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Optimization and Prediction of Melting Temperature of Mild Steel Weldment, Using Genetic Algorithm

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Abstract
Melting temperature which indicates the temperature at which solid changes to liquid due to the application of heat is one of the important parameters considered in Tungsten Inert Gas (TIG) welding when appraising the integrity of welds. In the domain of welding, a good melting temperature results in the formation of a dense weld pool. This study is conducted to optimize and predict the melting temperature of mild steel weldment, using Genetic Algorithm. The result from theGenetic Algorithmshows that a combination of current of 239.03A, voltage 29.87V, welding speed 56.59mm/s, welding time 79.15sec, feed rate 130mm/s, will produce optimal melting temperature of 3432.46^{o}C.

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I. Introduction and literature review

Gas-Tungsten Arc welding (GTAW) is also identified as Heli Arc and TIG welding. Tungsten Inert Gas (TIG) is the ancient name for TIG welding process: it was formed during the late 1930s, during the time a desire for magnesium welding became obvious . The operation is known as Tungsten Arc Welding, then the modern nomenclature got popularity in technical books.

Rong-Hua (2003) studied the distribution of temperature in aluminium plates which are welded with tungsten arc. The following parameters were considered; the travel speed, the fusion heat, the heat conduction in the welding direction, distribution of the heat source, and the surface heat source. A numerical plan then was formed to find solution to the three dimensional problem. With the assistance of a mathematical model, the influence of welding variables such as the heat input of the weld, Source moving velocity on the penetration of the weld in moderately thick plates were discussed.

Patil (2013) Performed the welding parameters such as current, voltage, speed on the ultimate tensile strength (UTS) of A1511030 material of mild steel during welding. Taguchi method was used, an orthogonal array, signal to noise ratio and Analysis Of Variance (ANOVA) are employed to study.

Ravi Kumar (2014) studied the weld bead geometry in protected metal arc welding and that is multiple performance characteristics called grey relational garden and discovered the operation variables of welding current 140A, welding speed 4mm/sec and wind velocity 7m/s. Also found by ANOVA heat the most significant welding operation variable (47.71%) closely followed by (30.40%) welding speed and (19.54%) velosity respectively.

Ramanchandran (2015) Researched the different effects of the TIG welding on the Austenitic stainless steel 316L on micro structural alterations through destructive and nondestructive method and various parameters like tensile strength, hardness on varying the current, voltage and gas flow ratio respectively.

1.1 Using Genetic Algorithm

How the genetic algorithm works

Outline of the algorithm

1. The algorithm commences by forming a random initial population.

The algorithm then create a sequence of new populations.

2.Then at every step, the algorithm utilizes the individuals in the currents generations to form the fresh population. To form the fresh population, the algorithm executes the steps below

a. Grades every member of the present population by calculating its own value of fitness .
b. Weighs the present fitness grades to change them to a more applicable range of values.
c. Select the members, identified as parents, on the basis of their fitness.

d. Certain number of the individuals in present population which have the lower fitness are selected as the elite. Then these elite individuals are moved to the succeeding generation .
e. Create children out of the parents. Children are created by either random alterations to a one parent-mutation- or by joining the entries of the vector a two parents-crossover.
f. Replace the present population and the children to create the succeeding generation

1.2GENETIC ALGORITHM
Let X_1, X_2, X_3, X_4 and X_5 represent current, voltage, speed, time and feed rate respectively; f(x) the vector of fitness functions.
The optimization problem becomes

Min f(x), subject to

$$\begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \end{bmatrix} \geq 0; \begin{bmatrix} 160 \\ 20 \\ 35 \\ 50 \\ 70 \end{bmatrix} \leq \begin{bmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \end{bmatrix} \leq \begin{bmatrix} 240 \\ 30 \\ 75 \\ 80 \\ 140 \end{bmatrix}$$

