A Cooks Distance Approach To Obtain Optimum Liquidus Temperature Of TIG Mild Steel Weld

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Abstract- The liquidus temperature factor is a very important parameter considered to determine the quality and strength of a welded joint, this study employs the cooks distance approach to optimize the temperature at which the weld joint is completely liquid. Twenty experimental runs was generated, which guided as an experimental layout , 10 mm thickness of low carbon steel was selected for the experiment which was welded with the TIG welding process. The RSM model was used to develop an optimal solution that can explain the behavior of the welded joint with respect to the liquidus temperature, different diagnostic techniques were employed which includes the normal probability plot, contour plot and the cooks distance plot. The model developed has sufficient merit as the results obtained shows that the cooks distance values is within the range of 0 and 1 indicating the absence of outlier in the data making the optimal result strongly acceptable.

. **Keywords**: cooks distance ,optimum ,liquidus temperature ,mild steel weld, control

Introduction

Optimization of most welding processes of mild steel should result in a significant reduction in the production cost and improve the quality of fabricated engineering structures. In the refining processes, optimizing the slag regimes [1,] thermal and chemical homogenization of the melt [2] or filtration of steel [3] is very important to solve. Works toward optimizing the process of solidification of heavy forging ingots [5] were implemented in the casting and solidification of steel. Finally, an attention is focused on the fluid flow behavior of steel flow in the tundish [5], The methods of study of metallurgical processes are also based on knowledge of thermodynamic properties of materials occurring in a given technology nodes.

Knowledge of liquidus temperatures of mild steels is one of the most important factors, especially in dealing with the processes involved in the casting and solidification. The liquidus temperature is a very important parameter to consider for proper adjustment of models (physical or numerical) or in the final stage of applied knowledge of the real process, it is significantly affecting the final quality of the fabricated product. The liquidus temperature of steel plays a very significant role in metallurgical production, accurate liquidus temperature of mild steel is required for scientific investigation of solidification processes of molten steel by numerical simulation.[6]Temperature is a significant parameter, not only for processes of melting and hot forming, but also for steel welding. For the sake of optimizing the existing processes of steel manufacturing, it is important to know phase transformation temperatures, or temperatures at which steel loses its plasticity or strength [7]. Knowledge of the liquidus and solidus temperatures are critical parameters necessary for the optimal production of steel products ,correct setting of physical or numerical models are equally important for achieving the best steel melting and fabrication processes. The correct determination of these temperatures significantly influences the quality and properties of semi-finished products [8].optimization processes today have integrated some statistical techniques to increase the reliability of the optimal solution, the cooks distance is one of the statistical diagnostics employed. Cook's Distance (Di) is used for assessing influential observations in regression models. The problem of outliers or influential data in the multiple or multivariate linear regression setting has been thoroughly discussed with reference to parametric regression models.[9] The kernel density estimation was presented as a type of Cook's distance [10],and later suggested a type of Cook's distance in local polynomial regression.[11]The classical cook's distance was modified with generalized Mahalanob is distance in the context of multivariate elliptical linear regression models and they also establish the exact distribution for identification of outlier data points. The exact distribution of Cook's distance was used to evaluate the influential observations in multiple linear regression analysis. The authors showed the derived density function of the cook's distance in terms of the series expression form. Moreover, the first two moments of the distribution are derived and the authors computed the critical points of Cook's distance at 5% and 1% significance level for different sample sizes based on no.of predictors. Finally ,the numerical example shows the identification of the influential observations and the results extracted from the proposed approach is more scientific, systematic and it's exactness outperforms the traditional rule of thumb approach.[12]

2. Research Methodology

In this section, the materials and response surface methodology and the TIG welding process is described and explained. Furthermore, the RSM diagnostics and cooks distance results are explained and interpreted .In this study an optimum experimentation to control the liquidus temperature was conducted. Gas tungsten arc welding process was used to join the weld specimen made of low carbon steel. The first step taken was design an experimental matrix ,using the design expert software ,five set of welded sample was made for each experimental run which amounted to a total of one hundred weld samples.

2.1 Material selection

The material chosen for the welding experiments was low carbon steel also known as mild steel, it was choosen because of its availability This grade has high corrosion resistance and can be operated at elevated temperature., the Tungsten inert gas welding technique wa selected because of its fine weld product quality . A matching filler wire having similar property of the base metal was selected .For good arc stability and low spatter, 8% CO_2 mixed argon gas was chosen as a shielding gas.

