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Modeling and Simulation of Welding Parameters in Tungsten Inert Gas Welding of Mild Steel

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Abstract**—*Tungsten Inert Gas welding (TIG) is the most widely used welding technique for industrial application. The execution of Gas Tungsten Arc Welding is complex in nature, therefore there is need to simplify this technique while trying to reduce cost of production and at the same time improve on quality of weld joint. Therefore, there is need to model the interaction of control welding parameters against desired quality parameters. This research paper aimed at creating a second degree response surface quadratic model having three cross product terms of current and gap-width (IG), welding speed and gap-width (VG) and current and welding speed(IV) in order to visualize the interaction of current(I), welding speed(V) and geometric gap width of the welding joint(G). Comprehensive models were developed to show how control parameters interact with physical and geometric attributes optimally. The model was then simulated numerically in order to visualize the interaction of welding parameters against quality attributes such as heat affected zones, bead-width, and depth of penetration and tensile strength of the joint. Simulation models confirmed that mathematical models derived from second-degree response surface quadratic model fairly predicts optimal quality attributes of TIG weld joint in mild steel therefore simplifying the welding technique.*

Keywords**—** *Control Parameters; Modeling; Quality Attributes; Simulation.*

I. Introduction

Tungsten inert gas welding is multivariable non-linear welding process [3]. Non-linear and multi-variable mathematical models were developed for the selection of the optimum control parameters based on second order quadratic models [6]. In the experiment, control input parameters in form of (x) transform into an output that has one or more observable response variables (y) which is the quality attribute. Therefore, useful results and conclusions can be drawn from experiment. This can be achieved by carrying out modeling and simulation of welding parameters [2] [7].

II. Materials And Methods

A. Introduction

The research process involved a process of developing mathematical models that approximate relationship between input control variables and quality parameters. Numerical simulations of mathematical model were performed to visualize and predict the relationship between control parameters and quality attributes. Validation of simulated data was done against data from the literature research.

B. Mathematical Modeling of the effects of welding parameters.

Tungsten inert gas welding is multivariable non- linear welding process. Non-linear and multi-objective mathematical models were developed for the selection of the optimum processes parameters.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{12} x_1 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \varepsilon \quad (1)$$

The second order model in equation (1) includes linear terms, cross product terms and a second order term for each of the x's (I, G, V). If the function is generalize to have k *x*'s, we have k first order terms, k second order terms and then we have all possible pairwise first-order interactions. The linear terms just have one subscript. The quadratic terms have two subscripts.

There are $k \times \frac{(k-1)}{2}$ interaction terms [6]. In this case there are three interaction terms since k = 3.

This second order model in equation (1) is the basis for response surface designs under the assumption that although the hill is not a perfect quadratic polynomial in *k* dimensions, it provides a good approximation to the surface near the maximum or a minimum [4].

The second-degree response surface quadratic model in equation (1) can be modified to take the form in equation (2):

$$Y = b_0 + b_1V + \ldots.. + b_3G + b_{11}V^2 + \ldots\ldots + b_{33}G^2 + b_{12}VI + \ldots\ldots. + b_{23}IG.... \quad (2)$$

In this model, “b” values are the coefficients of which are constants. V, I and G are input parameters speed, current and gap width respectively. Y can take the form of quality parameter DOP, BDW, HAZ and UTS. The assumption here was that inert gas flow rate is kept constant and its variation has no significant effect on quality of welded joint. Another assumption was that arc length is kept at specified value for entire length of welding process. Again minor variation in arc length has no significant impact on quality of weld joint. The three interactions are the cross product terms of VI, IG and VG.

Generating mathematical modeling that approximate quality attribute as a function of current, welding speed and gap width. The constraints in control parameters are then defined to within acceptable limits and tolerance.

By substituting Y in general equation with HAZ the model can take the form of equation (3). The second order equation with input control variables welding speed (V), welding current (I) and gap width (G) is as shown.

