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Experimental Study to Increase the Life of Welding Nozzle

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Abstract: *This paper discusses selection of optimum welding parameters to increase welding nozzle life. Taguchi method was used for obtaining an orthogonal array of parameters selected. ANSYS work bench is used for calculating heat flux generated and temperature distribution along the welding nozzle. Reduction in heat flux generation will reduce spatter deposition and will prevent the increase of inner diameter of welding nozzle, hence increasing the life of welding nozzle.*

Keywords: *ANSYS work bench, Metal Inert Gas (MIG) Welding, Orthogonal array, Taguchi Method, Welding nozzle*

I. Introduction

GAS METAL ARC welding (GMAW) is a process that melts and joins metals by heating them with an arc established between a continuously fed filler wire electrode and the metals. The process is used with shielding from an externally supplied gas and without the application of pressure. In the 1920's, the basic concept of GMAW was introduced. However, it was not commercially available until 1948. At first it was considered to be, fundamentally, a high-current density, small diameter, bare metal electrode process using an inert gas for arc shielding. The primary application of this process was for welding aluminium. As a result, the term MIG (Metal Inert Gas) was used and is still a common reference for the process. Subsequent process developments included operation at low-current densities and pulsed direct current, application to a broader range of materials, and the use of reactive gases (particularly CO2) and gas mixtures. This latter development has led to formal acceptance of the term gas metal arc welding (GMAW) for the process because both inert and reactive gases are used. There are two operation modes of GMAW, which are semiautomatic and automatic modes. All commercially important metals such as carbon steel, high-strength low alloy steel, stainless steel, aluminium, copper, titanium and nickel alloys can be welded in all positions with this process by choosing the appropriate shielding gas, electrode, joint design and welding variables. [1]

Our project deals with increasing the life of a welding nozzle. A welding nozzle is a component which guides the welding rod during the welding nozzle. Increase in the life of the welding nozzle increases the production rate and also reduce the cost incurred due to it. Depth of fusion is defined as the thickness of the welded joint when two metals are fused together. It is one of the critical factors considered for determining the strength of a welded joint. Current, voltage and wire feed speed are the critical factors affecting the life of welding nozzle and depth of fusion.

II. Taguchi Method

The method presented in this study is an experimental design process called the Taguchi design method. Taguchi design, developed by Dr. Genichi Taguchi, is a set of methodologies by which the inherent variability of materials and manufacturing processes has been taken into account at the design stage [2]. Although similar to design of experiment (DOE), the Taguchi design only conducts the balanced (orthogonal) experimental combinations, which makes the Taguchi design even more effective than a fractional factorial design. By using the Taguchi techniques, industries are able to greatly reduce product development cycle time for both design and production, therefore reducing costs and increasing profit [3].

Taguchi proposed that engineering optimization of a process or product should be carried out in a three-step approach: system design, parameter design, and tolerance design. In system design, the engineer applies scientific and engineering knowledge to produce a basic functional prototype design. The objective of the parameter design [4] is to optimize the settings of the process parameter values for improving performance characteristics and to identify the product parameter values under the optimal process parameter values. The parameter design is the key step in the Taguchi method to achieving high quality without increasing cost. The steps included in the Taguchi parameter design are: selecting the proper orthogonal array (OA) according to the numbers of controllable factors (parameters); running experiments based on the OA; analyzing data; identifying the optimum condition; and conducting confirmation runs with the optimal levels of all the parameters [3].

1. Experimental Design

Mild steel plates of dimensions 20cm×15cm×3.2mm were prepared. The orientation of welding electrode with respect to weld joint was 17º - 20º, pressure of shielding gas is taken as 45kg/cm^2. The supply current was varied from 220 amps – 250 amps, voltage from 17V – 22V and wire feed speed from 6.35 m/min – 8.89 m/min.

1. Orthogonal Array

To select a suitable orthogonal array for experiments, the total degree of freedom needs to be determined. The degrees of freedom are defined as the number of comparisons between process parameters that need to be made to compute which level is better. For example, a three-level process parameter counts for two degrees of freedom. The degrees of freedom associated with interaction between two process parameters are given by the product of the degrees of freedom for the two process parameters [5]. Once the degrees of freedom required are known, the next step is to select an appropriate orthogonal array to fit the specific task. The degrees of freedom must be greater or equal to the process parameter. In this experiment we have 3 parameters and each of them has 3 levels. To test all possible combinations of these parameters we will have 27 cases, but instead using orthogonal arrays we can maximise the test coverage and carry out the experiment in only 9 cases. The type of orthogonal array used in this experiment is L_9.

