# EFFECT OF PROCESS PARAMETERS ON TENSILE STRENGTH IN GAS METAL ARC WELDED JOINTS AA7075-T6 ALUMINUM ALLOY BY USING REGRESSION AND RESPONSE SURFACE MODEL

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## Abstract

*Aluminum and its alloys have been used in recent times due to their light weight, moderate strength and good corrosion resistance. Aluminum alloy 7075-T6 has been researched upon especially as a potential candidate for aircraft material. This alloy is difficult to weld using conventional welding techniques like GTAW and GMAW. An attempt has been made in this paper to weld 7075-T6 alloy using GMAW with argon as a shielding gas. The welding experiment was carried out on Odor, Chennai and tensile strength tested on Ministry of Micro and small and Medium Enterprises Testing Center, Government of India, Chennai for the purpose of improving tensile strength. In order to formulate the equation between important welding parameters like current (I), Voltage (V), Welding Speed (WS) and Gas flow (GS) (predictors) and tensile strength (response) so that multiple regression as chosen and validated this model SPSS 16 and formulated the transfer function with interaction between predictors reported by Minitab 15.*

***Keywords:*** *AA 7075 aluminum alloy, Gas Metal arc welding, Regression Model, Response Surface model*

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## 1. INTRODUCTION

The preferred welding processes for fabricating the AA7075 alloy are frequently Gas Metal Arc Welding (GMAW) process due to their comparatively easier applicability and better economy. The weld Fusion Zone (FZ) typically exhibit coarse columnar grains because of the prevailing thermal conditions during weld metal solidification. This often results inferior weld mechanical properties and poor resistance to hot cracking. In GMAW welding, a continuous, consumable wire electrode and a shielding gas are fed through a welding gun. Researchers prefer GMAW welding because it is easier to execute, it produces a cleaner weld and it requires less cleanup than stick welding. It also offers better control when working with thin metals.

In the present study the welding of 6.35mm thick plate of AA7075-T6 alloy was carried out using Gas Metal Arc welding (GMAW) process.

## 2. LITERATURE REVIEW

**Ojha R.S and NehaBhadauria (2013)** studied IS2062 Mild Steel for GMAW Process optimization of process parameters using Response Surface Methodology. Experiments were conducted based on central composite Face Centered Cubic design and mathematical models were developed correlating the important controllable GMAW process parameters like Voltage (V), welding speed (S) and gas flow rate (G) with weld bead penetration.

**Hayati E, et al., (2011),** used Taguchi's method of design of experiments a mathematical model was developed using GMAW parameters such as, wire feed rate (W), welding voltage (V), nozzle-to-plate distance (N), welding speed (S) and gas flow rate (G) on weld dilution. After collecting data, signal-to-noise ratios (S/N) were calculated and used in order to obtain the optimum levels for every input parameter.

**Balasubramanian V and Lakshminarayanan A K (2009),** Studied FSW process parameters such as tool rotational speed, welding speed, axial force, play a major role in deciding the weld quality. Two methods, response surface methodology and artificial neural network were used to predict the tensile strength of friction stir welded AA7039 aluminum alloy. The experiments were conducted based on three factors, three-level, and central composite face centered design with full replications technique, and mathematical model was developed. Sensitivity analysis was carried out to identify critical parameters. The results obtained through response surface methodology were compared with those through artificial neural networks.

**DameraNageswara Rao (2012),** presented a review, made on Response Surface Method based Design of Experiments that have been employed for various welding processes by other researchers. This study predominantly focused on the usage of Response Surface Method in Welding.

**Sivasakthivel PS, Vel-Muruganb V and Sudhakaran R, (2012)** established relationship between welding input parameters like current, welding speed, welding gun angle and shielding gas flow rate through regression model for Gas Tungsten Arc Welded (GTAW) 202 Grade Stainless Steel Plates and developed mathematical model to correlate the process parameter to depth of penetration.

## 3. EXPERIMENTAL PROCEDURE

All the investigations were carried out in As Welded (AW) condition on ODOR Chennai. The GMAW was carried out manually, using HF 3000-AD and KEDLITE -40 respectively, 3 phase,210 and 240V ± 10%, 50Hz AC equipment having gas flow rate 25 to 30 liters/minute. In GMAW technique, top and bottom purging was provided with 99% pure argon. The GMAW joint was fabricated using ER-5183 electrodes respectively with a root gap of 1.6 mm. The weld bead quality and full penetration was achieved by selecting suitable welding parameters.

