# Genetic Algorithm for Optimization using Genealogy Plots to Investigate the Influences of Heat Input Ratio on Burn - Through Prevention at a GTAW Process

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***Abstract:** Gas Tungsten Arc Welding (GTAW) offers a variety of shielding gas for joining different steel plates with different thicknesses. It is a technique that enhances the service performance of welded joints using different gas flow rate values so as to have comparison between the joints made. To avoid weld burn-through, excessive heat input and too high welding current must be regulated at a GTAW process so as to control welding current and achieve a sufficient heat input that will prevent weld burn-through and produce quality welds free from spatter. During welding, escape of gas when prevented, will produce clean joints, slow cooling (allows gases to escape) and proper shielding (absorbing the gases $C0_2$, $N_2$ and $H_2$ from the atmosphere). This paper investigates burn-through prevention in welds produced, using Genetic Algorithm (GA) for optimization using genealogy plots to study the influence of Gas Flow Rate (F) ,welding current and heat input ratio on burn-through in welds. Genetic Algorithm was used for optimization in order to reach optimal solution after satisfying constraints used. In order to alleviate the problem that burn -through defect poses on welds, a matrix design was developed to determine the experimental results obtained and the results were applied to the GA model for optimization in order to obtain optimal values of responses as well as optimal values of input process parameters. Genealogy plots were used to validate the model. The genetic algorithm optimization results showed that the gas flow rate should be set to 17.67 lit/min for optimum input process parameter value. Heat input ratio optimal values of 21.96KJ/min and welding current optimal value set at 167.3 amperes were established.*

***Index Terms:** Genetic Algorithm (GA), Genealogy plots, Heat input Ratio, welding current (I), Burn-through defect and GTAW process*

## I. INTRODUCTION

The Gas Tungsten Arc Welding (GTAW) process, is one of the techniques of manufacturing, widely used for joint welding. Formation of appropriate weld bead free from burn-through effect is dependent on proper selection of input process parameter such as welding current. Optimum parameter value selection is done using the GA models. In this research, Genetic Algorithm (GA) is used to select the optimum input process parameters and the relationship between the optimum values and optimal values were determined. Genetic Algorithm settings used a population type called the double vector using a 50 population size, Randomly selected at a 100 generation. A scaling function using rank, with a Roulette Wheel Selection (RWS) function, elite count of 2 and a cross over fraction of 0.8 was used for the investigation.

## II. LITERATURE SURVEY

1. Parks, G. T., Miller, J., (2001) An Empirical Investigation of Elitism in Multi-objective Genetic Algorithm. Was investigated by the Author. Elitism, which is choosing the fittest individuals in a selection was used to carryout a multi-objective optimization setting. Excess penetration as a defectives checked using GA model. Input process parameters such as welding current, (I) welding angle, ($W^o$) travel speed Ts and Heat Affected HAZ zone were used to analyze the effect of excess penetration on mild steel plate and the responses: weld penetration (up) and Dilution rate (DR) were optimized. Optimal process parameters for the GA model for weld penetration WP= 20.02mm$^2$ and Dilution Rate DR = 43.3%. optimal values for input process parameters were
   Current I = 136.3
   Welding angle $W^o = 15^o$
   Travel speed Ts = 83mm/min
   Heat Affected Zone HAZ = 19.51
   The weld defect, Excessive penetration was investigated and the optimal parameter settings obtained when use, will help to eradicate excessive weld penetration in welded products.

## III. PLANNING AND SET UP OF EXPERIMENTAL INVESTIGATION

The dimension of the bead- on- plate at a GTAW process, is greatly dependent on the number of factors. Hence, This research have selected two factors: Gas flow rate (lit/min) and heat input (KJ/min). The filler metal used in the ER 70 S-6, the welding experiment was performed using shielding Argon gas (100%) as well as using the miller multi -purpose welding machine.

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**TABLE 1: Filler Metal Used In the Welding Experiment**

| Filler metal type | Filler metal mark (standard) | Diameter | Weight | Melting temp. |
|---|---|---|---|---|
| Solid wire | ER 70 S-6 | 3.2mm | 78.5kg/m$^2$ | |

The heat input of the test welds were varied from 20 – 24KJ/min using variations in speed from 70 – 110 mm/min. As a result, this process can produce neat welds free from porosity over a wide variety of joints.

Equipments

- Facial mask
- GTAW torch
- Miller multi- purpose welding Machine
- Abrasive
- Grinding Machine
- Shielding gas cylinder with Argon gas

