# Optimization and Prediction Of MIG Welding Process Parameters Using ANN

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***Abstract* - Welding is widely used by manufacturing engineers and production personnel to quickly and effectively set up manufacturing processes for new products. The MIG welding parameters are the most important factors affecting the quality, productivity and cost of welding. This paper presents the influence of welding parameters like welding current, welding voltage, Gas flow rate, wire feed rate, etc. on weld strength, ultimate tensile strength, and hardness of weld joint, weld pool geometry of various metal material during welding. By using DOE method, the parameters can be optimize and having the best parameters combination for target quality. The analysis from DOE method can give the significance of the parameters as it give effect to change of the quality and strength of product.**

***Keywords* - Optimization, MIG Welding, ANN, GA**

## I. INTRODUCTION

Metal Inert Gas welding as the name suggests, is a process in which the source of heat is an arc formed between a consumable metal electrode and the work piece, and the arc and the molten puddle are protected from contamination by the atmosphere (i.e. oxygen and nitrogen) with an externally supplied gaseous shield of inert gas such as argon, helium or an argon-helium mixture. No external filler metal is necessary, because the metallic electrode provides the arc as well as the filler metal. It is often referred to in abbreviated form as MIG welding. MIG is an arc welding process where in coalescence is obtained by heating the job with an electric arc produced between work piece and metal electrode feed continuously. A metal inert gas (MIG) welding process consists of heating, melting and solidification of parent metals and a filler material in localized fusion zone by a transient heat source to form a joint between the parent metals. Gas metal arc welding is a gas shielded process that can be effectively used in all positions.

## II. WORKING PRINCIPLE OF MIG WELDING

The electrode in this process is in the form of coil and continuously fed towards the work during the process. At the same time inert gas (e.g. argon, helium, Co2) is passed around electrode from the same torch. Inert gas usually argon, helium, or a suitable mixture of these is used to prevent the atmosphere from contacting the molten metal and HAZ.

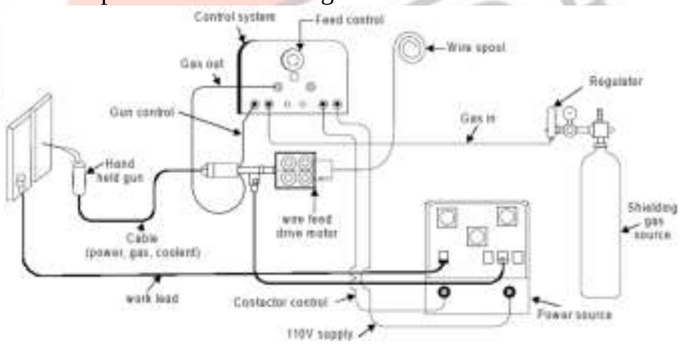



Figure 1: MIG welding Process Setup

When gas is supplied, it gets ionized and an arc is initiated in between electrode and work piece. Heat is therefore produced. Electrode melts due to the heat and molten filler metal falls on the heated joint. The weld bead geometry, depth of penetration and overall weld quality depends on the following operating variables.

- Electrode size, Welding current, Arc voltage
- Arc travel speed, welding position
- Gas Flow rate, Shielding Gas composition
- Electrode extension

**III. PARAMETERS WITH LEVELS FOR MIG WELDING:**

| Process Designation | Parameters | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|
| A | Welding speed | 4.5 | 5.5 | 6.5 |
| B | Welding current | 150 | 170 | 190 |
| C | Gas pressure | 12 | 15 | 18 |