The components of the fitness function, f(x) are

$$f_1 = 1438 + 20.6X_1 + 13.3X_2 - 8.2X_3 + 11.4X_4 + 11.2X_5 + 0.043X_1X_2 - 0.047X_1X_5 - 0.32X_2X_4 - 0.045X_4X_5 - 0.0458X_1^2$$

$$f_2 = 653 + 11.9X_1 - 5.9X_2 - 8.25X_3 - 3.38X_4 + 6.582X_5 + 0.032X_1X_5 + 0.033X_3X_4 - 0.03X_1^2$$

$$f_3 = 41 + 0.092X_1 - 0.52X_2 - 0.09X_3 + 0.39X_4 - 0.14X_5 + 0.00072X_1X_3 - 0.0021X_1X_4 + 0.0046X_2X_5 + 0.00069X_3X_5 - 0.0013X_3^2$$

$$f_4 = -74.124 + 0.3663*X_1 + 2.6655X_2 + 1.6834X_3 + 0.019708X_1X_2 - 0.0079X_1X_3 - 0.06204X_2X_3$$

$$\begin{bmatrix} f_1 \\ f_2 \\ f_3 \\ f_4 \end{bmatrix} = \begin{bmatrix} T_s \\ T_m \\ \eta \\ HI \end{bmatrix}$$

All but the melting efficiency are to be minimized. Since we desire to maximize the melting efficiency, ɳ, we therefore minimize – f_3
The following options along with the fitness function were fed into the genetic algorithm toolbox in MatLab software
Number of variables: 5
Population type: Double vector
Population size: 75 (15* Number of variable)
Creation function: Feasible Constraint dependent
Initial population: Default (created using the fitness function)
Initial score: Default
Initial range: Default – [0, 1]
Selection function: Tournament
Tournament size: 2
Crossover fraction: 0.8
Mutation function: Constraint dependent
Crossover function; Scattered
Migration fraction: 0.2
Migration Direction: Both
MigrationInterval: 20
Stopping Criteria

- Generations: 1000 (200* no of variables)
- Time limit: Infinite
- Fitness limit: Infinite
- Stall generations: 100
- Function tolerance: 0.0004

An initial population of seventy five (75) individuals was generated along with the associated Score values as shown in table 4.31.

Table 1. Population and Score

	Population					**Score**			
	I	V	V	T	FR	T_s	T_m	ɳ	HI
1	240.00	30.00	35.03	79.98	139.99	1155.40	3570.38	43.57	163.01
2	240.00	30.00	35.02	79.19	139.98	1158.94	3572.13	43.65	163.03
3	165.39	29.98	74.98	78.21	70.09	1234.76	2141.56	43.07	52.90
4	240.00	30.00	35.02	79.89	139.99	1155.80	3570.52	43.58	163.03
5	165.02	20.71	64.07	77.15	109.87	1386.84	2674.67	45.90	50.90
6	240.00	30.00	35.03	79.97	139.99	1155.43	3570.41	43.57	163.01
7	239.17	29.68	52.52	79.53	125.79	1234.79	3360.33	44.35	124.97
8	239.03	29.87	56.59	79.15	130.99	1230.89	3432.46	44.72	117.30
9	240.00	30.00	35.01	79.17	139.54	1160.07	3565.80	43.65	163.06
10	164.14	20.00	75.00	70.22	116.30	1386.17	2733.49	44.83	39.96
11	165.37	29.98	74.99	78.22	70.10	1234.61	2141.46	43.07	52.87
12	165.37	29.98	74.99	78.22	70.11	1234.62	2141.48	43.07	52.87
13	165.02	20.71	64.07	77.15	109.87	1386.84	2674.67	45.90	50.90
14	164.16	20.00	75.00	70.22	116.30	1386.23	2733.65	44.83	39.96
15	165.39	29.98	74.98	78.21	70.09	1234.77	2141.56	43.07	52.89
16	165.48	29.98	74.96	78.21	70.09	1235.28	2142.26	43.07	52.95
17	239.02	29.90	68.82	79.34	87.01	1356.26	2801.65	42.90	92.23
18	240.00	30.00	35.02	79.89	139.99	1155.80	3570.52	43.58	163.03
19	240.00	30.00	35.01	79.16	139.54	1160.11	3565.86	43.65	163.06
20	238.86	29.86	42.19	79.47	94.56	1285.25	2917.99	43.04	146.79
21	240.00	30.00	35.02	79.91	139.99	1155.71	3570.53	43.58	163.02
22	223.56	29.51	56.73	79.09	70.49	1391.90	2518.12	43.06	107.90
23	239.99	26.15	39.47	72.81	140.00	1234.91	3599.58	44.22	134.73
24	165.37	29.98	74.99	78.22	70.10	1234.61	2141.46	43.07	52.87
25	227.43	20.31	74.52	79.75	70.63	1527.50	2550.28	43.93	52.02
26	239.17	29.68	52.52	79.53	125.79	1234.79	3360.33	44.35	124.97
27	239.95	30.00	35.26	79.55	105.00	1240.65	3072.22	42.86	162.48
28	164.53	24.04	75.00	77.06	108.00	1333.16	2606.60	45.05	45.10
29	165.45	29.98	74.97	78.21	70.10	1235.10	2142.12	43.07	52.93
30	165.39	29.98	74.97	78.21	70.09	1234.79	2141.62	43.07	52.92
31	240.00	27.10	35.87	73.91	140.00	1214.06	3594.71	43.92	146.26
32	195.85	29.69	74.89	79.92	70.49	1367.86	2352.81	42.66	63.63
33	239.03	30.00	35.83	79.68	100.49	1255.79	3004.33	42.82	160.69
34	167.79	23.83	72.48	77.36	107.02	1350.28	2630.52	45.21	48.44
35	211.70	29.98	74.72	78.80	71.90	1398.85	2462.64	42.43	70.28
36	239.14	29.96	42.17	79.31	93.63	1285.61	2905.67	43.01	147.49
37	234.17	29.45	48.25	77.47	74.17	1362.12	2617.43	43.04	129.88
38	195.86	29.80	73.13	79.65	70.93	1366.42	2361.89	42.81	66.83
39	239.97	29.98	64.95	79.82	81.80	1356.69	2730.99	42.70	100.88
40	236.72	29.91	46.90	79.15	74.16	1346.64	2620.33	42.69	136.09
41	239.09	30.00	45.89	79.94	139.45	1184.22	3554.64	44.44	139.95

