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Parameter Optimization of Gas Metal Arc Welding Using Taguchi Method

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Abstract— Gas metal arc welding (GMAW) is currently one of the most popular welding methods, especially in industrial environments. In order to meet the global competition and the survival of products in the market a new way of thinking is necessary to change and improve the existing technology and to develop products at economical price. It means not only to invest in procuring new equipments but also effectively control the process variables involved in any manufacturing process. These process variables must be measured and controlled to get the desired valuable outputs. This paper presents a methodology to find optimum input variables in GMAW process using taguchi method. The typical process for welding parameters depends upon the ability to measure and control the process variables involved in the welding process.
Keywords— GMAW, input variables, weld bead geometry, signal to noise ratio.

I. INTRODUCTION

Gas metal arc welding (GMAW), sometimes referred to by its subtypes metal inert gas (MIG) welding or metal active gas (MAG) welding, is a welding process in which an electric arc forms between a consumable wire electrode and the workpiece metal, which heats the workpiece metal, causing them to melt, and join. Along with the wire electrode, a shielding gas feeds through the welding gun, which shields the process from contaminants in the air. The process can be semi-automatic or automatic. A constant voltage, direct current power source is most commonly used with GMAW, but constant current systems, as well as alternating current, can be used. There are four primary methods of metal transfer in GMAW, called globular, short circuiting, spray, and pulsed-spray, each of which has distinct properties and corresponding advantages and limitations.
Quality is an important factor in current manufacturing world. Quality can be defined as the degree of customer satisfaction. Quality of products depends on how it perform in desired circumstances. The quality of a weld depends on mechanical properties of the weld metal which in turns depends on metallurgical characteristics and mechanical composition of the weld. In other words, quality of weld depends on in process parameters. Gas Metal Arc Welding (GMAW) is a multi objective and multifactor metal fabrication technique.

II. GAS METAL ARC WELDING

The GMAW welding process is easily found in any industry whose products require metal joining in a large scale. It establishes an electric arc between a continuous filler metal electrode and the weld pool, with shielding from an externally supplied gas, which may be an inert gas, an active gas or a mixture. The heat of the arc melts the surface of the base metal and the end of the electrode. The electrode molten metal is transferred through the arc to the work where it becomes the deposited weld metal (weld bead). The quality of the welded material can be evaluated by many characteristics, such as bead geometric parameters (penetration, width and height) and deposition efficiency (ratio of weight of metal deposited to the weight of electrode consumed). These characteristics are controlled by a number of welding parameters, and, therefore, to attain good quality, is important to set up the proper welding process parameters. But the underlying mechanism connecting then (welding parameters and quality characteristics) is usually not known. Gas metal arc welding (GMAW) is increasingly employed for fabrication in many industries because of its great advantages over others techniques, like its versatility, since it can be applied to any welding position, and can be easily integrated into many robotic production lines. These advantages have motivated many researchers to study GMAW process in detail; otherwise all the important commercial metals such as carbon steel, stainless steel, aluminum, nickel alloys, among others, can be welded in any position with GMAW process by choosing appropriate shielding gas, electrode, and welding variables. For this reason is very important the knowledge of optimal input parameters to generate weld beads with good appearance and quality.

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III. FILLER MATERIAL

In this work were used AWS: A5.18 Grade- Class ER70S-2 - This classification covers filler metals that contain small amounts of titanium, zirconium, and aluminum, in addition to the normal deoxidizing elements of manganese and silicon. These wires are commonly referred to as "triple deoxidized wires". They will produce sound welds in all types of carbon or mild steels. They are especially suited for welding carbon steels that are rusty or have mill scale on the surface. Weld integrity will vary with the amount of oxides on the surface of the steel. They may be used with CO_2, argon-CO_2, or argon-O_2 shielding gas mixtures. They work well in the short-circuiting mode for out-of-position welding.

