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EVALUATION OF MECHANICAL PROPERTIES OF ADDITIVELY MANUFACTURED SS308L WALL COMPONENT

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Abstract: In contrast to subtractive manufacturing techniques like machining, additive manufacturing, also known as 3D printing, fast prototyping, or freeform manufacturing, is the process of adding materials to build items from 3D model data, typically layer by layer. The process variations have the greatest impact on the cost, productivity, and quality of additive components. Numerous studies have been conducted on the effects of process variables such as wire feed speed, voltage, and current. The welding process settings have a direct impact on the quality of components made via additive manufacturing. In this study, stainless steel 304L (the substrate) with dimensions of 220 x 140 x 8 mm and stainless steel 308L (the workpiece) with a diameter of 1.2 mm are used to create wall components using a 6-axis robot welding system from YASKAWA. SS308L is frequently utilized in gas pipelines, oil industries, and cryogenic applications. In this study, GMAW and CMT welding techniques are used to create SS308L wall components. The SS308L wall components' mechanical properties were examined. The GMAW and CMT procedures both use fixed parameters. Current, voltage, gas flow rate, wire feed rate, and torch speed are the fixed parameters. The impact strength of wall assemblies created using the CMTAW process is greater than that of GMAW wall assemblies.

Keywords: Wire arc additive manufacturing, 308L stainless steel, mechanical properties

1. INTRODUCTION

In contrast to subtractive manufacturing techniques like machining, additive manufacturing, also known as 3D printing, fast prototyping, or freeform manufacturing, is the process of adding materials to build items from 3D model data, typically layer by layer. The process variations have the greatest impact on the cost, productivity, and quality of additive components. Additive Manufacturing technology is unique Production Method because, manufacturing of products through automation and machine learning methods to keep a minimum raw material waste and reduction in Production time[1]. The direct Energy Deposition (DED) technique is used to distribute wire and powder directly to the molten as feed stock material. When compared to powder, the ability to employ wire as a easy availability of material and lowers the cost per kg and increases resource utilization. Wire feed technology is the most effective additive technique for this reason it is adapted to the production of massive components [2]. In WAAM arc can be created using gas metal arc welding for the WAAM process (GMAW), Gas Tungsten Arc Welding (GTAW), and Plasma Arc Welding (PAW) [3]. The highest deposition rate among these methods is achieved by GMAW, which is around two to three times as fast as GTAW and PAW. As a result, it is better suited for production large metal parts [4]. A welding power supply, wire feed system and welding torch of the WAAM units a typical welding apparatus. Motion can be produced by both CNC and robotic systems. In WAAM a component is made by a consumable electrode that facilitates the movement of the wire with the torch [5]. The MIG method has a variation called Cold Metal Transfer, in this Droplet separation is aided by wire retract motion is the fundamental of the CMT process, so that heat input is decreases [6]. In CMT, the wire is pushed into the molten pool created by the arc during the first stage or arc cycle. The arc is extinguished and the welding current

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is decreased when the filler metal reaches the weld pool. The separation of the droplets was seen during the short circuit phase. The cycle then restarts when the arc ignites and forces the wire into the weld pool. The current at the GMAW is constant during deposition whereas the actual value fluctuates between peak and bottom, leaving the CMT with zero current (during the short circuit phase). When compared to the CMT short circuit approach, the cooling rate is quite low for conventional spray transfer and pulsed spray transfer. Consequently, a low heat input procedure like CMT can greatly the mechanical qualities of WAAM carbon steel components should be improved [7].

Based on the Literature review, it is assumed that no other studies are comparing GMAW and CMT processes for the fabrication of SS308L Thick wall components. The performance of the WAAM Processed SS308L has not been documented. SS308L is widely used in automobile parts, building structures, and pipelines.

This study provides a deeper understanding of the fabrication of SS308L Thick wall components by WAAM technique using GMAW and CMT processes. The influence of heat input on the mechanical properties was examined on the SS308L wall components. In addition, the impact and hardness of the SS308L wall components have been studied to assess the capability of the WAAM components with automobile industrial applications.