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$$HAZ=4.2575-2.2533V+0.0782I+0.1976G+0.3521V^2-0.000125I^2-0.021332G^2-0.006771VI+0.000108VG+0.001068IG \quad (3)$$

By substituting Y in general equation with UTS (tensile load) the model can take the form of equation (4). The second order equation with input control variables welding speed (V), welding current (I) and gap width (G) is as shown.

$$UTS=9.80670+238.03487V+8.1026I+4.03520G-75.10056V^2-0.039932I^2-7.09132G^2-0.059915VI+0.73102VG+0.04571IG \quad (4)$$

By substituting Y in general equation with BDW the model can take the form of equation (5). The second order equation with input control variables welding speed (V), welding current (I) and gap width (G) is as shown.

$$BDW=3.30264+0.44804V+0.089617I+0.074330G-0.21720V^2-0.000127I^2-0.004656G^2-0.011222VI-0.027623VG+0.000764IG \quad (5)$$

By substituting Y in general equation with DOP the model can take the form of equation (6). The second order equation with input control variables welding speed (V), welding current (I) and gap width (G) is as shown.

$$DOP=0.64380+0.066086V+0.006967I+0.087895G-0.019590V^2-0.000039I^2-0.014173G^2+0.000503VI-0.020985VG+0.000332IG \quad (6)$$

C. *Numerical simulation*

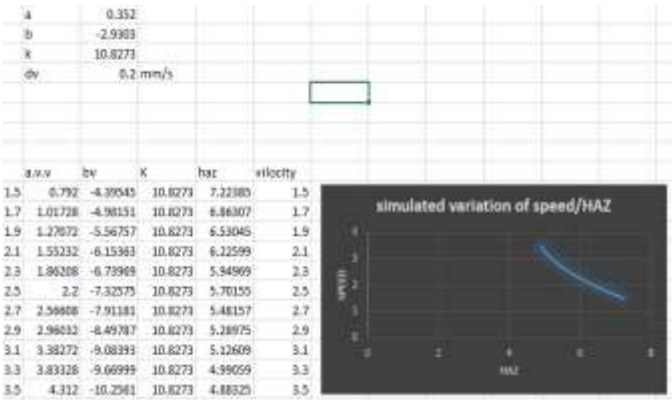
- Numerical Simulation of the effects of welding control parameters on the quality weld attributes of mild steel.

This step involves testing each model by varying single welding parameter at time while holding the other two parameters constant. The developed model took several values of input parameters while producing the several quality parameters. The whole process is extremely cumbersome but with the help of numerical simulation, the computer can simplify computation process and plot the relationship in a graph and make it simple to visualize the interaction of input parameter and there influence or effect on output parameters. The mathematical model was simplified, individual components programed in Matlab R2017a software. The numerical data were fed into Microsoft excel software in order to generate simulated curves. The simulated data predicted optimal values of input parameters that will yield desirable values of a quality weld parameter.

- Simulation of quality parameter against control variables

The control parameters welding speed, welding current and gap width were varied each at a time. The first step involve varying the welding speed at 100Amps while the gap width is varied from <0.1, 0.1, and 0.2mm. The second step involved varying the welding current at a recommended welding speed of 210mm/min while the gap width is varied from <0.1, 0.1, and 0.2mm. The third step involves varying the welding current at a gap width of 0.15mm while the welding speed is adjusted from 90mm/min, 150mm/min to 210mm/min. Each time control parameters were varied, quality parameters such as bead width, heat affected zones, and depth of penetration and ultimate tensile strength were recoded for further analysis. The procedure was performed at different levels of gap width. The simulated models had been canvased in detail in order to visualize how mathematical model behave as input control variables is changed systematically. From the models one could easily tell the optimal values of input control variables that favors desirable quality parameters. Figure 1, figure 2, figure 3 and figure 4 shows sample simulated models with specific control parameters indicated.