**Figure 1: Final welded specimen**

**Fig 2: Sectioning of a 10mm thick mild steel plate**

**Fig 3: An abrasive and a polished test sample**

A V – groove of angle 60$^0$ tacked weld, using GTAW was welded using a flat position (IG). In this investigation, optimization using Genetic Algorithm and validation, using genealogy plots to investigate the influence of heat input ratio on burn- through prevention at a GTAW process, was thoroughly investigated with the algorithm setting of Heat Input Ratio (H.I.R) as shown in Table 2. Table 2 shows the heat input F-count values plot and Table 5, shows the analysis for the genealogy plot. The values of the welding current, welding voltage, welding speed and gas flow rate was recorded in Table 3. Heat input was calculated using equations. Equation for calculating heat input values:

$$Heat\ input = \frac{v\ x\ I\ x\ 60}{S\ x\ 1000}\ (KJ/min$$

**TABLE 2: Heat Input F – Count Values for Genetic Algorithm (GA)**

| Iterations | Generations | Chromosomes | Best F-count | Mean f (x) | Stall generation |
|---|---|---|---|---|---|
| 1 | 800 | 1100100000 | 20.71 | 23.87 | 2 |
| 2 | 850 | 1101010010 | 21.96 | 23.47 | 3 |
| 3 | 900 | 1110000100 | 23.71 | 22.63 | 4 |
| 4 | 950 | 1110110110 | 24.71 | 21.16 | 5 |
| 5 | 1000 | 11111010000 | 26.71 | 22.55 | 6 |
| 6 | 1050 | 11010100010 | 20.98. | 20.91 | 7 |
| 7 | 1100 | 10000100100 | 26.71 | 22.18 | 8 |
| 8 | 1150 | 10001111100 | 25.71 | 26.46 | 9 |
| 9 | 1200 | 10010110000 | 21.96 | 25.68 | 10 |
| 10 | 1250 | 10011100010 | 22.71 | 26.14 | 11 |
| 11 | 1300 | 10100111000 | 25.71 | 26.32 | 12 |
| 12 | 1350 | 10101000110 | 21.86 | 24.54 | 13 |
| 13 | 1400 | 10101111000 | 24.71 | 22.43 | 14 |
| 14 | 1450 | 10110101010 | 25.71 | 23.74 | 15 |
| 15 | 1500 | 10100111100 | 23.67 | 24.41 | 16 |
| 16 | 1550 | 11000001110 | 21.79 | 20.86 | 17 |

Optimization using tool box of MATLAB

Genetic Algorithm (GA) setting:

Population size = 50

Stall generation = 100

Probability of mutation/uniform rate = 8.0, Cross over rate = 0.8

**TABLE 3: Factors and Their Units**

| Factors | | Low | High | Units |
|---|---|---|---|---|
| Current | I | 100 | 170 | Ampere |
| Voltage | V | 14 | 20 | Volts |
| Speed S | S | 70 | 110 | mm/min |
| Gas flow rate | F | 12 | 19 | Lit/min |

Constraints:

Subject to the constraints that H.I.R takes the maximum value and

$1_{min} \leq I \leq I_{max}$ i.e $100 \leq I \leq 170$ Amperes

$V_{min} \leq V \leq V_{max}$ i.e. $14 \leq V \leq 20$ volts

$S_{min} \leq S \leq S_{max}$ i.e. $70 \leq S \leq 110$ mm/min

$F_{min} \leq F \leq F_{max}$ i.e. $12 \leq F \leq 19$ lit/min

steady state error and reference signal. This result in from a 50 optimisation runs with a 100 generation as shown in fig 4. The genealogy plot shows errors lying between the referencesignal point 0 and the system output signal at pointis changed in such a way that the error between the referernce signal from point O and the system output signal at point 50,it increases from 0 to 50, hence fitness values of global optimality lies here.

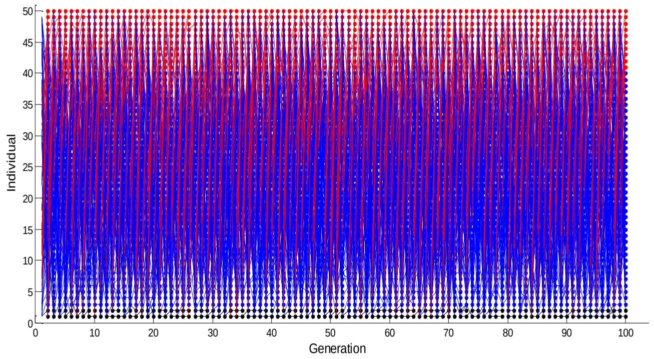



**Fig 4: Genealogy plot for Heat Input Ratio**

Analysis of genealogy plot
Red colours (represents cross over children)
Blue colours (represents mutation children)
Black colour (represent Elite children)

**TABLE 5: Responses and The Fitness Function**

| Response | Heat input ratio KJ/mm (HIR) |
|---|---|
| Heat input ratio (HIR) | KJ/mm |
| Genealogy plot for individuals | Increased control signal |
| Best network for response | 10 – 35 individuals |
| Error zone | 36 – 50 individuals |
| Fittest individual | 0 – 30 generations |
| Cross over rate | 0.8 |
| Mutation rate | 0.01 |
| Fitness function optimal value from genealogy plot | 21.96KJ/mm |

**TABLE 6: Results of Genetic Algorithm Optimal Values**

| Factors | | GA optimal values (Genealogy plots) | |
|---|---|---|---|
| Welding current I | 100 – 170 Amp | 137.3 amperes | |
| Welding speed S | 70 – 110 mm/min | 88.6 mm/min | |
| Welding volts V | 14 - 20 Volts | 18.2 volts | |
| Gas flow rate F | 12 – 19 Lit/min | 17.67 lit/min | 16.27lit/min |

