Evaluations of combination of parameters for ARC welding by using RSA technique

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Abstract: The experiments have been conducted on (Grade IS: 2062) mild steel specimens under L_{27} orthogonal array Taguchi design for TIG welding input process parameters i.e. current (I), voltage (V) and Root gaps (Rg). Later deposition rate, hardness and tensile strength of weld and green quality, worker performance, noise generation and surface defects/ appearance have been considered as quantitative and qualitative objectives function, respectively. Next, Fuzzy Interference System (FIS) modeling of qualitative excluding the quantitative objectives have carried out. After defuzzification of qualitative objectives function, a RSA (Ration System Analysis) approach is applied for Evaluation of combination of parameters for TIG ARC welding.

Keywords: TIG welding process, designing of process parameters, Fuzzy modeling RSA approach.

I. INTRODUCTION OF WELDING:

Welding is the permanent joining process of similar or dissimilar metals with or without the application of heat and pressure. Unlike other manufacturing process, welding is employed to produce a single component; welding processes are employed to assemble different members to yield the desired complex pattern.

II. MULTIPLE-OBJECTIVE EVALUATION PROBLEMS:

These problems consist of a finite number of alternatives experiments /options, explicitly known at the starting of the solution process. Each alternative is represented by its performance in multiple-objective. The problem may be defined as finding the best alternative for the decision-making group, or finding a set of suitable alternatives. One may also be interested in 'sorting' or 'classifying' alternatives Chu and Varma, 2012; Sahu et al., 2015).

The objective of the research work is to TIG welding based an quantitative and quantitative multi-objective index, which could tackle MIG welding quantitative input process parameters i.e. current, voltage, feed rate, power consumption etc., and qualitative parameters i.e. welder intention, environmental aspects etc finding the optimum setting among input parameters

III. EXPERIMENTAL SET UP AND DETAIL OF EXPERIMENTS:

The course of action of parametric optimization of TIG welding process. Experiments were conducted using SUPRA INVTIG500 welding machine by DC electrode positive power supply. Test pieces of size 200mm×150mm×5 mm were cut from mild steel (Grade IS: 2062) plate. Flux cored mild steel electrode (E71T-1) of 1.3 mm diameter was employed for welding. CO_2 gas at a constant flow rate of 15 L/min was used for shielding. The experimental setup used consists of variation of the process parameters of TIG welding at third-level. Table. 1 revealed the composition of mild steel (Grade IS: 2062) plate. While Table. 2 revealed the variation of three process parameters i.e. welding current (I), ampere, Arc voltage (V), volts, electrode sickout (S), mm at 1-3 levels and their seven outputs such as hardness, deposition rate, tensile strength as quantitative outputs, whereas Sound generation, (C6), Surface imperfection (C7), as quantitative output objectives functions in the context of TIG welding process, Athawale and Chakraborty (2011), Abhulimen and Achebo (2014), Brauers and Zavadskas (2006), Berretta, et al., (2007). Chandel et al., (1997), Chakraborty (2011). The setup is shown by Fig. 1.

Fig: 1. Set up of TIG welding

Table: 1. Variation of three process parameters at 1-3 levels

<table>
<tr><td colspan="3">Process parameters</td><td>Level-1</td><td>Level-2</td><td>Level-3</td></tr>
<tr><td colspan="2" rowspan="3">Inputs process parameters</td><td>Welding current (I), ampere</td><td>185</td><td>225</td><td>265</td></tr>
<tr><td>Arc voltage (V), volts</td><td>24</td><td>28</td><td>32</td></tr>
<tr><td>Root gaps (Rg), mm</td><td>1</td><td>2</td><td>3</td></tr>
<tr><td rowspan="7">Output objective functions</td><td rowspan="3">Numerical data modeling</td><td colspan="4">Hardness, (C_1)</td></tr>
<tr><td colspan="4">Deposition rate, (C_2)</td></tr>
<tr><td colspan="4">Tensile strength, (C_3)</td></tr>
<tr><td rowspan="4">Fuzzy data modeling</td><td>Harm for environmental, (C_4)</td><td colspan="3">DM_1,DM_2---k</td></tr>
<tr><td>Performance of welder, (C_5)</td><td colspan="3">DM_1,DM_2---k</td></tr>
<tr><td>Sound generation, (C_6)</td><td colspan="3">DM_1,DM_2---k</td></tr>
<tr><td>Surface imperfection (C_7)</td><td colspan="3">DM_1,DM_2---k</td></tr>
</table>

