Using Random Vibration During Arc Welding To Improve Weld Bead Hardness

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ABSTRACT-

Due to its rapid deposition rates and low equipment cost and feed stock materials, wire and arc additive manufacturing (WAAM) is a 3-D metal printing process derived from arc welding and appropriate for creating massive components. This new technology has gained a lot of traction in the welding community for fabricating different grades of structural components. The WAAM technique was used to produce an ER70S-6 low carbon-alloy steel part in this investigation. The produced components were also subjected to a hardness and wear test. The Brinell hardness measurement machine was used to conduct the hardness test. The average hardness obtained by this technology was slightly higher than that generated by conventional procedures. The wear test was carried out in a wear testing machine in which a section of the produced components was cut and fastened to allow sliding with a stainless steel revolving disc. The wear test was conducted at two different loads-1 kg and 2 kg, and the wear rate was computed and compared to that of a conventionally manufactured mild steel component, revealing that the wear rate was lower in the case of WAAM component, as well as the rate of increase in wear rate with increasing load. The impact of preheating the base plate on surface appearance was also investigated, with the results indicating that preheating the base plate reduced humping and so improved the surface look of the generated layers.

Keywords- Wire and arc additive manufacturing, Hardness, Wear, humping.

1 Introduction

Wire and arc additive manufacturing (WAAM) is also a popular wire-fed AM process. The WAAM process can be further grouped into gas metal arc welding (GMAW), gas tungsten arc welding (GTAW) and plasma arc welding (PAW) depending upon the type of heat source applied. A schematic diagram of the GMAW, GTAW AND PAW process is shown in figure. GMAW is a type of welding process in which an electric arc is produced between the workpiece metal and a consumable wire electrode. The wire is generally held normal to the substrate. There are basically four types of metal transfer methods in GMAW namely short-circuiting, spray, pulsed-spray and globular; each have distinct characteristics. Moreover, a modified version called cold metal transfer (CMT) which is based on controllable dip transfer mode mechanism is also widely applied for technique because of its low heat input and high rate of deposition.

In GTAW and PAW processes, a non-consumable tungsten electrode is used to produce the weld. The wire feed orientation in PAW and GTAW is liable to vary and is different from that of GMAW and it influences the quality of the deposit making the process planning more complex. The zone of high temperature in case of plasma arc narrower than in case of GTAW process which results in the deposition of relatively narrower weld beads. The energy of arc produced in case of plasma welding can be three times to that of GTAW weldi ng that would cause less weld distortion and smaller welds with larger welding speeds. A computer interface is used to be programmed the experimental process and obtain the experimental outcomes. The robot controller is used for coordinating both the welding pro cess and motion of the robot. The welding process is controlled by a programmable GMAW power source. A large industrial robot applies the welding torch movement for deposition of metal and consequently a large profiler to measure the profile of the bead. W. Ou et al.[1] In this research work the authors tried to develop, test and utilize a 3-D model of flute flow and heat transfer to calculate and obtained temperature and velocity fields, rates of cooling and solidification and deposit size shape parameters. The obtained geometries of the fusion zone and rates of cooling for various travel speeds, arc powers and thermal cycles having considered convective molten metal flow was found comparable and will agreed with the experimental data for H13 tool steel deposits. C.V Hayden et al [2] In this paper the authors investigated the mechanical properties of stainless steel 304 and mild steel ER70S deposited by wire and arc additive manufacturing(WAAM). Different mate rial properties of both components where analyzed for hardness and wear in the direction of deposition, in building direction, due to the difference in thermal background of the material. It was observed that wear rates decreased and micro hardness increase along the length of deposition. The effort was made to analyze material properties of the built-up parts and compare to that of the wrought parts. C.R. Cunningham et al [3] In this paper strategies and process for high quality arc additive manufacturing was analyzed and investigated. The authors identified material processing challenges like development of high residual stress, undesirable microstructure and phase transformation during solidification.

