A hybrid methodology for optimizing MIG welding process parametersin joining of dissimilar metals

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A B S T R A C T

In this paper application of Taguchi and Grey relational analysis methodologies in determining optimal process parameters for MIG Welding are presented. Taguchi method is widely used in designing the optimal experiments, while grey relation analysis is useful in decision making when multiple criteria's are considered, this combination serves as an effective tool in determining the optimal parameters of the pro- cess. In the present work welding current, voltage, speed, bevel angle were considered as input parameters in joining two dissimilar metals (AISI1044 & AISI1018), as these influence the output characteristics like tensile strength and hardness, these parameters need to be optimized. Selection and peer-review under responsibility of the scientific committee of the International Conference on Recent Advances in Materials, Manufacturing & Energy Systems.

1. INTRODUCTION

1.1 MIG WELDING

MIG welding is an arc welding system wherein a non-stop solid wire electrode is fed thru a welding gun and into the weld pool, joining the 2 base materials together. A protecting fuel is likewise dispatched thru the welding gun and protects the weld pool from infection. In reality, MIG stands for steel inert gas.

MIG (Metal Inert Gas) Or Gas Metal Arc Welding (GMAW) is a welding technique in which a consumable metal electrode is used to supply the electric arc to sign up for the metal portions collectively in the surroundings of a defensive fuel. Shielding gasoline protects the weld from atmospheric contamination. Constant voltage, direct cutting-edge strength source is used to supply the arc.

Fig 1 .MIG Welding

In 1948, GMAW was first developed by H. E. Kennedy from the Battelle Memorial Institute. In the earlier GMAW, electrode of smaller diameter and constant voltage is used. It gave a

high deposition rate, but the high cost of inert gases, its usage is limited to non-ferrous materials and prevented cost savings. In 1953, they used CO_2 as a welding atmosphere. In 1958, GMAW has been modified to short-arc variation. Due to this, welding was used in many industries and it became popular by making thin materials also suitable to weld. Today, GMAW is commonly used in many industrial welding processes due to its versatility, speed and it can be easily adapted to robot for automation.In MIG welding process heat is generated by the transfer of electrons between continuous wire feed and base metal. This heat will melt the continuous wire, base plate metal and they will solidify together to form a sound joint. The shielding gases are allowed to flow from the weld gun along with wire feed to prevent the oxidization due to the atmospheric gases at the weld area. Due to this, better surfaces as well as sound joints are produced.

Fig2. Equipments of Mig Welding

The Parts in for MIG Welding:-

1. Welding gun along with wire feed unit.
2. Tool style.
3. Power Source
4. Electrode
5. Shielding gases.

2. Literature review

Satyaduttsinh P. Chavda, Jayesh V. Desai, Tushar M. Patel [1] investigated on MIG welding process and also on Taguchi's DOE Method. They gave the idea about optimizing parameters of the MIG welding process by using Taguchi's DOE Method. In this paper, they reviewed different previous works from different papers and gave advantages of using Taguchi

method. They concluded that current, voltage, speed, shielding gas, gas flow rate, wire feed rate, the diameter of wire etc. are most significant factors in GMAW process and these parameters will influences the various characteristics of weldments.