2.2 *Welding Process Parameters*

The welding process parameters consists of current, voltage, gas flow rate, their range of values are shown in table 1

.

Table 1: process parameters

Factors	Unit	Symbol	Low (-1)	High (+1)
Welding Current	Ampere	I	130	170
Welding Voltage	Volts	V	20	24
Gas Flow Rate	Lit/min	GFR	13	17

2.3 Conducting the experiments using the design matrix

Weld experiments were conducted using a 10mm thick mild steel plate was welded with a 60° single V-groove with root face butt weld. Tor the welding current varying from 130 to 170 amps , gas flow rate 13 to 17 lit/min and voltage 20 to 24 voltsIn the present work, mild steel plates of 10mm thickness and 60 mm lengths were butt joined using the desired filler rod at varying levels of current voltage and gas flow rate t by manual TIG welding process. This three parameters were taken as variable for present study and their three levels were chosen for which responses were measured, and the central composite design was selected as the experimental design method. These parameters with their levels are shown in table 1 . The experimental data for the liquidus temperature is presented in table 2

Table 2: experimental data

Run	I	V	GFR	σ_R (MPa) Residual stress	T_L (°C) Liquidus temperature	η (Kg/(m.s)) Viscosity
1	130.00	21.50	12.50	407.8	1650	0.007564
2	130.00	21.50	12.50	388.3	1655	0.007495
3	110.00	20.00	11.00	340.42	1631	0.007875
4	110.00	23.00	11.00	307	1645	0.007634
5	130.00	21.50	12.50	405.47	1650	0.007564
6	130.00	24.02	12.50	472.54	1680	0.007167
7	163.64	21.50	12.50	385.73	1736	0.006514
8	130.00	21.50	12.50	388.3	1655	0.007495
9	110.00	23.00	14.00	289	1624	0.007938
10	96.36	21.50	12.50	234.8	1645	0.007634
11	150.00	20.00	14.00	410.28	1700	0.006921
12	130.00	21.50	15.02	405.47	1650	0.00756
13	150.00	20.00	11.00	380	1660	0.00767
14	130.00	21.50	12.50	388.3	1655	0.007495
15	130.00	18.98	12.50	405.47	1650	0.007564
16	110.00	20.00	14.00	318	1624	0.007638
17	150.00	23.00	11.00	445.88	1706	0.006645
18	130.00	21.50	9.98	364.32	1632	0.00782
19	130.00	21.50	12.50	405.47	1650	0.007564
20	150.00	23.00	14.00	445.88	1724	0.006645

3 Results and Discussion

The diagnostics case statistics which shows the observed values of liquidus temperature against their predicted values is presented in table 3 The diagnostic case statistics actually give insight into the model strength and the adequacy of the optimal second order polynomial equation

Table 3: Diagnostics case statistics report of liquidus temperature

Standard	Actual	Predicted	Residual	Leverage	Internally Studentized	Externally Studentized	Influence on Fitted Value	Cook's	Run
1	1631.00	1633.37	-2.37	0.670	-0.917	-0.909	-1.294	0.170	3
2	1660.00	1659.24	0.76	0.670	0.294	0.280	0.399	0.018	13
3	1645.00	1648.06	-3.06	0.670	-1.183	-1.211	-1.724	0.284	4
4	1706.00	1701.93	4.07	0.670	1.573	1.720	1.45	0.502	17
5	1624.00	1629.70	-5.70	0.670	-2.202	-2.911	-1.15	0.984	16
6	1700.00	1698.57	1.43	0.670	0.554	0.534	0.761	0.062	11
7	1624.00	1626.39	-2.39	0.670	-0.923	-0.916	-1.304	0.173	9
8	1724.00	1723.26	0.74	0.670	0.288	0.274	0.390	0.017	20
9	1645.00	1637.75	7.25	0.607	2.571	1.19	1.21	* 1.02	10
10	1736.00	1740.95	-4.95	0.607	-1.755	-2.002	-1.49	0.476	7
11	1650.00	1647.29	2.71	0.607	0.960	0.956	1.188	0.142	15

