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Linear Regression analysis with one parameter for the Estimation of Ultimate Tensile Strength for the TIG welded Al-65032

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Abstract: Multivariate analysis is a useful tool for determining the relationship between numerous input and output factors. Welding parameters such as shielding gas pressure, current, torch angle, electrode size, electrode projection, arc length, and others affect the fabric qualities of a weldment in TIG welding. Joint characteristics such as groove angle, land, root gap, and preheating temperature all have an impact. However, a variety of noise characteristics, such as variations in base material qualities, the quality of noble gas utilised, ambient circumstances, workmanship, and so on, add variability into the process. In this study, a linear regression analysis is used to predict ultimate tensile strength of TIG welded Al-65032 by varying four parameters one at a time: inert gas pressure, current, joint groove angle, and base metal preheating temperature. An L-9 orthogonal array is chosen for experimentation to reduce the number of experiments in data base architecture.

Key words: Al-65032, Linear regression, Orthogonal array, TIG welding,

Introduction

A set of statistical procedures for estimating relationships between a dependent variable and one or more independent variables is known as regression analysis. Adrien-Marie Legendre and Carl Friedrich Gauss set the mathematical foundations for multivariate analysis in the first decade of the nineteenth century, when they individually described the technique of least squares and used it to the determination of celestial body orbits. Since then, both the mathematical complexity of regression techniques and their applications to a wide range of scientific domains have advanced significantly. Dana Pisaca et al. [1] gave a concise overview of the regression analysis utilised in neurosurgery. Mir Jafar Sadegh Safari et.al. [2] developed and applied a multi-output multivariate analysis model to simultaneous output variables, spring water and lake water levels, using the Urmia lake as a case study. Josmar Mazucheli [3] applied parametric and nonparametric quantile regression to biomedical data from Brazil, Kovid 19 data folks. Multivariate analysis was utilised by Vivian W.Y. Tamet.al [4] to forecast the compressive strength of CO2 concrete. Vladimir Konecnya et al. [5] used multi criterion regression analysis to determine the demand for bus transportation in Ceske Budejovice, Czech Republic, as a function of independent variables such as fare, population income, connection supply, transportation quality, and car ownership. Jinlong Wang et al. [6] use vector multivariate analysis to do rail steel wear study. Using multidimensional multivariate analysis of actual reservoir data from the Sukharev field with numerous operational, geological, and reservoir attributes at various stages of the sector pressure, Inna N. Ponomareva [7] described the technique of determining the formation pressure. Xingping Hana et al. [8] employed meta-regression analysis to determine the predictive value of cervical cancer patients' pre-treatment systemic hemato-immunological indices. Balazs Miko [9] used multivariate analysis to determine the flatness inaccuracy. Using multiple correlation analysis, Jamiu Oyekan Adegbite et al. [10] established a link between the porosity, permeability, and pore neck size of transition zone samples in carbonate reservoirs. Mohamed Mahmoud Ali and colleagues [11] Using multivariate analysis, predicted the relationships between hardness and tensile properties of aluminum-silicon alloys generated by various modifiers and grain refineries.

Because of the non-uniform heating and cooling temperatures used in the welding procedures, the mechanical characteristics of the weld joints are significantly lower than those of the base materials [12]. As a result, parametric analyses on the mechanical properties of weld specimens are required for a certain metal and a specific procedure. Al-65032 is a precipitation-hardening aluminium alloy that is one of the most widely used for general-purpose applications. Welding aluminium alloys is a challenging task. Tungsten noble gas (TIG) arc welding is still the most popular joining method for aluminium alloy components because of its flexibility, high production efficiency, and superior weld formation [13]. TIG welding process is influenced by number of parameters individually and combinedly with a high complexity of interactions. The complex interaction of the parameters results into a good variation in the weldment properties, geometry, and metallurgical features. Within the current work a linear regression analysis is carried out to find the relation of UTS of TIG welded AL-65032 specimen with gas pressure, current, grove angle, preheating temperature, one at a time.

Input Parameter selection

Table 1: The input variables

S.No	Input Parameter	Level 1	Level 2	Level 3
1.	Pressure (KPa)	104	125	139
2.	Current (Amps)	145	150	160
3.	Groove angle (Deg)	45	60	70
4.	Pre-heating (^{O}C)	125	150	175

The input variable selected are pressure, current, groove angle and preheating for reducing the number of experiments an orthogonal array L-9 is selected for experimentation. Experiments conducted with the Taguchi Orthogonal arrays will give the reasonably accurate results even in partial factorial case. So in the current work the validity of this hypothesis is tested.

The three levels of the parameters selected after preliminary experiments are given in table 1. With four parameters and three levels Orthogonal array L9 was selected for the experimentation and the levels of the parameters shown in table 1 are assigned to the OA and presented in table 2.

Experimentation

Standard test pieces with dimensions 150mm X 150mm X 6mm are cut from the Al-65032 alloy sheet are prepared with a saw machine. The plates are grooved to the desired angle on a milling machine. The milled pieces were engraved with a specific number for identification. The pieces were pickled. Hydrochloric Acid is used for the process. A ready to weld sample of weld specimen is presented in Fig 1 and the test pieces are shown in Fig 2. Experiments are conducted on welding machines presented Fig 3.

