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Assessment of the Combined Effects of Input Parameters on Solidus and Liquidus Temperature in TIG Welding

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Abstract- Solidus and Liquidus temperatures are important parameters in processes such as welding and heat treatment as the temperature ranges at which the liquid weld metal begins to solidify and the base metal or filler material achieves its melting point by changes from a solid to a liquid state are crucial metrics in welding. The quest for optimality and stability of the process is a major concern to the professionals in the industry. The application of the surface plot in the investigation of the combined effect of input parameters on liquidus and solidus temperature was pursued in this study using Response Surface Methodology. The central composite design matrix was used to obtain data from sets of experiments. Expert software was used to design the experimental matrix and then a set of experiments was performed according to the matrix generated and surface plots were used to carry out a behavioral comparison. With the data collected from twenty experimental runs in this study, the result of the surface plot shows that a desired value of Liquidus and solidus temperature depends on current, voltage, speed, and the liquidus and solidus temperature decreases proportionately as the input parameters increase.

Keywords: Surface Plots, Liquidus, Solidus, Welding, Response Surface Methodology

1 INTRODUCTION

Welding is a risky activity thus safety measures must be taken to prevent burns, electric shocks, visual impairment, inhalation of toxic fumes, and exposure to strong ultraviolet radiation. By utilizing intense heat to melt the components together and then allowing them to cool, which results in fusion, welding is a fabrication method that unites materials, typically metals or thermoplastics [1]. Welding is separate from lower temperature processes that don't melt the base metal (parent metal), such brazing and soldering. The base metal is normally melted first, followed by the addition of a filler material to create a pool of molten metal (the weld pool), which cools to form a joint that, depending on the weld design (butt, full penetration, fillet, etc.), may be stronger than the base metal [2]. The input parameters are the variables that can be controlled or adjusted to influence the welding process. These parameters directly affect the heat input, arc characteristics, and overall weld quality. Some

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common input parameters in TIG welding include Welding voltage, speed and Current. Welding current is expressed in amperes (A), less heat and shallower penetration are produced by lower currents, whereas more heat and deeper penetration are produced by higher currents. The weld pool temperature is impacted by the welding current, which also has an impact on the liquidus and solidus temperatures. Arc voltage, expressed as a difference in electrical potential between the tungsten electrode and the workpiece, is expressed in volts (V). It affects the stability and length of the arc. The heat input and weld pool size are impacted by arc voltage changes, which also have an impact on the liquidus and solidus temperatures [3]. To create a weld, pressure can either be applied alone, in combination with heat, or both. In order to prevent contamination or oxidation of the filler metals or molten metals during welding, a shield is also necessary [4]. Tungsten inert gas (TIG) welding is a thermal process that depends upon heat conducted through the weld joint materials [5]. The melting temperature necessary to weld materials in the TIG welding is obtained by inducing an arc between a tungsten electrode and the work piece. When a substance is heated or melted, the temperature at which the transition from a solid to a liquid phase begins is referred to as the liquidus temperature [6]. It is a crucial temperature for several metallurgical procedures, including as heat treatment, casting, and welding. The liquidus temperature is a crucial consideration while welding since it establishes when the base metal or filler material achieves its melting point and changes from a solid to a liquid state[7]. The solidus temperature refers to the temperature at which a material solidifies or transforms from a liquid phase to a solid phase during cooling or solidification [8]. The solidus temperature, which shows the temperature range at which the liquid weld metal begins to solidify, is a crucial metric in the context of welding. The transition from a fully liquid to a partially solid state of the substance is represented by this point. Uncontrolled solidus and liquidus temperature leads to excessive heat generated in the material which create wider heat affected zone, alters the microstructure of the material and also induce residual stresses in the material [9], [10]. In this study, the application of surface plots in response surface method to compare the liquidus and solidus temperature was pursued**.** The aim was to compare the effect of input parameters on the liquidus and solidus temperature in TIG welding using 3D surface plots. This is helpful in TIG Welding Process Optimization because understanding the combined effects of input parameters on these temperatures helps in determining the compatibility of different materials for TIG welding and crucial for selecting suitable filler materials, preventing overheating or underheating of the base metal, and ensuring metallurgical compatibility in multi-material welding applications. Understanding the solidus temperature and controlling the cooling process during welding is essential for achieving desired weld properties and avoiding defects. Welders need to ensure that the weld metal cools within the appropriate solidus temperature range to promote proper solidification, grain structure formation, and the development of desired mechanical properties.

