ISSN: 0974-5823 Vol. 6 No. 3 October-December, 2021

International Journal of Mechanical Engineering

Process Parameter Optimization in Pulsed Current GTA Welding Process on ASTM 106 Grade –B Steel Pipes

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Date of Submission: 16th April 2021 Revised: 29th September 2021 Accepted: 24th October 2021

How to Cite: **G Prakasham, et. al. (2021). Process Parameter Optimization in Pulsed Current GTA Welding Process on ASTM 106 Grade-B Steel Pipes. International Journal of Mechanical Engineering 6(3), pp.1724-1730**

***Abstract* - The present research work aims to optimize the process parameters in the Pulsed Current Gas Tungsten Arc Welding (PCGTAW) process by employing Design of Experiment (DOE) technique on ASTM 106 Grade- B Steel pipes. Taguchi method based orthogonal array, L9 for four factors Pulse current (PC), Background Current (BC), Pulse Frequency (PF), and Pulse on time (PO) with three levels are employed. The higher the better reaction is picked to decide the ideal conditions for maximum ultimate tensile strength. The optimum values are found to be 220 A pulse current, 100 A background current, 4 Hz pulse frequency, and pulse on-time 60 %. ANOVA is implemented to gauge each factor's % contribution. The outcomes indicate that background current and pulse current are the significant process parameters to yield maximum ultimate tensile strength. Confirmation experiments are conducted to validate the results.**

Index Terms – Pulsed Current, Pulse Frequency, ANOVA, L9 Orthogonal Array, Ultimate Tensile Strength.

INTRODUCTION

Pulsed current GTA welding is a variation of TIG welding in which the current pulse between a high and low level is shown in Figure 1. Pulse welding is welding with a welding current that constantly varies from a high amperage and back again. This allows a welder to join a thin section of the material. Pulse welding produces deeper penetration without putting much heat into the base metal. [1] Pulsed gas tungsten arc welding is most commonly preferred to weld thin sections of stainless steel, non-ferrous metals such as aluminium, magnesium and copper alloys. ASTM A106 Grade- B steel pipe is the traditional specification for low carbon steel for high-pressure and temperature service. ASTM A106 Grade B is a pipe material typically utilized in modern industrial plants, power plants, oil processing plant, and chemical Industries.

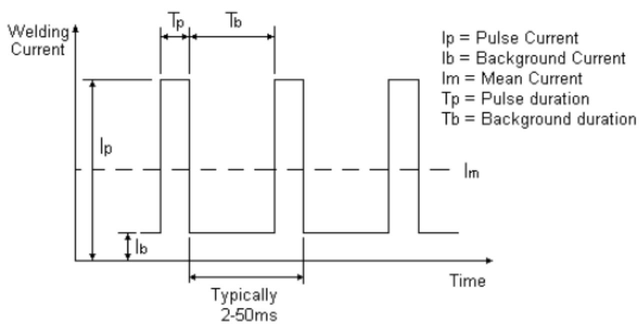


FIGURE 1
Pulse Current Gas Tungsten Arc Welding Process (twi-global.com)

Low carbon steels like ASTM 106 Grade- B steels are used as piping materials because of their tolerance to mildly elevated temperature, high pressures, more corrosive resistance, and decent mechanical properties [2] They are most commonly used in power generation industries, petrochemical industries, boilers, and oil and gas enterprises where the channeling should ship liquids and gases that exhibit higher pressure and temperatures levels. They offer good strength and are relatively inexpensive. Carbon steels were extensively used for drill pipes in the oil and gas industry [3], reported that the welding heat input caused in critical changes in microstructure at heat affected zone.[4] In this article it is presented that if welding heat input increases it affects the residual stress contours. To reduce heat input at heat-affected zone, and weld zone pulsed current GTA welding process are preferred in these experiments [5]. Pulse Current Gas Tungsten Arc (PCGTA) welding displays the fine equiaxed dendrites are observed related to Constant Current GTA welding [6].