42	236.49	29.91	64.15	78.30	77.09	1375.36	2655.36	42.77	100.76
43	237.64	29.52	61.02	78.76	77.35	1370.69	2664.74	42.84	106.28
44	165.37	29.98	74.99	78.22	70.11	1234.62	2141.48	43.07	52.87
45	238.48	29.62	73.68	79.94	71.05	1406.23	2570.33	41.95	81.23
46	239.76	29.88	42.80	79.71	120.35	1221.83	3287.70	43.70	146.19
47	238.87	30.00	67.37	79.12	138.85	1234.09	3539.14	45.27	95.45
48	165.45	29.98	74.97	78.21	70.10	1235.10	2142.12	43.07	52.93
49	165.37	29.98	74.99	78.22	70.10	1234.61	2141.46	43.07	52.87
50	237.30	28.69	71.67	79.78	71.47	1414.02	2576.05	42.29	82.18
51	164.16	20.00	75.00	70.22	116.30	1386.24	2733.66	44.83	39.96
52	228.14	29.74	74.51	79.68	70.47	1413.55	2520.47	42.07	76.11
53	193.04	20.02	70.51	71.61	129.10	1459.66	3145.58	45.10	49.70
54	239.99	29.68	36.03	77.15	139.99	1173.83	3577.85	43.92	159.28
55	164.72	29.92	75.00	72.34	80.56	1250.98	2274.68	43.31	52.56
56	239.87	28.84	38.69	74.19	134.32	1213.56	3505.61	44.24	149.56
57	233.15	29.97	70.16	78.28	74.03	1396.29	2596.24	42.47	87.31
58	218.36	28.70	71.69	79.17	70.86	1418.95	2488.65	42.70	75.24
59	240.00	30.00	35.03	79.75	139.58	1157.45	3565.05	43.59	163.01
60	238.61	29.95	58.48	79.64	76.65	1358.86	2655.76	42.67	113.51
61	239.95	29.99	38.51	79.97	138.02	1167.70	3540.98	43.83	155.72
62	239.64	29.98	61.38	79.65	82.76	1348.06	2745.11	42.83	108.13
63	180.00	29.26	74.98	79.16	70.47	1316.18	2252.82	43.02	57.09
64	240.00	30.00	35.03	79.99	139.99	1155.37	3570.34	43.57	163.01
65	240.00	30.00	35.02	79.89	139.99	1155.80	3570.52	43.58	163.03
66	165.45	29.98	74.97	78.21	70.10	1235.11	2142.12	43.07	52.93
67	240.00	30.00	35.03	79.99	139.99	1155.38	3570.36	43.57	163.01
68	240.00	30.00	35.02	79.19	139.98	1158.94	3572.13	43.65	163.03
69	240.00	30.00	35.01	79.42	139.54	1158.95	3565.21	43.62	163.06
70	238.47	30.00	75.00	79.69	70.45	1405.98	2560.59	41.80	79.57
71	240.00	30.00	35.03	79.98	139.99	1155.40	3570.38	43.57	163.01
72	238.91	29.96	51.57	79.31	85.71	1323.70	2788.93	43.02	127.95
73	240.00	30.00	35.01	79.16	139.54	1160.11	3565.86	43.65	163.06
74	211.70	29.98	74.72	78.80	71.90	1398.85	2462.64	42.43	70.28
75	239.99	26.15	39.47	72.81	140.00	1234.92	3599.58	44.22	134.73