IV. EXPERIMENTAL PROCEDURE



Fig.No.1 GMAW Experimental setup

A. Materials And Methodology

The following machines and consumables were used for the purpose of conducting experiment.
A constant current gas metal arc welding machine
Welding manipulator,
Wire feeder,
Filler material Stainless Steel wire of 1.2mm diameter (ER – 70S 2),
Gas cylinder containing a mixture of890% argon and 20% of carbon dioxide,
Alloy steel plate (grade EN – 8).

Test plates of size 150 x 75x 10mm were cut from alloy steel plate of grade EN-8 and one of the surfaces was cleaned to remove oxide and dirt before cladding. ER – 70S 2 triple deoxidized wire which provides defects free from weld deposits. A mixture of argon and carbon dioxide gat at flow rate was used for shielding. The properties of base metal and filler material were shown. The important and most difficult parameters found from trail run is wire feed rate. The wire feed rate is proportional to current. The selection of the welding electrode wire based on the matching the mechanical properties and physical characteristics of the base metal, weld size and existing electrode inventory.

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Table 1. Chemical Composition of Base Metal

Element	Chemical Composition En8 wt (%)		
	Min	Max	Observed
Carbon, C	0.35	0.45%	0.38%
Manganese, Mn	0.60	1.0%	0.91%
Silicon, Si	0.5	0.35%	0.21%
Sulphur, S	-.--	0.6	0.01%
Phosphorus, P	-.--	0.6	0.01%

Table 2. Chemical Composition of Filler Wire

Element	Phosphorus, P	Aluminum, Al	Silicon, Si	Manganese, Mn	Carbon, C	Sulphur, S	Zirconium, Zr
Content %	0.025	0.05	0.45	0.9	0.150	0.035	0.02

B. Plan Of Investigation

The research work was carried out in the following steps. Identification of factors, finding the limit of process variables, development of design matrix, conducting experiments as per design matrix, recording responses, development of taguchi method and determination S/N ratio values.

1) *Identification Of Factors:* Welding parameters are the variables that can be changed or modified in the process and can affect the characteristics of the electric arc and modify the shape of the weld deposited. Since measured responses depend on many parameters, in this work are taken in consideration the variables which direct action and interaction have a significant influence on the external geometry of the weld bead (with shielding gas and electrode constant). Then, welding voltage, wire feed rate and welding speed were established as input variables.
2) *Finding The Limit Of Process Variables:* Balance among the input parameters in gas metal arc welding (GMAW) characterizes the metal transfer modes, microstructure and influences the geometry and mechanical properties of welded joints. The appropriate selection of microstructure is an important factor to futher improve the weldability, strength and toughness behaviour, the time involved in the production is more and also the processing steps are linearly increased. Costly and time consuming experiments are required in order to determine the optimal welding process parameters due to complex nature of the welding process. Problems that do not have algorithmic solutions or algorithmic solutions are too complex to be found.

Table 3. Welding parameters and respective levels

Parameters	Factor Levels				
	Unit	Notation	-1	0	1
Welding Current	Amps	I	155	175	210
Welding Speed	mm/min	S	100	150	200
Welding Voltage	voltage	V	30	35	40
Welding Time	mm/sec	T	90	75	35

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3) Development Of Design Matrix

Trial Number	Design Matrix			
	V	S	F	I
1.	1	1	1	1
2.	1	2	2	2
3.	1	3	3	3
4.	2	2	3	1
5.	2	3	1	2
6.	2	1	2	3
7.	3	3	2	1
8.	3	1	3	2
9.	3	3	2	1