Rapid solidification is achieved in the Pulse Current Gas Tungsten Arc (PCGTA) welding due to the lower heat input which is responsible for the fine microstructure. It has been observed that these pipes are joined using Tungsten Inert Gas (TIG) welding process with ER70S3 filler wire, the root is welded with 1.6 mm diameter wire and finish weld with 2.5 mm filler wire. It is observed that the mix of temperature cycles in root and finish with low welding heat input shows significant change in grains at base metal, as well as in HAZ (Heat-Affected Zone). The same results are not reported with high heat input [7]. Investigates on microstructure and mechanical properties of Monel 400 and AISI 316 dissimilar joints using pulsed current GTA welding, ERNiCrMo-3 as a filler wire. Heat affected zone is minimized and small grain coarsening was identified at the boundary of stainless steel because of thermal properties [8]. The effects of filler metal on the segregation and mechanical properties in AISI 904L material were improved due to the low heat input supplied to the base metal and migrated grain boundaries are seen at the weldzone of AISI 904L weldments [9]. Investigated the outcome of pulsed GTA welding on mechanical properties and microstructure, because of the variation in the base and pulse current may reason of undercooling of the metal in the weld zone since heat input at weld pool is rapidly reduced in between pulse and background current of pulse tungsten inert gas welding [10]. Pulse current leads to a moderately better and more equiaxed grain structure in GTA weldsInterestingly, traditional persistent current welding brought about overwhelmingly columnar grain structures [11]. The GTA welded AA (aluminium alloy) joint fabricated by pulsed current welding technique displays predominant ultimate tensile properties contrasted with the regular TIG welding process [12]. Studied process parameter optimization in pulsed TIG welding process of aluminium alloys by varying different gas mixtures and reported that formation of fine dendritic microstructure brought about progress of mechanical properties [13]. The metallographic investigation uncovers a fine grain structure at the weld pool, which brings about good mechanical properties. The persistence of the current work is to obtain finest process parameters in the PCGTAW process to yield more ultimate tensile strength.

MATERIALS AND METHODS

ASTM 106 Grade- B steel pipe with 5 mm thickness and 50 mm outer diameter is shown in Figure 2. is carefully chosen for the present work

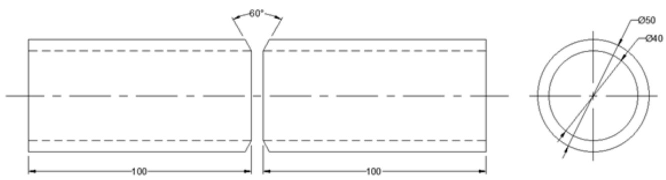


FIGURE 2
Schematic Diagram of ASTM 106 Grade B Steel Pipe

The most common angles for V grooves are 60^0 (2×30^0). A land is generally required a width of 1mm and the root opening between the parts to be welded is 1.5 mm is shown in Figure 3.

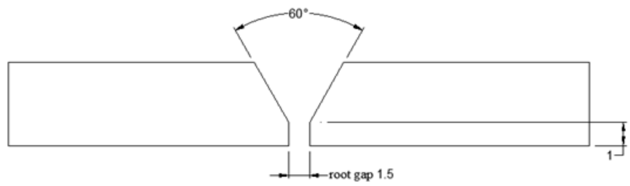


FIGURE 3
Schematic diagram of V groove, Root opening

FIGURE 4
Sample Specimens before welding

Sample specimens with groove angles are machined with CNC machine and fixed with C clamps are shown in Figure 4 & 5. Table I shows base metal composition and Table II shows filler wire composition.