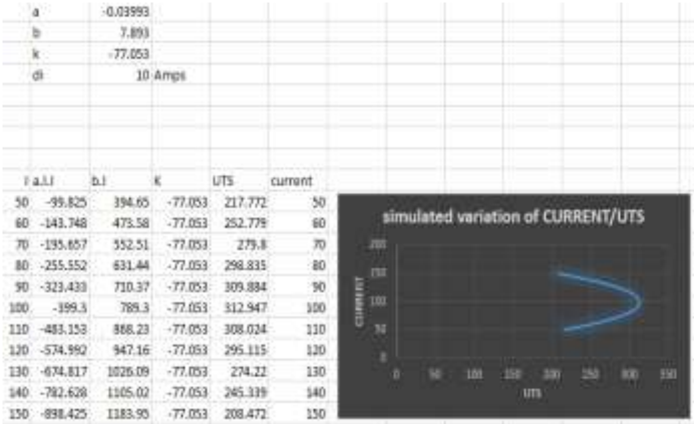
- Samples of simulated data



a	0.352
b	-2.9303
k	10.8273
dv	0.2 mm/s

	a.v.v	bv	K	haz	velocity
1.5	0.792	-4.39545	10.8273	7.22385	1.5
1.7	1.01728	-4.98151	10.8273	6.86307	1.7
1.9	1.27072	-5.56757	10.8273	6.53045	1.9
2.1	1.55232	-6.15363	10.8273	6.22599	2.1
2.3	1.86208	-6.73969	10.8273	5.94969	2.3
2.5	2.2	-7.32575	10.8273	5.70155	2.5
2.7	2.56608	-7.91181	10.8273	5.48157	2.7
2.9	2.96032	-8.49787	10.8273	5.28975	2.9
3.1	3.38272	-9.08393	10.8273	5.12609	3.1
3.3	3.83328	-9.66999	10.8273	4.99059	3.3
3.5	4.312	-10.2561	10.8273	4.88325	3.5

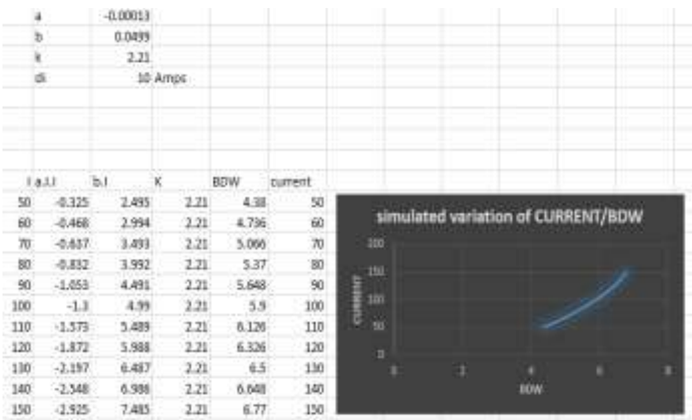
Fig. 1: Simulation of HAZ against welding current at 100 Amps, G=<0.1mm (source)



a	-0.03993
b	7.893
k	-77.053
di	10 Amps

I	a.I.I	b.I	K	UTS	current
50	-99.825	394.65	-77.053	217.772	50
60	-143.748	473.58	-77.053	252.779	60
70	-195.657	552.51	-77.053	279.8	70
80	-255.552	631.44	-77.053	298.835	80
90	-323.433	710.37	-77.053	309.884	90
100	-399.3	789.3	-77.053	312.947	100
110	-483.153	868.23	-77.053	308.024	110
120	-574.992	947.16	-77.053	295.115	120
130	-674.817	1026.09	-77.053	274.22	130
140	-782.628	1105.02	-77.053	245.339	140
150	-898.425	1183.95	-77.053	208.472	150

Fig.2: Simulation of UTS against welding current at welding speed of 210mm/min, G=<0.1mm (source)



a	-0.00013
b	0.0499
k	2.21
di	10 Amps

I	a.I.I	b.I	K	BDW	current
50	-0.325	2.495	2.21	4.38	50
60	-0.468	2.994	2.21	4.736	60
70	-0.637	3.493	2.21	5.066	70
80	-0.832	3.992	2.21	5.37	80
90	-1.053	4.491	2.21	5.648	90
100	-1.3	4.99	2.21	5.9	100
110	-1.573	5.489	2.21	6.126	110
120	-1.872	5.988	2.21	6.326	120
130	-2.197	6.487	2.21	6.5	130
140	-2.548	6.986	2.21	6.648	140
150	-2.925	7.485	2.21	6.77	150

Fig. 3: Simulation of BDW against welding current at welding speed of 210mm/min, G=<0.1mm (source)

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III. Results And Discussions

A. Validation of simulated models

The model data from literature review were used to validate the model from this research. The data from experiment for different control parameters is shown in table1, table 2 and table 3.

B. Variance in heat affected zones (HAZ)

From the research optimal combination of welding speed, welding current and gap width that minimizes HAZ at weld joint was obtained. The high value of HAZ is 7.58mm when welding speed of 90mm/min and welding current of 100Amps was obtained, while the minimum HAZ of 2.94mm was observed while doing a welding speed of 210mm/min at welding current of 80Amps. In addition other quality parameters such as ultimate tensile strength and depth of penetration of the joint were considered. When these other parameters were considered, a welding speed of 210mm/min with welding current of 130Amps and a gap width of 0.15mm were found to be suitable for minimum HAZ without compromising on other quality parameters.

