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EXPERIMENTAL ANALYSIS OF TUNGSTEN INERT GAS (TIG) WELDING AT ZERO DEGREE TEMPERATURE

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ABSTRACT:
The present work has been carried out for Experimental analysis of Tungsten Inert Gas (TIG) welding at zero degree Celsius. Due to their exceptional characteristics, stainless steel of designation AISI 316L is select for our work. During welding temperature variations recorded by thermocouple and operated by AGILENT software. We measured Bead width, Depth of penetration (DOP) and hardness of weldzone as well as heat affected zone. Regression analysis is to predict the relationship between the output and input variable and found appreciable R-square value for all the responses. To observe the effect of each parameter on different responses main effect plot has been drawn by MINITAB. By the present investigation it can be conclude that TIG welding on stainless steel of grade AISI 316L is feasible on higher hardness of weldment requirement for less thickness of plate while the ambient temperature is about zero degree Celsius. Secondly, significant changes are found in weld bead geometry while the plate temperature is at zero degree Celsius.

Keywords:
Tungsten inert gas welding, Regression analysis, Grey based Taguchi optimization, etc.

INTRODUCTION

TIG welding process is commonly known as gas tungsten arc welding (GTAW), in which we use the heat generated by an electrode of non-consumable [1]. Our present work is done for TIG welding at the place where ambient temperature is about zero degree Celsius [2].

This welding process can be use by both manual as well as automatic methods. There are numbers of parameters which influence the work piece geometry, weld characteristics, heat affected zone (HZ), bed width (BW) and depth of penetration (DOP) etc. Here we use non-consumable tungsten electrode to produce weld[3]. All setup of this type of gas arc welding (Fig 1) with work piece and zero-degree plate setup (Fig 2) is shown in below figure:

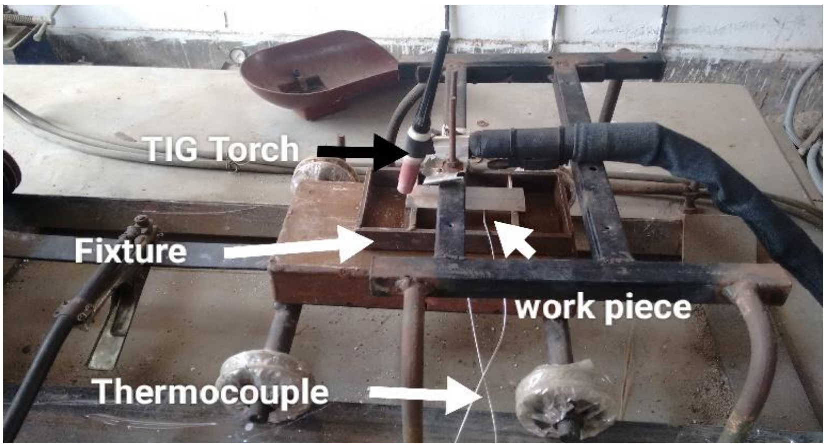

Fig 1 TIG welding setup

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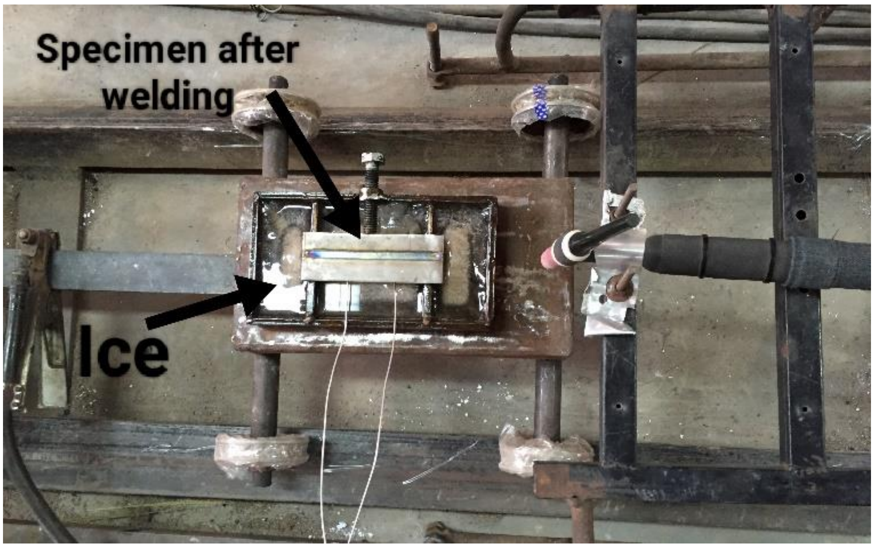

Fig 2 TIG welding with zero degree plate setup

TIG welding process is mostly use to weld thin type stainless steel[4] and non ferrous metals such as magnesium, aluminum, and copper[5][6]. Here we use to fulfill our requirements stainless of grade AISI 316L.