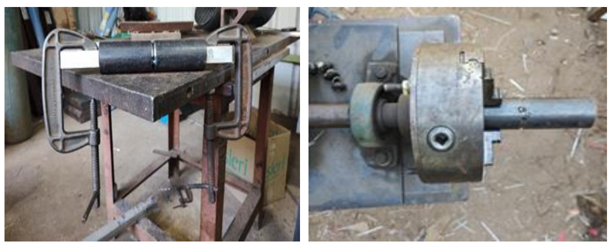


FIGURE 5
Pipes Fixed with C clamps for tack weld

FIGURE 6

Sample Specimens after welding

FIGURE 8

Tensile specimen samples cut with Wire EDM

Table I
ASTM 106 Grade- B steel chemical composition

Element	C	Mn	S	P	Si	Cr	Ni	Mo	Cu
Weight %	0.21	0.60	0.01	0.27	0.057	0.014	0.007	0.007	0.017

Table II
Filler Material ER70S2 chemical composition

Element	C	Mn	S	P	Si	Cr	Ni	Mo	V	Cu
Weight %	0.07	1.2	0.035	0.025	0.65	0.15	0.15	0.015	0.03	0.05

The PCGTAW experiments are conducted manually using the Indus Arc welding equipment. Taguchi design parameters and its levels are displayed in Table III. The pipes are cleaned thoroughly before conduction of experiments. Shielding gas of Argon with a flow rate of 14 lit /min. used protect the weld pool with a constant speed of 125.6 mm/min. to obtain maximum ultimate tensile strength.

Table III
Design factors and levels

Parameters	**Levels**		
Pulse Current (PC), A	180	200	220
Background Current (BC), A	100	110	120
Pulse Frequency (PF), Hz	4	6	8
Pulse on Time (PO) %	40	50	60

RESULTS AND DISCUSSION

Experiments are conducted as per Taguchi design with pulsed current GTA welding Process. Fig 7. Shows ASTM E08 standard tensile test specimen schematic diagram.

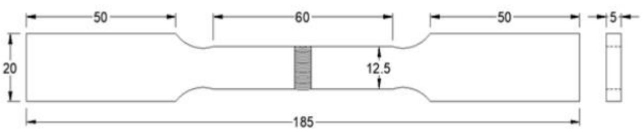


FIGURE 7

Tensile test specimen as per ASTM E08 standards

FIGURE 9

Tensile specimen samples before testing

FIGURE 10
Tensile specimen samples after testing

In Fig 8 shows tensile test specimens are cut with wire electrical discharge machining process as per ASTM E08 standards. In Fig 9 shows all the tensile specimens are failed at base metal and the values obtained by tensile tests are indicate that weld strength is more than that of base metal.

The S/N ratio corresponding to Taguchi L_9 orthogonal array is conducted and tabulated in Table IV.

Table IV. L9 Orthogonal array

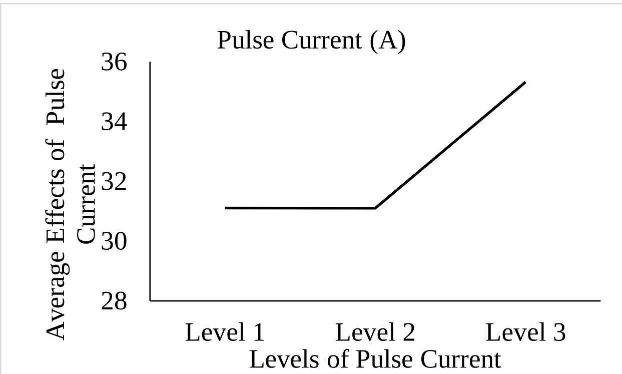
Table V. Experimental outcomes for Ultimate tensile strength and equivalent S/N ratios

Standard Trial Order	Random Trial Order	Control Factors			
		Pulse Current (A)	Background Current (A)	Pulse Frequency (Hz)	Pulse On (%)
1	5	1	1	1	1
2	3	1	2	2	2
3	9	1	3	3	3
4	1	2	1	2	3
5	7	2	2	3	1
6	2	2	3	1	2
7	4	3	1	3	2
8	6	3	2	2	3
9	8	3	3	1	1