12	1680.00	1680.41	-0.41	0.607	-0.144	-0.137	-0.170	0.003	6
13	1632.00	1632.43	-0.43	0.607	-0.151	-0.144	-0.179	0.004	18
14	1650.00	1647.27	2.73	0.607	0.967	0.964	1.198	0.145	12
15	1650.00	1652.57	-2.57	0.166	-0.624	-0.604	-0.270	0.008	1
16	1650.00	1652.57	-2.57	0.166	-0.624	-0.604	-0.270	0.008	19
17	1655.00	1652.57	2.43	0.166	0.592	0.572	0.255	0.007	14
18	1650.00	1652.57	-2.57	0.166	-0.624	-0.604	-0.270	0.008	5
19	1655.00	1652.57	2.43	0.166	0.592	0.572	0.255	0.007	2
20	1655.00	1652.57	2.43	0.166	0.592	0.572	0.255	0.007	8

To diagnose the statistical properties of the liquidus temperature response surface model, the normal probability plot of residual presented in Figure 1

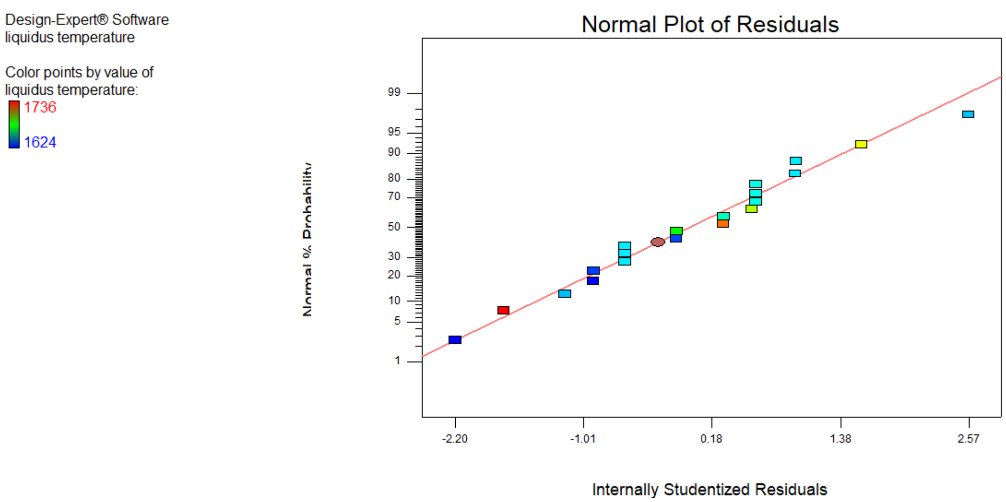

Figure 1: Normal plot of residuals for liquidus temperature

In order to detect a value or group of values that are not easily detected by the model, the predicted values is ploted against the actual values, for liquidus temperature which is shown in the figure 2

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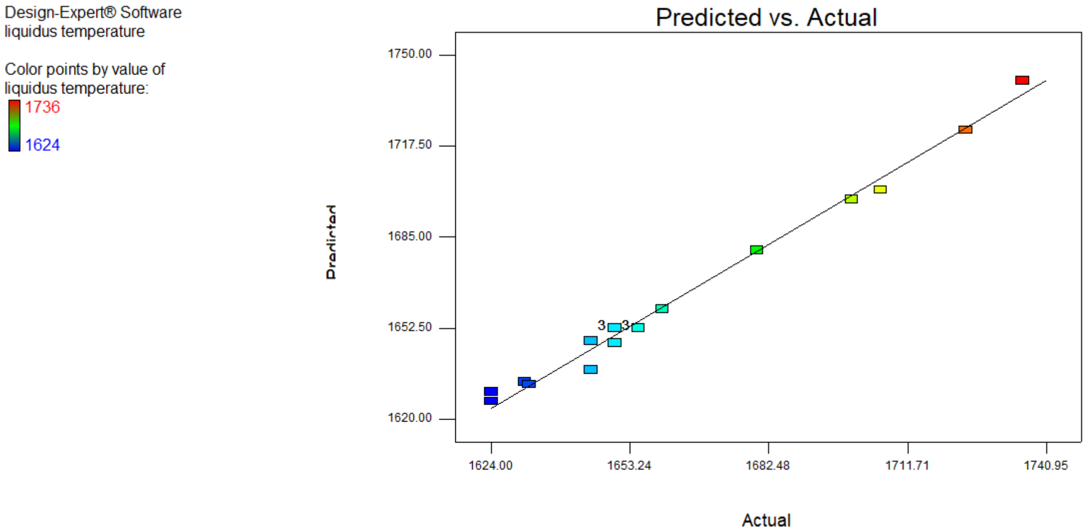