Table: 2. Experimental layout for the welding process parameters using the orthogonal array and result of conducted experiments

Ex. no.	I	V	S	Hardness (HB)	Deposition Rate (Kg/hr_	Tensile strength (MPa)
1.	1	1	1	327.12	2.51	351.1
2.	1	1	2	475.31	2.71	357.5
3.	1	1	3	479.53	2.75	396.8
4.	1	2	1	467.88	2.56	418.9
5.	1	2	2	595.28	2.68	457.8
6.	1	2	3	525.96	3.15	487.3
7.	1	3	1	440.82	2.19	367.7
8.	1	3	2	519.51	2.93	467.5
9.	1	3	3	516.53	3.21	479.4
10.	2	1	1	325.56	2.13	347.6
11.	2	1	2	467.88	2.31	454.7
12.	2	1	3	471.06	2.22	457.9
13.	2	2	1	456.56	2.61	487.8
14.	2	2	2	531.51	2.69	467.2
15.	2	2	3	546.54	3.17	498.1
16.	2	3	1	396.66	2.41	457.2
17.	2	3	2	523.56	2.94	447.8

18.	2	3	3	568.73	3.15	547.7
19.	3	1	1	425.31	2.52	347.6
20.	3	1	2	485.09	2.91	467.4
21.	3	1	3	445.09	2.98	457.8
22.	3	2	1	424.15	3.95	412.4
23.	3	2	2	515.09	3.94	467.9
24.	3	2	3	488.41	3.11	478.3
25.	3	3	1	319.96	2.97	347.1
26.	3	3	2	464.15	3.08	487.5
27.	3	3	3	575.83	3.54	511.3

IV. MULTI-OBJECTIVE OPTIMIZATION:

Since the traditional Taguchi technique deals with single response. Therefore, due to the availability of qualitative and quantitative output objectives function of TIG welding process parameters, the traditional taguchi technique has become ill capatable to tackle three quantitative and four qualitative objectives. Therefore, a hybrid technique has been utilized from decision making point of view.

In the presented research work, among the three output objectives, hardness has considered as Higher-the-better (HB) criterion and deposition rate has considered as Lower-the-better (LB), while strength of weld has considered as Higher-the-better (HB).

Moreover, four subjective objective / criterions were considered i.e. Harm for environmental, (C_4), Performance of welder, (C_5), Sound generation, (C_6), Surface imperfection (C_7), where Harm for environmental, (C_4), Performance of welder, (C_5), has considered as Higher-the-better (HB) criterion and Sound generation, (C_6), Surface imperfection (C_7) has considered as Lower-the-better (LB) criterion. Later these modeled by triangular fuzzy interference system, as dealt with uncertainty. For fuzzy modeling of said qualitative output objectives, a team of decision makers were facilitated by Linguistic scale corresponding to triangular fuzzy scale. The adapted linguistic scale in term of triangular fuzzy interference system membership function corresponding to ratings and weight are given below:

Unsatisfactory (U)-(0,0,0.25), Poor (P)-(0,0.25,0.5), Medium (M)-(0.25,0.5,0.75), Satisfactory (S)-(0.5,0.75,1), Excellent (E)-(0.75,1,1) for assessing rating.

Unimportant (UI)-(0,0.1,0.3), Slightly Important (SI)-(0,0.2,0.5), Fairly Important (FI)-(0.3,0.45,0.7), Important (I)-(0.5,0.7,0.8), Very Important (VI)-(0.7,0.9,1)) for assessing weights.