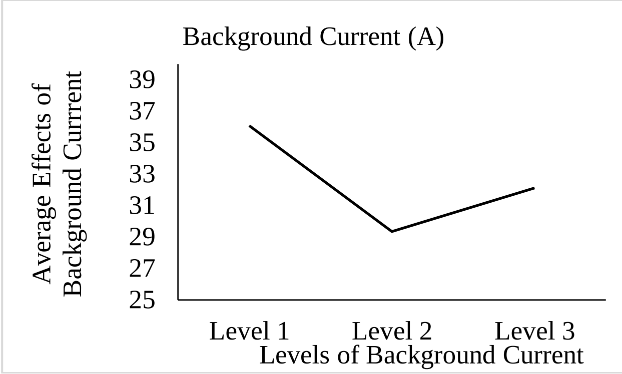
Table VI. S/N Ration factors

S. No	Factors	Level 1	Level 2	Level 3
1	Pulse Current(A)	31.11	31.10	35.32
2	Background Current(A)	36.08	29.35	32.11
3	Pulse Frequency (Hz)	33.63	33.01	30.90
4	Pulse on Time %	31.25	33.21	33.07

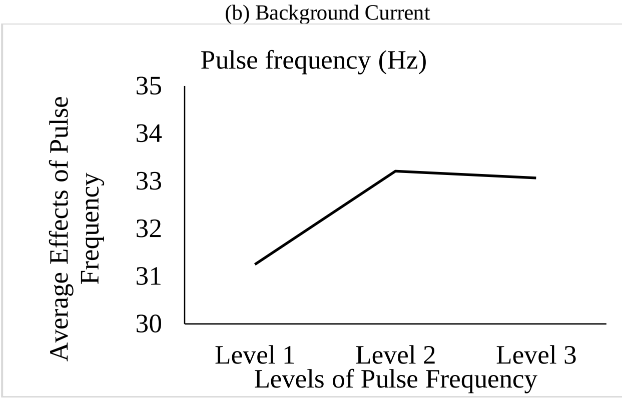
S. No	Control Factors				Ultimate Tensile Strength (MPa) Trial 1	Ultimate Tensile Strength (MPa) Trial 2	S/N ratio
	Pulse Current (A)	Background Current (A)	Pulse Frequency (Hz)	Pulse on (%)			
1	180	100	4	40	476.13	455.64	34.53
2	180	110	6	50	457.26	459.03	29.15
3	180	120	8	60	459.20	458.31	29.66
4	200	100	6	60	468.04	464.15	35.71
5	200	110	8	40	462.28	451.50	25.07
6	200	120	4	50	463.54	455.00	32.51
7	220	100	8	50	463.32	464.60	37.98
8	220	110	6	60	456.89	468.62	33.87
9	220	120	4	40	446.65	466.94	34.23



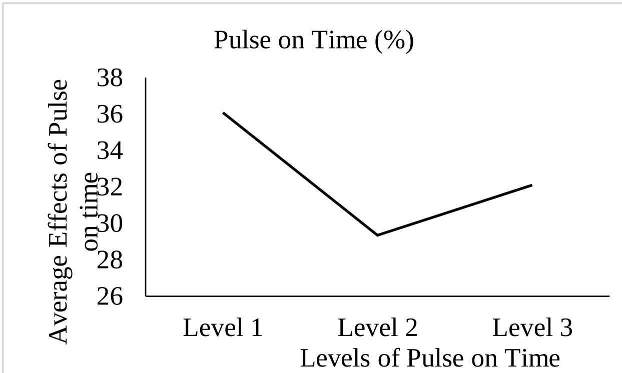
(a) Pulse Current



(b) Background Current



(c) Pulse Frequency



(d) Pulse on Time

FIGURE 11
The S/N response graphs for Ultimate tensile strength (a) Pulse current, (b) Background current,
(c) Pulse frequency and (d) Pulse on time %.

As shown in Fig. 11, Background and Pulse current is the greatest significant factor chosen in this work to yield maximum ultimate tensile strength. The maximum tensile strength obtained in sample 1. It is also observed that the least ultimate tensile strength was obtained in the case of sample 9. The optimum level/factor grouping of PCGTAW process parameters is obtained by employing Taguchi method. The optimum values of pulse current 200A, Background current 100 A, Pulse on time 50% and Pulse frequency is 4Hz are tabulated in table VII.