Figure 2: Plot of Predicted Vs Actual for liquidus temperature

As can be seen from the graph, the points are close to the line of fit. The model essentially is able to predict most of the data points. To determine the presence of a possible outlier in the experimental data, the cook's distance plot was generated for the liquidus temperature response.The cook's distance is a measure of how much the regression would change if the outlier is omitted from the analysis. A point that has a very high distance value relative to the other points may be an outlier and should be investigated. The generated cook's distance for the liquidus temperature is presented in Figures 3

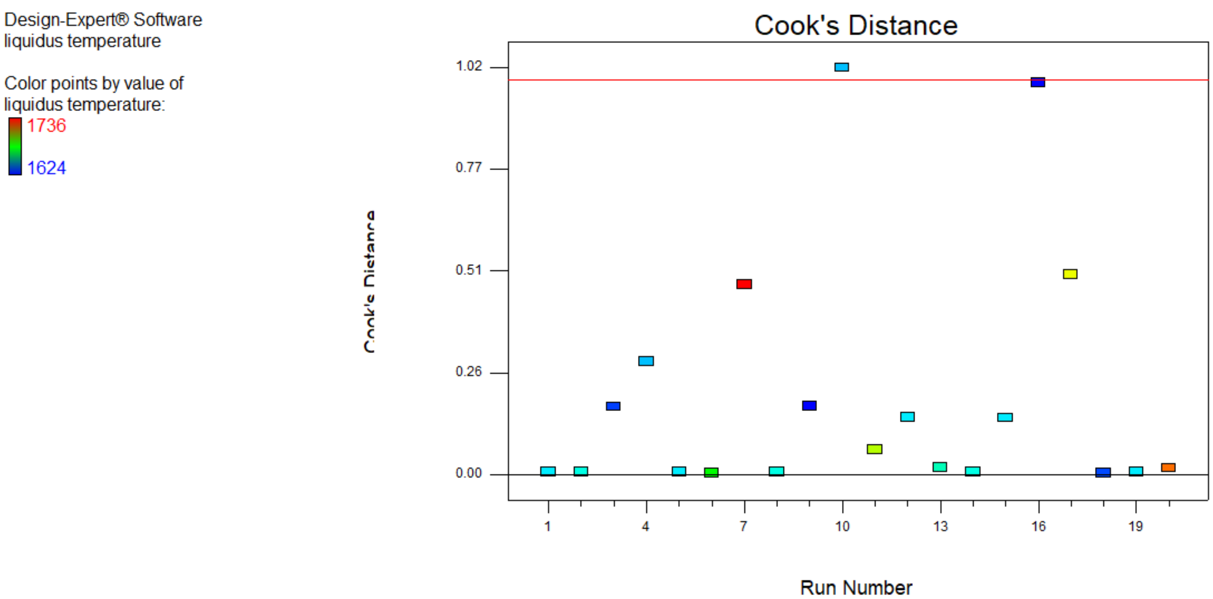

Figure 3: Generated cook's distance for liquidus temperature

Table 4: numerical optimal solutions

Number	current	voltage	gas flow rate	residual stress	liquidus temperature	Viscosity	Desirability
1	**110.00**	**21.38**	**11.00**	**313.512**	**1636.15**	**0.00778952**	**0.824**
2	110.00	21.50	11.00	312.913	1636.73	0.00777898	0.824
3	110.03	21.22	11.00	314.687	1635.48	0.00780179	0.823
4	110.00	21.61	11.00	312.546	1637.29	0.00776914	0.823
5	110.00	21.35	11.02	313.721	1636.08	0.00779009	0.823
6	110.00	21.32	11.02	313.959	1635.95	0.00779222	0.823
7	110.00	20.95	11.00	316.841	1634.58	0.00781926	0.822
8	110.00	20.77	11.00	318.932	1634.09	0.0078294	0.819
9	110.00	20.70	11.00	319.789	1633.95	0.00783267	0.818
10	110.00	20.29	11.00	326.128	1633.4	0.00784758	0.808
11	110.00	20.77	11.17	319.937	1634.6	0.00780994	0.807
12	110.00	20.02	11.00	331.233	1633.36	0.00785263	0.798
13	110.00	22.75	11.00	316.64	1645.64	0.00762966	0.795
14	110.00	21.65	11.60	314.634	1637.66	0.00774297	0.793
15	110.00	22.73	14.00	302.079	1625.38	0.00793753	0.790

