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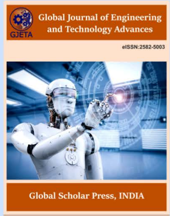

(REVIEW ARTICLE)

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Optimization and prediction of heat input of mild steel weldment, using genetic algorithm

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Abstract

In welding materials, the purpose is to resist the variation of the microstructure of the material and retain the mechanical properties and the chemical properties. Most welded joint fail due to the utilization of poor welding process. This poor welding process produces a minimum heat input that could cause insufficient melting of the electrode, insufficient melting of the electrode is responsible for inadequate penetration of liquid metal into the welded joint. Literature has shown that produced welded joints by insufficient penetration of the liquid metal have low bearing capacity. This indicates that such welded joints would not be able to sustain the design load. In order to achieve deep liquid metal penetration, optimizing and prediction of heat input of mild steel weldment, utilizing genetic algorithm is studied. The purpose of this study therefore is to develop models that would minimize the heat input. Genetic Algorithm which imitates the evolution progression and functions on the principle of the natural theory choice with evolution was utilized for the result analysis. It was shown as a result that combination of welding time 79.15 sec current of 239.03 A welding speed of 56.59 mm/s voltage of 29.87 v feed rate of 130 mm/s will produce optimal heat input of 117.30 KJ

Keywords: Optimization; Prediction; Heat; Heat Input; Mild Steel; Weldment.

1. Introduction

1.1. Literature Review

Welding is the operation of merging two metal pieces or plastic together by heating to their melting temperature in addition to or the absence of the pressure and in addition to or the absence the utilization of filler metal. The filler metal have a melting point almost same as the base metal. When a welded joint becomes too hot, it dissipates the heat quickly, cooling too quickly, causing internal stress in both the weld and base metal [1]. Ordinarily, quicker rates of cooling causes damage to the welded part due to the fact that they cause the zone affected by heat to break. According to [2], the effort to quantify residual stresses in welding and the effort to quantify flow of heat goes back to the 1930's when [3] developed analytical model for welding theory. The reason heat input is extremely important in certain application is due to the fact that it holds large bearing on its cooling rate. [4] described heat input as a comparative quantity of the transferred energy per length of the weld. Just as the preheat and the interpass temperature, it is a significant feature as it has influence on the rate of cooling, that can also affect the metallurgical structure of the weld, the heat affected zone, as well as the mechanical properties .It is generally well known that increased heat input results in breaking of the weld metals and the vicinity of the HAZ [5] .The breaking happens due to the development of severe residual stress and unnecessary metallurgical alterations in the welded part. Also, excess heat input can bring about too much volume

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of the ferrite content of the weld deposit, which reduces the corrosion resistance and leads to premature failure during service [5].

[6] investigated the impart of changing the heat input on properties of manual metal arc deposits having 0.6 – 1.8% Mn and microstructure. He varied the heat between 0.6 and 4.3KJ/mm and observed an increase in bead size followed by a minimization in the volume of acicular ferrite and a general coarsening of the joint welded in the microstructure.

2. Methodology

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

2.1. Using Genetic Algorithm

2.1.1. How the genetic algorithm functions

Algorithm outline

- The algorithm starts by forming an arbitrary original population.
- 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 performs the steps below
  - Grades every member of the present population by calculating its own value of fitness.
  - Weighs the present fitness grades to change them to a more applicable range of values.
  - Select the members, identified as parents, on the ground of their fitness.
  - Certain number of the individuals in present population which have the lower fitness are selected as the elite. Then these individual elites are moved to the succeeding generation.
  - 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.
  - 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

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

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

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

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

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

All others except the melting efficiency are minimized. Since we want to increase the melting efficiency, ɳ, we consequently decrease – 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
Original population: Setting (formed utilizing the fitness function)
Original score: Default
Setting original range: Default – [0, 1]
Choice 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
Ending Standard

- Generations: 1000 (200* no of variables)
- Limit of time: Endless
- Soundness limitation: Endless
- Stop generations: 100
- Function acceptance: 0.0004

An original 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

Sr. No.	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 plots the genealogy of individuals. Lines beginning at one generation unto succeeding generation are colored as follows:

- Red lines represent mutation children - formed by making little arbitrary variations in the individuals in the population, which provide genetic difference and allow the genetic algorithm check a larger area.
- Blue lines indicate crossover children which are formed by combining two individuals, or parents, to form a new individual, or child, in the generation next.
- Black lines indicate elite individuals which correspond to the individuals in the present generation having the best fitness values, the algorithm creates. These individuals spontaneously continue to exist to the succeeding generation.
- Twenty seven (27) solutions were obtained from iterations over six hundred (600) generations.