Table 1
Chemical composition of the 308L stainless steel wire and 304L stainless steel

C	P	S	Cr	Ni	Mo	Si	Cu	Mn	N	Fe
0.03	0.03	0.03	21	11	0.50	0.65	0.75	2.5	0.10	balance
0.08	0.045	0.030	20	10.5	-	0.75	-	2.0	-	balance

EXPERIMENTAL WORK

2.1 Materials and fabrication of wall

The rectangular wall components were manufactured on a poster steel plate (base plate) with dimensions of 220x140x8 mm. As a filler material, the solid wire ER308L with 1.2 mm diameter was used. The chemical composition of the filler wire and base plate material utilized in this investigation is presented in Table 1. The welding machine CMT Advanced TPS400i (Figure 1) was used as a welding power source during the deposition process and therefore the filler wire was supplied to the welding torch, which was kept stationary employing a stationary table for every layer.

Figure 1. GMAW-CMT WAAM setup used to fabricate SS308L wall component

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Table 2
Optimized WAAM process parameter used to fabricate the component

Parameter	GMAW Process	CMT Process
Current	175 A	166 A
Wire feed rate	6.5 cm/min	6.5 cm/min
Voltage	22.4 V	14 V
Gas flow rate	15 l/min	15 l/min
Torch speed	25 cm/min	25 cm/min

The welding torch was kept constant perpendicular to the bottom plate, just give movement through robot arm in x and y direction. The steel rectangular Wall parts were built with GMAW and CMTAW using optimized process parameter (presented in Table 2) and Figure 2,3.

Figure 2. Image of SS308L wall component by using the GMAW process

Table 3 presents the scale of the produced 308L SS wall parts that were built full of 35- layer and 50-layer fabricated WAAM boards and AM boards that were sequentially added on the same board.

Table 3
Dimensions of manufactured rectangular wall components

Geometry	GMAW	CMTAW
Average wall thickness(mm)	8	7.6
Average single layer height(mm)	2.5	2.4
Length of the rectangular wall(mm)	142	145
Total height of the rectangular wall(mm)	75	120

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Figure 3. Image of SS308L wall component by using CMT process.

RESULTS AND DISCUSSION

Impact toughness evaluation

Figure.5. Displays images of the bottom and top portions of rectangular wall GMAW and CMTAW components that were evaluated for Charpy impact. Table 4 displays the impact toughness test results for samples taken from the bottom and top portions of rectangular wall components made of carbon steel. The impact results of GMAW and CMTAW are shown in graph (Figure.4.).

Table 4
Impact toughness properties of rectangular wall components

Process	Sample	Impact toughness at RT (J)
GMAW	Bottom	58 J
	Top	51 J
CMTAW	Bottom	61 J
	Top	69 J

The following conclusions are drawn from the findings: i) The specimen taken from the GMAW component's bottom portion had more toughness than the top part; ii) The specimens taken from the CMTAW component's bottom portion showed less toughness than the top part; iii) Regardless of the location, the CMTAW component offers higher impact toughness than the GMAW component (bottom and top);