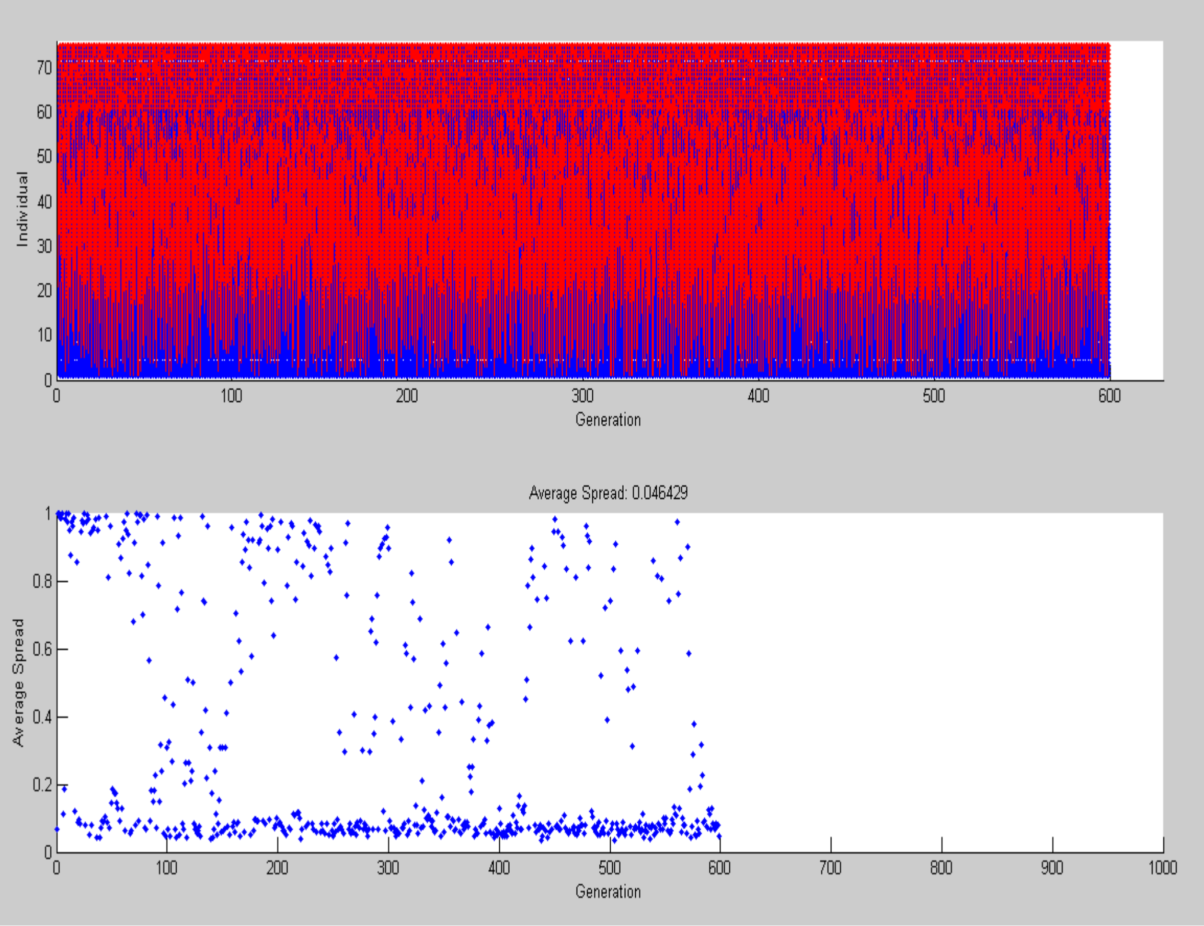

Fig 1. Plot of Genealogy and Average pareto spread

Fig 1. plots the genealogy of individuals. Lines from one generation to the next are color-coded as follows:

- Red lines indicate mutation children - formed by making small random changes in the individuals in the population, which provide genetic diversity and enable the genetic algorithm to search a broader space
- Blue lines indicate crossover children which are formed by combining two individuals, or parents, to form a new individual, or child, for the next generation
- Black lines indicate elite individuals which correspond to the individuals in the current generation with the best fitness values, the algorithm creates. These individuals automatically survive to the succeeding generation
- Twenty seven (27) solutions were obtained from iterations over six hundred (600) generations.