Table VII. Optimum process parameters

S. No	Factors	Levels	Values
1	Pulse Current(A)	3	220
2	Background Current(A)	1	100
3	Pulse Frequency (Hz)	1	4
4	Pulse on Time (%)	2	50

Analysis of variance (ANOVA) results

Analysis of variance (ANOVA) is used to normalize the impact and relative status of the different factors. The degrees of freedom (DOF), Sum of square (SS), the variance (V), and the %of contribution of the total variation (P) are utilized. The each factor % of contributions obtained by the Analysis of variance (ANOVA) outcomes are tabulated in Table VIII.

Table VIII: Percentage of factors in Analysis of Variance (ANOVA)

Colum /Factor	DOF	Sum of squares (SS)	Variance (V)	Percentage (%)	Rank
Pulse Current, A	2	35.58	17.79	28.80	2
Back Ground Current, A	2	68.57	34.48	55.50	1
Pulse Frequency, Hz	2	12.22	6.11	9.89	3
Pulse -on Time %	2	7.16	3.58	5.79	4

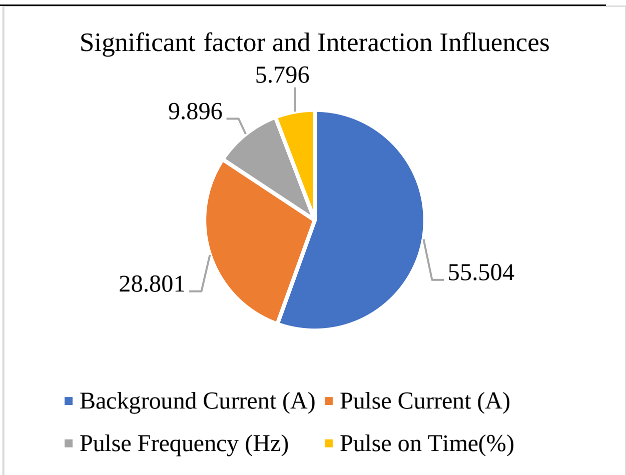


FIGURE12
Significant factors and Interaction Influences shown in Pie chart.

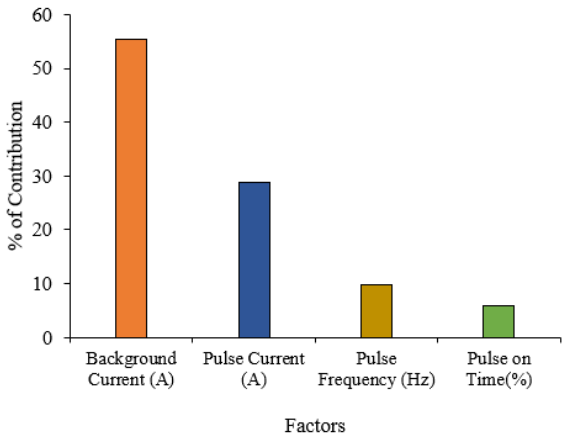


FIGURE 13
Percentage of Contribution & factors

ANOVA analysis showed that background current and pulse current are found to be more influence factor, pulse frequency and pulse on time are less influence factor than other process parameters. Background current has the most significant factor on the ultimate tensile strength with 55.50% , and pulse current influence is 28.80 %. The pulse frequency and pulse on time current are low impact factor with only 9.89 % and 5.79 % make a contribution correspondingly.

CONCLUSIONS

The following inferences can be drawn from the current work are enumerated under.

- ✓ The foremost has the foremost significant influence on the maximum ultimate tensile strength are background current and second most important factor is pulse current.
- ✓ The percentage contribution of the Background current is 55.50%, Pulse current are 28.80 % respectively for maximum ultimate tensile strength.
- ✓ The process parameters obtained at background current 220 A, Pulse current 100 A, Pulse frequency 4Hz and pulse on time 50 % are the optimized values.

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