**IV. DOE FOR MIG WELDING:**

| No. | Run Order | Welding Speed | Welding Current | Gas Pressure | Hardness | UTS |
|---|---|---|---|---|---|---|
| 1 | 1 | 4.5 | 150 | 12 | 228 | 563 |
| 2 | 2 | 5.5 | 150 | 12 | 222 | 562 |
| 3 | 3 | 6.5 | 150 | 12 | 220 | 557 |
| 4 | 4 | 4.5 | 170 | 12 | 228 | 572 |
| 5 | 5 | 5.5 | 170 | 12 | 225 | 573 |
| 6 | 6 | 6.5 | 170 | 12 | 223 | 566 |
| 7 | 7 | 4.5 | 190 | 12 | 235 | 599 |
| 8 | 8 | 5.5 | 190 | 12 | 229 | 587 |
| 9 | 9 | 6.5 | 190 | 12 | 235 | 579 |
| 10 | 10 | 4.5 | 150 | 15 | 235 | 573 |
| 11 | 11 | 5.5 | 150 | 15 | 232 | 566 |
| 12 | 12 | 6.5 | 150 | 15 | 230 | 562 |
| 13 | 13 | 4.5 | 170 | 15 | 238 | 591 |
| 14 | 14 | 5.5 | 170 | 15 | 235 | 588 |
| 15 | 15 | 6.5 | 170 | 15 | 237 | 581 |
| 16 | 16 | 4.5 | 190 | 15 | 242 | 611 |
| 17 | 17 | 5.5 | 190 | 15 | 239 | 593 |
| 18 | 18 | 6.5 | 190 | 15 | 237 | 586 |
| 19 | 19 | 4.5 | 150 | 18 | 241 | 582 |
| 20 | 20 | 5.5 | 150 | 18 | 238 | 577 |
| 21 | 21 | 6.5 | 150 | 18 | 236 | 572 |
| 22 | 22 | 4.5 | 170 | 18 | 244 | 593 |
| 23 | 23 | 5.5 | 170 | 18 | 241 | 591 |
| 24 | 24 | 6.5 | 170 | 18 | 239 | 585 |
| 25 | 25 | 4.5 | 190 | 18 | 248 | 619 |
| 26 | 26 | 5.5 | 190 | 18 | 245 | 602 |
| 27 | 27 | 6.5 | 190 | 18 | 243 | 596 |

**V. ANOVA ANALYSIS:**

**Analysis of Variance for Tensile strength**

| Source | DF | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|
| WELDING SPEED | 2 | 1418.00 | 709.00 | 12.69 | 0.418 |
| CURRENT | 2 | 3698.67 | 1849.33 | 33.10 | 0.005 |
| VOLTAGE | 2 | 40.67 | 20.33 | 0.36 | 0.000 |
| ERROR | 20 | 1117.33 | 55.87 | | |
| TOTAL | 26 | 6274.67 | | | |

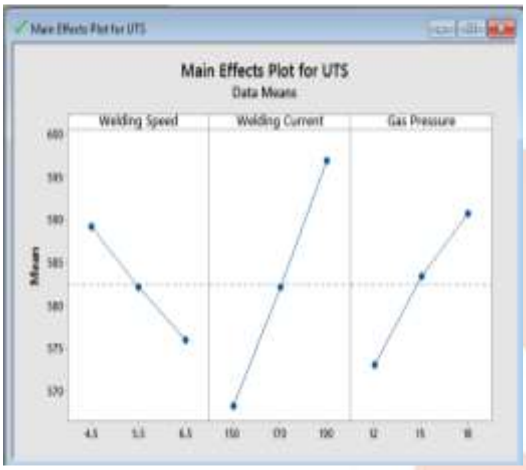
According to the analysis done by the Minitab software, if the values of probability are less than 0.05, it indicated that the factors are significant to the response parameters. Comparing the p-value to a commonly used α-level = 0.05, it is found that if the p-value is less than or equal to α, it can be concluded that the effect is significant, otherwise it is not significant. From ANOVA result it is observed that the Gas Pressure and current are influencing parameter for tensile strength and these two parameters are highly influencing parameter compare to Welding Speed for ultimate tensile strength. The confidence level (CL) used for investigation is taken 95% for this investigation. The parameter R2 describes the amount of variation observed in material removal rate is explained by the input factors. R2 = 94.31 % which indicate that the model is able to predict the response with high accuracy.