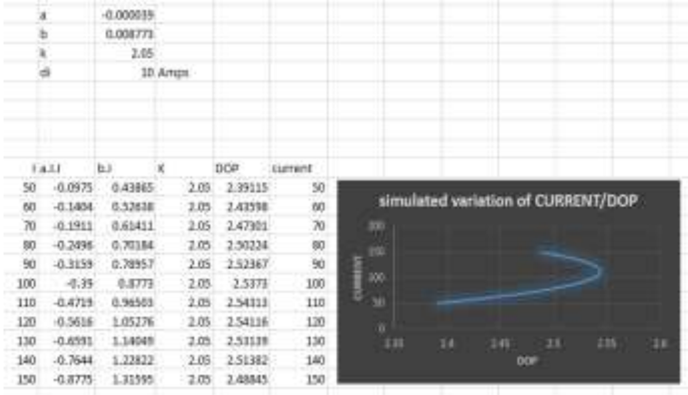

Fig.4: Simulation of DOP against welding current at a welding speed of 210mm/min, G=0.15mm (source)

TABLE 1: Quality tests results (factorials-welding speed/gap width-Average parameter) at 100 Amps.

GAP(mm) G	Welding speed (V) mm/min		Welding current=100Amps			
	90		150		210	
	Quality parameters (DOP,BDW,HAZ,UTS)					
< 0.1	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT
	DOP(mm)	2.58	DOP	2.16	DOP	0.96
	BDW(mm)	6.16	BDW	5.84	BDW	4.32
	HAZ(mm)	7.58	HAZ	6.64	HAZ	5.68
	UTS(N/mm^2)	181.02	UTS	171.58	UTS	143.44
0.1	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT
	DOP(mm)	2.9	DOP	2.62	DOP	1.76
	BDW(mm)	6.42	BDW	5.68	BDW	4.2
	HAZ(mm)	6.0	HAZ	5.78	HAZ	3.58
	UTS(N/mm^2)	220.52	UTS	210.1	UTS	191.09
0.2	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT
	DOP(mm)	2.38	DOP	1.76	DOP	1.12
	BDW(mm)	6.46	BDW	5.72	BDW	4.26
	HAZ(mm)	5.78	HAZ	4.4	HAZ	3.62
	UTS(N/mm^2)	215.56	UTS	207.31	UTS	182.26

TABLE 2: Quality tests results (factorials-welding current/gap width-Average parameter) at 210mm/min.

GAP(mm) G	Welding Current (I) Amps		Welding speed=210mm/min			
	80		100		130	
	Quality parameters (DOP,BDW,HAZ,UTS)					
< 0.1	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT
	DOP(mm)	1.66	DOP	2.5	DOP	2.94
	BDW(mm)	5.86	BDW	5.96	BDW	7.78
	HAZ(mm)	3.62	HAZ	4.88	HAZ	6.08
	UTS(N/mm^2)	169.92	UTS	182.41	UTS	221.63
0.1	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT
	DOP(mm)	2.02	DOP	2.82	DOP	2.98
	BDW(mm)	5.60	BDW	6.42	BDW	7.0
	HAZ(mm)	4.5	HAZ	5.07	HAZ	6.38
	UTS(N/mm^2)	173.27	UTS	206.72	UTS	234.96
0.2	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT
	DOP(mm)	1.44	DOP	2.42	DOP	2.8
	BDW(mm)	6.02	BDW	6.24	BDW	8.042
	HAZ(mm)	4.48	HAZ	4.8	HAZ	7.2
	UTS(N/mm^2)	114.36	UTS	153.0	UTS	218.1

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TABLE 3: Quality tests results (factorials-welding speed/welding current-Average parameter) at a gap width of 0.15mm.