The paper developed on approach to address material processing challenge by implementing quality improving ancillary techniques. Erhard Brandl et al [4] In this work, the authors investigated the microstructure, morphology and hardness of the titanium (Ti6Al4V) blocks produced by wire feed additive layer manufacturing. The deposition of blocks which was 7 layers high and 7 beads wide were produced using Ti6Al4V wire and Nd: YAG laser. Two different groups of parameters were applied and these different post heat treatment conditions were analyzed. B.Dutta et al [5]In this paper, the authors tried to carry a cost effective approach for fabrication of titanium compone nts by using power metallurgy on titanium alloy Ti6Al4V with additive manufacturing. The mechanical property and microstructure of Ti6Al4V produced were listed and compare with cast and wrought product and economic advantages were listed. Zhi Peng Ye et al [6] In this work, the authors carried out the work on hybrid additive manufacturing which is based on pulse laser wire depositing and milling for fabricati ng high performance products with good surface finish. The experimental work revealed that wire feeding performance is a crucial factor that affects weld pool and fast melting and solidification, besides process stabilization which has good influence on microstructure and surface finish. M.J.Bermingham et al [7] In this paper the authors carried out research work for controlling the microstructure and properties of Ti-6Al-4V component fabricated by wire and arc additive manufacturing with trace boron

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additions. It was observed that the addition pro vides an effective way to remove the harmful anisotropic microstructures. The addition observed up to 40% improvement in plasticity without loss in strength under uniaxial compression.

2 objectives

1. Mechanical characterization of the mild steel sample: hardness and wear testing of the WAAM fabricated mild steel sample and compare with the mild steel products fabricated with conventional manufacturing methods.

2. To study the effect of pre-heating the base plate on humping phenomenon of mild steel component fabricated by WAAM.

3 Experimental setup

CNC machines, MIG machine, Robotics WAAM Platform, Carbon dioxides Cylinder, and Wire feed Mechanism.


Figure : Ador FONTECH (mini CNC 1530)
Figure: MIG machine and CO_2 cylinder


Figure : Wire feed Mechanism
Figure : Robotic WAAM platform

3.1 Materials Used

1. Mild steel (ER70S-6) (as feedstock wire of diameter 0.8 mm) Table: Chemical composition of the ER70S-6 feedstock wire (wt %)

C	Mn	Si	Cr	Ni	Mo	S	V	Cu	P
0.06-0.15	1.40-1.85	0.80-1.15	0.15 max	0.15 max	0.15 max	0.04 max	0.03 max	0.50 max	0.03 max

2. Mild steel (A36) (as base plate of thickness 3 mm)

Table: Chemical composition of the A36 base plate (wt %)

Fe	C	Mn	Si
98.0 min	0.29	1.0	0.28

4 Methodology

The used robotics WAAM platform and other equipments are shown on the above figures. The fabricated component has total height of about 23mm containing 9 layers. The base plate was ASTM A36 mild steel with 3 mm thickness which was thoroughly cleaned using stainless steel wire brushing and degreased by Acetone prior to the WAAM to avoid porosity formation during the fabrication process. The ER70S-6 wire with 0.8mm diameter was used as the feed stock materials with chemical composition given in table1. A GMAW machine with a torch mounted on a 6 axis Fanuc robot was employed as the power source of the process. The process was carried out using the following parameters: An arc voltage of 20 volt wire feeding rate of appx. 10 meter per minute, arc current of about 120 ampere, scanned rate of about 500mm per minute and carbon dioxide as the shielding gas with the flow rate of about 10 litres per minute. A steady state deposition and a homogenous microstructure on all layers of the wall along the building direction should be expected due to the similarity of the thermal cycle associated with the solidification of each layer.