Doreswamy Deepak, Rajendra Beedu [2] worked on CNC machine for Multi-parameter optimization of turning operation's by conducting experimentation on material AISI1044 using G×rey Relational Analysis. The cylindrical shaped Carbon steel with dimensions 40 150 mm was taken for experimentation. Three input parameters considered for optimisation are cutting speed, Feed rate, Depth of cut. Three levels are taken for optimization. Experimentation was done according to L9 OA, which is obtained from 3 parameters and 3 levels. Increased metal removal rate and smoother surfaces are achieved by effectively utilizing the GRA in optimization process. They concluded that GRA was the best suitable optimization technique for multi-parameter optimization.UgurEsme, Melih Bayramoglu, Yugut Kazancoglu, Sueda Ozgun[3] worked on the TIG welding process for obtaining the optimal values for selected parameters by using the combination of taguchi and grey relational analysis methodologies. Four parameters (i.e. Travel speed, Current, Gas flow rate, Gap distance) had been taken as input parameters and each parameter with four levels were choosen for experimentation. For this he has taken the parameters like bead width, height, its penetration and tensile load applied on that particular area. 16 experiments (obtained from Taguchi's L16(44) orthogonal array) were conducted through joining of two AISI1018 Mild steel plates in order to get the optimal values for the TIG welding process. The Results obtained from experiments were analyzed using Grey Relational Analysis method combined with Taguchi Method (S/N ratio) and Grey Relational Grades (GRGs) were calculated. Finally optimization values were obtained by analyzing S/N ratios. Further (ANOVA) is used for knowing which parameters are mostly influencing the properties of the weld elements and confirmation test was done to confirm optimization values. The results have shown that the various parameters which are taken into consideration gave optimal values by the application of hybrid methodology. They concluded that Taguchi method is a very effective tool for process optimization under limited number of experimental runs. And also Taguchi method can be clubbed with the GRA method, where multiple parameters are needed to be optimized.

Dheeraj Singh, Vedansh Chaturvedi, JyotiVimal [4] investigated the optimal process parameters of Tungsten inert gas (TIG) welding by application of Signal to Noise Ratio Methodology. They introduced a new parameter i.e. Gun angle along with three com- mon parameters (current, gas flow rate, welding speed) and four levels of each parameter. In order to obtain the better weld bead geometry the appropriate objective has been selected. By the use of OA, 16 Experiments were conducted in order to join two AISI304 thin stainless steel plates (30 250 1.2 mm) on TIG welding machine (Lincoln Invertec 350 V pro). Along with Grey Relational Analysis, the S/N ratio is calculated to obtain the most effective parameters.

Prasenjit Mondal, Dipankar Bose [5] has investigated on the joining of dissimilar metals i.e. AISI 304 with IS 1079 using MIG welding process by using the Fuzzy Logic method. Input parame- ters are Welding current, welding voltage, weld speed and three levels of each parameter were considered. The optimum value was predicted using MINITAB16 software. Finally, the ANOVA method is applied to find contribution % of input parameters.

Sampath Kumar, Rajasekaran, Arun Kumar, Amrish Raj [6] established the relationships

between process parameters for Fric- tion Stir Welding (FSW) of using Grey relational analysis. Interaction plots and contour plots were drawn to study the effect of FSW parameters on the tensile strength.

Cristian Fin Schneider, Camila Pereira Lisboa, Rodrigo de Almeida Silva and Richard Thomas Lermen [7] were carried out an experimental study on combined welding techniques i.e. by combining of the TIG followed MIG welding processes by applying Taguchi methodology (robust design method). The different parameters (from both TIG and MIG welding process) and 27experimental trails are conducted on SAE 1045 steel plates. The different parameters are taken into the consideration and experiments are conducted by changing the levels of them. This gave the information i.e. penetration was greatly affected by the welding speed, wire feed rate, voltage and current intensity maintained during the welding process They plot the graphs for each output parameter to evaluate affecting input parameter on that output parameter.

Amit Kumar, M. K. Khurana and Pradeep K. Yadav [8] presented the application of Taguchi method is clubbed with GRA method. This combined method is used to get optimized multiple factors (bead width& height, welding penetration and HAZ) of GMAW by joining AISI 1044 carbon plates of steel. The experiments have been performed according to the orthogonal array of L9. ANOVA applied and it reveals that speed and voltage of weld are mostly influencing the weldments properties, while the current is not effective as much as speed and voltage on the process.

Jay Joshi, Manthan Thakkar, Sahil Vora [9] studied the effect of MIG welding parameters (Electric current, Feed rate, Gas flow)as well as TIG welding parameters(Electric current, Gas flow) using Grey Relational Analysis. ANOVA methodology used to analyze grey relational grade to find out the effect of each parameter. Regression Analysis Equations are found out by use of MINITAB16 software.