I- Welding current; S- Welding speed; V- Welding voltage; F- Wire feed rate

4) Recording response: Impact Testing -- To check the toughness of the weld we have done the testing in charphy method to identify the weld quality of the material. After we had finished the welding, the work piece was marked and cut the specimens of standard size 55x10x10mm placed for charphy impact test in that v-groove point where we can check the load to the area of withstand capacity in the material. Toughness is, broadly, a measure of the amount of energy required to cause an item a test piece or a bridge or a pressure vessel to fracture and fail. The more energy that is required then the tougher the material. There are two main forms of impact test, the *Izod* and the *Charpy* test. Both involve striking a standard specimen with a controlled weight pendulum travelling at a set speed. The amount of energy absorbed in fracturing the test piece is measured and this gives an indication of the notch toughness of the test material. These tests show that metals can be classified as being either 'brittle' or 'ductile'. A brittle metal will absorb a small amount of energy when impact tested, a tough ductile metal a large amount of energy. It should be emphasised that these tests are *qualitative*, the results can only be compared with each other or with a requirement in a specification they *cannot* be used to calculate the fracture toughness of a weld or parent metal, such as would be needed to perform a fitness for service assessment. The Charpy specimen Unotch are used for the testing of brittle materials such as cast iron and for the testing of plastics. The Vnotch specimen is the specimen of choice for weld testing. The current British Standard for Charpy testing is BS EN ISO 1481: 2009 and the American Standard is ASTM E23. The standards differ only in the details of the strikers used. The standard CharpyV specimen, illustrated in *Fig.1.* is 55mm long, 10mm square and has a 2mm deep notch with a tip radius of 0.25mm machined on one face.

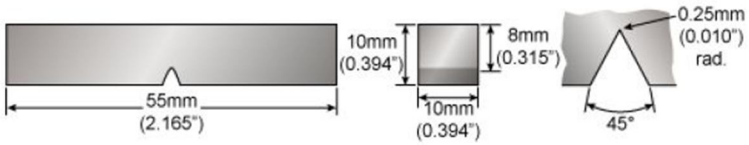


Fig.No.2 standard Charpy'V 'specimen

To carry out the test the standard specimen is supported at its two ends on an anvil and struck on the opposite face to the notch by a pendulum as shown in *Fig.2.* The specimen is fractured and the pendulum swings through, the height of the swing being a measure

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of the amount of energy absorbed in fracturing the specimen. Conventionally three specimens are tested at any one temperature, see *Fig.3*, and the results averaged.

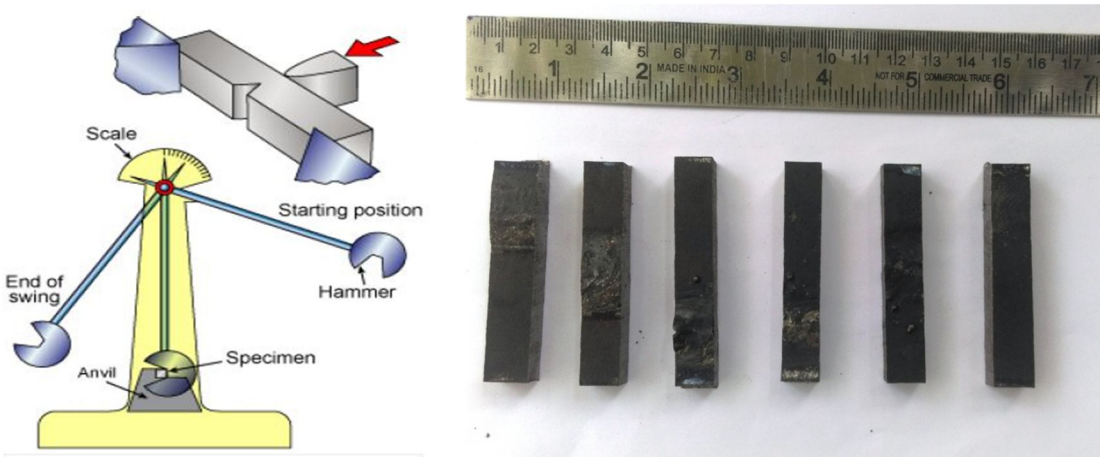


Fig.No.3 CHARPHY Testing Machine

By selecting the specimen with variables combinations of welding parameters marked points to the notch in the impact test we got the result by analyzing the nine specimens around the notch ones to minimize the error in the readings. The impact test values are shown in the table.