II METHODOLOGY

This study is centred on a statistical design of experiment (DOE) using central composite design (CCD) method. In identification of process parameters, those considered are current, voltage and welding speed. The central composite design matrix was developed using the design expert software producing 20 experimental runs. The central composite designCCD is popularly known for its robustness and capability of handling two to four input parameters and multiple responses. The input parameters and output parameters make up the experimental matrix and the responses recorded from the samples were used as the data. The Response surface methodology (RSM) model was employed and the surface plots extracted aided in inerpreaion and comparison of the behaviours of the input parameters in relation to the Solidus and Liquidus temperature. Experimental design was done with the aid of design expert. The total number of experimental runs that can be generated using the CCD is defined as;

$$N = 2^n + n_o + 2n \qquad (1)$$

where;
N = the number of experimental runs based on CCD design
2^n = the number of factorial points
n_0 = the number of center points
2n = the number of axial points
n = the number of variables

III RESULTS AND DISCUSSION

In this study, twenty experimental runs were carried out, each experimental run comprising the current, voltage and speed.

Table 1: Experimental results

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Run	**Current (Amp)**	***Voltage (V)***	**Welding speed (m/min)**	**Liquidus Temp(degree C)**	**Solidus Temp(degree C)**
1	155.00	16.50	0.24	1137	1032
2	155.00	18.50	0.45	1315	1207
3	155.00	18.50	0.45	1437	1322
4	155.00	18.50	0.45	1437	1202
5	170.00	18.50	0.43	1342	1023
6	170.00	19.50	0.43	1237	1032
7	145.00	18.50	0.43	1187	1037
8	155.00	18.50	0.43	1315	1079
9	170.00	18.50	0.38	1437	1237
10	155.00	17.50	0.45	1537	1035
11	130.0	18.50	0.38	1132	1037
12	155.00	18.50	0.38	1315	1205
13	155.00	17.50	0.38	1437	1017
14	130.0	17.50	0.45	1535	1019
15	130.0	17.50	0.45	1537	1037
16	130.0	18.50	0. 60	1395	1039
17	155.00	18.50	0. 60	1435	1037
18	1255.00	19.50	0. 60	1538	1037
19	125.00	19.50	0.38	1189	1135
20	125.00	19.50	0.45	1315	1109

To study the effects of current and voltage on the Liquidus temperaure, 3D surface plots presented in Figure 1 was employed.

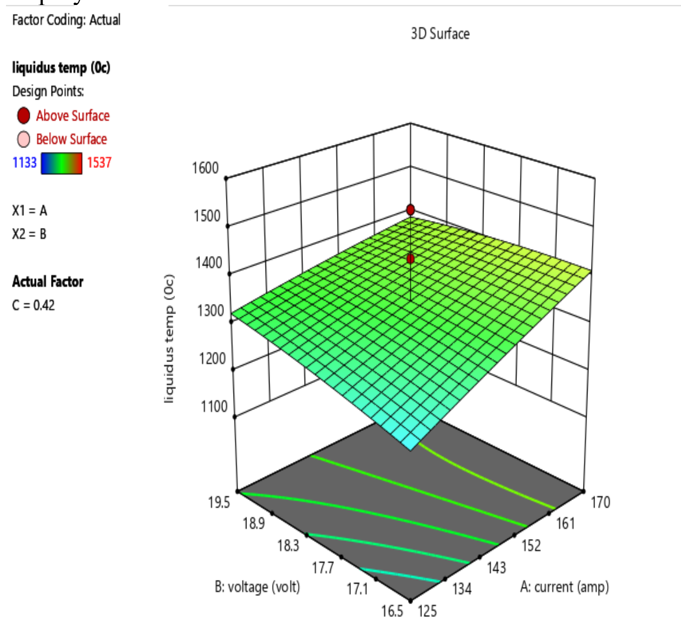

Fig. 1: Surface plot for Liquidus temperature, current and voltage

To study the effects of current and welding speed on the Liquidus temperature, 3D surface plots presented in Figure 4.2 was employed.