The contour plots showing liquidus temperature variable against the optimized value current and voltage is presented in Figure 4

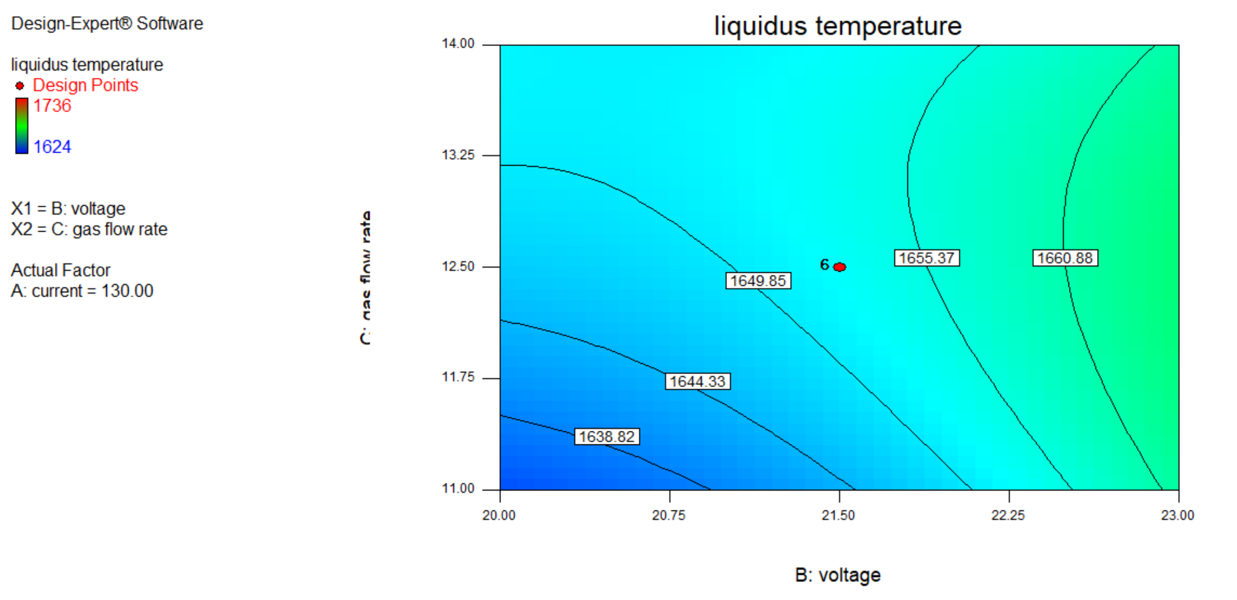

Figure 4: Predicting liquidus temperature using contour plot

3.2 Discussion

The second order quadratic model was selected as the best model that can optimize the liquidus temperature in the TIG welding process , The diagnostics case statistics which shows the observed values of liquidus temperature against their predicted as presented in table 3 The diagnostic case statistics actually give insight into the model strength and the adequacy of the optimal second order polynomial equation In order to detect a value or group of values that are not easily detected by the model, the predicted values is ploted against the actual values, for liquidus temperature which is shown in the figure 2To determine the presence of a possible outlier in the experimental data, the cook's distance plot was generated for the liquidus temperature response.The cook's distance is a measure of how much the regression would change if the outlier is omitted from the analysis. A point that has a very high distance value relative to the other points may be an outlier and should be investigated. The model developed has sufficient merit to control the liquidus temperature optimally

4. Conclusion

This study was carried out to develop models to optimize the liquidus temperature of mild steel joints using the TIG welding process . The RSM technique was employed to develop the models and the cooks distance was used to measure the integrity and reliability of the model. the diagnostic case statistics showed the residuals ,predicted, actual and the cooks distance values for the liquidus temperature model. The cooks distance falls within the range of 0 and 1 indicating that there is no outlier in the data making the optimal solution strongly accepted

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