### 3.1 Tensile Strength Investigation on AA 7075 –T6 Aluminum Alloy Weldments:

The tensile specimens were prepared as per ASTM E8M-04 standards. The tensile test was done in a 100 KN, Servo Mechanical Controlled Universal Testing Machine (UNITEK –UTE 40). The tensile test was carried out at the rate of 1.5KN /min as per ASTM testing specification on Ministry of Micro and small and Medium Enterprises Testing Center, Government of India. The GMAW weldments are shown in Fig.1

The welding experimental set up used for GMAW is shown in Fig. 2. The welding process parameters and tensile strength are listed in below table 1.


**Fig -1:** Welding Experimental set up used for GMAW

**Fig.2** Fabricated Weldments by GMAW

**Table -1:** The welding process parameters and tensile strength

| Sl. No | Tensile Strength (TS) N/mm2 | Current (I) | Voltage (v) | Welding speed (WS) (mm/min) | Gas flow (GF) (Lit/hr) |
|---|---|---|---|---|---|
| 1 | 188 | 180 | 30 | 85 | 14 |
| 2 | 192 | 185 | 30 | 85 | 14 |
| 3 | 201 | 190 | 31 | 80 | 12 |
| 3 | 204 | 190 | 31 | 80 | 12 |
| 4 | 198 | 190 | 31 | 85 | 14 |
| 5 | 214 | 195 | 32 | 75 | 10 |
| 6 | 225 | 200 | 32 | 75 | 10 |
| 7 | 205 | 190 | 31 | 80 | 12 |
| 8 | 212 | 200 | 32 | 75 | 10 |
| 9 | 198 | 185 | 30 | 85 | 14 |
| 10 | 211 | 195 | 32 | 75 | 10 |
| 11 | 216 | 200 | 32 | 75 | 10 |
| 12 | 181 | 180 | 30 | 85 | 14 |
| 13 | 184 | 185 | 30 | 85 | 14 |
| 14 | 191 | 195 | 30 | 85 | 14 |
| 15 | 195 | 200 | 30 | 85 | 14 |
| 16 | 188 | 180 | 30 | 85 | 14 |
| 17 | 188 | 180 | 30 | 85 | 14 |
| 18 | 192 | 185 | 30 | 85 | 14 |
| 19 | 201 | 190 | 31 | 80 | 12 |
| 20 | 204 | 190 | 31 | 80 | 12 |
| 21 | 198 | 190 | 31 | 85 | 14 |
| 22 | 214 | 195 | 32 | 75 | 10 |
| 23 | 225 | 200 | 32 | 75 | 10 |
| 24 | 205 | 190 | 31 | 80 | 12 |
| 25 | 212 | 200 | 32 | 75 | 10 |
| 26 | 198 | 185 | 30 | 85 | 14 |
| 27 | 211 | 195 | 32 | 75 | 10 |
| 28 | 216 | 200 | 32 | 75 | 10 |
| 29 | 181 | 180 | 30 | 85 | 14 |
| 30 | 184 | 185 | 30 | 85 | 14 |
| 31 | 188 | 180 | 30 | 85 | 14 |

## 4. MULTIPLE REGRESSION MODEL DEVELOPMENT

Regression analysis is mathematical measure of average relationship between two or more variables in terms of original units of data. Regression is used to create an equation (or) transfer function from the measurements of the system's inputs and outputs acquired during a passive or active experiment (Kazmier, 2005). Multiple regression analysis was conducted using tensile strength (TS) as a dependent variable and Current (I), Voltage (V), Welding speed (WS), Gas flow (GF) as the independent variables.

### 4.1 GMAW - Regression Analysis for Tensile Strength

SPSS 16 was used to analyze the response of this study. Pearson correlation was used to analyses correlation among the seven variables. All the variables were significantly correlated with one another at 0.001.

$$TS = f (I, V, WS, GF)$$

Gas flow (GF) are not significant in explaining the variation in tensile strength, we developed the reduced regression that excluded the variables.

The reduced model has the following form:

$$TS = f (I, V, WS)$$

$R^2$ Value summary, ANOVA and regression coefficient for GMAW are presented in the table 2, 3 and 4.