WELDING SPEED (mm/min)	Welding current (I)Amps	Gap width =0.15mm				
	80		100		130	
	Quality parameters (DOP,BDW,HAZ,UTS)					
90	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT
	DOP(mm)	1.0	DOP	1.32	DOP	2.28
	BDW(mm)	5.58	BDW	6.6	BDW	6.95
	HAZ(mm)	6.08	HAZ	6.36	HAZ	6.86
	UTS(N/mm^2)	137.86	UTS	188.62	UTS	210.5
150	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT
	DOP(mm)	1.6	DOP	2.56	DOP	2.98
	BDW(mm)	6.2	BDW	6.48	BDW	6.94
	HAZ(mm)	4.08	HAZ	5.16	HAZ	5.58
	UTS(N/mm^2)	227.44	UTS	251.04	UTS	255.10
210	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT	TEST SAMPLE	AVR PRMT
	DOP(mm)	1.3	DOP	2.92	DOP	3.0
	BDW(mm)	4.84	BDW	6.16	BDW	7.42
	HAZ(mm)	2.94	HAZ	5.36	HAZ	5.92
	UTS(N/mm^2)	116.2	UTS	229.7	UTS	264.14

Drawing conclusion from the experimental data the following observations were made:

From the data in table1 and sample simulated model in figure1 for a gap width of less than 0.1mm, the comparison in table 4 can be drawn:

TABLE 4: Comparison of experimental data with model data of HAZ

Welding speed	90mm/min	150mm/min	210mm/min
Experimental data for (HAZ)	7.58mm	6.64mm	5.68mm
Model for (HAZ)	7.22mm	5.7mm	4.88mm
% Error	5.0%	16%	16%
Average % error			12%

The model fairly predicts the expected quality in heat affected zone with minimal marginal error. Hence the model can be described as valid.

C. Trends in tensile loading

A close observation will show that ultimate tensile strength of TIG weld joint of welded specimens as shown in table 1, table 2 and table 3 closely resembles the tensile test report in figure 5, figure 6 and figure 7 being sample test reports indicating ultimate tensile strength of the welded specimens.

It is therefore quite obvious that with increase in welding speeds lower heat energy inputs results hence less depth of penetration and poor bonding strength resulting in lower ultimate tensile strength. A close observation will also show that increasing welding current result in high heat energy inputs hence higher ultimate tensile strength. This variance of ultimate tensile strength of weld joint with varying heat energy input can be attributed to the degree of w depth of penetration and level of bonding strength at the weld joints. The initial increase in ultimate tensile strength can be due to increase in bonding strength and penetration as the heat energy per unit length is increased.

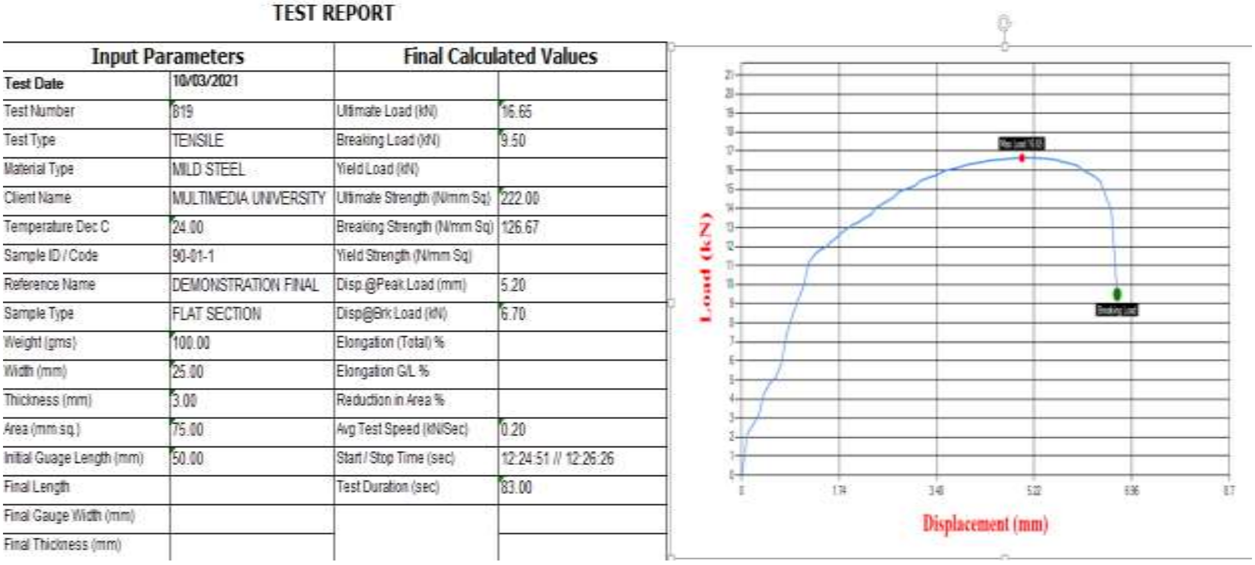
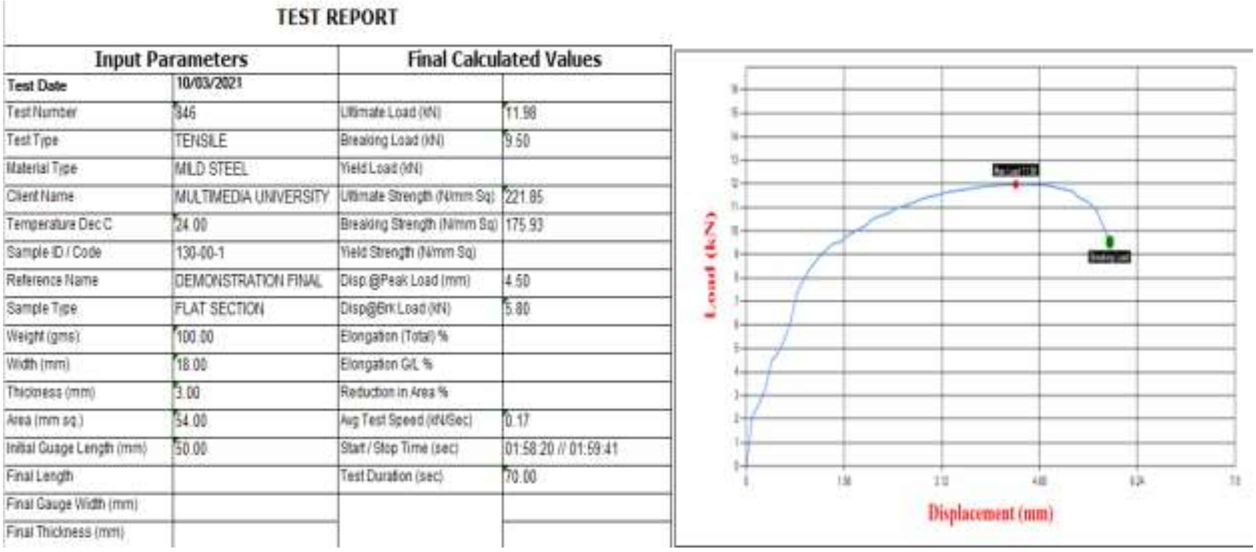


