PARAMETRIC STUDY AND INVESTIGATIONS OF SURFACE QUALITY OF GTAW- BASED WIRE ARC ADDITIVE MANUFACTURING

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INTRODUCTION

Wire Arc Additive Manufacturing (WAAM) is a production process used to 3D print or repair metal parts. WAAM is similar to welding, as it includes layer by layer deposition for large parts with fewer complexities.

WAAM is automated and controlled by a computer program and performed by a robot arm to build complex geometries. This manufacturing technology uses an electric arc to melt a metal wire, which is then deposited layer by layer to create a 3D object.

OBJECTIVE

- Parametric Study and Investigations of surface quality of GTAW- Based Wire arc Additive Manufacturing of ER70S-6 Mild Steel.
- Analysis of Surface Roughness for GTAW component of single layer deposition.
- Analysis of Welding Speed, Welding Current and Shielding Gas Flow Rate using Taguchi and ANOVA

Experimental Setup

- 6-axis Robotic arm
- Wire feeder
- GTAW welding system
- Power Supply
- Shielding gas setup
- Monitoring and control system
- Non-contact type Optical Profilometer

Methodology

Selection of materials

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Find the process parameters

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Create experimental table

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Perform all the experiments

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Measure Sa & Sz values

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Analysis of input parameters

Process Parameters for GTAW based WAAM for Mild Steel (ER70S-6)

Process Parameters	Values/Ranges
Wire diameter(d)	1.2mm
Standoff distance(l)	5mm
Torch angle	90º
Wire Feed rate(f)	1m/min
Shielding gas	Argon(Ar)

Base Plate dim : 250x100x5 (mm)

Factors and their respective values

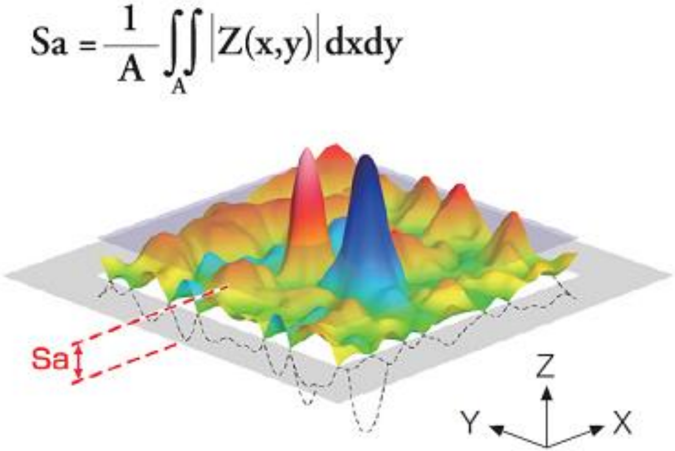
S/No.	Factors	Type	Level1	Level2	Level3
01	**Welding Current(A)**	Fixed	140	150	160
02	**Welding Speed (cm/min)**	Fixed	10	12	14
03	**SGFR(L/min)**	Fixed	10	15	20

Experimental Table

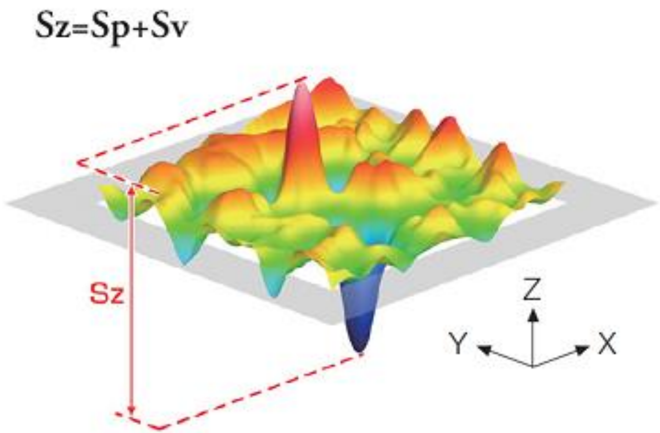
(Orthogonal arrays L9 DOE based on Taguchi)

S.No.	C1 Travel Speed (cm/min)	C2 Welding Current (A)	C3 SGFR (L/min)	C4 Sa (µm)	C5 Sz (µm)
1	10	140	10	43.471	307.487
2	10	150	15	63.375	356.164
3	10	160	20	71.891	408.153
4	12	140	10	34.114	305.694
5	12	150	15	53.097	306.918
6	12	160	20	73.861	396.642
7	14	140	10	30.443	278.990
8	14	150	15	46.285	328.072
9	14	160	20	52.388	338.264