To find the optimum setting among input process parameters of TIG welding process, the qualitative objective function were defuzzified by technique proposed by (Chu and Varma, 2012) and then crisp qualitative cum quantitative objectives were merged in TIG welding process parameters. Eventually, technique for order of preference by similarity to ideal solution merged with multi objective optimization 'hybrid approach' has been used to find the optimum setting among input process parameters of TIG welding process.

V. THE RATIO SYSTEM ANALYSIS:

Normalize the decision matrix $X = (x_{ij})_{mn}$ using the following equation:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{n} x^2_{ij}}}, \quad i = 1,2,3,.......m,, \quad j = 1,2,3,.......n \qquad \text{.........................(1)}$$

Here r_{ij} is the normalized criterion rating.

Calculate the weighted normalized decision matrix $v = (v_{ij})_{mn}$ ....(2)

These indicators are added (if desirable value of indicator is maximum) or subtracted (if desirable value is minimum), thus the summarizing index of each alternative is derived in this way:

$$y_i^* = \sum_{j=1}^{g} x_{ij}^* - \sum_{j=g+1}^{n} x_{ij}^* \qquad \text{..............(3)}$$

Here $g = 1,..., n$ denotes number of objectives to be maximized. Then every ratio is given the ranks. The higher index representing the higher ranks.

In some cases, it is often observed that some attributes are more important than others. In order to give more importance towards an attribute, it could be multiplied with its corresponding weight (significance coefficient) (Brauers and Zavadskas, 2009). When these attribute weights are taken into consideration, Eq. (4) becomes as follows:

$$y_i^* = \sum_{j=1}^{g} w x_{ij}^* - \sum_{j=g+1}^{n} w x_{ij}^* \qquad \text{……….......(4)}$$

Here w_j is the weight of j_{th} attribute.

VI. PARAMETRIC OPTIMIZATION: TIG WELDING PROCESS:

In presented research work, the full factorial design L_{27} orthogonal array has been considered to be conducted the experimental with respect to welding process parameters i.e. Welding current (I), Arc voltage (V) and Root gaps (Rg) mm, to obtain the outputs such as hardness, deposition rate and strength of weld has, shown in Tables. 1.

Later, the appropriateness rating against four qualitative objective functions such as Sound generation, (C6), Surface imperfection (C7) assigned by DMs in linguistic terms, and then modeled by Triangular Fuzzy Interference System number set. Fuzzy appropriateness rating against qualitative objectives function assigned by expert' panel and then aggregated by equation (1-5) for all qualitative objective functions, has been shown in Tables. 3-7.

Next, Fuzzy priority weight against quantitative and qualitative objectives function assigned by expert' panel and then aggregated by Triangular fuzzy rule Chu and Varma, 2012, both has been shown in Tables. 8. Defuzzification priority weight has been normalized to get sum of weights against all objective function equal to 1.

Later, normalization of all parameters, beneficial and no-beneficial in nature has been carried out to bring the values in the interval of [0, 1] by using Equ (1). Then, all parameters are multiple by its normalized weights to compute weight normalized matrix by using Equ (2), shown in Table. 9. y_i is computed by Equ (4), shown in Table. 10.

The final results have been procured by exploring dominance theory, shown in Table. 10.

Table. 3. Appropriateness rating assigned by expert' panel against qualitative objective and aggregated fuzzy appropriateness rating, (C_4)