D. Bahar, Md. Nawaz Sharif, K. Shravan Kumar and D. Reddy [10] investigated the process parameters of MIG welding to optimize the hardness and ultimate tensile strength (UTS) of a weld bead formed by joining the dissimilar materials: mild steel (MS 1018) and stainless steel (SS 316) using Taguchi technique and Grey relational analysis. Considering 4 levels of parameters (volt- age, welding speed, gas flow and feed rate), 16 experiments are conducted. Subsequently MINITAB software is introduced and used to analyze the optimal values of the experiments.

Lakshmananvellaichamy and SathiyaPaulraj [11] had worked with welding on dissimilar metals of Incoloy 800HT and P91 steel using GTAW or TIG Welding. Multiple characteristics were opti- mized by effectively utilizing GRA method. The input parameters taken are current, voltage, speed. The output parameters are Tensile strength, Hardness and Toughness.

A. Al-Refaie, L. Al-Durgham, and N. Bata [12]done research to propose a method for optimizing multiple characteristics in the Taguchi method by clubbing with regression models and GRA. They took five parameter model and three levels. Experiments con- ducted as per L16 orthogonal array and S/N ratios were calculated for each experiment. The proposed approach was found efficient for all the illustrated three cases. It is concluded that the approach can be effectively utilized in optimizing multi quality

parameters in variety of applications on the Taguchi method.

3. Optimization methods

3.1 Taguchi method

Genichi Taguchi, an engineer, also a statistician, created a statis- tical method for enhancing the quality of produced goods. The method was named as Taguchi method. After that, this method is applied to other fields in Engineering. This method involves in find- ing out the optimum results of a process. In Taguchi method, min- imum number of experimental trails was conducted, instead oftesting all possible combinations (i.e. factorial design). Due to this, the time and resources are saved. The Orthogonal Arrays (OA) gives the set of experiments to conduct experiments. The experimental data was analyzed and the quality of components produced was evaluated.

Steps in Taguchi method:

1. Determine the quality characteristic/objective.
2. Finding the control factors and their levels.
3. Design of a suitable OA Matrix and define the data analysis.
4. Conduct the experimental trails & obtain output values.
5. Analyze the values and obtain optimum levels of parameters.
6. Perform the verification experiment and plan the future action.

3.2. Grey relational analysis

GRA method is the best method, where multiple attribute situ- ations are present. The using of GRA method is advantageous since the calculations are simple and straightforward. GRA is based on geometrical mathematics. GRA is suitable for solving complicated interrelationships between multiple factors and variables and has been successfully applied on cluster analysis, robot path planning, project selection, prediction analysis, performance evaluation, and factor effect evaluation and multiple criteria decision. In this method, the overall evaluation of the multiple response processis based on grey relational grade. Here, optimization is done by converting the complicated multiple process values into a single grey relational grade and optimal parametric combination is then evaluated which would result highest Grey relational grade.

Steps in Grey Relational Analysis method:

1. Determine the quality characteristic/objective.
2. Finding the control factors and their levels.
3. Design of a suitable OA Matrix and define the data analysis.
4. Conduct the experimental trails & obtain output values.
5. Normalization of data.
6. Finding out Grey relational Coefficient.
7. Calculation of Grey relational Grade.
8. Ranking & Selection of Optimal values.

3.3. Proposed hybrid methodology

Mostly Taguchi method is used for optimization of single parameter. By combining Taguchi with grey relational analysis optimization based on multiple parameters can be done easily and effectively. The grey relational analysis involves calculation of grey

relational coefficient for each parameter. Averaging of all grey relational coefficients will gives grey relational grade (GRG) and S/N ratio values are calculated to these GRGs.

Steps in Hybrid Methodology:

1. Determine the quality characteristic/objective: It is finding out the suitable output characteristic, which needs to be increased or decreased for getting better output in terms of quality.

2. Finding the control factors and their levels: A controlled factor is a characteristic that can be controllable parameter. Initially all the factors which influencing the output characteristic must be list down & then control factors, which are going to be opti- mised are selected through brainstorming.

Factor: A factor is a variable under study; an input that can be controlled.

Level: A level is a value that a factor can assume when used in an experiment.