- Sa and Sz values are measured using Optical Profilometer



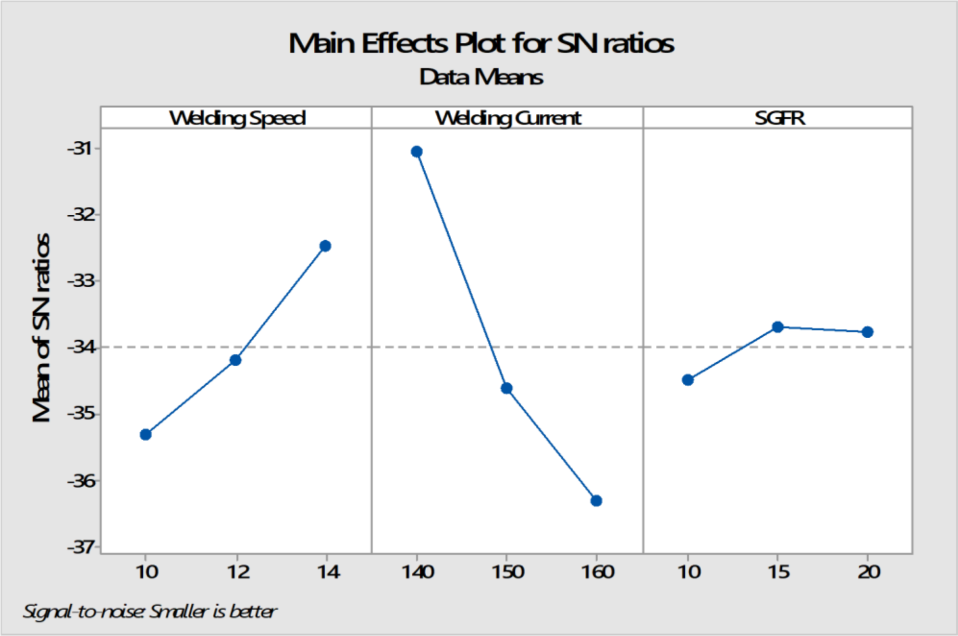
Sa (Arithmetical Mean Height)



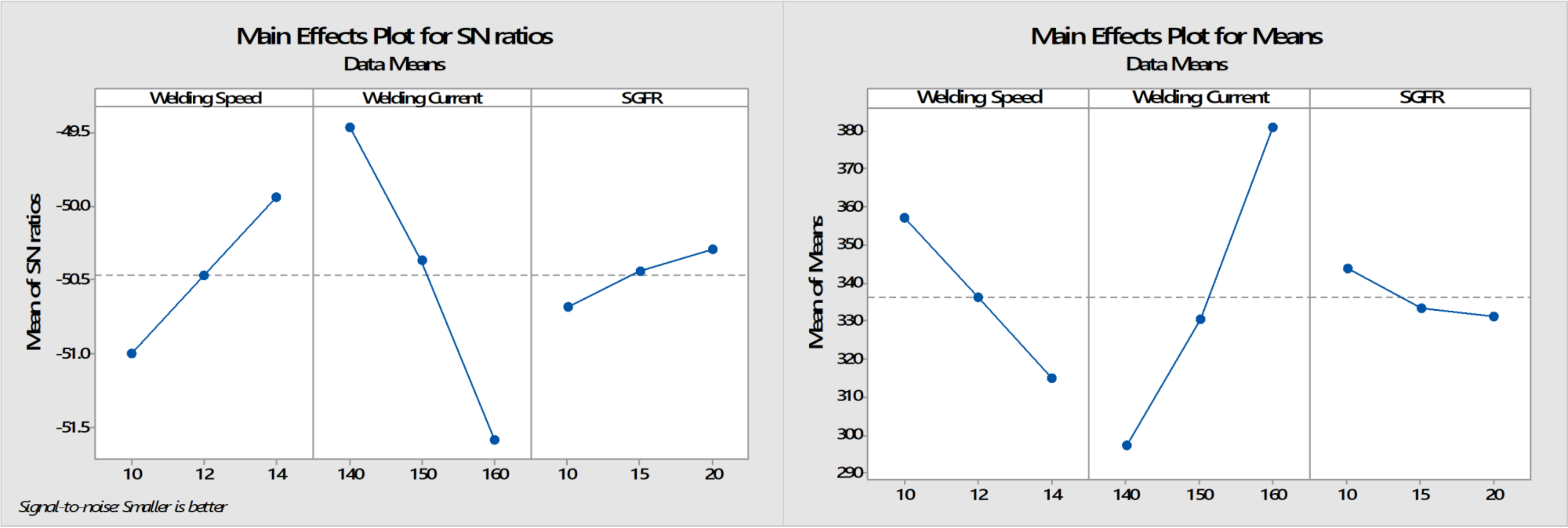
Sz (Maximum Height)