**Table -2:** Summary of $R^2$ for Regression Model

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | 0.983 | 0.965 | 0.963 | 2.90690 |

**Table -3:** ANOVA for GMAW

| Model | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Regression | 8494.897 | 3 | 2831.632 | 335.101 | 0.000 |
| Residual | 304.203 | 27 | 8.450 | | |
| Total | 8799.100 | 30 | | | |

**Table -4:** Coefficients for GMAW

| Model | Un standardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|
| | B | Std. Error | Beta | | |
| (Constant) | 1753.930 | 257.108 | | 6.822 | 0.000 |
| Current | -4.277 | 0.989 | -0.395 | -4.325 | 0.000 |
| Voltage | -3.587 | 1.013 | -0.471 | -3.540 | 0.001 |
| Weld speed | -9.846 | 0.987 | -1.756 | -9.978 | 0.000 |
| Gas flow | -0.622 | 0.783 | -0.047 | -0.795 | 0.432 |

SPSS 16 based on the analysis, formulated the transfer function for tensile strength shown in the equation:

$$\mathbf{TS = - 4.277\ I - 3.587\ V - 9.846\ WS + 1753.930 \ldots\ldots\ldots (1)}$$

## 5. RESPONSE SURFACE MODEL

The above transfer function is simple and not specifies the interaction between the predictors and need additional experimental data to estimate squared terms. So that RSM as chosen, and formulate the transfer function with interaction reported by Minitab 15.RSM is a collection of mathematical and statistical techniques that are useful for the modeling and analysis of problems in which a response of interact is influenced by several variables (Montgomery, 2002).

Minitab 15 based on the analysis, formulated the transfer function with interaction shown in this equation:

$$\mathbf{TS = -4.99444\ I + 5.47500\ V - 11.0722\ WS - 0.151389\ V{*}V + 1832.02 \ldots\ldots\ldots\ldots (2)}$$

### 5.1 Surface Plot

The above transfer function is a mathematical description of the system behavior and validated the transfer function with interaction using surface plot. Surface plot allow us to visualize the system's behavior (Antis et al., 2006). The surface plot is shown in Figure 3.

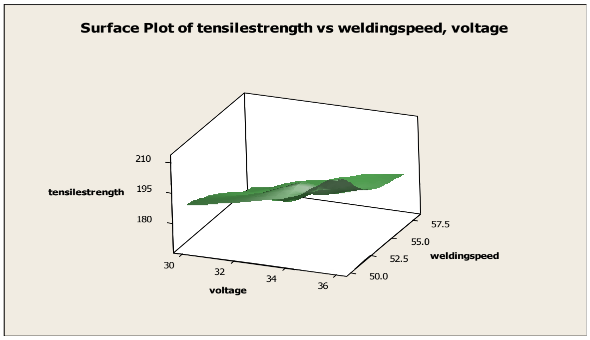


**Fig 3** Surface plot for tensile strength Vs Welding speed and Voltage

The Welding speed (WS) Vs voltage (V) surface plot is a plane because the welding speed (WS) Vs voltage (V) appear as linear terms and do not interact (Montgomery, 2002).

## 6. MODEL VALIDITATION

The regression models such as multiple regression model and response surface regression model have explained the variation accounts for 96.5 percent (ref R Square value from SPSS 16 and Minitab 15) of the total Variation seen in the experiment (Ng et al., 2004).

The F ratio is significant at the 0.00 level, which means that the results of the regression models could hardly have occurred by chance (Chacker and Jabnoun, 2003).

The quality of the regression can also be assessed from a plot of residuals versus the fitted values. The plot shows no observable structure ref. Fig. 4.

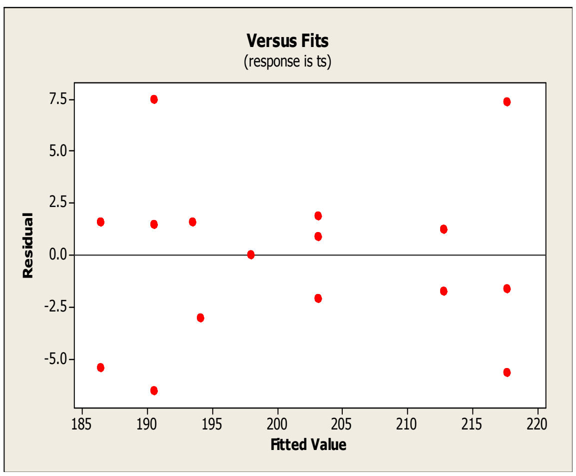


**Fig 4** Surface plot Residual Vs Fitted Value

## CONCLUSIONS

The resulting multiple regression model
From above equation 1
There is a negative relationship between the welding speed (WS) and tensile strength (TS), Current (I) and tensile strength (TS) and Voltage (V) and tensile strength (TS) welding speed (WS) and tensile strength (TS) as the regression coefficient is 9.846 Mathematically, it means that the tensile strength will decrease 9.846 % if the welding speed increases 1% without change of all other predictors (Cao et al., 2006).

The Resulting response surface modal
From above equation 2
Voltage (V) and voltage (V) pair, welding speed (WS) and welding speed (WS) pair, have a low interaction coefficient, which does not affect the response much.

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