3. Design of an appropriate Orthogonal Array Matrix and performing experimentation: Orthogonal arrays are found out using number of parameters and levels of parameters. It is predefined and usually requires only a fraction of the full factorial combinations since in each pair of columns, all factor combinations occur at the same number of times. Experimental trails need to be conducted according to the combination sets of parameters, which are obtained from orthogonal array. The output parameters are to be measured by testing the experimental pieces on a desired testing machine or with proper equipment.

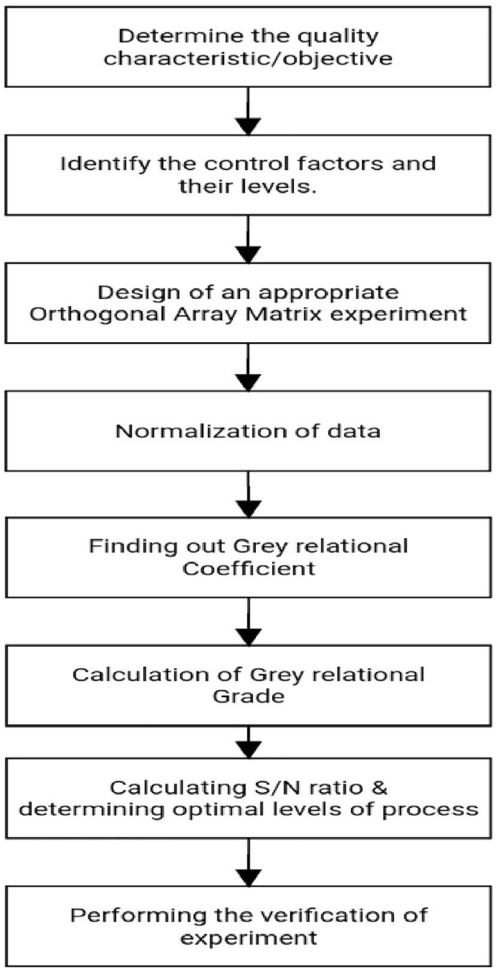

Fig. 1.3Flow Chart for Hybrid Methodology.

4. Normalization of data

- The experimental response data are to be normalized in the range of 0 and 1. This normalization is done because it is difficult to compare between the different kinds of factors because they exert a different value. Three formulas can be used for this purpose

$$x_{\text{norm}} = \frac{x - \min(x)}{\max(x) - \min(x)}$$

This formula is used when the corresponding output value needto be maximized

$$X_{norm} = \max(x) - x / \max(x) - \min(x)$$

This formula is used when the corresponding output value needto be minimized.

$$X_{norm} = x - x_0 / \max x - x_0$$

This formula is used when the corresponding output value need to be maintained at certain value.

- Finding out Grey relational Coefficient (GRC)

The GRC is calculated by following steps:

- The absolute difference of the compared series and the referential series should be obtained. And the maximum and the minimum difference should be found.
- Calculation of the GRC using following formula.

$$\xi_i(k) = \frac{\Delta\min + \xi\Delta\max}{\Delta_{oj}(k) + \xi\Delta\max}$$

Generally, Distinguishing coefficient $p = 0.5$

- Calculation of Grey relational Grade:
  Grey relational Grade can be obtained by averaging the GRC values in each row.
- Calculating S/N ratios & determining optimal levels of process: Here Taguchi method was introduced and the S/N values for Grey Relational Grade were calculated using following formula $S=N$ ¼ —10 log 1=y^2 =N. By using S/N ratios, graphs need to be plotted and optimisation values to be find out by analysis.

- Perform the verification experiment: It is needed to be verify, whether the given result by that method is valid or not by con- ducting experiment with optimal values.

5. EXPERIMENTAL MANNER AND OUTCOMES

5.1.1 SELECTION OF MATERIAL

In this examine, we used multiple metals to join by using the usage of MIG welding gadget. The two distinct metals are AISI1044 and AISI1018 mild metallic. The size of Mild steel plates is 150 * 40 * 8 mm.

