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

Godfrey Sibete[1],Tonbra Eyitemi[2]

[1]Department of Mechanical Engineering, Niger Delta University,Wilberforce Island, Bayelsa state, Nigeria.

[2]Department of Mechanical Engineering, Nigeria Maritime University, Okerenkoko, Delta State, Nigeria.
godfresibet@yahoo.com

ABSTRACT

Solidus temperature which indicates the temperature at which an alloy is completely solid is one of the important parameters considered in the welding of alloy in Tungsten Inert Gas (TIG) welding when assessing the performance and integrity of an alloy. In the field of welding, and metallurgy, a good solidus temperature results in the formation of high quality alloy. In order to achieve a good solidus temperature, the optimization and prediction of solidus temperature of mild steel weldment, using genetic algorithm is studied. The purpose of this study therefore is to develop model that would minimize solidus temperature. The result from the genetic algorithm 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, will produce optimal solidus temperature of 1230.89oC.

1. Introduction and Literature Review

The welding industry as a whole incorporates several means and methodologies of completing welding projects. MIG welding, soldering and arc welding are just the start of an extensive list. Another way to fuse metals come in the configuration of (TIG) welding. Tungsten Inert Gas is a method that utilizes an electrode of tungsten to heat up the metal which is welded. To shield the weld from impurity while welding, protecting in form of an inert gas, such as argon, is utilized and may also be utilized for any other metals/thickness.TIG welding is valued highly as a result of itsquality, versatility and usability. Truly, the operation can be employed to other metals more than any other technique, able to weld metals such as copper, steel, brass, bronze, magnesium, nickel, aluminium, and gold..

Gadewar et al (2010) Studied the influence of operation variables of TIG welding like current, work piece thickness of the geometry of the bead of SS304,gas flow rate. It was discovered that the operation variables studied have effect on the mechanical properties to a large extent.

Esme et al (2009) Studied the multi-response optimizing of TIG welding for the optimal variable combination to producefavourable geometry of the bead of joints welded utilizing the analysis of Grey rational and the method of Taguchi.

Kishore et al (2010) analysed the influence of operation variables for the welding of AA6351, utilizing the TIG welding. Many control agents were discovered to influence weld quality predominantly. The percentage contributes from each parameter were computed by means of which optimal variables were identified. ANOVA method was used to check the adequacy of the data obtained.

In agreement with Myers et al 1989) many industries today, now apply the Response Surface Methodology in formulating new products, especially in the chemical engineering industries, where there is need for the process optimization.

2. Methodology and Theory

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

2.1 Using Genetic Algorithm

How the genetic algorithm works

Outline of the algorithm

1. The algorithm begins by creating a random initial population.

2.The algorithm there after form a product of fresh populations. 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 ground 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

2.2 GENETIC 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 except the melting efficiency are to be minimized. Since we desire to maximize the melting efficiency, η, 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 4.31 Population and Score

	Population					Score			
	I	V	V	T	FR	T_s	T_m	ƞ	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

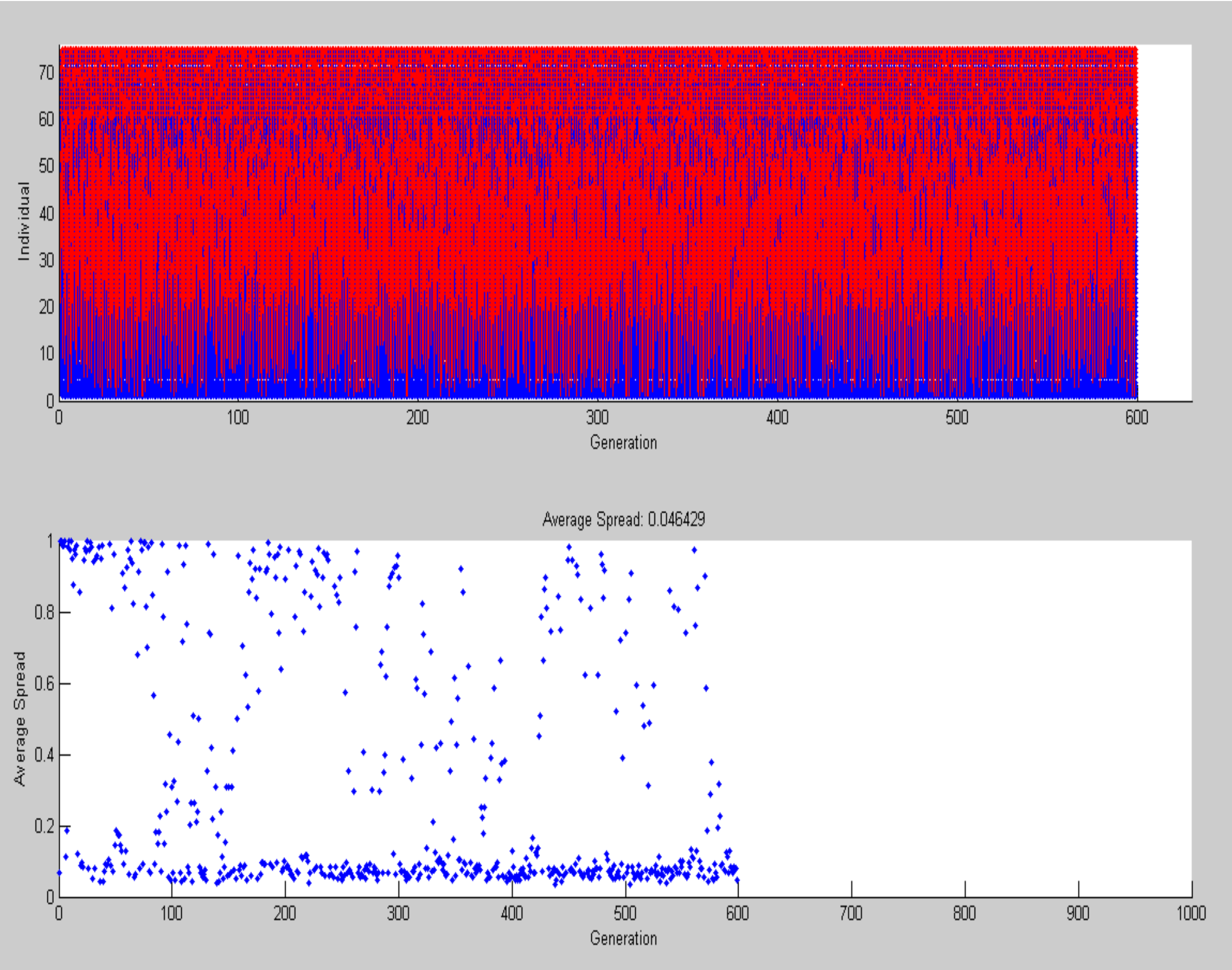

Fig 4.42 Plot of Genealogy and Average pareto spread

Fig 4.42 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 present generation with the best fitness values, the algorithm creates. These individuals automatically survive to the next generation
- Twenty seven (27) solutions were obtained from iterations over six hundred (600) generations.

The solutions are as shown in table 4.32 while the generations are shown in table 4.33

Table 4.32 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

3. Results and Discussion

In this study, Genetic Algorithm was used to predict the solidus temperature of the 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, will produce optimal solidus temperature of 1230.89^{o}C.

4. Conclusion

The integrity of a weld is decided by the quality of the weld bead geometry. Solidus temperature is a very important factor considered in assessing the integrity of an alloy. In this study, model to optimize and predict solidus temperature of the mild steel has been developed. In this study, an approach employing the genetic algorithm for optimizing and predicting weld solidus temperature of the 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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