Table 1: Basic Orthogonal Array

Sr. Number	Parameter 1	Parameter 2	Parameter 3
1.	1	1	1
2.	1	2	2
3.	1	3	3
4.	2	1	2
5.	2	2	3
6.	2	3	1
7.	3	1	3
8.	3	2	1
9.	3	3	2

Table 2: MIG Welding Parameters and their Levels

Parameter	Level 1	Level 2	Level 3
Current (amps)	220	235	250
Voltage (V)	17	20	22
Wire Feeder Speed (m/min)	6.35	7.62	8.89

Table 3: Designed Orthogonal Array

Sample Number	Current(Amp)	Voltage(Volts)	Wire Feeder Speed(m/min)
1.	220	17	6.35
2.	220	20	7.62
3.	220	22	8.89
4.	235	17	7.62
5.	235	20	8.89
6.	235	22	6.35
7.	250	17	8.89
8.	250	20	6.35
9.	250	22	7.62

2. Experimental Results

1. Penetration Test Results

	Code	Target (mm)	Measured (mm)
Depth of fusion	L3	0.42	0.471
Gap	L2	1	0.589
Throat	L1	1.96	2.667
Leg length	L4	3	4.353

	Code	Target (mm)	Measured (mm)
Depth of fusion	L3	0.42	0.865
Gap	L2	1	0.373
Throat	L1	1.96	2.948
Leg length	L4	3	5.706

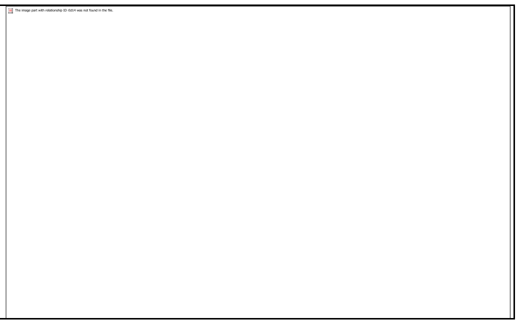
	Code	Target (mm)	Measured (mm)
Depth of fusion	L3	0.42	1.314
Gap	L2	1	0
Throat	L1	1.96	3.258
Leg length	L4	3	6.353

	Code	Target (mm)	Measured (mm)
Depth of fusion	L3	0.42	0.529
Gap	L2	1	0.217
Throat	L1	1.96	2.807
Leg length	L4	3	4.765

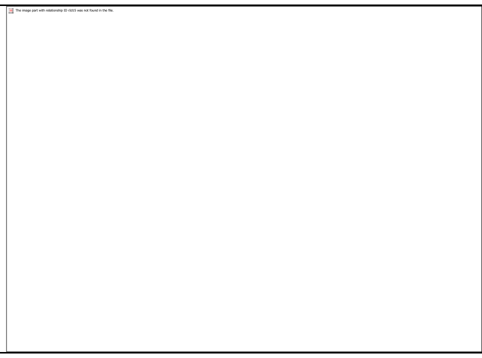
	Code	Target (mm)	Measured (mm)
Depth of fusion	L3	0.42	1.235
Gap	L2	1	0.432
Throat	L1	1.96	3.099
Leg length	L4	3	5.882

	Code	Target (mm)	Measured (mm)
Depth of fusion	L3	0.42	0.569
Gap	L2	1	0.256
Throat	L1	1.96	2.92
Leg length	L4	3	5.207

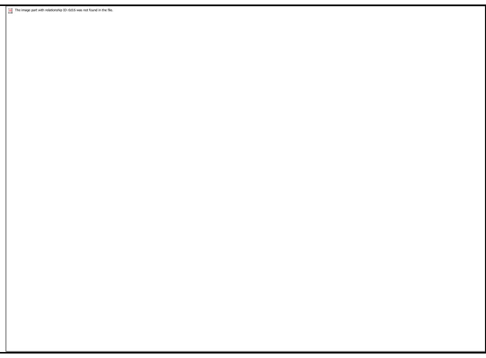
	Code	Target (mm)	Measured (mm)
Depth of fusion	L3	0.42	0.667
Gap	L2	1	0
Throat	L1	1.96	2.706
Leg length	L4	3	5.04



