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

Sibete. G[1], Eyitemi. T[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.

Corresponding Author: Godfrey Sibete

ABSTRACT

Melting efficiency which indicates how much of the heat deposited by the welding operation is used to produce melting is one of the most important parameters considered in Tungsten Inert Gas (TIG) welding when assessing the performance of welds. In the field of welding, a good melting efficiency results in the development of a dense weld pool. This study is conducted to optimize and predict the melting efficiency of mild steel weldment, using Genetic Algorithm. Genetic Algorithm (GA), which is an optimization method that mimics the evolution process and operates on the basis of the theory of natural selection and evolution was used to analyse the results. The result shows that a combination of current 239.03A, voltage 29.87V, welding speed 56.59mm/s, welding time 79.15 sec, feed rate 130mm/s, will produce optimal melting efficiency of 44.72.

Keywords: Melting Efficiency, Mild Steel Weldment, Genetic Algorithm, Optimization and Prediction

1. INTRODUCTION AND LITERATURE REVIEW

The TIG welding process is extensively used in modern industrial manufacturing, this process is known for its economy, ability to join similar and dissimilar metals at very high temperature, low heat affected zone, absence of slag, good weld appearance, high quality weld, high heat concentration with little or no smoke or fumes made it suitable for both ferrous metals. Basically, TIG weld quality is strongly distinguished by the weld bead geometry.

Urena et al (2014) investigated the influence of the interface transformation between the Al alloy matrix and SiC particle reinforcement on the rupture behaviour in TIG welded Al matrix composites. TIG welding was performed on AA2014/SiC/Xp sheets of 4mm thickness utilizing current settings in the range of 37-155 A and voltage of 14-16.7 V. It was discovered from the experimental results that, the failure happened in the weld metal with a tensile strength that is lower than 50% of the parent material. Fracture of the joint welded was controlled by interface deboning through the interface reaction Layer. Probability of interface failure rises in the weld zone due to formation of Aluminium-carbide which lowers the matrix/ reinforcement interface strength.

Simhachalam et al (2015) carried out studies on the influence of welding operation parameters on the mechanical properties of stainless steel -316 (18Cr-8N) welded by TIG welding. The size of the specimen is 40x15x5mm for the experiment discovered that the current has a very important effect, though the filler rod also have some influence which is also similar to the current but when compared to current it is less important. MINITAB software is employed for the prediction of the depth of penetration, hardness and impact strength.

Sanjeev (2016) did the experiment for the optimization of the condition for performing the welding on Utra-90 specimen where he alters the current and the voltage while the gas flow rate is kept constant and discovered that the welding joint which is not made properly below 50A and above 200A, from there the burning of specimen started.

Ravinder(2016) researched the Optimization of the parameters of TIG welding of stainless steel (202) with mild steel by utilizing Taguchi method and discovered the control factor that had changing influence on the tensile strength, the arc voltage which have the highest influence and also discovered the optimum parameter for the tensile strength, current 80 A, Arc voltage 30 V and GFR 6 lt/min.

2. METHODOLOGY AND THEORY

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

2.1 Using Genetic Algorithm

1. How the genetic algorithm functions
2. Outline of the algorithm

a. The algorithm starts by forming a random start population.
b. Then the algorithm forms a sequence of new populations. At every step, the algorithm utilizes the individuals in the currents generations to form the new population. To form the new population, the algorithm does the following steps below.
c. Gives score to every member of the present population by calculating its fitness value.
d. Weighs the raw fitness scores to change them into a more useful range of values.
e. Members are identified as parents, on the basis of their fitness.
f. Certain individuals in present population having lower fitness are then selected as elite. These elite individuals are moved on to the next population.
g. forms children from the parents. Children are formed by either random alterations to a single parent-mutation-or by combination of the vector entries of a pair parents-crossover.
h. Replace the present population and the children to produce the next 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 but 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
Migration Interval: 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	η	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

Table 4.31 Continued...

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

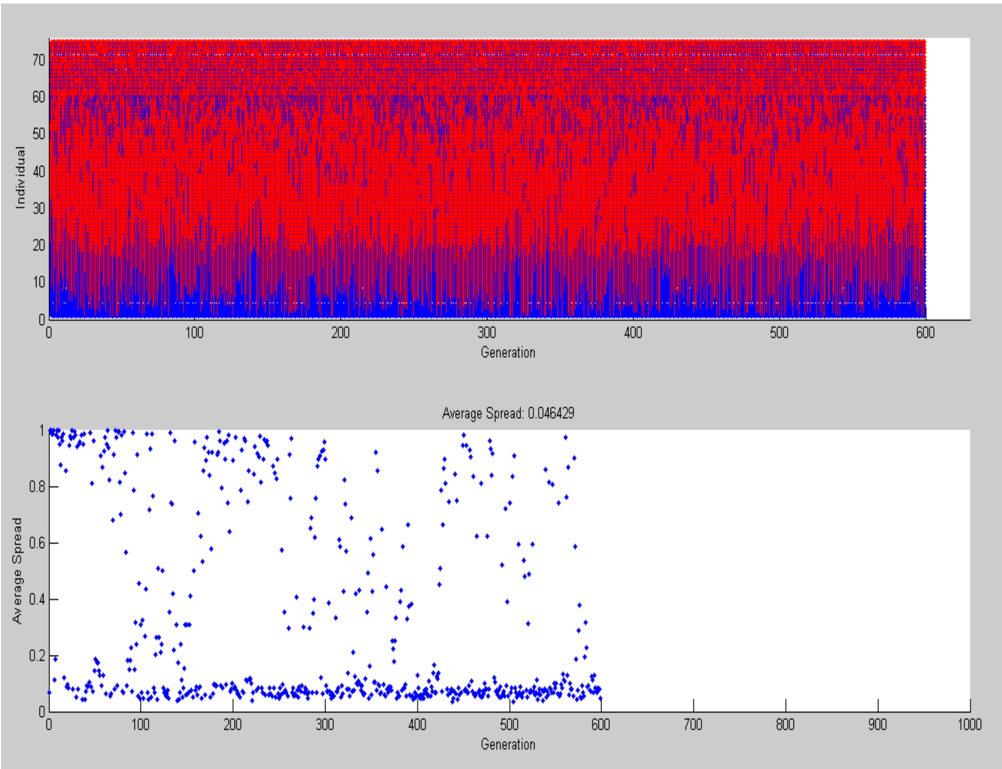

Fig 4.42 Plot of Genealogy and Average pareto spread

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	η	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 which is an optimization method that mimics the evolution process and operates on the basis of the theory of natural section and evolution was used to analyse the results. The result shows that a combination of current of 239.03A, voltage 29.87V, welding speed 56.59mm/s, will produce optimal melting efficiency of 44.72

4. CONCLUSION

The integrity of a weld is ascertained by the quality of the weld bead geometry. Melting efficiency is a significant factor considered in assessing the integrity of the weld. In this study, an approach using the genetic algorithm for optimizing and predicting weld melting efficiency 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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