Coding on CNC machine (ador FONTECH, Mini CNC 1530)

```
G92 X0 Y0
G91X0Y0
G01 X50
G01 Y45
G01 X-45
G01 Y-45
G01 X-5
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After one layer is deposited the process is repeated so as to get a total of 9 layers.

5 Result and Discussion

5.1Wear test:

A portion of the fabricated component was cut and wear testing was performed on it with the help of wear testing machine as shown in figure.

Fig: Wear Testing Machine

Here we have a circular disc which is coupled with an electric motor. On the disc we have position to keep the sample in contact with it with the help of a fixing device and there is another position to keep the weights. The distance of the sample disc contact point from the centre of the disc was 40 mm and the rpm of the circular disc were 400.

One kg weight was put on the loading position.

Before starting the test, we measured the weight of the sample which was found to be 5.76 gram. Now we fix the sample over the revolving disc and the electric motor is switched on for 10 minutes.

After 10 minutes, we take out the sample and measure its weight which was found to be 5.70 grams. Difference in weight= (5.76-5.70) gram

=0.06 gram

i. Wear rate in terms of mg/min was calculated to be (0.06×1000)/10=6mg/min. ii. Wear rate in terms of cm3/ min was calculated as

=loss in volume per min

=loss in mass per min/density.

= (6×10-3)/ (7.85)

$=0.76\times10^{-3}$ cm^3 /min.

iii. Wear rate in terms of cm3 per unit sliding length (here cm3 /m) is calculated as:

We have sliding length per second is equal to 2π RN/60

$=(2\times3.14\times40\times10^{-3}\times400)/60$

=1.67 m/s

Wear rate in terms of cm^3 /m was calculated as:

(Wear rate (in terms of cm^3 /min))/ (60×sliding length per second (in terms of m/s))

$= (0.76\times10^{-3})/ (60\times1.67)$ cm^3 /m

$= 0.076 \times10^{-4}$ cm^3 /m

Now we perform the wear test of same sample with load of 2kg with all parameters same, we find that change in mass was found to be

0.09 grams

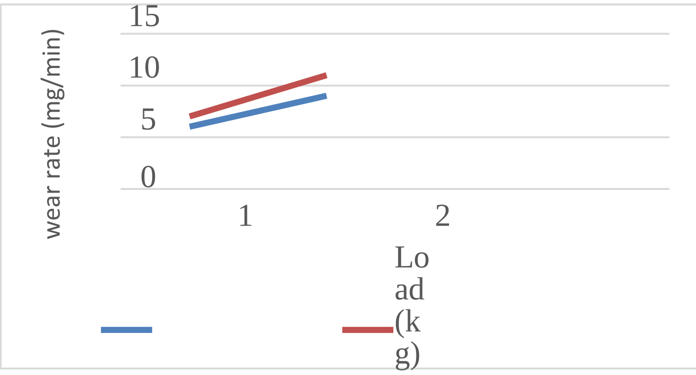
Sliding time = 10min

Wear rate in terms of mg/min, cm^3 /min and cm^3 /m was found to be 9mg/min, 1.146×10^{-3} cm^3 /min and 0.1143×10^{-4} cm^3 /m. respectively

Load (kg)	Wear rate		
	Mg/min	cm^3/min	cm^3/m
1	6	7.6×10^{-4}	7.6×10^{-6}
2	9	11.46×10^{-4}	11.43×10^{-6}

When the same experiment was on general mild steel component, we find the following results

Load (kg)	Wear		
	mg/min	cm^3/min	cm^3/m
1	7	8.9×10^{-4}	8.8×10^{-6}
2	11	14×10^{-4}	13.9×10^{-6}



WAAM sample gen. mild steel comp.

5.2Hardness Test