Appropriateness rating assigned by expert' panel against qualitative objective and aggregated fuzzy appropriateness rating, (C_4)						AFR
L_{1-27}	DM1	DM2	DM3	DM4	DM5	
L_1	M	E	E	E	P	(0.50,0.75,0.85)
L_2	P	M	U	M	M	(0.15,0.35,0.60)
L_3	S	M	M	M	P	(0.25,0.50,0.75)
L_4	S	M	E	M	P	(0.35,0.60,0.80)
L_5	U	E	M	M	M	(0.30,0.50,0.70)
L_6	U	E	M	M	M	(0.30,0.50,0.70)
L_7	M	E	E	M	U	(0.40,0.60,0.75)
L_8	M	E	E	U	U	(0.35,0.50,0.65)
L_9	M	M	E	U	U	(0.25,0.40,0.60)
L_{10}	M	M	E	U	M	(0.30,0.50,0.70)
L_{11}	M	M	U	M	M	(0.20,0.40,0.65)
L_{12}	U	M	M	M	P	(0.15,0.35,0.60)
L_{13}	M	M	M	M	P	(0.20,0.45,0.70)
L_{14}	M	M	M	M	M	(0.25,0.50,0.75)
L_{15}	M	E	M	U	U	(0.25,0.40,0.60)
L_{16}	M	E	P	M	M	(0.30,0.55,0.75)
L_{17}	U	E	P	M	M	(0.25,0.45,0.65)
L_{18}	M	E	M	U	M	(0.30,0.50,0.70)
L_{19}	U	U	P	U	U	(0.00,0.05,0.30)
L_{20}	M	U	P	M	P	(0.10,0.30,0.55)
L_{21}	U	M	M	M	P	(0.15,0.35,0.60)
L_{22}	M	U	M	M	M	(0.20,0.40,0.65)

L_{23}	U	M	P	U	M	(0.10,0.25,0.50)
L_{24}	U	U	M	U	M	(0.10,0.20,0.45)
L_{25}	M	E	E	E	P	(0.50,0.75,0.85)
L_{26}	P	M	U	M	M	(0.15,0.35,0.60)
L_{27}	S	M	M	M	P	(0.25,0.50,0.75)

Table. 4. Appropriateness rating assigned by expert' panel against qualitative objective and aggregated fuzzy appropriateness rating, (C_5)

Appropriateness rating assigned by expert' panel against qualitative objective and aggregated fuzzy appropriateness rating, (C_5)						AFR
L_{1-27}	DM1	DM2	DM3	DM4	DM5	
L_1	U	E	E	E	E	(0.60,0.80,0.85)
L_2	E	U	U	M	E	(0.35,0.50,0.65)
L_3	E	U	M	M	E	(0.40,0.60,0.75)
L_4	E	M	U	E	E	(0.50,0.70,0.80)
L_5	E	E	E	E	E	(0.75,1.00,1.00)
L_6	M	E	U	E	M	(0.40,0.60,0.75)
L_7	E	E	E	E	E	(0.75,1.00,1.00)
L_8	E	E	M	U	E	(0.50,0.70,0.80)
L_9	E	M	E	U	U	(0.35,0.50,0.65)
L_{10}	M	M	E	U	U	(0.25,0.40,0.60)
L_{11}	E	U	E	M	M	(0.40,0.60,0.75)
L_{12}	U	U	U	M	P	(0.05,0.15,0.40)
L_{13}	M	E	U	U	P	(0.20,0.35,0.55)
L_{14}	M	E	M	U	S	(0.35,0.55,0.75)
L_{15}	M	U	M	U	S	(0.20,0.35,0.60)
L_{16}	M	E	U	M	S	(0.35,0.55,0.75)
L_{17}	E	E	U	M	S	(0.45,0.65,0.80)
L_{18}	E	E	U	U	U	(0.30,0.40,0.55)
L_{19}	E	U	U	M	U	(0.20,0.30,0.50)
L_{20}	M	U	U	E	P	(0.20,0.35,0.55)
L_{21}	U	M	M	E	P	(0.25,0.45,0.65)
L_{22}	M	U	M	E	S	(0.35,0.55,0.75)
L_{23}	E	M	M	E	S	(0.50,0.75,0.90)
L_{24}	E	U	M	U	S	(0.30,0.45,0.65)
L_{25}	U	E	E	E	E	(0.60,0.80,0.85)
L_{26}	E	U	U	M	E	(0.35,0.50,0.65)
L_{27}	E	U	M	M	E	(0.40,0.60,0.75)