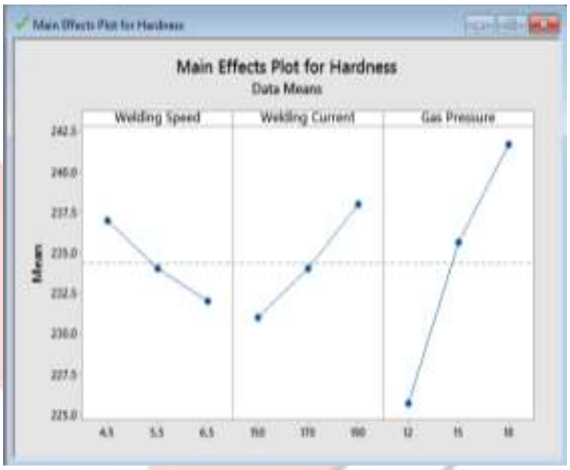
**Analysis of Variance for Hardness**

| Source | DF | Adj SS | Adj MS | F | P |
|---|---|---|---|---|---|
| WELDING SPEED | 2 | 1246.52 | 623.259 | 50.43 | 0.256 |
| CURRENT | 2 | 173.41 | 86.704 | 7.02 | 0.000 |
| VOLTAGE | 2 | 9.19 | 4.593 | 0.37 | 0.000 |
| ERROR | 20 | 247.19 | 12.359 | | |
| TOTAL | 26 | 1676.30 | | | |

According to the analysis done by the Minitab software, if the values of probability are less than 0.05, it indicated that the factors are significant to the response parameters. Comparing the p-value to a commonly used α-level = 0.05, it is found that if the p-value is less than or equal to α, it can be concluded that the effect is significant, otherwise it is not significant. From ANOVA result it is observed that the Gas Pressure and current are influencing parameter for tensile strength and these two parameters are highly influencing parameter compare to Welding Speed for Hardness.

## VI. MAIN EFFECTS PLOT




The main effects plot for Tensile strength versus Gas Pressure, welding current and Speed is shown in fig.5.3, which is generate from the value of mean of Tensile strength as per table 5.2 in minitab-17 statistical software is useful to find out optimum parameter value for response variable. Fig.5.3 shows that High Tensile strength will meet at Gas Pressure 18 psi, welding current 190 A and Speed 4.5 m/min. The graph generate by use of minitab-17 statistical software for Tensile strength is shown in fig.5.3

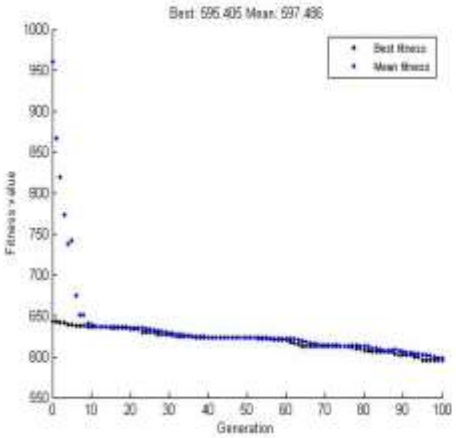
Fig.4.4 shows that high Hardness value will meet at Gas flow rate 18 psi, Welding current 190 A and Welding Speed 4.5 m/min. The graph generate by use of minitab-17 statistical software for Hardness is shown in fig.4.4. From the fig.4.3, it has been concluding that the optimum combination of each Process parameter for higher Tensile strength is meeting at high Gas Pressure [A3], high welding current [B3] and low Welding Speed [C1].

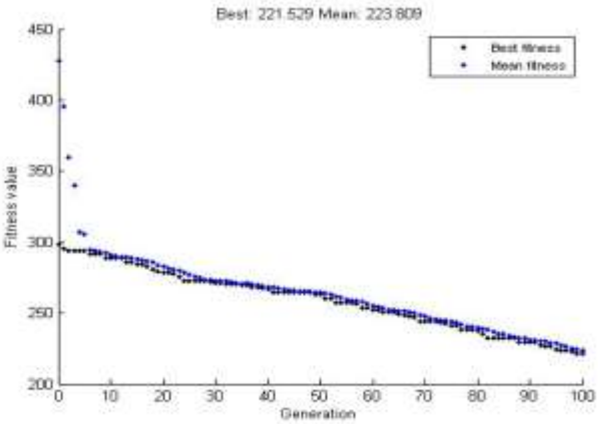
## VII. OPTIMIZATION USING GA

Figure 7.1 shows the GA output of best measured response of maximum Ultimate Tensile Strength. Three different initial population sizes were considered while running the GA. Test of 5 runs were conducted for each population size and the best results have been shown. Table 7.1 lists the values of control parameters and the response predicted using GA for maximum Ultimate Tensile Strength with population size 15, 20 and 25 respectively.