One portion of the fabricated component was cut and hardness testing was performed on it with Brinell hardness testing machine shown in figure.

Fig : Brinell Hardness Testing Machine

The Brinell hardness number is calculated by using the formula

BHN = $2P/\pi D(D-\sqrt{D^2-d^2})$ Where BHN = Brinell hardness number (kgf/mm^2)

P =Applied force in kilogram force (kgf) D = diameter of indenter (mm)

d = diameter of indentation (mm) In our experiment,

P =3000 kgf

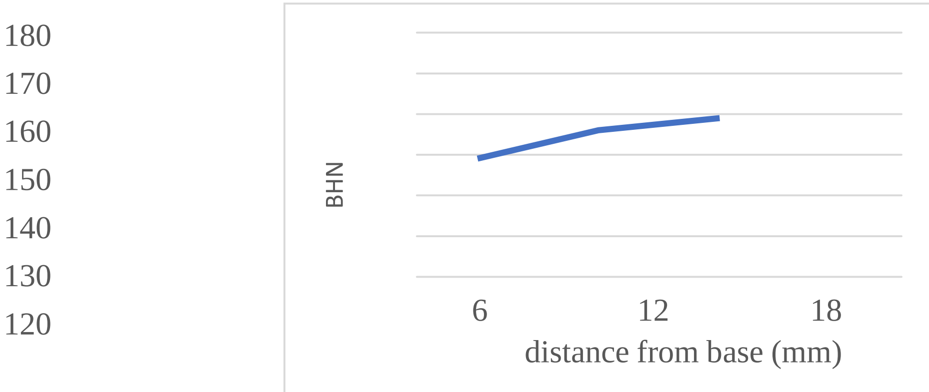
D = 10 mm

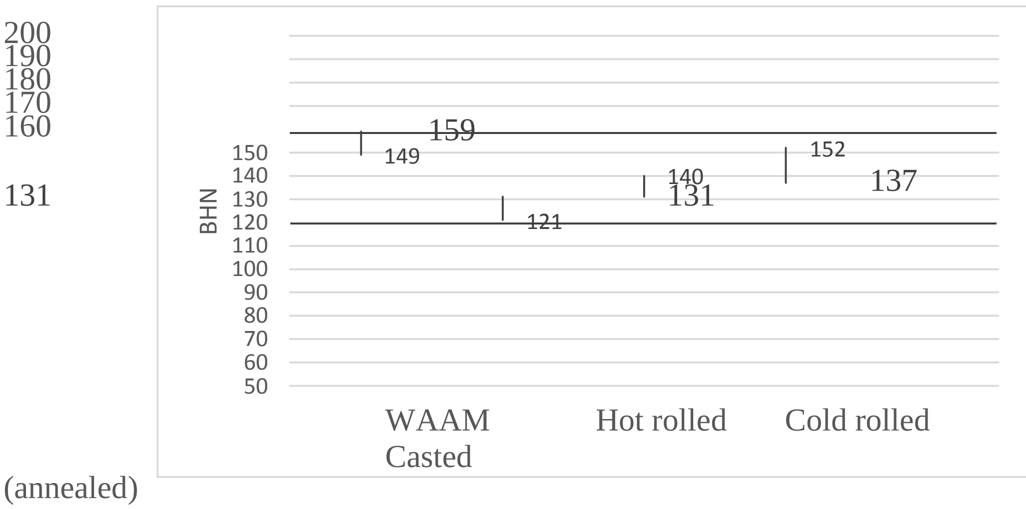
Hardness testing was performed at bottom, middle and top portion of the sample.

The following indentation results were obtained

Distance from base (mm)	Diameter of indentation (d)(mm)
6mm	4.90
12 mm	4.80
18 mm	4.75

When we put the above results in BHN formula, we get the BHN at bottom, middle and top portion of the sample to be 149,156, and 159 respectively.





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The hardness testing results show that hardness of the WAAM component was comparable with the of different process.

5.3 Effect of preheating the base plate on surface appearance

It is known that in wire arc additive manufacturing (WAAM), each preceding layer acts as the subbase for succeeding layer dep osition. In the succeeding layer deposition, the molten metal spreads out on the previous layer and forms a new layer. So, the surface appearance of the newly deposited layer is dependent on the previous one. Since smoothness and consistency in layer appearance has the advantag e on the surface quality of the final part produced, the role of the base plate temperature cannot be ignored in this regard.

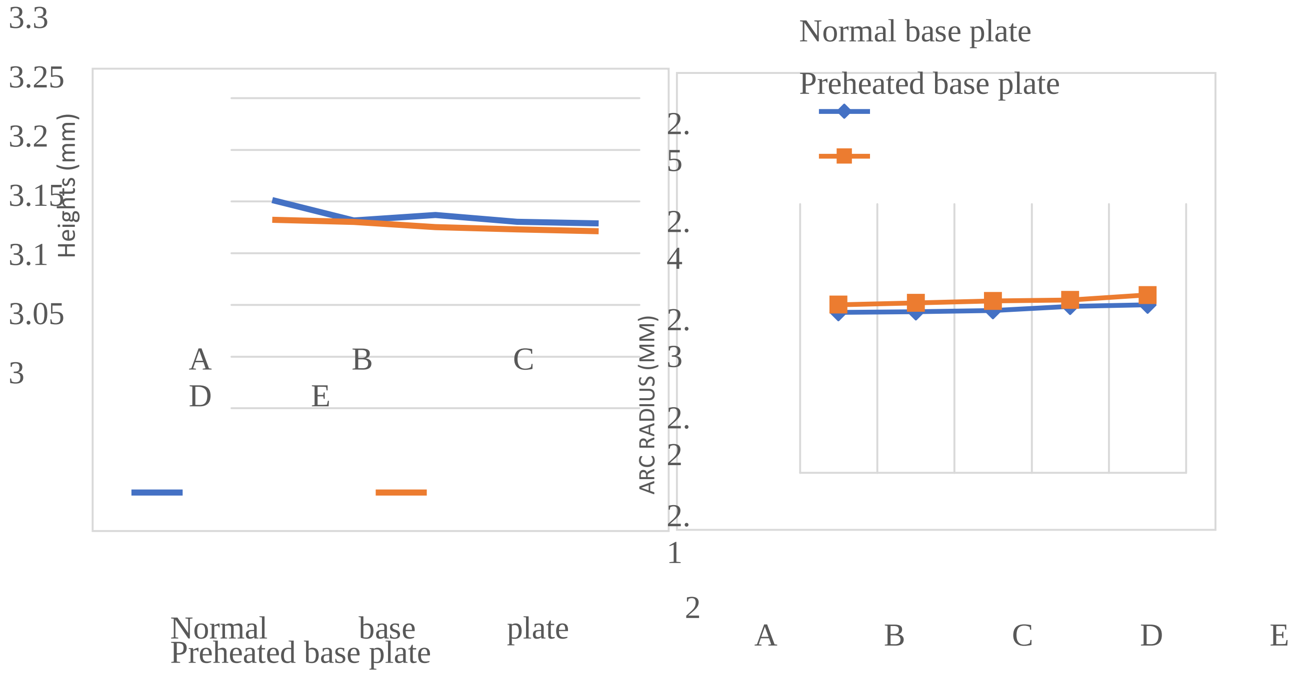
One important phenomenon that is usually observed is the undulate surface, which is also known as humping bead in welding. It is thought that the pressure of the arc pushes the metal (in molten state) to the rear of the weld pool with a thin film of liquid metal remaining beneath the arc. With the welding gun travelling away, there will be premature solidification of the thin layer leading to the appearance of the humping bead by impeding the flow back of the molten metal.

The interpass temperature of the initial layer that would be the preheating temperature can have an important effect on surface appearance as increased interpass temperature would prolong the premature solidification and can enhance the wettability of the molten metal. Hence we wold now compare the humping phenomenon between two single layers-one deposited on a base plate without preheating and the other after preheating. The preheating of the base plate was done to achieve a temperature approximately 50^0C in such a way that there would be uniform preheating throughout the base plate. All other parameters would be similar for these two layers deposition. Single layer dep osition was chosen so that only effect can be seen and this effect would proceed to subsequent layers resulting in better surface finish of the final part produced.