Table 5. Design of Experiments and Observed Values of Toughness

Run	Welding voltage V	Welding speed S	Wire feed rate F	Welding current I	Impact strength KJ/mm^2
1.	30	100	150	150	5.345
2.	40	200	200	150	5.091
3.	35	150	225	150	5.201
4.	35	100	200	200	4.801
5.	40	150	150	175	4.836
6.	30	150	200	175	4.218
7.	35	200	150	175	5.018
8.	40	100	225	200	4.655
9.	30	200	225	200	5.127

V. RESULT AND DISCUSSION

A. Development Of Taguchi Method

Taguchi Analysis: Toughness versus V, S, F, I

Linear Model Analysis: SN ratios versus V, S, F, I

Estimated Regression Coefficients for SN ratios for Toughness Measurement as shown in the Minitab Calculation below,

Term Coef

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Constant	46522.3
V	365.1
S	26.6
F	-72.8
I	-492.8
V*V	-5.3
S*S	-0.1
F*F	0.2
I*I	1.4

Analysis of Variance for Toughness

Source	DF	Seq SS	Adj SS	Adj MS		
Regression	8	922970	922970	115371		
Linear 4	1	95722		733729	183432	
V	1	1944		33941		33941
S	1	29963		22650		22650
F	1	29931		106964	106964	
I	1	133884	230535	230535		
Square	4	727248	727248	181812		
V*V	1	34672	34672		34672	
S*S	1	250808	17236		17236	
F*F	1	220343	76640	76640		
Total	8	92297				

B. Determination S/N Ratio Values

Table 6 Response Table for Signal to Noise Ratios Larger is better

Level	V	S	F	I
1	13.75	13.85	14.09	14.34
2	13.99	13.50	13.42	13.40
3	13.73	14.11	13.96	13.73
Delta	0.26	0.61	0.66	0.94
Rank	4	3	2	1

Regression Analysis: T versus V, S, F, I

The regression equation is T = 6132 - 3.6 V + 0.88 S - 0.47 F - 6.42 I

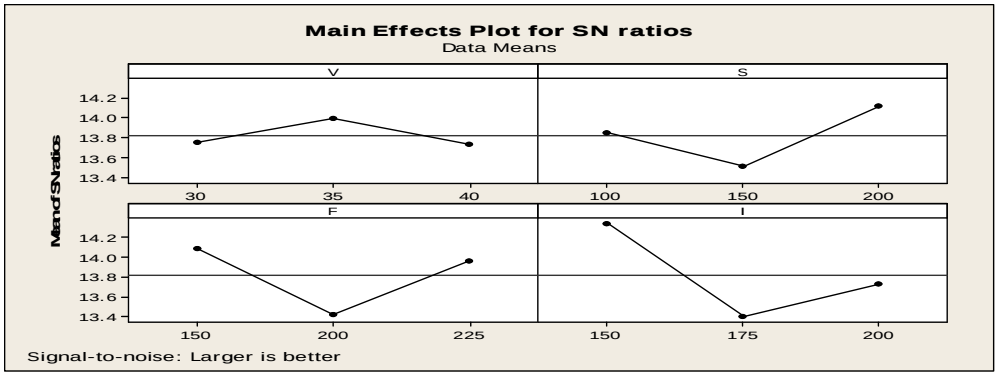
Predictor	Coef SE	Coef	T	P
Constant	6132	1935	3.17	0.034
V	-3.60	34.81	-0.10	0.023
S	0.878	3.537	0.25	0.016
F	-0.473	4.832	-0.10	0.027
I	-6.424	7.486	-0.86	0.039
S = 426.394	R-Sq = 91.2%		R-Sq(adj) = 25.60%	

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C. Conformation Test

Welding Current gives 37% on weld bead toughness is the first ranked position
Wire Feed Rate is the second ranked position on bead impact strength. It contributed 34%
Welding speed parameter contributes 27% on stress load. So it is the third ranked
Welding voltage has least contributed one. It is give 23%