| Ext No. | Population Size | Process Variables | | | Response |
|---|---|---|---|---|---|
| | | Welding Speed | Welding Current | Gas Pressure | UTS |
| 1 | 15 | 6.40134 | 176.012 | 14.9614 | 591.453 |
| 2 | 20 | 6.42410 | 176 | 15.0471 | 595.405 |
| 3 | 25 | 6.30012 | 176.004 | 14.658 | 594.532 |

| Ext No. | Population Size | Process Variables | | | Response |
|---|---|---|---|---|---|
| | | Welding Speed | Welding Current | Gas Pressure | UTS |
| 1 | 15 | 6.15 | 152 | 12.02 | 222.177 |
| 2 | 20 | 6.49 | 150 | 12.3 | 221.529 |
| 3 | 25 | 6.14 | 153 | 12.15 | 223.897 |




## VIII. MICROSTRUCTURE ANALYSIS

The microstructures of the welded joint thus obtained from joining of two similar plates of S.S 316 were magnification scale of 500X. The microstructure of base metal shows Step structure and Austenitic grains with twins.

Base Metal Microstructure

HeatZone

The microstructure of heat affected zone shows partially elongated Austenitic grains in network form, The microstructure of the test specimen at optimal combination of process variables, Welding Speed, Welding current, Gas flow rate is shown in Figures. Due to fine grains size in heat affected zone the tensile strength is highest there.

## IX. REGRESSION MODEL

UTS = 452.8 - 6.611 Welding Speed + 0.7167 Welding Current + 2.944 Gas Pressure

Hardness = 177.28 - 2.167 Welding Speed + 0.1972 Welding Current + 2.407 Gas Pressure

## X. ANN MODEL GENERATION

Before applying inputs and outputs for ANN training, data have to be converted in to range of 0 to 1 or -1 to 1 i.e. data should be normalized for ANN training. An Equation 6.1 was used for data normalization which ranges the data to [0, 1]. Normalized and randomized result table is shown in Table 6.9

$$Xn = \frac{X - Xmin}{Xmax - Xmin}$$

Where,
Xn = Normalised Value of Variable X
X = Value of Variable X
Xmin = Minimum Value of Variable X
Xmax = Maximum Value of Variable X

All 27 experimental data sets are divided for training, validation and testing. 17 experimental data sets were trained by early stopping method which used for data sets for training, 5 data sets for validation and 5 models were use for tastings. It is clear that more data sets in training reduces processing time in ANN learning and improves generalization capability of models, so large number of data sets were used to train the models

| Exp. No. | Input Parameter | | | ANN Status | Output Parameter | |
|---|---|---|---|---|---|---|
| | **Pressure** | **Current** | **Speed** | | **Tensile Strength** | **Hardness** |