5.1.2 SELECTION OF MIG WELDING PARAMETERS AND THEIR TIERS

In this examine we chose the following parameters and degrees on the grounds that they will display tremendous impact at the weldments properties

5.1.3 SELECTION OF ORTHOGONAL ARRAY

Based on predefined orthogonal array matrix, we can get L9 orthogonal array for the aggregate of four parameters and 3 ranges.
The Table 2 shows the combination of parameters with various levels of parameters.
As in step with the Table 2, nine trails each path repeated twice for the same enter parameters were finished. The Fig. Three indicates the weldments received from the paths.

5.1.4 EXPERIMENTAL END RESULT

The Tensile energy of weldments had been tested the use of familiar testing device and additionally Hardness of welded location the usage of Brinell hardness checking out approach. The Table 3 indicates the tensile power and Hardness values for Weldments, which obtained from experimental trails.

TABLE 1
PARAMETER AND TRAILS

PARAMETERS	LEVEL1	LEVEL2	LEVEL3
Current (Ampers)	171	180	300
Voltage (volts)	21	28	35
Weld speed (m/min)	.92	98	1.3
Angles (degree)	30	45	60

TABLE 2
ORTHOGONAL ARRAY

EXP.NO	Current (Ampers)	Voltage (volts)	Weld speed (m/min)	Angles (degree)
1	171	21.5	.92	30
2	161	24.2	.94	45
3	164	25.8	.96	60
4	180	28.5	.97	60

5	214	29.9	1.2	45
6	248	31.5	.98	30
7	272	34.4	1.3	45
8	294	34.7	.92	45
9	328	35.9	.98	60

Fig 4. Weldments From The Trails

TABLE 3

Tensile strength and Hardness values of Weldments.

Exp. No.	Tensile Strength (MPa)	Hardness (BHN)

1	325	140.5
2	336.3	133
3	381.8	136
4	363.4	123.5
5	398.7	114
6	321.2	123
7	365.13	144.6
8	328.38	129.2
9	334.7	130.5

5.1.5 Analysis for finding out optimal level of a parameter

The S/N ratio values of each experimental trail were analysed to obtain optimal level of parameters. The Table 6 shows, analysed S/N ratio values for different levels of parameters.
The maximum value from each column will represents the opti-mal level of a parameter.
The graphs are plotted using S/N ratio values for different levels of a parameter shown in Fig. 4. The optimal values of MIG welding process are as in Table 7:

TABLE 4
TENSILE STRENGTH AND HARDNESS VALES OF WELDMENT

Exp. No.	Tensile Strength (MPa)	Hardness	Normalised Tensile Strength (MPa)	Normalised Hardness
1	325	140.5	.442	.336
2	336.3	133	.521	.234
3	381.8	136	.231	.631
4	363.4	123.5	.332	1
5	398.7	114	.398	.431
6	321.2	123	.448	.383
7	365.13	144.6	.512	.289
8	328.58	129.2	.439	.373
9	334.7	130.5	.14	.784

TABLE 5
GRC, GRG, S/N RATIO VALUES FOR ALL THE EXPERIMENTAL RUNS

Exp. No	GRC of Tensile Strength	GRC of Hardness	GREY RELATIONAL GRADE (GRG)	S/N RATIO
1	.432	.534	.483	-4.23
2	.321	.489	.405	-4.73
3	.349	.321	.335	-3.43
4	.412	.512	.462	-6.31
5	.298	.389	.3435	-5.89

6	.323	.412	.3675	-6.75
7	.444	.326	.385	-3.86
8	.532	.478	.505	-4.65
9	.639	.335	.487	-4.71

.