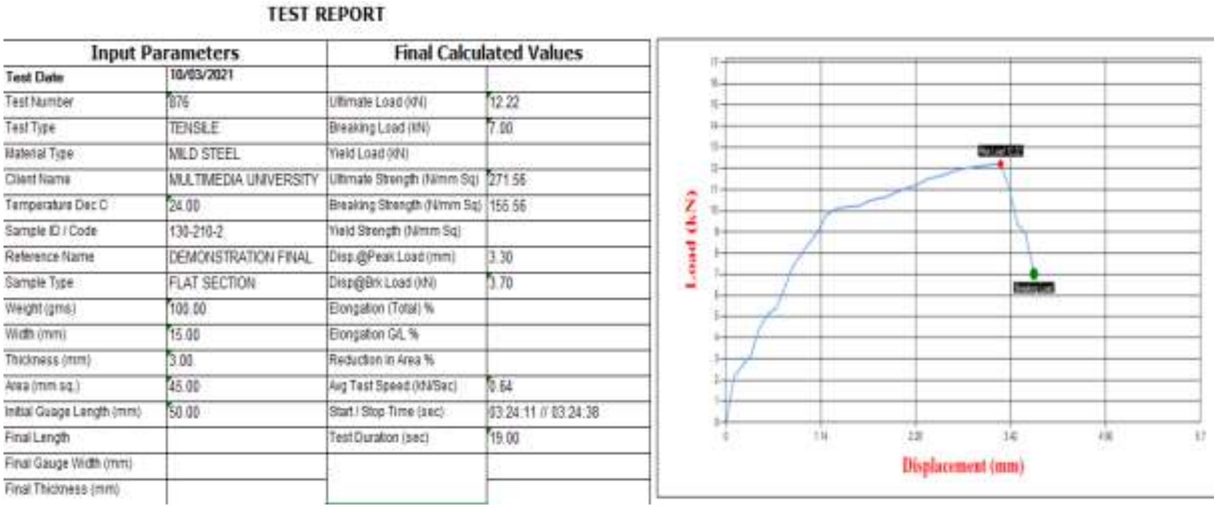
Fig. 5: Universal testing machine tensile test report for welding speed of 90mm/min, /current 100Amps/ gap width 0.1mm