Table.5. Appropriateness rating assigned by expert' panel against qualitative objective and aggregated fuzzy appropriateness rating, (C_6)

Appropriateness rating assigned by expert' panel against qualitative objective and aggregated fuzzy appropriateness rating, (C_6)						AFR
L_{1-27}	DM1	DM2	DM3	DM4	DM5	
L_1	S	E	E	E	P	(0.55,0.80,0.90)
L_2	S	M	U	M	M	(0.25,0.45,0.70)
L_3	U	M	M	M	M	(0.20,0.40,0.65)
L_4	S	E	E	E	P	(0.55,0.80,0.90)
L_5	S	S	E	E	M	(0.55,0.80,0.95)
L_6	U	E	M	E	M	(0.40,0.60,0.75)
L_7	U	E	M	E	E	(0.50,0.70,0.80)
L_8	M	M	P	M	E	(0.30,0.55,0.75)
L_9	M	M	S	M	E	(0.40,0.65,0.85)
L_{10}	M	P	S	P	M	(0.20,0.45,0.70)
L_{11}	E	M	U	S	M	(0.35,0.55,0.75)
L_{12}	U	M	U	S	P	(0.15,0.30,0.55)
L_{13}	M	M	M	S	P	(0.25,0.50,0.75)
L_{14}	M	M	M	S	S	(0.35,0.60,0.85)

L_{15}	M	S	M	U	S	(0.30,0.50,0.75)
L_{16}	S	S	E	M	S	(0.50,0.75,0.95)
L_{17}	U	E	E	M	S	(0.45,0.65,0.80)
L_{18}	S	E	M	U	U	(0.30,0.45,0.65)
L_{19}	U	U	M	M	U	(0.10,0.20,0.45)
L_{20}	M	U	P	M	P	(0.10,0.30,0.55)
L_{21}	U	M	M	M	P	(0.15,0.35,0.60)
L_{22}	S	U	E	M	S	(0.40,0.60,0.80)
L_{23}	U	M	E	U	S	(0.30,0.45,0.65)
L_{24}	U	U	M	U	S	(0.15,0.25,0.50)
L_{25}	S	E	E	E	P	(0.55,0.80,0.90)
L_{26}	S	M	U	M	M	(0.25,0.45,0.70)
L_{27}	U	M	M	M	M	(0.20,0.40,0.65)

Table. 6. Appropriateness rating assigned by expert' panel against qualitative objective and aggregated fuzzy appropriateness rating, (C_7)

Appropriateness rating assigned by expert' panel against qualitative objective and aggregated fuzzy appropriateness rating, (C_7)						AFR
L_{1-27}	DM1	DM2	DM3	DM4	DM5	
L_1	S	E	E	E	P	(0.55,0.80,0.90)
L_2	S	S	E	E	M	(0.55,0.80,0.95)
L_3	U	E	M	E	M	(0.40,0.60,0.75)
L_4	S	E	E	E	P	(0.55,0.80,0.90)
L_5	S	M	U	M	M	(0.25,0.45,0.70)
L_6	U	M	M	M	M	(0.20,0.40,0.65)
L_7	U	E	M	E	E	(0.50,0.70,0.80)
L_8	M	M	P	M	E	(0.30,0.55,0.75)
L_9	M	M	S	M	E	(0.40,0.65,0.85)
L_{10}	M	P	S	P	M	(0.20,0.45,0.70)
L_{11}	E	M	U	S	M	(0.35,0.55,0.75)
L_{12}	U	M	U	S	P	(0.15,0.30,0.55)
L_{13}	M	M	M	S	P	(0.25,0.50,0.75)
L_{14}	M	M	M	S	S	(0.35,0.60,0.85)
L_{15}	M	S	M	U	S	(0.30,0.50,0.75)
L_{16}	S	S	E	M	S	(0.50,0.75,0.95)
L_{17}	U	E	E	M	S	(0.45,0.65,0.80)
L_{18}	S	E	M	U	U	(0.30,0.45,0.65)
L_{19}	U	U	M	M	U	(0.10,0.20,0.45)
L_{20}	M	U	P	M	P	(0.10,0.30,0.55)
L_{21}	U	M	M	M	P	(0.15,0.35,0.60)
L_{22}	S	U	E	M	S	(0.40,0.60,0.80)
L_{23}	U	M	E	U	S	(0.30,0.45,0.65)
L_{24}	U	U	M	U	S	(0.15,0.25,0.50)
L_{25}	S	E	E	E	P	(0.55,0.80,0.90)
L_{26}	S	M	U	M	M	(0.25,0.45,0.70)
L_{27}	U	M	M	M	M	(0.20,0.40,0.65)