2 EXPERIMENTATION AND METHODOLOGY

Stainless steels have number of grades like 304/304L, 316/316L[7] etc. It is require to studied about all grades of stainless steel for appropriate grade material selection which fulfill the present investigation demand as well has number of application without affected by environmental condition and found during welding of 304/304L or any other stainless steel (chromium is present to avoid corrosion) at high temperature about 1000^0C chromium react [8] with carbon and form chromium carbide as a precipitate and it deplete the chromium[9].

Due to depletion of chromium corrosion resistance quality of steel reduced, but in 316L stainless steel carbon contain is very less so this problem can be reduced, then according to project boundary condition, properties require in material and applications like in food processing unit, kitchen appliances, heat exchanger, chemical container, and fluid pipe lines etc [10], AISI 316L stainless steel has been selected to performing present work.

In search of parameter range suitable for the selected specimen a considerable number of trial run are done and subsequent analysis viz depth of penetration (DOP), bead width (BW) is observed. For the experimental analysis we use 4 level parameter (Table 1) shown in below:

Table 1 Levels of process parameters

Parameters	Units	Notations	Level 1	Level 2	Level 3	Level 4
Current	**Amps**	I	120	140	160	180
Welding Speed	**m/min**	S	0.25	0.30	0.35	0.40
Gas Pressure	**Kg/cm2**	G	10	15	20	25

3 DATA COLLECTION AND ANALYSIS

After welding, the following data have been recorded.

1. Measurement of weld geometry viz. depth of penetration(DOP) and bead width(BW).
2. Micro hardness of weld zone and HAZ
3. Microstructure observed in weld zone and HAZ

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Value of depth of penetration (DOP), bead width, and hardness of weld zone and HAZ for both at Room Temperature and at Zero Degree Temperature(Table 2) about the four different levels are record.
which is given below in the table:

Table 2 Measured data related to bead geometry and hardness

EX. NO	TIG Welding at Room Temperature				TIG Welding at Zero degree Celcious Temperature			
	DOP (mm)	Bead Width (mm)	Hardness of weldzone (HV5)	Hardness of HAZ	DOP (mm)	Bead width (mm)	Hardness of Weldzone (HV5)	Hardness of HAZ
1	0.7985	4.4503	267.92	244.1	0.9214	5.1163	245.89	234.41
2	0.3038	2.2325	219.63	215.3	0.9394	5.9987	231.56	235.15
3	0.1977	2.1862	222.83	230.15	0.8867	5.2144	258.23	226.12
4	0.3007	2.4545	255.28	260.3	0.8545	4.2426	320.45	270.36
5	0.8241	4.4513	254.69	241.56	1.3214	5.9863	239.88	210.51
6	0.6545	3.0281	223.25	220.5	1.0221	4.987	236.05	217.45
7	0.665	4.7312	230.14	242.5	1.0458	5.5869	244.31	245.98
8	0.6115	3.3352	211.81	221.7	0.9054	4.4891	238.95	250.12
9	1.1126	6.5142	250.69	230.56	1.5784	6.6981	217.84	208.54
10	1.1242	6.5658	214.63	215.91	1.2201	6.7756	201.41	178.41
11	0.9958	3.0892	202.36	204.43	1.1058	5.4545	235.61	224.63
12	0.8527	5.2615	198.54	208.67	0.9756	5.2163	220.35	229.55
13	1.4152	8.5241	225.63	230.25	1.5984	8.2456	190.23	205.13
14	1.2421	7.3258	199.56	201.5	1.1156	7.5641	210.48	208.65
15	1.2024	6.4391	211.24	207.5	1.0741	7.1546	260.79	198.11
16	0.967	5.2698	229.99	222.3	1.3521	6.2581	300.81	264.89

3.1 OPTIMIZATION OF PROCESS PARAMETERS BY GREY BASED TAGUCHI METHODOLOGY

Parametric optimization has been done for finding optimal process parameters to maximize the depth of penetration and to minimize the bead width as well as hardness of weld zone. In present investigation Grey based Taguchi optimization has been done for both the cases.