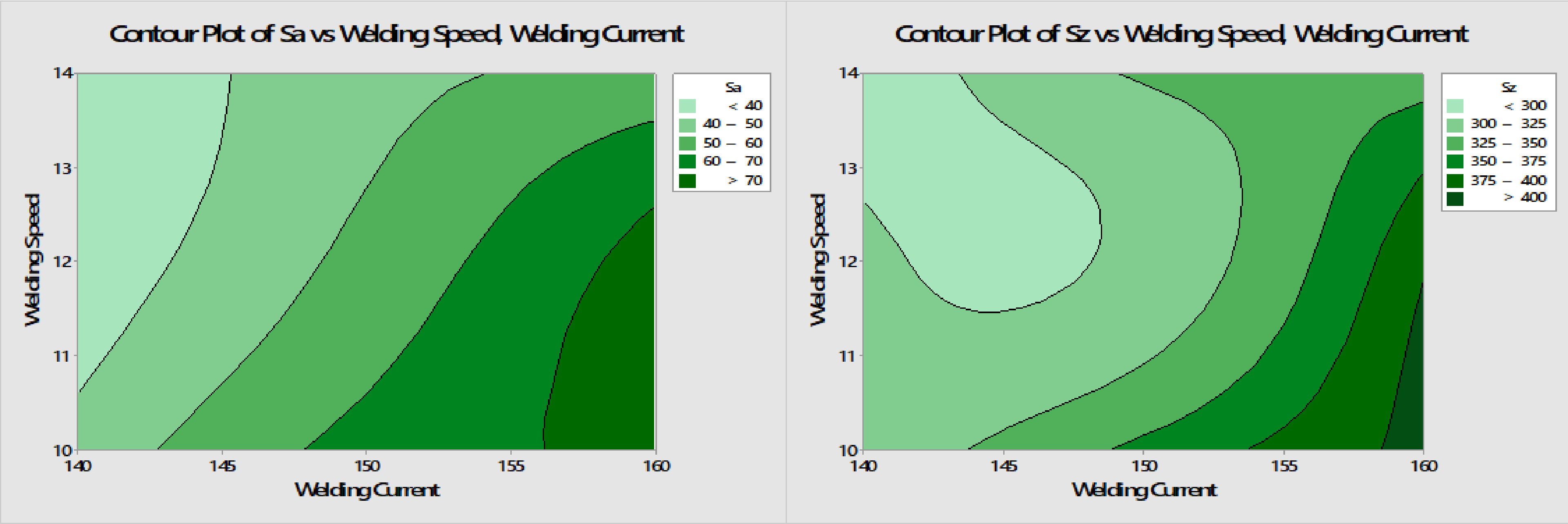
RESULTS AND DISCUSSION

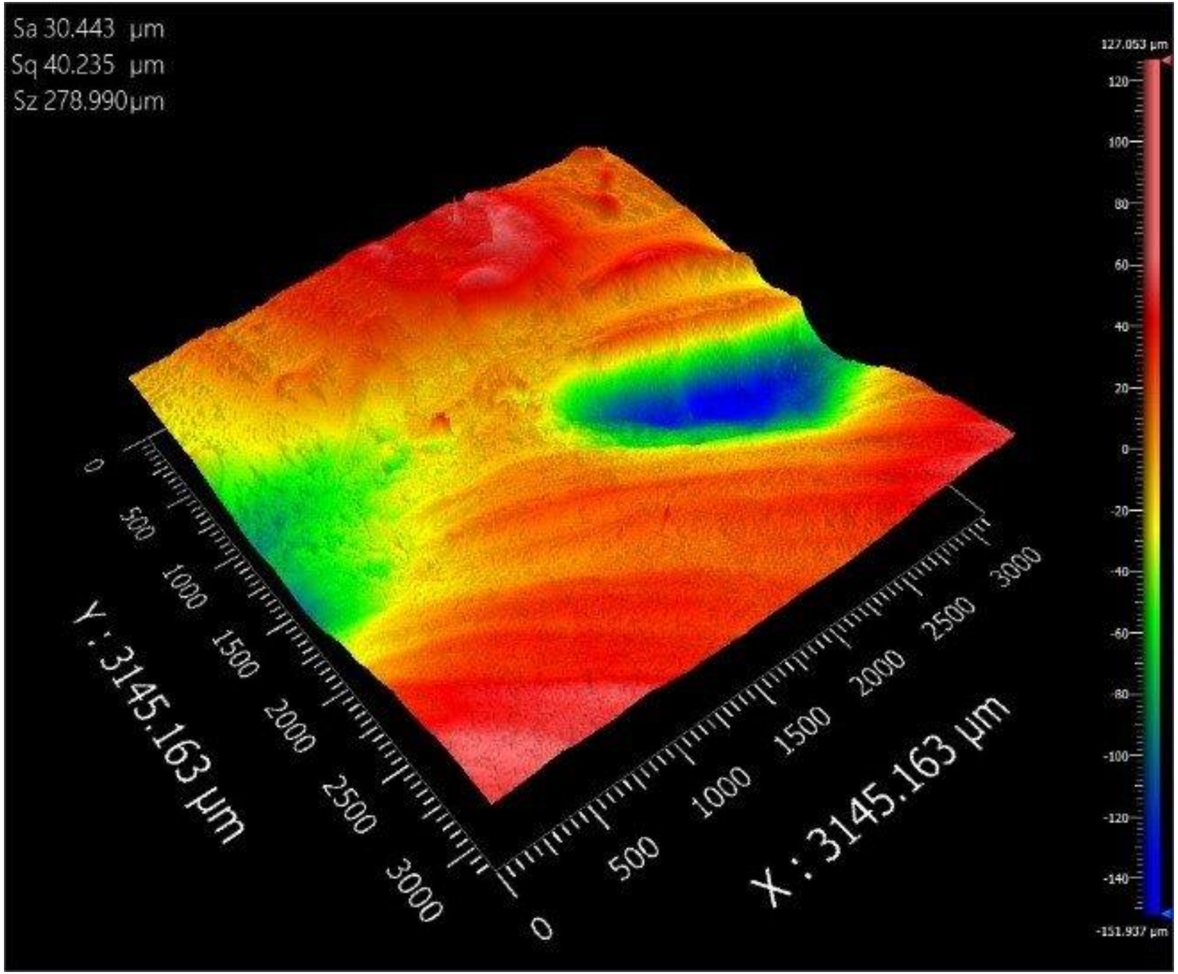
Signal-to-Noise Ratios (S/N) ratio plot and Mean plot for Sa values: Smaller is better



Signal-to-Noise Ratios S/N ratio plot for Sz values: Smaller is better




Contour Plot of Sa vs Welding Speed, Welding Current
Welding Speed
Welding Current
Sa
< 40
40 – 50
50 – 60
60 – 70
> 70
Contour Plot of Sz vs Welding Speed, Welding Current
Sz
< 300
300 – 325
325 – 350
350 – 375
375 – 400
> 400



Sa 30.443 μm
Sq 40.235 μm
Sz 278.990μm
127.053 μm
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-151.937 μm
Y : 3145.163 μm
0
500
1000
1500
2000
2500
3000
X : 3145.163 μm
0
500
1000
1500
2000
2500
3000

Analysis of surface quality using ANOVA

FOR REGRESSION EQUATION:

Regression Analysis: Sa versus Welding Speed, Welding Current, SGFR

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	1774.90	591.63	24.79	0.002
Welding Speed	1	410.37	410.37	17.20	0.009
Welding Current	1	1353.36	1353.36	56.71	0.001
SGFR	1	11.17	11.17	0.47	0.524
Error	5	119.32	23.86		
Total	8	1894.22			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
4.88505	93.70%	89.92%	76.94%

Regression Equation

Sa = -119.5 - 4.135 (Welding Speed) + 1.502 (Welding Current) - 0.273 (SGFR)

Regression Analysis: Sz versus Welding Speed, Welding Current, SGFR

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	13399.4	4466.5	12.51	0.009
Welding Speed	1	2666.1	2666.1	7.47	0.041
Welding Current	1	10490.8	10490.8	29.38	0.003
SGFR	1	242.4	242.4	0.68	0.447
Error	5	1785.4	357.1		
Total	8	15184.8			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
18.8967	88.24%	81.19%	54.60%

Regression Equation:

Sz = -145 - 10.54 (Welding Speed) + 4.181 (Welding Current) - 1.27 (SGFR)

CONCLUSION

- In terms of influence on Sa and Sz values, the order of importance among input parameters is: welding current has the greatest impact, followed by welding speed, with SGFR being the least influential. So, the optimum conditions for having the smallest value of surface roughness and waviness in all three parameters are 14 cm/min, 20L/min, and 140A.
- From the ANOVA analysis, the result shows that welding speed, welding current and SGFR are the significant parameters for the surface roughness however, welding current is the most influencing process parameter with 76.25 % contribution among the selected input parameter and SGFR is the least impactful parameter with 1.2 % contribution among the three parameters.

FUTURE WORKS

- Optimize parameters for multi-layer deposition
- Exploring into various materials beyond mild steel
- Analysis of stress on the weld bead.
- Analysis of the strength of the joint.

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THANK YOU