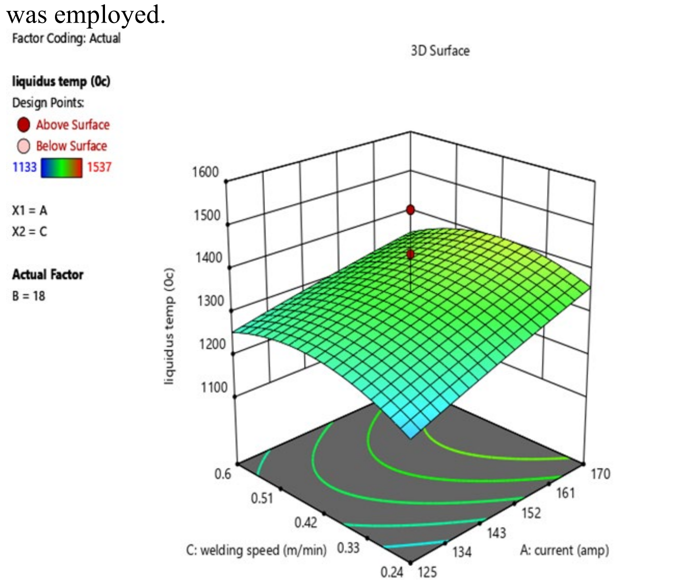

Fig 2: Liquidus temperature current and welding speed

To study the effects of voltage and welding speed on the Liquidus temperature, 3D surface plots presented in Figure 3 was employed.

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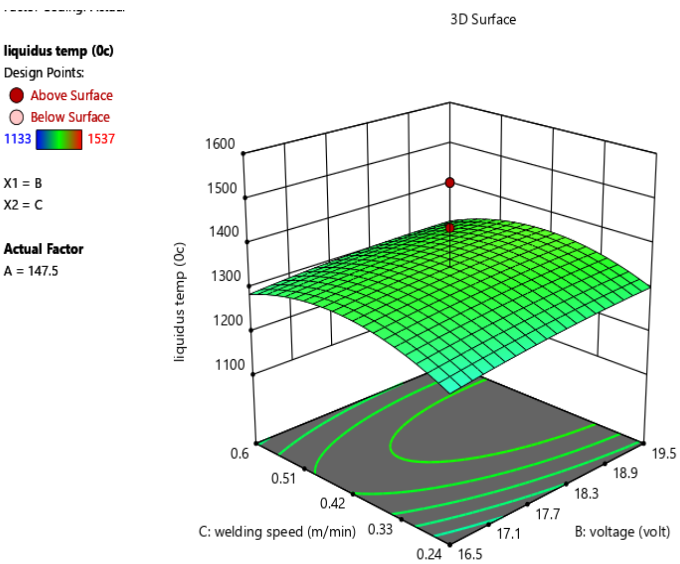

Fig. 3: Liquidus temperature, voltage and welding speed

The surface plots in Figures 1, 2 and 3 show the relationship between the input variables (current, voltage and welding speed) and the response variable (Liquidus temperature). liquidus temperature of 1350C, 22Amps of Current, 264 volts for voltage and 2481.02m/min in welding speed.

To study the effects of voltage and welding speed on the Solidus temperature, 3D surface plots presented in Figure 4 was generated as follows:

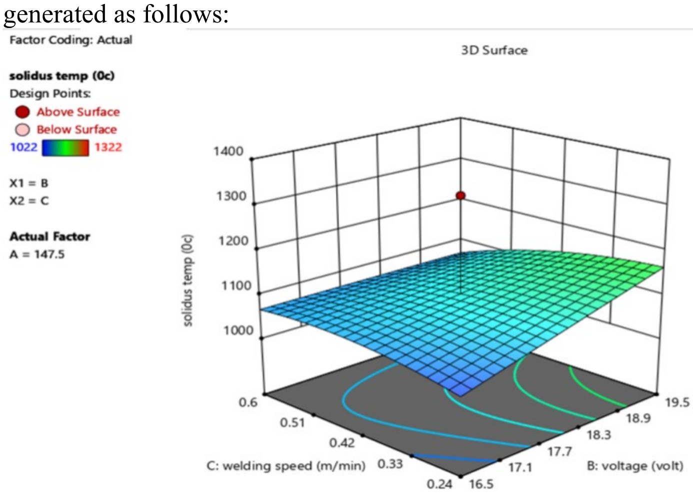

Figure 4: Solidus temperature, voltage and welding speed

To study the effects of voltage and current on the Solidus temperature, 3D surface plots presented in Figure 5 was employed.