Table 3 Normalized value of responses for welding at zero degree Celsius plate temperature

Sample no.	DOP(C) (mm)	Bead width(C) (mm)	Hardness in weld zone (C)(HV.5)	Normalized DOP (C)	Normalized Bead width (C)	Normalized Hardness in weld zone (C)
1	0.9317	5.3163	244.86	0.118244	0.776675	0.570275
2	0.9493	6.0363	225.16	0.128515	0.572185	0.700769
3	0.8867	5.1344	260.27	0.073282	0.792495	0.465850
4	0.8405	4.3526	319.88	0	1	0
5	1.2109	5.8690	240.97	0.611125	0.609885	0.624065
6	1.0412	5.1118	237.49	0.247870	0.805935	0.643448
7	1.0458	5.6849	273.16	0.265598	0.657399	0.599221
8	0.8745	4.5449	238.63	0.044533	0.938065	0.634558
9	1.5957	6.6872	218.49	0.967963	0.402472	0.791876
10	1.2188	6.8291	202.69	0.492871	0.349075	0.915829
11	1.1394	5.5114	235.75	0.375409	0.703786	0.657110
12	0.9718	5.1922	221.23	0.170809	0.782835	0.771195
13	1.6105	8.2447	191.85	1	0	1
14	1.1204	7.5629	220.59	0.363370	0.177111	0.853580
15	1.0897	7.2463	265.79	0.323849	0.255225	0.453615
16	1.3545	6.3515	300.55	0.665147	0.485727	0.150810

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4 RESULTS

Present investigation has been done on two boundary condition to observed the effect of boundary condition as well as process parameters on different mechanical properties and microstructure(fig 3). Microstructure (20X) of base metal (BM) shown below:

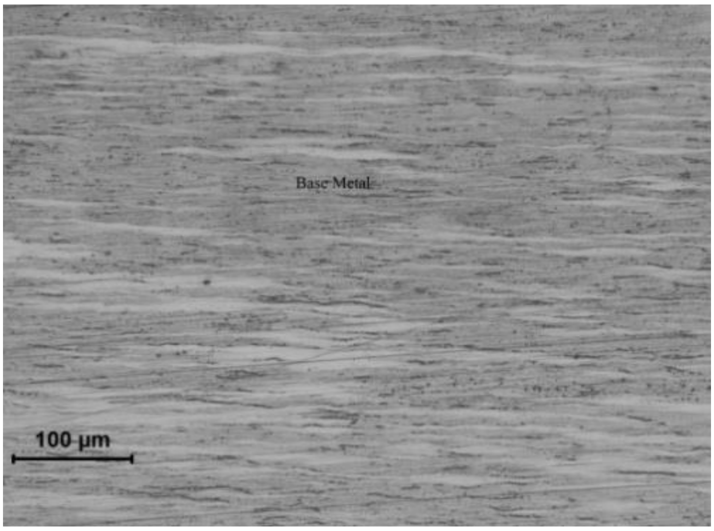

Fig 3 Microstructure view of BM(20x)

