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Optimization of Process Parameter of Submerged Arc Welding By Using Response Surface Method and Genetic Algorithm

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Abstract-*Submerged arc welding (SAW) is a high quality, high deposition rate welding process commonly used to join plates of higher thickness The main objectives to identify main factors, viz. Current, Voltage, Standoff distance and Travel speed, there way of affecting the welding bead parameters, influence of the interactions among the main factors and finally to determine the optimum settings of the main factors. An orthogonal array is constructed for four input process parameters a) Welding current, b) Voltage c) Standoff distance, d)Travel speed to the value of temperature. A probability distribution curve is drawn with help of MINITAB software to ascertain the validity of the experiments where the results fall close to the mean value. Using RSM model a linear equation is obtained and feeding this equation in Genetic Algorithm to get final equation.*

Keywords-"Submerged arc welding; SAW, response surface method; RSM, genetic algorithm; GA."

INTRODUCTION

There are many types of manufacturing process is available such as casting, forging, welding. From many manufacturing process, welding is very common and most popular types of fabrication process. Welding is a process of joining different materials. It is more economical and is a much faster process compared to both casting and riveting .Welding is classified in many ways such as by joining similar metal and joining dissimilar metals. A dissimilar type of welding is further classified in many ways such as fusion welding, non-fusion welding and low dilution welding. But we will be discussing only on submerge arc welding which is under the fusion welding process. The research on controlling metal transfer modes in SAW process is essential to high quality welding procedures. Quality has now become an significant issue in today's manufacturing world [1]. In a submerged arc welding process, the concept of temperature distribution is essential in order to control the HAZ (heat-affected zone) dimensions and get the required bead size and quality [2]. The Submerged Arc Welding process is selected because of the complex set of variables involved in the process as well as its important applications in the manufacturing of significant equipment having a lot of economic and social implications [3]. Submerged arc welding is an 'Arc Welding' process in which the arc is concealed by a blanket of granular and fusible flux. Heat for SAW is generated by an arc between a bare, solid metal (or cored) consumable-wire or strip electrode and the work-piece. The arc is maintained in a cavity of molten flux or slag which refines the weld metal and also protects it from atmospheric contamination. In this research submerged arc welding is performed on rolled thick plate with welding type Longitudinal as well as circumferential welds using SAW.

PROBLEM IDENTIFICATION

Submerged arc welding is well well-matched to use with welding wire and high welding currents leading to high deposit rates. As a result, it is the leading process in many heavy industry applications such as making thick wall vessels for power station manufacturing wind towers and for offshore construction. The performance of conventional SAW depends on the practice of the operators. Error between the measured and the real values of welding conditions is accumulated as time goes on. Therefore, the weld quality cannot be certain because of the error. Even if a number of welding defects occur, workers are not able to find out the cause of defects because the measured signals show a big dissimilarity with the actual values. If the error between monitored and measured signals occurs, workers are able to easily correct the actual welding conditions.

METHODOLOGY

We using experimental data and check as well as compared that parameter on Minitab software.
Orthogonal array is used to design sets of experiment. After comprehensive study of literature available, internet suffering, industry feedback and discussion with practicing technicians it is found that four process parameters viz. Welding current, voltage, standoff distance and travel speed are dominating performance parameters for submerged arc welding process. The selected input parameters with 3 levels each are mentioned in table I. The performance parameters are Temperature and Quality of welded joint.

Table I -Process parameters and their levels

Factors	**Process parameters**	**LevelI**	**Level II**	**Level III**
A	Welding current (amp)	400	500	600
B	Voltage (v)	30	32	36
C	Standoff distance (mm)	25	27	30
D	Travel speed (mm/min)	125	`150	175

Performance parameters: Based on the literature review and discussion with practicing Engineers, following two performance parameters are selected.

- Temperature
- Repair result

These are one of the most important quality characteristics in the welding of thick plate which influences the performance of mechanical parts as well as cost.

Welding is carried out with SAW machine. This machine is available in METALFABHIGHTECHB PVT.LTD., MIDC area Nagpur (M.H.). They allowed doing all the necessary experiments. They also provided the ultrasonic testing facilities on the welded joint to find failure of welded pipe.

Signal to Noise ratio

The experimental results are transform in to a signal to noise (S/N) ratio. Taguchi recommends the use of S/N ratio to measure the quality characteristics deviating from the desired values. The S/N ratio for each level of process parameters is computed based on the signal to noise analysis.