Figure 4. Graph for signal to noise (S-N) ratio for toughness



VI. CONCLUSIONS

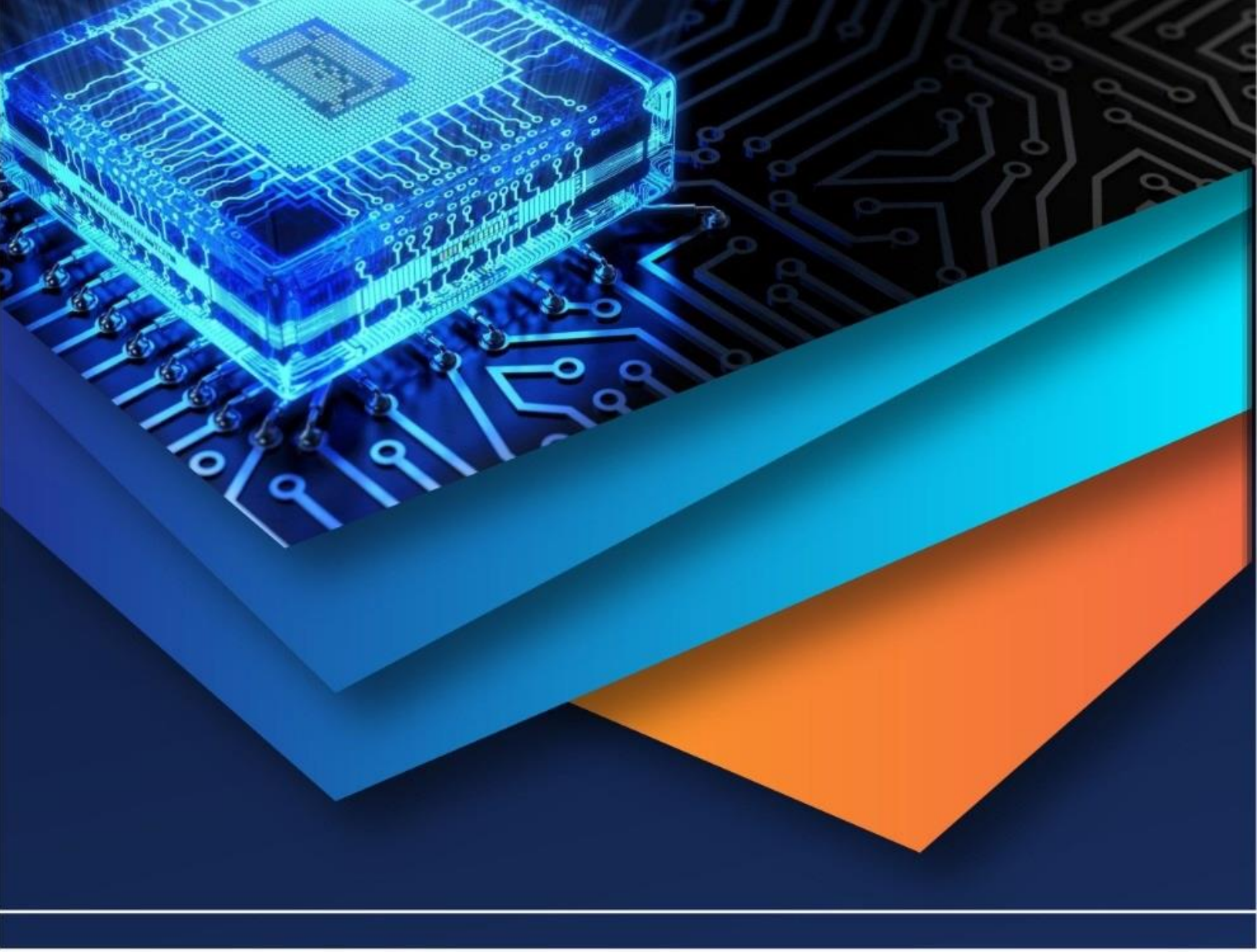
Based on the above study, it can be observed that the developed model can be used to identify the better combination of weld bead strength within the applied limits of process parameters. This method of predicting the process parameters can be used to get minimum percentage of welding dilution and maximum load withstand capacity of toughness properties. In this approach the seventh combinations is predicted as the optimized values within the constrained limits.

Toughness measurement results were analyzed by using Minitab Taguchi Signal to Noise Ratio method. This is the residual signal to noise ratio graph plotted and get the separate input parameters belongs their contribution both bead width is.

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