4.1 EFFECT OF PARAMETERS ON DEPTH OF PENETRATION(DOP)

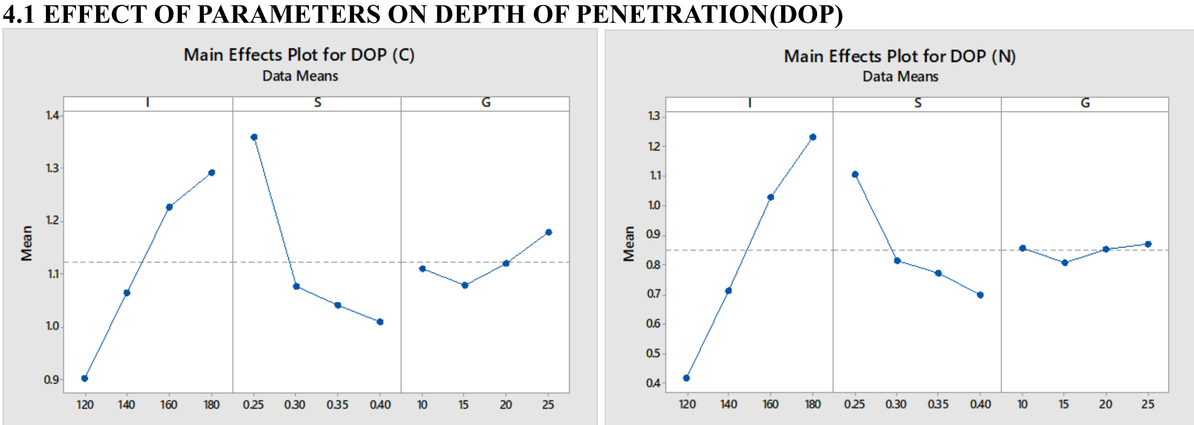

Fig 4 Graph of main effects plot for DOP (C) and DOP (N)

4.2 EFFECT OF PARAMETERS ON BEAD WIDTH(BW)

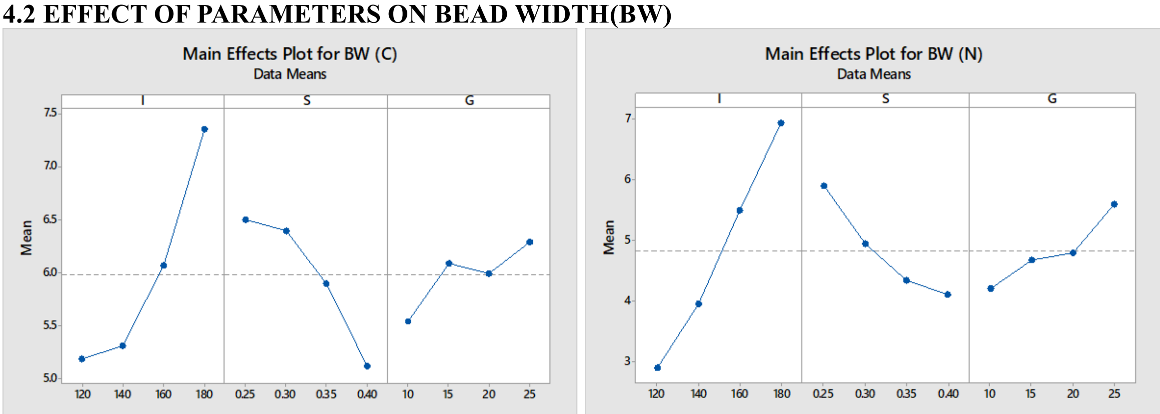

Fig 5 Graph of main effects plot for BW (C) and BW (N)

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4.3 EFFECT OF PARAMETERS ON HARDNESS OF WELD ZONE(HW)

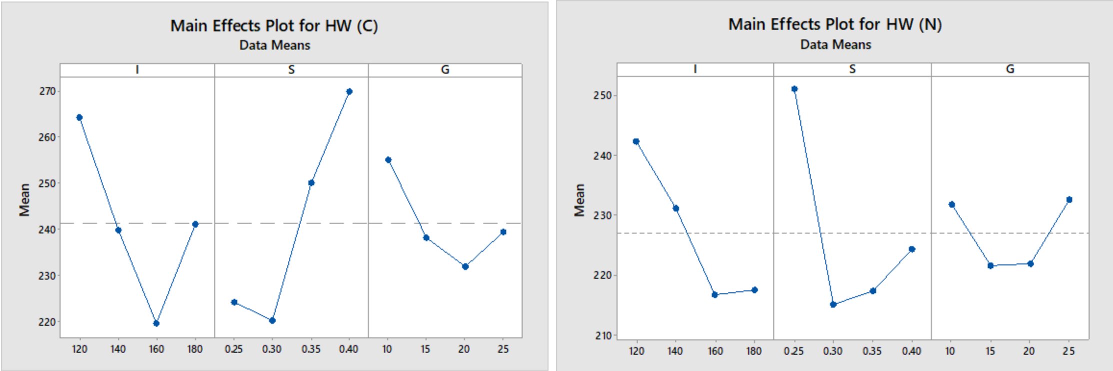

Fig 6 Graph of main effects plot for HW (C) and HW (N)