There are three Signal-to noise ratios used for optimization of static problem.

Smaller is better

$$S/N = -10 * \log\left(\Sigma(Y^2)/n\right)$$

Where Y = responses for the given factor level combination and n = number of responses in the factor level combination.

Above formula is used to define the S/N ratio for all undesirable characteristics like defects etc. for which the ideal value is zero. Also, when an ideal value is finite and its maximum or minimum value is defined, then the difference between measured data and ideal value is expected to be as small as possible.

Larger is Better

$$S/N = -10 * \log\left(\Sigma(1/Y^2)/n\right)$$

Where Y = responses for the given factor level combination and n = number of responses in the factor level combination. This case has been converted to smaller-the-better by taking the reciprocals of measured data.

Table II**:** Shows the fractional factorial design of experiment (L9, Orthogonal Array)

Input process variables				**Output variables**		**Signal to Noise (S/N) ratio**	
Welding Current	**Voltage**	**Standoff Distance**	**Travel Speed**	**Temp.**	**Repair result**	**SN Temp high**	**SN Result high**
400	30	25	125	1928	88	65.7021	38.88
400	32	27	150	1860	92	65.3902	39.27
400	36	30	175	1728	31	64.7508	29.82
500	30	27	175	2680	24	68.5626	27.60
500	32	30	125	2530	89	68.0624	38.98
500	36	25	150	2700	93	68.6272	39.36
600	30	30	150	3024	36	69.6116	31.12
600	32	25	175	3240	80	70.2109	38.06
600	36	27	125	2900	89	69.2479	38.98

Response Surface Methodologies (RSM)

Engineers often wish to determine the values of the process input parameters at which there spouses reach their optimum. The optimum could be either a minimum or a maximum or a maximum of a particular function in terms of the process input parameters. RSM is one of the optimization techniques currently in widespread use in describing the performance of the welding process and finding the optimum of the responses of interest.

RSM is a set of mathematical and statistical techniques that are useful for modeling and predicting the response of interest affected by a number of input variables with the aim of optimizing this response. RSM also specifies the relationships among one or more measured responses and the essential controllable input factors. When all independent variables are measurable, controllable and continuous in the experiments, with negligible error, the response surface can be expressed by

Y = f (x1, x2, x3….. xk)………………………….....(3)

Where: k is the number of independent variables

To optimize the response 'y', it is necessary to find an appropriate approximation for the true

Functional relationship between the independent variables and the response surface. Usually a second order polynomial equation is used in RSM

$y = \beta_o + \Sigma\, \beta_i X_i + \Sigma \beta_{ii} X_{ii}^2 + \Sigma\, \beta_{ij}\, X_i X_j + \varepsilon$...........(4)

Response surface designs are useful for modeling a curved quadratic surface to continuous factors. If a minimum or maximum response exists inside the factor region, a response surface model can pinpoint it. Three distinct values for each factor are necessary to fit a quadratic function, so the standard two-level designs cannot fit curved surfaces. The most popular response surface design is the central composite design, illustrated in the figure to the left below. It combines a two-level factorial and two other kinds of points:

i) Centre points, for which all the factor values are at zero (or midrange) value.

ii) Axial (or star) points, for which all but one factor are set at zero (midrange) and that one factor is set at outer (axial) values.

In present work custom response surface method (RSM) has been applied for analysis of data and determination of governing equation because the number of experiment are as per L9 orthogonal array. The final governing mathematical equation in terms of factors and responses that predict the results with reasonable accuracy have been obtained through MINITAB 18.Stepwise regression method; which eliminates the significant model terms automatically was applied. Table II represent the values obtained for different RSM process for each output parameters viz. Temperature & Repair result respectively.