## IV. VALIDATION OF RESULTS

**Table 7: Genealogy Heat Input Ratio (KJ/mm)**

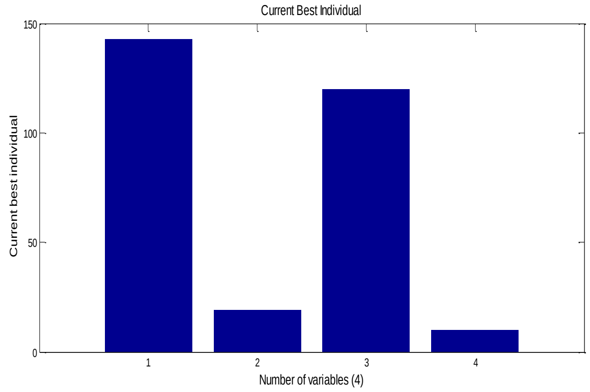
| | |
|---|---|
| Maximum shoot | 0.990 |
| Steady state error | 0.001 |
| Genealogy plot for individuals 15, 10 and 5 | increase control signal |
| Function | Heuristic |
| Creation Function | Uniform |

Using colours, the red colour represent the cross over children and the infeasible region, the blue region represent the mutation children and the feasible region where there is best network with minimal errors (little or no discrepancies). The black region represents the Elite children.

A steady state of 0.0001 was reached after 50 generations which remained constant further. Optimized values for weld penetration Area using a bead –on-plate procedure in a Gas Tungsten (Arc welding (GTAW) process = 20.27mm$^2$ from the genealogy plots. Current and speed were process parameters that played key roles with Gas flow rate and voltage constant. The errors lied between individuals 40 and individuals 50 as fittest Individuals lie between Individuals 0-30.

### A. Current best individual for heat input ratio

The variables (process parameters) are current, voltage, speed and gas flow rate. From the figure above, the current best individuals identified by the genetic algorithm model are welding current and welding speed. It clearly shows that high welding current affects the response (weld penetration area) as well as speed.




Welding current 2-welding voltage 3-welding speed 4-gas flow rate Fig. 5: Current best individual for heat input ratio

The value of current is 142amperes, voltage is 19volts, speed is 120mm/min, gas flow rate is 16Lit/min. The gas flow rate is high, speed is high, voltage is high and the current is also high. This shows that heat input ratio as a response parameter presented input parameter values that were high using the Genetic Algorithm model.

**Table 8: Comparison of Genealogy Plot for the three dimensions**

| | H.I.R |
|---|---|
| Maximum shoot | 0.990 |
| Steady state error | 0.0001 |
| Genealogy plot for individuals | Increased control signal |
| Function | Heuristics |
| Creation Function | Uniform |
| Fitness function from genealogy plot | 21.96 |

Heat Input Ratio optimal values lie within the blue region of 10- 35 individuals and the best Network for genealogy plot for percentage dilution lie within the blue region of 10- 45 individuals. The fittest individuals lie between generation 0-20 for weld penetration Area, Generation 0-30 for Heat Input Ratio and Generation 0-50 for percentage Dilution.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## V. CONCLUSION

The Genetic Algorithm optimization estimated a solution (heuristics) for the response Heat Input ratio as 21.96kJ/min with a welding current of 137.3amperes .Welds produced using obtained optimal values ,were free from burn-through defect as a moderate current of 137.3 amps ,using a correct filler metal such as ER70 S 6 and a moderate welding speed of 88.6 mm/min ,power supply using voltage of 18.2 volts with a gas flow rate of 17.67 lit/min were established.

## VI. CONTRIBUTION TO KNOWLEDGE

1 .optimization of heat input ratio was established using Genealogy plots.

2. A sufficient amount of welding current that will prevent burn-through in welded joints have been established.

3. A welding speed not too fast, with a short arc length, and adequate supply of Voltage using the optimal parameters ,was established in this study.

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## AUTHOR'S PROFILE

**Omoyibo – Kingsley, Queeneth Adesuwa** is a researcher in the field of welding Engineering, was born 5th of July and is a member of the Nigeria society of Engineers (MNSE) 2016 and a registered member of the council for the regulation of Engineering practices in Nigeria (COREN)2016. she earned her undergraduate degree (B.Eng) in Petroleum Engineering in 2006 from the University of Benin, UNIBEN, Benin City, Edo State, Nigeria. She has a Masters degree in Industrial Engineering (M.Eng) from the Department of Production Engineering from the same University in 2012. She is a doctoral student (Ph.D), in the Department of Production Engineering (Industrial Engineering option) for 2014/2015 session, from the same University. Her research interest are in the area of Production Engineering( Industrial option ) with specific interest in metal joining process, weld parameter optimization, weld defects avoidance, weld quality enhancement , Gas wastage reduction/eradication, scheduling/sequencing and Engineering mathematics. Professor Joseph Ikechukwu Achebo is a researcher and a professor in the field of welding engineering