	Code	Target (mm)	Measured (mm)
Depth of fusion	L3	0.42	1.079
Gap	L2	1	0.219
Throat	L1	1.96	2.723
Leg length	L4	3	4.863



	Code	Target (mm)	Measured (mm)
Depth of fusion	L3	0.42	1.49
Gap	L2	1	0.256
Throat	L1	1.96	2.986
Leg length	L4	3	6.804

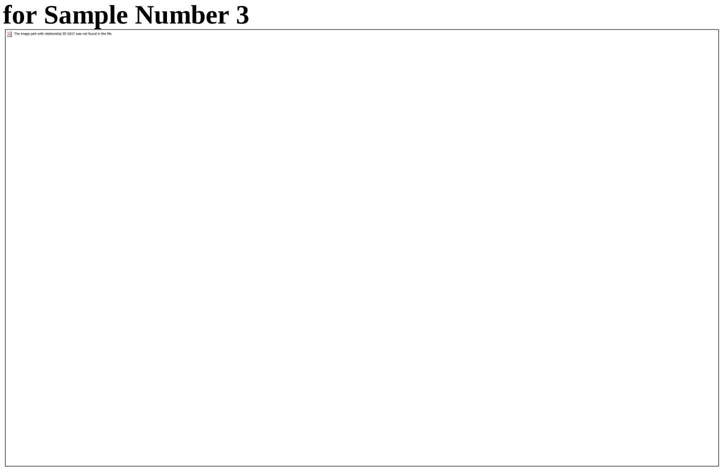


1. By visual inspection the weld quality of sample number 3, 5 & 9 were found to be of required quality.

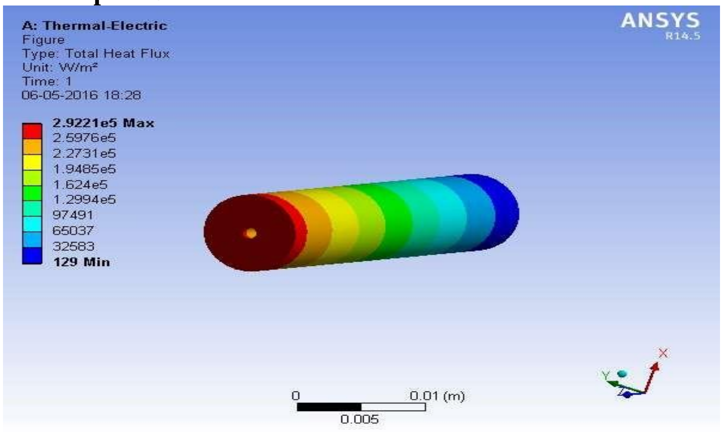
III. Calculation of Heat Flux Generated Using Ansys

The heat flux generated on the tip of the welding nozzle was calculated using current, voltage and temperature. The temperatures generated in each of the welding nozzle tips were measured using the PLC.

1. ANSYS Analysis for Sample Number 3



2. ANSYS Analysis for Sample Number 5



3. ANSYS Analysis for Sample Number 5

4. ANSYS Result Table

Table 4: Result Table for ANSYS

Voltage (Volts)	Current (Ampere)	Temperature (^{o}C)	Heat Flux (W/m^2)
20	235	1410	125.27 – 2.8375e^5
22	220	1442	129 – 2.9221e^5
22	250	1484	133.95 – 3.0345e^5

As the heat flux is minimum for the values (voltage 20 V and current 235 Amp) and as the depth of penetration is maximum for maximum value of wire feed speed, therefore, selecting the experiment with wire feed speed of 8.89 m/min. (Experiment number 5 from Orthogonal Array Table)

IV. Conclusion

Optimum parameter for welding of mild steel specimen of dimension 20cm×15cm×3.2mm, when current is 235 Amp, arc voltage 20 Volts, wire feed speed 8.89 m/min, temperature of 1410^{o}C and wire diameter 1.2mm comes out to be:

1. When the voltage was taken as a variable parameter the depth of penetration was 1.235mm (target 0.42mm). This was obtained at a voltage of 20 Volts.
2. The maximum depth of penetration was observed when the wire feed speed was maximum (8.89 m/min)
3. At the voltage value of 20 Volts and at a temperature of 1410^{o}C the heat flux range obtained was 125.27 W/m^2 to 2.8375e5 W/m^2
4. It is found that the parameter design of Taguchi method provides a simple, systematic and efficient methodology for the optimisation of welding parameters.

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