LINEAR RSM GENRALISED EQUATION

S/N Temp = 62.35 + 0.02205 Current - 0.0719 Voltage - 0.137 Distance + 0.0034 TravelSpeed

S/N Repair result = 72.7 + 0.0003 Current + 0.406 Voltage - 1.058 Distance- 0.1425 Travel Speed

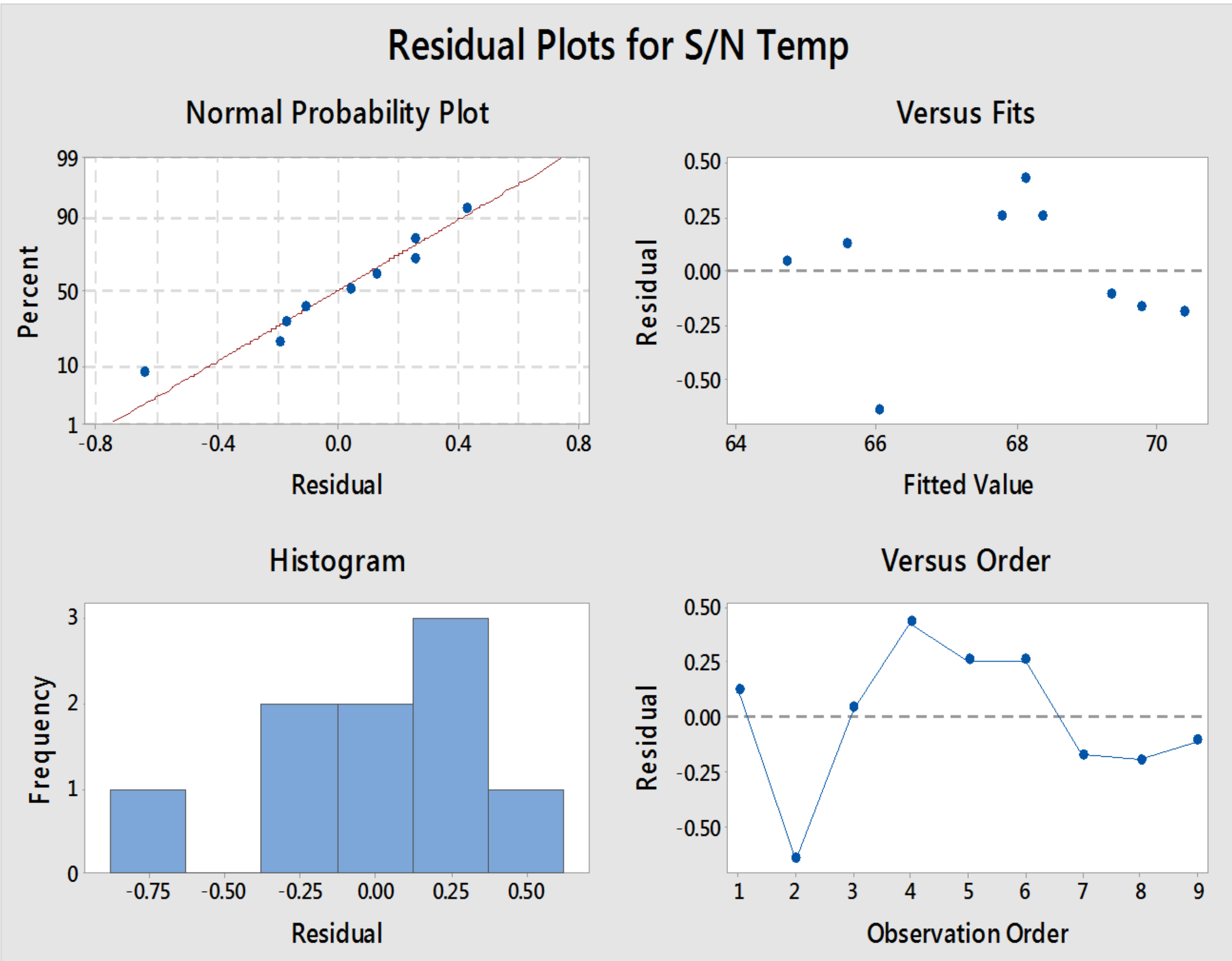

Fig 1- Residual plot (four in one) for temperature

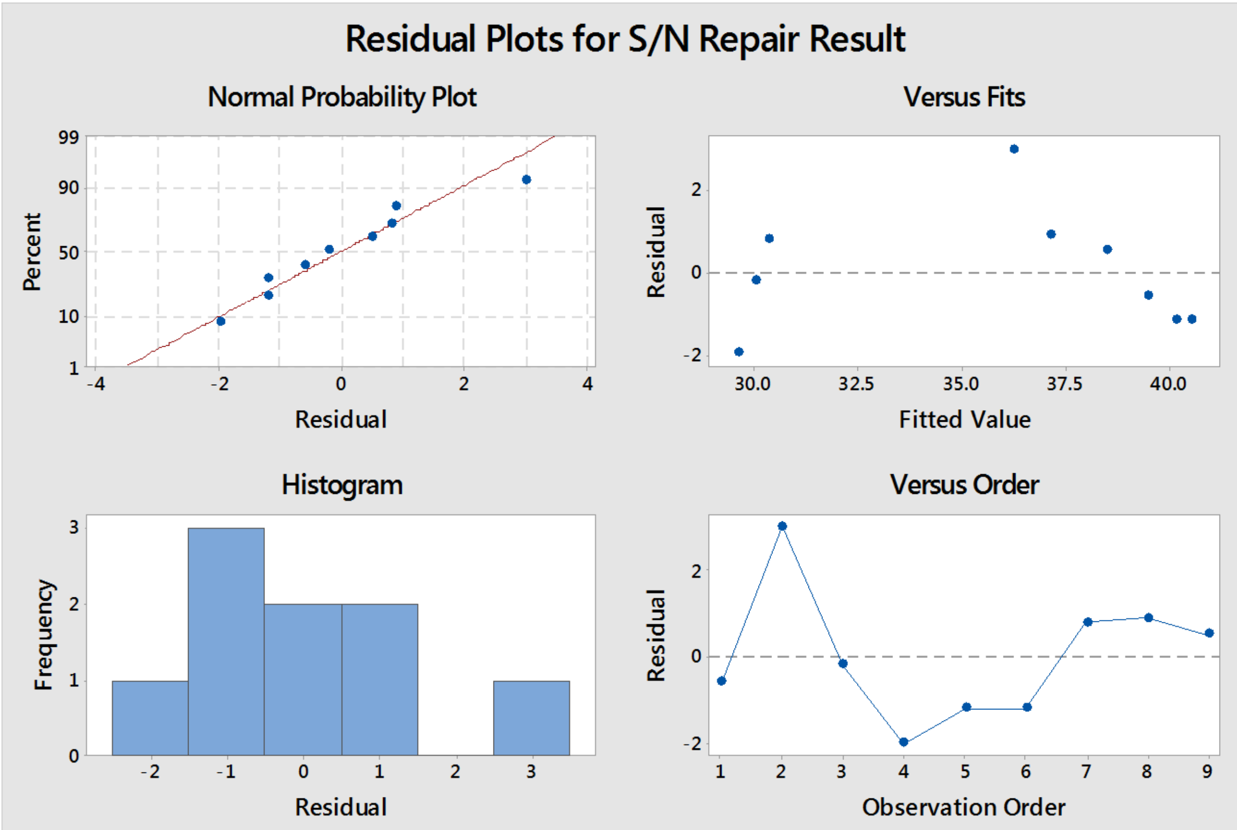

Fig 2- Residual plot for repair result

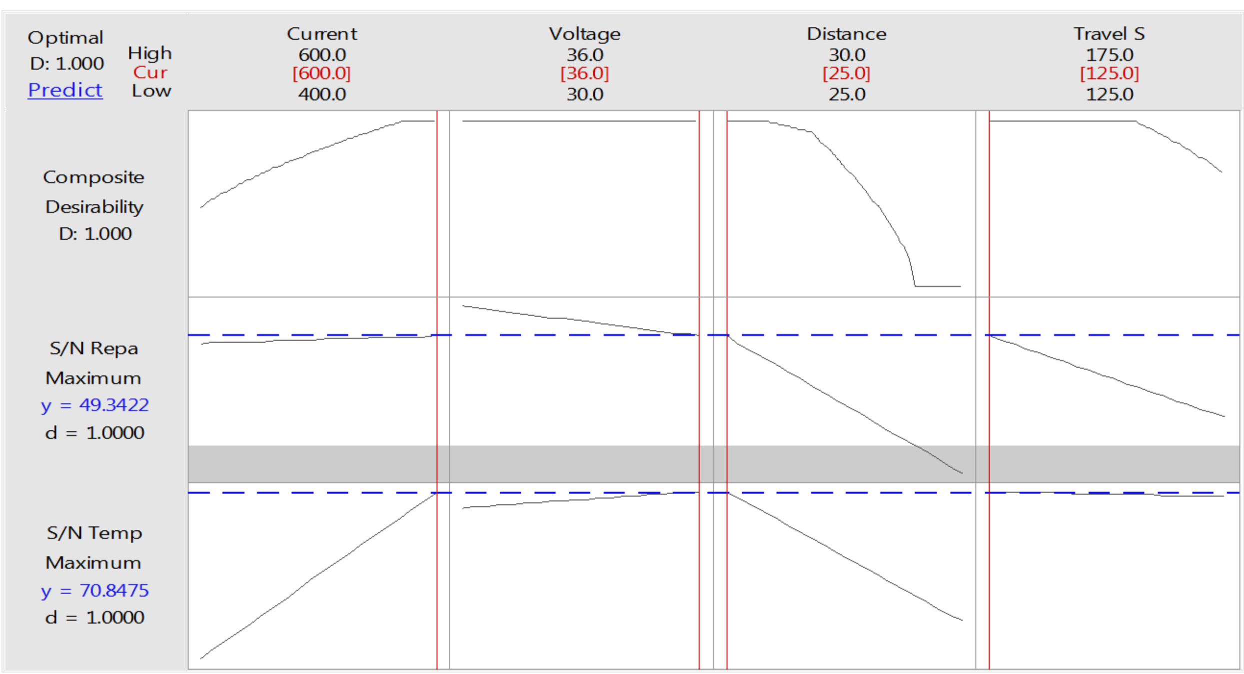

Figure 3: Graphical representation of Response Surface Method (RSM) optimization Result

Form figure 3 we not obtained optimal temperature and repair result.

Optimization by Genetic Algorithm

Using RSM model a linear equation is obtained and feeding this equation in Genetic Algorithm to get final equation. To get desired to be minimum uses of resources, investigation into effect of process parameter on performance parameter and its optimization is necessary.
Solution generated by GA is termed as chromosomes and collection of chromosomes is called population. A chromosome is composed from genes which value can be either numerical, binary, character or symbols that depend on the problem want to be solved.