The solutions are as shown in table 2.

Table 2. Individuals and function values

	X					Fval			
	I	V	S	T	FR	T_s	T_m	ɳ	HI
1	239.03	29.87	56.59	79.15	130.99	1230.89	3432.46	44.72	117.30
2	164.14	20.00	75.00	70.22	116.30	1386.17	2733.49	44.83	39.96
3	239.02	29.90	68.82	79.34	87.01	1356.26	2801.65	42.90	92.23
4	165.37	29.98	74.99	78.22	70.10	1234.61	2141.46	43.07	52.87
5	239.95	30.00	35.26	79.55	105.00	1240.65	3072.22	42.86	162.48
6	164.53	24.04	75.00	77.06	108.00	1333.16	2606.60	45.05	45.10
7	240.00	27.10	35.87	73.91	140.00	1214.06	3594.71	43.92	146.26
8	195.85	29.69	74.89	79.92	70.49	1367.86	2352.81	42.66	63.63

9	239.03	30.00	35.83	79.68	100.49	1255.79	3004.33	42.82	160.69
10	239.14	29.96	42.17	79.31	93.63	1285.61	2905.67	43.01	147.49
11	195.86	29.80	73.13	79.65	70.93	1366.42	2361.89	42.81	66.83
12	239.97	29.98	64.95	79.82	81.80	1356.69	2730.99	42.70	100.88
13	236.72	29.91	46.90	79.15	74.16	1346.64	2620.33	42.69	136.09
14	239.09	30.00	45.89	79.94	139.45	1184.22	3554.64	44.44	139.95
15	239.76	29.88	42.80	79.71	120.35	1221.83	3287.70	43.70	146.19
16	238.87	30.00	67.37	79.12	138.85	1234.09	3539.14	45.27	95.45
17	228.14	29.74	74.51	79.68	70.47	1413.55	2520.47	42.07	76.11
18	164.72	29.92	75.00	72.34	80.56	1250.98	2274.68	43.31	52.56
19	233.15	29.97	70.16	78.28	74.03	1396.29	2596.24	42.47	87.31
20	240.00	30.00	35.03	79.75	139.58	1157.45	3565.05	43.59	163.01
21	238.61	29.95	58.48	79.64	76.65	1358.86	2655.76	42.67	113.51
22	239.95	29.99	38.51	79.97	138.02	1167.70	3540.98	43.83	155.72
23	239.64	29.98	61.38	79.65	82.76	1348.06	2745.11	42.83	108.13
24	240.00	30.00	35.03	79.99	139.99	1155.37	3570.34	43.57	163.01
25	238.47	30.00	75.00	79.69	70.45	1405.98	2560.59	41.80	79.57
26	238.91	29.96	51.57	79.31	85.71	1323.70	2788.93	43.02	127.95
27	211.70	29.98	74.72	78.80	71.90	1398.85	2462.64	42.43	70.28

II. Methodology and Theory

The method of achieving the objectives of the research is explained in this chapter.

III. Results and Discussion

In this study, Genetic Algorithm was used to predict the melting temperature of TIG welds. The result shows that a combination of current of 239.03A, voltage 29.87V, welding speed 56.59mm/s, welding time 79.15sec, feed rate 130mm/s, produce optimal melting temperature of 3432.46^{o}C.

IV. Conclusion

The integrity of a weld is determined by the quality of the weld bead geometry. Melting temperature which indicates the temperature at which solid changes to liquid due to the application of heat is one of the important parameters considered in TIG welding when appraising the performance of the welds. In this study, model to optimize and predict melting temperature of mild steel has been developed. In this study, an approach utilizing the genetic algorithm for optimizing and predict weld melting temperature of mild steel weldment to improve the integrity of welded joints has been successfully introduced and its effectiveness and efficiency well demonstrated.

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