition time for making the thin-wall portion and the interval time were reduced. In DE-GMAW based AM, the substrate reached a lower peak temperature during deposition than in GMAW based AM. DE-GMAW is used for depositing thin-wall components. Based AM, as opposed to GMAW based AM, may increase manufacturing efficiency while decreasing heat input to the substrate.

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