TABLE 6
S/N RATIO VALUES FOR DIFFERENT LEVELS OF PARAMETERS

Level	Current (Amps.)	Voltage (Volts)	Speed (m/min	Angle (Degree)
Lvl1	-7.51	-4.45	-4.43	-6.014
Lvl2	-6.93	-5.89	-4.89	-4.03
Lvl3	-5.31	-5.63	-6.36	-5.098

TABLE 7
OPTIMAL VALUES OF MIG WELDING PROCESS

Current (Amps)	Voltage (Volts)	Weld Speed (m/min	Angle (degrees)
300	21.5	.92	45

TABLE 8
TENSILE STRENGTH AND HARDNESS VALUES OBTAINED FROM THE CONFIRMATION TEST

Tensile Strength (MPa)	Hardness
432.6	144.6

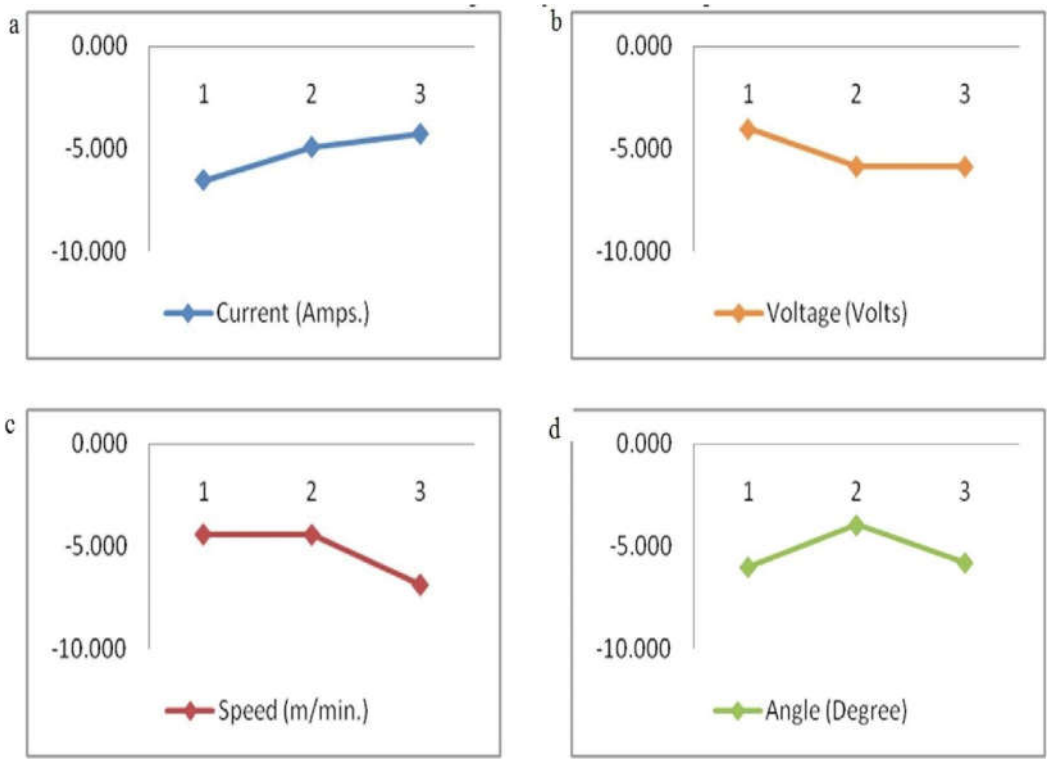

Figure 5.S/N ratio Graph for (a) Current;(b) Voltage; (c) Weld Speed; (d)Angle.

5.1.4 CONFIRMATION TEST

Confirmation trail was conducted using above optimal values to confirm that the obtained values will give better Tensile strength and Hardness.

From the confirmation test, we observed better Tensile strength and Hardness. The Tensile strength and Hardness values of the confirmation test.

CONCLUSION

Nine experimental trails each trail repeated twice were con- ducted as per the orthogonal array, the data obtained is analysed using the hybrid algorithm. From the weldment obtained by join- ing the two dissimilar metals (AISI1044 & AISI1018) using MIG welding process, it is noticed that characteristics like tensile strength and hardness has been improved, when the process, is been carried out at the following optimal parameter values i.e current at 300 Amps, voltage at 21.5Volts, weld speed of 0.92 m/min and angle at 45 degrees.

From Graphs, It is observed that the tensile strength and hard- ness of weld area increases with increase in the current and tensile strength and hardness of weld area decreases with increase in Voltage as well as Weld speed. And the tensile strength and hardness are high at angle of 45 degrees.

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