4.4 EFFECT OF PARAMETERS ON HARDNESS OF HAZ(HZ)

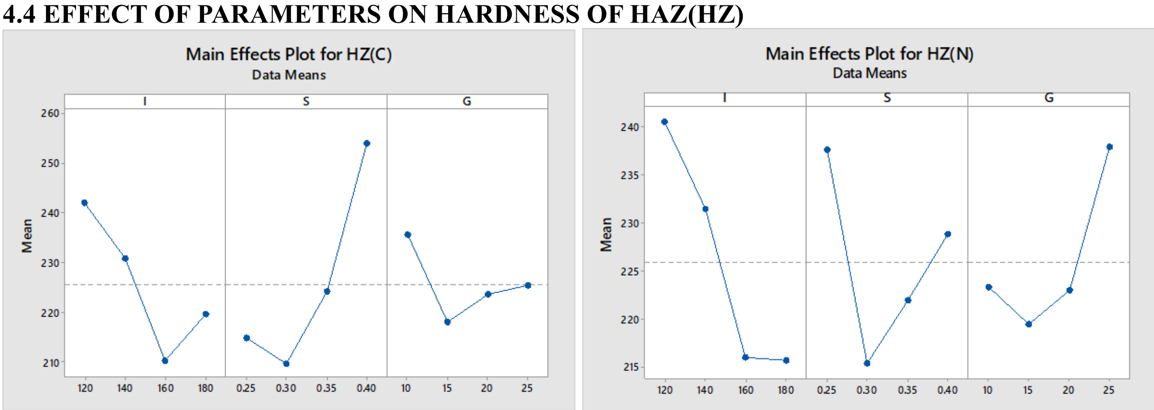

Fig 7 Graph of main effects plot for HZ (C) and HZ (N)

4.5 GREY BASED TAGUCHI OPTIMIZATION5

The optimal process control parametric combination for TIG welding at zero degree Celsius plate temperature becomes **I3S1G4** (current 160 Amp, speed 0.25 m/min and gas pressure 25 Kg/cm^2) and for TIG welding at room temperature becomes **I4S2G3** (current 180 Amp, speed 0.30 m/min and gas pressure 20 Kg/cm^2).

4.5.1 CONFIRMATORY TEST

Optimized parameters are not matching with orthogonal parametric design. But from the regression equations which have been got from regression analysis of all the attributes value of bead geometries and hardness of weld zone can be calculated.

From Regression equation, for both the boundary condition different responses at optimized parameters are shown below in table

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Table 4 Responses at optimized parameters for TIG welding

Boundary cases	Depth of penetration (mm)	Bead width (mm)	Hardness of weld zone ($HV_{.5}$)
For TIG welding at zero degree Celsius plate temperature	1.7085	7.22037	203.83
For TIG welding at room temperature	1.3221	7.5994	205.181

5 CONCLUSIONS

In this work, it is highlighted that Tungsten Inert Gas welding is feasible where the ambient temperature is at zero degree Celsius without preheating the work piece of material. Grey based Taguchi Optimization methodologies can solve multi-objective optimization problem through a case study in TIG welding. Selected weldment attribute like depth of penetration ,bead width and hardness of weld zone have been optimized.So the conclusion can be summarized based on present work:

1. It has been observed that, process parameters viz welding current, welding speed and gas pressure played key role in TIG welding.
2. DOP and BW of weldment found more in case of TIG welding at zero degree Celsius plate temperature.
3. Hardness of weld zone as well as HAZ found more in case of TIG welding at zero degree Celsius plate temperature.
4. It has been also clear that grains size at fusion zone for TIG welding at zero degree Celsius plate temperature found smaller than the grains size for TIG welding at room temperature. For lower heat input area of heat affected zone found less in case of TIG welding at zero degree Celsius plate temperature compare than area of HAZ in case of TIG welding at room temperature, but no significant changes of HAZ area has been found for higher heat input in both the cases.
5. From temperature variation graph for both the situationviz TIG welding at zero degree Celsius plate temperature and at room temperature has higher temperature rise for second case.Higher cooling rate have found in case of welding at zero degree Celsius plate temperature.
6. Regression analyses of the responses have been done. After analysing the model summary of regression analysis, value of R-sq found appreciable for all the responses, which indicated that the equation got from regression analysis provide adequate relationship between output and input variables.
7. Grey based Taguchi optimization has been done within the experimental range for both the boundary condition and found that for TIG welding at zero degree Celsius plate temperature, welding speed 0.25 m/min, welding current 160 amp and gas pressure 25 Kg/cm^2 is the optimal parameters setting and for TIG welding at room temperaturewelding speed 0.30 m/min, current 180 amp, gas pressure 20 Kg/cm^2 is the optimal parameter setting. And responses have been also calculated for optimized parameters by regression equation.

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