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | Validation | 0 | 1 |
| 2 | 0 | 0 | 0.5 | Testing | 0.4 | 0.2 |
| 3 | 0 | 0 | 1 | Training | 0.8 | 0.4 |
| 4 | 0 | 0.5 | 0 | Training | 0.2 | 0.6 |
| 5 | 0 | 0.5 | 0.5 | Training | 0.4 | 0.8 |
| 6 | 0 | 0.5 | 1 | Testing | 0.8 | 1 |
| 7 | 0 | 1 | 0 | Validation | 0.4 | 0 |
| 8 | 0 | 1 | 0.5 | Training | 0.6 | 0.2 |
| 9 | 0 | 1 | 1 | Testing | 1 | 0.4 |
| 10 | 0.5 | 0 | 0 | Testing | 0 | 0.6 |
| 11 | 0.5 | 0 | 0.5 | Training | 0.2 | 0.8 |
| 12 | 0.5 | 0 | 1 | Testing | 0.6 | 0 |
| 13 | 0.5 | 0.5 | 0 | Training | 0.2 | 1 |
| 14 | 0.5 | 0.5 | 0.5 | Training | 0.6 | 0.2 |
| 15 | 0.5 | 0.5 | 1 | Training | 1 | 0.4 |
| 16 | 0.5 | 1 | 0 | Training | 0.2 | 0.6 |
| 17 | 0.5 | 1 | 0.5 | Validation | 0.8 | 0.8 |
| 18 | 0.5 | 1 | 1 | Validation | 1 | 0.4 |
| 19 | 1 | 0.5 | 0 | Validation | 0 | 0.6 |
| 20 | 1 | 0.5 | 0.5 | Training | 0.4 | 1 |
| 21 | 1 | 0.5 | 1 | Training | 0.8 | 0 |
| 22 | 1 | 1 | 0 | Training | 0.4 | 0.2 |
| 23 | 1 | 1 | 0.5 | Training | 0.6 | 0.8 |
| 24 | 1 | 1 | 1 | Training | 1 | 0.2 |
| 25 | 1 | 0 | 0 | Training | 0.4 | 0.4 |
| 26 | 1 | 0 | 0.5 | Training | 0.8 | 0.6 |
| 27 | 1 | 0 | 1 | Training | 1 | 0.8 |

**Post Processing**

In the course of this dissertation, many different networks were tried and examined. This phase focused on network architectures that produced reasonable and consistent results for the problem. ANN model is trained by changing and storing proper weights in inter connection links between neurons lying in various layers. These weights values are the responsible parameters which gives prediction capability to trained ANN models. [44] Weights in connection links among input and hidden neurons, and neurons in hidden and output layer are shown in Table.

**Weights in between input parameters and neurons in hidden layers**

| **Weights In between Input Parameters and Neurons in Hidden Layers** | | | | | | |
|---|---|---|---|---|---|---|
| | **N1** | **N2** | **N3** | **N4** | **N5** | **N6** |
| **P** | 16.7346 | -16.8101 | -16.7827 | 16.7727 | -16.7987 | 16.7894 |
| **C** | -16.6166 | 16.6011 | -16.6962 | 16.6351 | -16.7240 | -16.6982 |
| **S** | -17.8132 | 17.7856 | 16.7325 | -16.6755 | 17.6960 | 16.6350 |
| | **N7** | **N8** | **N9** | **N10** | **N11** | **N12** |
| **P** | -16.7981 | 16.7941 | 16.8106 | -16.8527 | -16.8101 | -16.8100 |
| **C** | 16.6942 | -16.7360 | 16.7425 | 16.8325 | 16.7646 | -16.7988 |
| **S** | -16.6786 | -16.7762 | 17.6321 | -17.6521 | 17.7521 | 16.9325 |

**Weights in between neurons in hidden layers and output parameters**

| **Weights In between Neurons in Hidden Layers and Output Parameters** | | | | | | |
|---|---|---|---|---|---|---|
| | **N1** | **N2** | **N3** | **N4** | **N5** | **N6** |
| **UTS** | -0.4632 | -0.1811 | -0.3257 | 0.3193 | 0.2106 | 0.3644 |
| | **N7** | **N8** | **N9** | **N10** | **N11** | **N12** |
| **UTS** | 0.1846 | 0.5345 | -0.1822 | 0.3420 | 0.1619 | -0.5928 |
| | **N1** | **N2** | **N3** | **N4** | **N5** | **N6** |
| **Hardness** | 0.4559 | -0.1721 | -0.3456 | 0.4491 | -0.3512 | 0.3745 |
| | **N7** | **N8** | **N9** | **N10** | **N11** | **N12** |
| **Hardness** | 0.1745 | 0.4535 | -0.1721 | 0.2521 | 0.1521 | -0.6821 |

**XI. REFERENCE**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