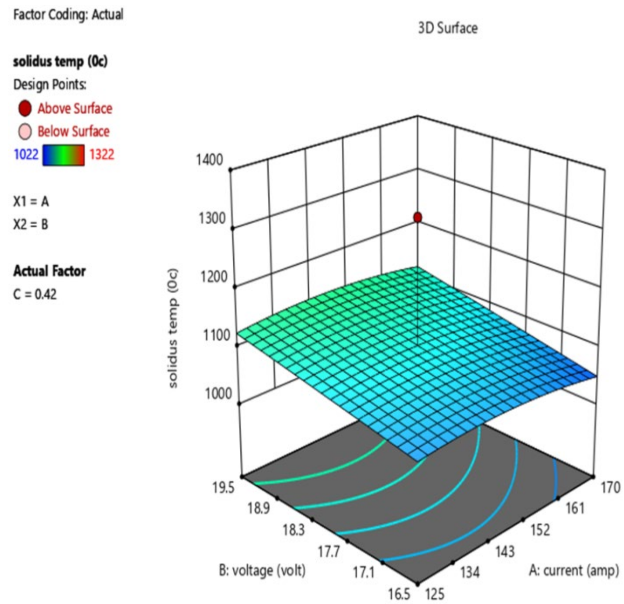

Figure 5: Solidus temperature, voltage and Current

To study the effects of voltage and current on the Solidus temperature, 3D surface plots presented in Figure 6 was employed.

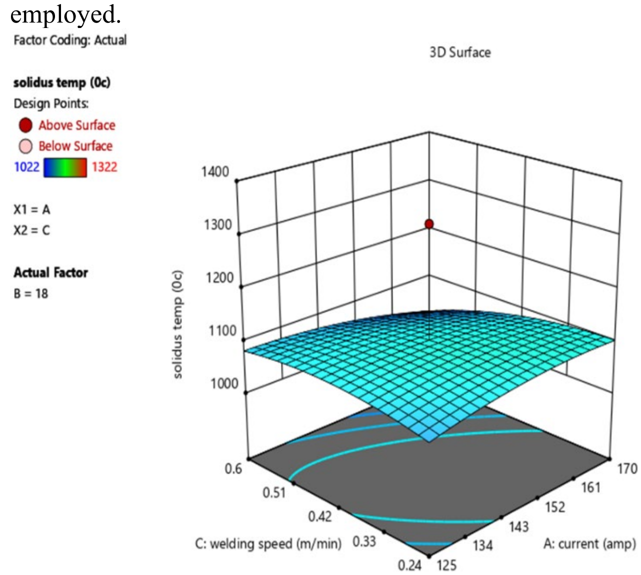

Figure 6: Solidus temperature, welding speed and Current

The surface plots in Figures 4, 5 and 6 show the relationship between the input variables (current, voltage and welding speed) and the response variable (Solidus temperature) At solidus temperature of 1050C, 8.86Amps of current, voltage of 68.83volts and 3313.53m/min in welding speed.

IV CONCLUSION

The Combined Effect of Input Parameters on liquidus and solidus temperature using 3D surface plot which is a 3dimensional surface plot employed to give a clearer concept

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of the response surface has been studied, It was observed that liquidus and solidus temperature decreases proportionately as the input parameters increase. Based on the data collected from the experimental runs in this study, the surface plots show the relationship between the input variables (current, voltage and welding speed) and the response variables (Liquidus temperature and solidus temperature). liquidus temperature of 1350C, 22Amps Current, 264 volts for voltage and 2481.02m/min in welding speed and solidus temperature of 1050C, 8.86Amps of current, voltage of 68.83volts and 3313.53m/min in welding speed.

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