Table. 7. Priority fuzzy weight assigned by expert' panel against all objective and aggregated priority weight, (C_1-C_7) and crisp & normalized crisp values

C_j	Priority weight (in linguistic term)					AFW	Crisp value	Normalized crisp value
	DM_1	DM_2	DM_3	DM_4	DM_5			
C_1	FI	I	I	FI	FI	(0.38,0.55,0.74)	0.555	0.13
C_2	FI	FI	FI	FI	FI	(0.30,0.45,0.70)	0.473	0.11
C_3	FI	VI	VI	SI	FI	(0.40,0.58,0.78)	0.585	0.13
C_4	FI	I	I	I	FI	(0.42,0.60,0.76)	0.595	0.13
C_5	I	I	I	SI	FI	(0.36,0.55,0.72)	0.545	0.12

C_6	FI	I	I	FI	FI	(0.38,0.55,0.74)	0.559	0.13
C_7	FI	I	I	FI	FI	(0.38,0.55,0.74)	0.551	0.12
							4.414	1

Table.8. Mixed objectives function matrix

L_{1-27}	C_1	C_2	C_3	C_4	C_5	C_6	C_7
	0.13	**0.11**	**0.13**	**0.13**	**0.12**	**0.13**	**0.12**
L_1	327.12	2.51	351.1	0.709	0.758	0.759	0.587
L_2	475.31	2.71	357.5	0.363	0.500	0.463	0.500
L_3	479.53	2.75	396.8	0.500	0.587	0.413	0.500
L_4	467.88	2.56	418.9	0.587	0.673	0.759	0.709
L_5	595.28	2.68	457.8	0.500	0.927	0.774	0.363
L_6	525.96	3.15	487.3	0.500	0.587	0.587	0.500
L_7	440.82	2.19	367.7	0.587	0.927	0.673	0.587
L_8	519.51	2.93	467.5	0.500	0.673	0.537	0.500
L_9	516.53	3.21	479.4	0.413	0.500	0.637	0.413
L_{10}	325.56	2.13	347.6	0.500	0.413	0.450	0.500
L_{11}	467.88	2.31	454.7	0.413	0.587	0.550	0.413
L_{12}	471.06	2.22	457.9	0.363	0.191	0.326	0.363
L_{13}	456.56	2.61	487.8	0.450	0.363	0.500	0.450
L_{14}	531.51	2.69	467.2	0.500	0.550	0.600	0.500
L_{15}	546.54	3.17	498.1	0.413	0.373	0.513	0.413
L_{16}	396.66	2.41	457.2	0.537	0.550	0.737	0.537
L_{17}	523.56	2.94	447.8	0.450	0.637	0.637	0.450
L_{18}	568.73	3.15	547.7	0.500	0.413	0.463	0.500
L_{19}	425.31	2.52	347.6	0.106	0.327	0.241	0.106
L_{20}	485.09	2.91	467.4	0.313	0.362	0.313	0.313
L_{21}	445.09	2.98	457.8	0.363	0.450	0.363	0.363
L_{22}	424.15	3.95	412.4	0.413	0.550	0.600	0.413
L_{23}	515.09	3.94	467.9	0.276	0.724	0.463	0.276
L_{24}	488.41	3.11	478.3	0.241	0.462	0.291	0.241
L_{25}	319.96	2.97	347.1	0.709	0.758	0.759	0.709
L_{26}	464.15	3.08	487.5	0.363	0.500	0.463	0.363
L_{27}	575.83	3.54	511.3	0.500	0.587	0.413	0.500