The parameters chosen to study the effect of humping was height and arc radius of the bead at 5 points namely A, B, C, D and E at similar positions. The measurement was taken on CMM and following results were obtained:

Heights at different points (mm)	Normal base plate	Preheated base plate
A	3.2016	3.1824
B	3.1816	3.1802
C	3.1870	3.1752
D	3.1804	3.1731
E	3.1791	3.1712

Arc radius at different points (mm)	Normal base plate	Preheated base plate
A	2.2981	2.3128
B	2.2996	2.3164
C	2.3021	2.3198
D	2.3098	2.3216
E	2.3124	2.3310



The combined effect of decreased average bead height and increased average arc radius values in case of pre-heated base plate suggests that preheating the base plate prolong the solidification time and that results in reduced humping phenomenon than that with normal base plate.

6 Conclusion

The current research, named "examination of influencing parameters on mechanical characteristics of wire arc additive manufacturing," has produced the following results: 1. The hardness and wear rate of mild steel components generated by wire arc additive manufacturing (WAAM) were equivalent to mild steel components created by general traditional manufacturing techniques, according to Brinell hardness and wear evaluation results. Aside from making it feasible to construct components as intended quickly and with high deposition rates while using fewer manual skills, the WAAM process does not impair the mechanical qualities of components produced using other conventional methods. 3 A B C D E Heights 3.05 3.1 3.15 3.2 3.25 3.3 (mm). a standard base plate Base plate that has been preheated a year in 2019 IJRAR Volume 6, Issue 2 (June 2019) www.ijrar.org (E-ISSN 2348-1269, P-ISSN 2349-5138) E-ISSN 2348-1269 E-ISSN 2348-1269 E-ISSN 2348-1269 E- www.ijrar.org IJRAR19K7986 International Journal of Research and Analytical Reviews (IJRAR) 76 2. The phenomena of humping is decreased to some extent when the base plate is preheated, as evidenced by lower average height of the bead and larger average arc radius than the equivalent values observed in a normal base plate. 3. After a regulated pre-heating of the base plate, the product's surface look improves.

Referance

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