TEST REPORT

Input Parameters		Final Calculated Values	
Test Date	10/03/2021		
Test Number	346	Ultimate Load (kN)	11.98
Test Type	TENSILE	Breaking Load (kN)	9.50
Material Type	MILD STEEL	Yield Load (kN)	
Client Name	MULTIMEDIA UNIVERSITY	Ultimate Strength (N/mm Sq)	221.85
Temperature Dec C	24.00	Breaking Strength (N/mm Sq)	175.93
Sample ID / Code	130-00-1	Yield Strength (N/mm Sq)	
Reference Name	DEMONSTRATION FINAL	Disp.@Peak Load (mm)	4.50
Sample Type	FLAT SECTION	Disp@Brk Load (kN)	5.80
Weight (gms)	100.00	Elongation (Total) %	
Width (mm)	18.00	Elongation G/L %	
Thickness (mm)	3.00	Reduction in Area %	
Area (mm sq.)	54.00	Avg Test Speed (kN/Sec)	0.17
Initial Guage Length (mm)	50.00	Start / Stop Time (sec)	01:58:20 // 01:59:41
Final Length		Test Duration (sec)	70.00
Final Gauge Width (mm)			
Final Thickness (mm)			

Fig.6: Universal testing machine tensile test report for welding current of 130 Amps/ welding speed 210mm/min/ gap width <0.1mm



TEST REPORT

Input Parameters		Final Calculated Values	
Test Date	10/03/2021		
Test Number	876	Ultimate Load (kN)	12.22
Test Type	TENSILE	Breaking Load (kN)	7.00
Material Type	MILD STEEL	Yield Load (kN)	
Client Name	MULTIMEDIA UNIVERSITY	Ultimate Strength (N/mm Sq)	271.56
Temperature Dec C	24.00	Breaking Strength (N/mm Sq)	156.56
Sample ID / Code	130-210-2	Yield Strength (N/mm Sq)	
Reference Name	DEMONSTRATION FINAL	Disp.@Peak Load (mm)	3.30
Sample Type	FLAT SECTION	Disp@Brk Load (kN)	3.70
Weight (gms)	100.00	Elongation (Total) %	
Width (mm)	15.00	Elongation G/L %	
Thickness (mm)	3.00	Reduction in Area %	
Area (mm sq.)	45.00	Avg Test Speed (kN/Sec)	0.64
Initial Guage Length (mm)	50.00	Start / Stop Time (sec)	03:24:11 // 03:24:38
Final Length		Test Duration (sec)	19.00
Final Gauge Width (mm)			
Final Thickness (mm)			

Fig.7: Universal testing machine tensile test report for welding current of 130 Amps/welding speed 210mm/min/gap width 0.15mm

Making comparison from the data in table 2 and sample simulated model in figure 2 for a gap width of less than 0.1mm and welding speed of 210mm/min, the comparison in table 5 can be drawn:

TABLE 5: Comparison of experimental data with model data of UTS

Welding current	80Amps	100Amps	130Amps
Experimental data(UTS)	169.92MPa	182.41 MPa	221.63 MPa
Model (UTS)	298.84 MPa	312.9 MPa	274.22 MPa
% Error	43.0%	41.7%	19.1%
Average % error			34.6%

The percentage error of the model with respect to experimental data is below 50%. The model accuracy can be improved by better defining the constraints. However, it is rational to state that the model is valid with minor adjustment of constraints.

D. Variance in Beadwidth

The values of beadwidth increase with welding current while it decreases with increase in welding speed. This can be attributed to heat energy input in the process of metal fusion. The higher the heat input, the higher depth of penetration, hence higher beadwidth. There is also positive relationship between beadwidth and tensile strength of the weld joint. This is attributed to improved bonding strength as beadwidth increases. There is little effect in beadwidth as gap width is increased, that implies gap width is not a factor when determining beadwidth. Finally, beadwidth is a good indicator for weld depth of penetration, bonding strength and physical attributes of weld-bead with respect to potential welding defects.

From the data in table 2 and sample simulated model in figure 3 for a gap width of less than 0.1mm, the following comparison in table 6 can be drawn:

TABLE 6: Comparison of experimental data with model data of BDW

Welding current	80Amps	100Amps	130Amps
Experimental data(BDW)	5.86mm	5.96mm	7.78mm
Model (BDW)	5.37mm	5.9mm	6.5mm
% Error	9.0%	1.0%	19.6%
Average % error			9.8%

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The deviation of 9.8% of the model value from experimental value of beadwidth is relatively small which therefore confirmed that the model is valid with certain degree of accuracy.