To measure the suitability of solution generated by GA, these chromosomes undergo for a process called "fitness function". Some chromosomes in the population made through the process, called "crossover" and produced new chromosomes called "offspring". Gene composition of the new chromosomes is combination of their parents. In the generation, few chromosomes undergoes for mutation in their gene. The number of chromosomes undergo for cross over and mutation are controlled by value of cross over rate and mutation rate

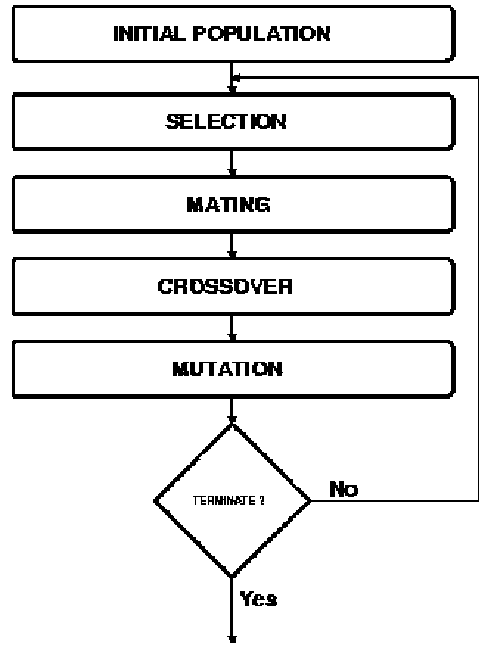

Figure 4: Flow diagram of Genetic Algorithm [https://i.stack.imgur.com]

In order to optimized the value of response parameters viz. Temperature and repair result through Genetic Algorithm Fitness function is constructed using response function by GA technique which are given below.

Temperature = 792+6.080 current – 18.1 voltage -37.4 distance + 1.93 speed

Repair result = 311 - 0.0100 current + 2.52 voltage - 6.88 distance - 0.873 speed

In present optimization work Temperature and repair result are desired to be maximum Hence now the aim is to minimize the Objective function.
In order to optimize the present problem using GA, the following parameters have been selected to obtain optimal solution with less computational effort.
Population size = 50
Maximum number of generations = 1000
Mutation probability (Pm) = 0.01
Total string length = 50
Random selection = 0.05
The programming of GA is done with PYTHON 2.7.14 software. In this, optimization work, total 1000 population is generated out of which 50 population are selected on random basis using roulette wheel method. A specific probability of each operator is fixed, keeping the mutation probability sufficiently small. The crossover and mutation probabilities are taken as 0.2 and 0.3 respectively. To generated population, 20% most fit and 5% low fit data are selected and rest child are generated. Selection parent is made on random basis using roulette wheel technique. The technique specified for selection, a random number between 0 and 1 is multiplied with the sum of fitness of the string, this string is selected from the "old-pop." in this manner, 2 strings are selected for mating and 2 new string, child 1 and child2 are created using the GA operators. Out

of the original 50 strings and newly created 50 strings, 20% most fit and 5% low fit populations are retained. In this manner, 1000 generations are continued, before the algorithm converges into the fit unique solution.