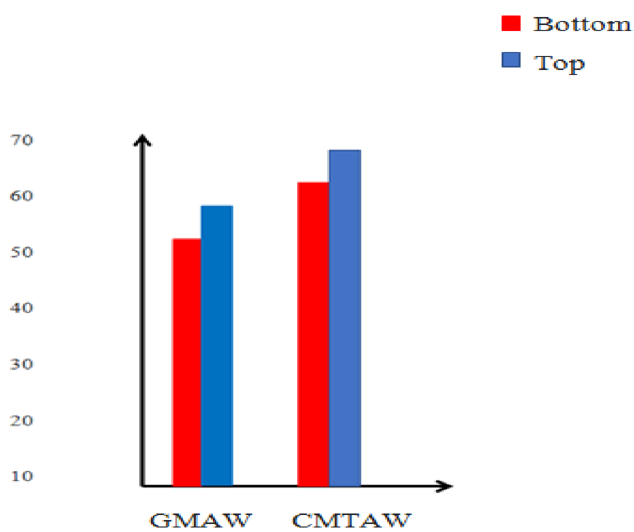

Fig.4. Impact result graph

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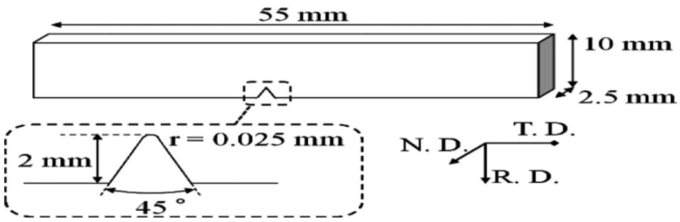
iv) The top area of the CMTAW component has an impact toughness that is 21% higher than the GMAW component. Similarly, the bottom portion of the GMAW component has a toughness that is 2.5% higher than the GMAW component.

a)



b)

Figure 5. a) Dimension of the impact specimen b) image of the Impact specimen

Hardness evaluation

The hardness distribution along the build direction of the GMAW and CMTAW wall assemblies (spacing from 1mm to 14 mm) is shown in Fig.6, indicating that there are no major differences in the microhardness along the build direction of the fabricated 308L carbon steel wall assemblies.

Figure 6. Image of micro hardness specimen

Hardness was measured at the bottom and top centre portions of the GMAW and CMTAW wall components, and their average values are shown in Table 5. Figure 7. shows the graph of Vickers micro hardness distribution on the surface.

Table 5
Average micro hardness readings of wall components

Process	Location	Average hardness: $HV_{0.5}$
GMAW	Bottom	148
	Top	159
CMTAW	Bottom	167
	Top	171

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From the hardness test results, the following disturbances were obtained: I) The hardness measured from the lower region of the GMAW assembly showed less than the upper region. ii) The hardness measured from the top of the CMTAW assembly is higher than the bottom. iii) Regardless of the area (bottom and top), CMTAW components have high stiffness compared to the GMAW components.

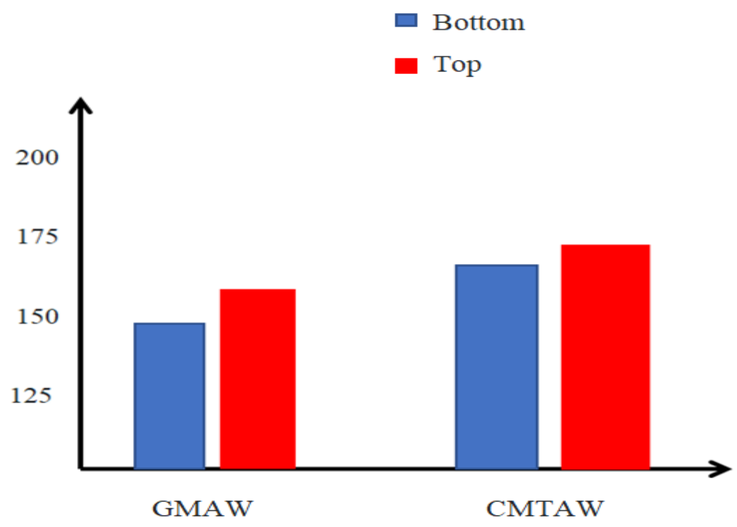

Figure 7. Vickers micro hardness distribution on the surface

iv) The stiffness of the top of the CMTAW assembly is 6.03% higher than that of the GMAW assembly. Likewise, the lower zone hardness of the CMTAW component is 3.63 % higher than that of the GMAW component.

CONCLUSION

In this study, the mechanical properties and microstructural characteristics of carbon steel wall components fabricated by GMAW and CMT processes were evaluated. This study yielded the following key findings.

i. The main process parameters of GMAW and CMT processes, including welding current, voltage, and moving speed, significantly affect the size and shape of individual welds. The voltage and traverse speed has a large effect on the width of the weld bead, while the welding current and traverse speed has a significant effect on the height of the weld bead.

ii. The GMAW 308L wall and CMT 308L wall were successfully constructed without major defects such as cracks, and a strong bond between the deposited layers was also observed. The height of the wall is relatively regular, and the material deposition efficiency can reach 93%.

iii. The top of the CMTAW wall part showed higher hardness values than all other samples due to the rapid cooling rate .

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