E. Variance in depth of penetration

The values of depth of penetration increase with welding current while it decreases with increase in welding speed. This can be attributed to heat energy input; the higher the heat input, the higher depth of penetration, hence more metal fusion at weld joint. There is also positive relationship between depth of penetration and tensile strength of the weld joint. This observation is attributed to improved bonding strength as depth of penetration increases. There exist a nominal value of welding current and gap width that when exceeded, the depth of penetration starts to decline. A current of 120Amps and a gap width of 1.5mm were found to be the optimal parameters for a fairly good depth of penetration.
From the data in table 3 and sample simulated model in figure 4 for a gap width of 0.15mm and welding speed of 210mm/min, the comparison below can be drawn:

TABLE 7: Comparison of experimental data with model data of DOP

Welding current	80Amps	100Amps	130Amps
Experimental data(DOP)	1.3mm	2.92mm	3.0mm
Model (DOP)	2.502mm	2.54mm	2.53mm
% Error	48.0%	14.9%	18.5%
Average % error			27%

The model predicts the expected quality in depth of penetration with small margin of error of 27% hence the model is valid.

IV. RECOMMENDATION

TIG welding consists of several variables and for this reason the research recommends welding speeds of 120mm/min-175mm/min. This welding speed range is sufficient if applied alongside welding current range of 100Amps-140Amps while limiting weld joint gap width of 0.15mm ±0.02mm for optimal welding control parameters for excellent weld quality.

Therefore, tungsten inert gas welding technology should be refined in order to make it adaptable and reliable. For this reason, the research is recommending that the welding parameters be subjected to further strong computation algorithms such as is fuzzy logics and neural networks in order to obtain clarity of interaction of welding control parameters with quality attributes. This will herald the application of artificial intelligence in order to help in choosing welding parameters while executing TIG welding.

Further specific research should be carried out on variety of l cutting edge metallic materials such as titanium and aerospace grade aluminum among others in order to refine control parameters to suit optimal quality welding attributes of these specific materials.

V. CONCLUSION

From this research, the effect of welding parameters on quality of the weld joint of TIG welding in mild steel was successfully investigated. The welding control parameters that were investigated were welding speed, welding current and gap width of joint. The weld quality was assessed based on quality parameters beadwidth, depth, of penetration, heat affected zone and ultimate tensile strength. Based on the results obtained, the following conclusions were drawn:

The numerical models can fairly predict the expected optimal values of welding control parameters that exhibit good weld quality. The models derived from the second response surface quadratic model are ideal for predicting expected control parameters and quality parameters of TIG welding. However, attention is necessary while defining constraints in the mathematical model in order to approximate to reality by choosing coefficient constants appropriately.

Numerical simulation makes it possible to see the interactions of welding current, welding speed and welding geometric gap width. The simulated models confirmed the validity of the mathematical models in comparison with experimental data. Hence the conclusion can be drawn that the second degree response surface quadratic models developed were valid with high degree of accuracy. It is important tool in modeling of TIG welding parameters and quality parameters of variety of engineering metallic materials that can be TIG welded.

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REFERENCES

[1] P. N. Patel, "A Review of Parametric Optimization of Tig Welding," International Journal of Computational Engineering Research, no. 04, pp. pp 27-31, 2014.
[2] N. Ramesh, "Parametric Optimization of TIG Welding Process in Butt Joining of Mild Steel and Stainless Steel," International Journal of Current Engineering and Technology, no. 6, 25 October 2016.
[3] B. Kokangul, "Mathematical Modeling for Prediction and Optimization of TIG Welding Pool Geometry," 2008.
[4] R. K. L. L. Y.M. Zhang, "Characterization and real-time measurement of geometrical appearance of the weld pool," Int. J.Mach. Tools Manuf, vol. 36, no. 7, pp. 799-816, 1996.
[5] S. Barik, "Advancement in welding technology and Materials: Improving Productivity," ROURKELA, 2013.
[6] K. Esme, "Mathematical Modeling For Prediction," Metalurgija, 2009.
[7] P. Mohan, "Study The Effects of Welding Parameter on TIG Welding of Aluminium Plate," 2014.