RESULT

The binary data is obtain by genetic algorithm are decoded to provide the optimized machining parameters on the basis of regression genetic algorithm.

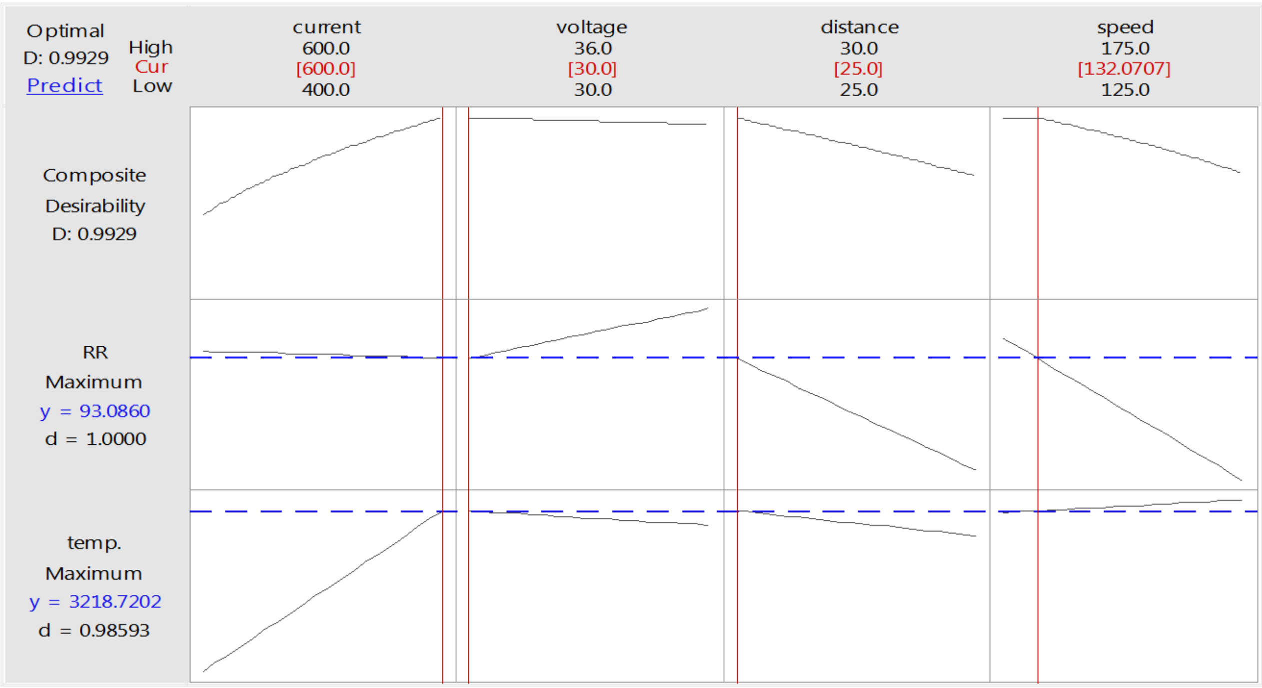

Fig 5- Optimum response parameter obtained by Genetic Algorithm

Table 3- Optimum set of process parameters

Process Parameters	Optimal Values
Welding current (amp)	600
Voltage (volt)	30
Standoff Distance (mm)	25
Travel Speed (mm/min)	132.070

Table 4- Performance parameters at optimal process parameters

Performance Parameters	Achieved Values
Temperature	3218.7202$^{\circ}C$
Repair result	93 %

CONCLUSION

It can be concluded that among the various welding parameter such as arc voltage (V) and arc current (I) which affects the temperature (T) mostly. so if we use these parameter to get high quality weld (join) The temperature depends not only on flux and filler wire but also on the rate of heat input and heat dissipation which in turns depend on the thickness of plate and the angle of groove. Thus we get temperature (3218.7202℃) and repair result (93%) on which quality of welding or weld joined are more suitable**.**

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