Table 2: Orthogonal Array after assigning the values

Run	Pressure (KPa)	Current (Amps)	Groove angle (Deg)	Pre-heating (OC)
1.	104	145	45	125
2.	104	150	60	150
3.	104	160	70	175
4.	125	145	60	175
5.	125	150	70	125
6.	125	160	45	150
7.	139	145	70	150
8.	139	150	45	175
9.	139	160	60	125

The tensile test was carried out. The UTS values for various trials are presented in Table 3. For all the parameters output values at the levels 1, 2, 3 are summed up and averaged. The averaged values are presented in the table 3 against A1, A2 and A3 and the values are plotted in Fig 4 to know the variation.

Fig 1: A sample of specimen before welding

Fig 2: Tensile test samples

Fig 3: TIG 355 Welding Power Source

Table 3: Ultimate Tensile strength values for various trials

Run	Pressure	Current	Angle	Pre-heating	UTS(MPa)
1	1	1	1	1	185.2
2	1	2	2	2	190.3
3	1	3	3	3	192.5
4	2	1	2	3	193.5
5	2	2	3	1	191.8
6	2	3	1	2	184.9
7	3	1	3	2	186.8
8	3	2	1	3	180.7
9	3	3	2	1	185.5
A1	189.33	188.50	183.60	187.50	
A2	190.07	187.60	189.77	187.33	
A3	184.33	187.63	190.37	188.90	

Regression Analysis:

a single variable linear regression analysis is carried out to identify the effect of each variable independently to understand the effect of each variable in isolation. Matlab is used to carry out the single variant regression analysis. Fig 4 shows a scatter plot of the variation of UTS with gas pressure. A linear curve is fitting is done with Matlab and linear regression equation is found out to be

$$UTS\ (in\ MPa) = -0.1931 * Pressure\ (in\ KPa) + 204.396$$

It is also observed that there exists a negative correlation between UTS and gas pressure.

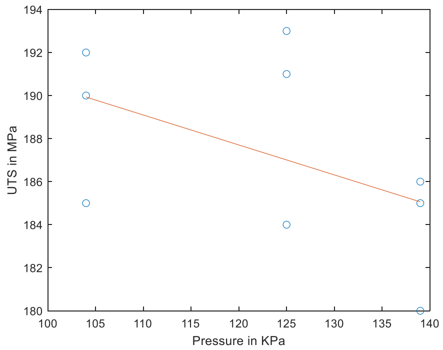

Fig 4: Variation of UTS with the variation of gas pressure

Scatter plot between UTS and current is plotted and shown in Fig 5. It also shows strong negative correlation between UTS and current. The corresponding regression equation is found out to be

$$UTS\ (in\ MPa) = -0.0571 * Current\ (in\ Amp) + 196$$

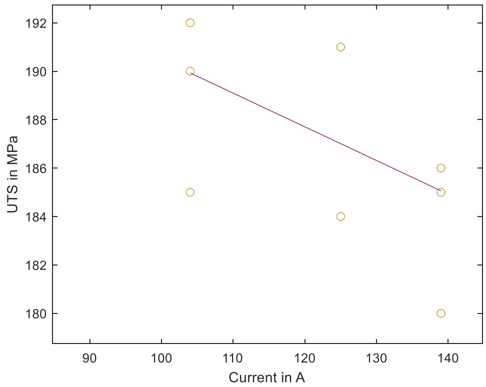

Fig 5: Variation of UTS with the variation of current

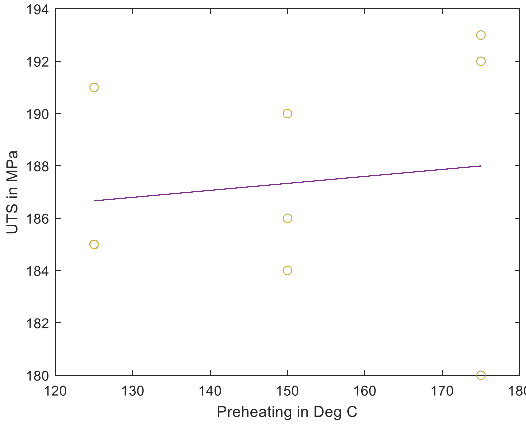

Fig 6: Relation between UTS and preheating temperature

From Fig 6, it is observed that there exists a slight positive correlation exists between UTS and preheating temperature with the linear regression equation given bellow

$$UTS\ (in\ MPa) = 0.0267 * Preheating\ (in\ Deg\ C) + 183.33$$

The slopes of regression equations are observed to be -0.1931, -0, 0571 and 0.0267 for gas pressure, current and preheating temperature respectively which indicates that the gas pressure has predominance over other two factors.

Conclusions

In the current work a single variable linear regression analysis is carried out to identify the effect of gas pressure, current and preheating temperature on UTS of TIG welded AL65032 alloy. Linear curve fitting is done and the relations are obtained. The following points were observed during the study.

- Gas pressure and current has negative correlation with the UTS and preheating temperature has positive correlation.
- Out of the parameters gas pressure has highest influence on the UTS of the material.

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