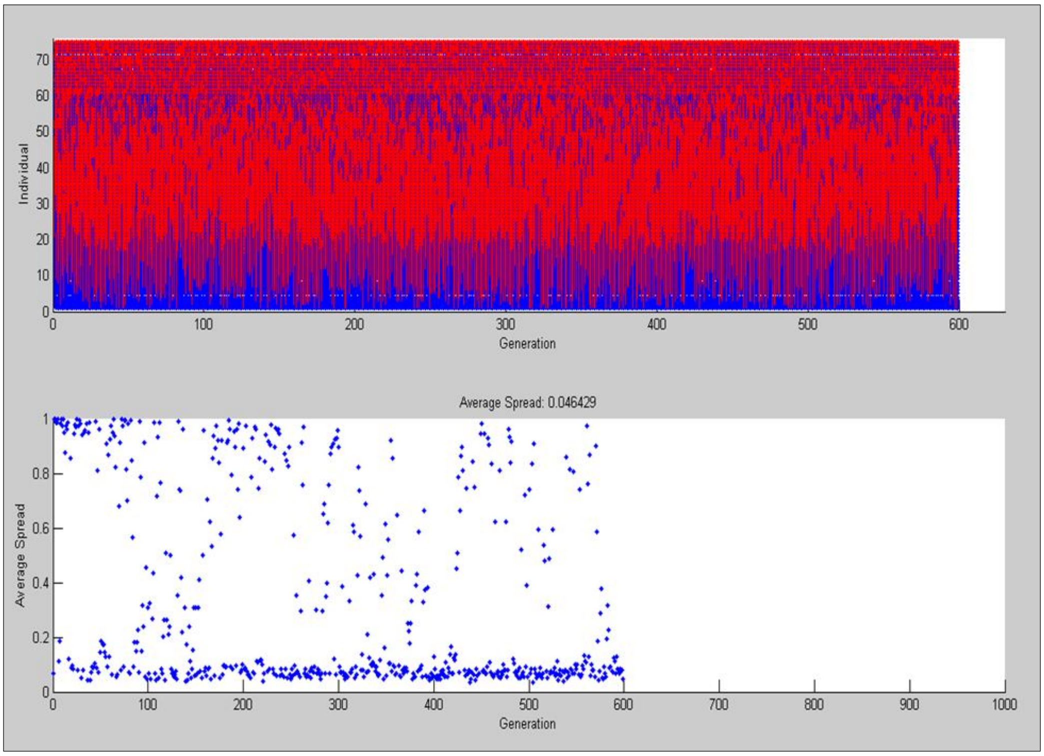

Figure 1 Plot of Genealogy and Average pareto spread

The solutions are as shown in table 2 below

Table 2 Individuals and function values

Sr.No.	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 was used to predict the heat input of TIG welds. The result displays that combination of feed rate 130 mm/s voltage 29.87 v welding time 79.15 sec current 239.03 A welding speed 56.59 mm/swill produce optimal heat input of 117.30 KJ.

4. Conclusion

The quality of a weld is decided by the heat input degree of the weld metal, the lower the heat input the better the quality of the weld. In this study, model to optimize and predict heat input has been developed. In this study, an approach utilizing the genetic algorithm for optimizing and predicting weld heat input of the mild steel weldment to improve the integrity of welded joints has been successfully introduced and its effectiveness and efficiency well demonstrated.

Compliance with ethical standards

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Disclosure of conflict of interest

In this research work the two authors have a common concern or aim, as such have both contributed significantly towards the success of this study. The two authors are compatible as there is no conflict of interest.

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