Table.9. Weighted normalized matrix

L_{1-27}	C_1	C_2	C_3	C_4	C_5	C_6	C_7
L_1	0.017	0.018	0.020	0.038	0.030	0.034	0.029
L_2	0.025	0.020	0.020	0.020	0.020	0.021	0.025
L_3	0.025	0.020	0.022	0.027	0.023	0.019	0.025
L_4	0.024	0.019	0.024	0.032	0.027	0.034	0.035
L_5	0.031	0.020	0.026	0.027	0.037	0.035	0.018
L_6	0.027	0.023	0.027	0.027	0.023	0.027	0.025
L_7	0.023	0.016	0.021	0.032	0.037	0.031	0.029
L_8	0.027	0.021	0.026	0.027	0.027	0.024	0.025
L_9	0.027	0.023	0.027	0.022	0.020	0.029	0.021
L_{10}	0.017	0.016	0.020	0.027	0.016	0.020	0.025
L_{11}	0.024	0.017	0.026	0.022	0.023	0.025	0.021

L_{12}	0.025	0.016	0.026	0.020	0.008	0.015	0.018
L_{13}	0.024	0.019	0.027	0.024	0.014	0.023	0.022
L_{14}	0.028	0.020	0.026	0.027	0.022	0.027	0.025
L_{15}	0.029	0.023	0.028	0.022	0.015	0.023	0.021
L_{16}	0.021	0.018	0.026	0.029	0.022	0.033	0.027
L_{17}	0.027	0.021	0.025	0.024	0.025	0.029	0.022
L_{18}	0.030	0.023	0.031	0.027	0.016	0.021	0.025
L_{19}	0.022	0.018	0.020	0.006	0.013	0.011	0.005
L_{20}	0.025	0.021	0.026	0.017	0.014	0.014	0.016
L_{21}	0.023	0.022	0.026	0.020	0.018	0.016	0.018
L_{22}	0.022	0.029	0.023	0.022	0.022	0.027	0.021
L_{23}	0.027	0.029	0.026	0.015	0.029	0.021	0.014
L_{24}	0.026	0.023	0.027	0.013	0.018	0.013	0.012
L_{25}	0.017	0.022	0.020	0.038	0.030	0.034	0.035
L_{26}	0.024	0.022	0.027	0.020	0.020	0.021	0.018
L_{27}	0.030	0.026	0.029	0.027	0.023	0.019	0.025

Table.10. Preferences order by ratio system analysis corresponding to experiments

$L_{1\text{-}27}$	**RSA**	
	y_i^*	
	Preferences orders	
L_1	0.019520	22
L_2	0.023263	20
L_3	**0.047981**	**1**
L_4	0.013249	26
L_5	0.035925	5
L_6	0.033294	9
L_7	0.030211	13
L_8	0.039728	2
L_9	0.025859	18
L_{10}	0.026710	17
L_{11}	0.036565	4
L_{12}	0.018055	24
L_{13}	0.028467	16
L_{14}	0.031161	11
L_{15}	0.023232	21
L_{16}	0.019109	23
L_{17}	0.031906	10
L_{18}	0.029415	15
L_{19}	0.012913	27
L_{20}	0.029598	14
L_{21}	0.033462	8
L_{22}	0.025814	19
L_{23}	0.035032	6
L_{24}	0.030711	12
L_{25}	0.018774	25
L_{26}	0.034024	7

L_{27}	0.036571	3

VII. CONCLUSION:

After applying the hybrid technique, the optimum setting among parameters in extent of MIG welding process has found as:

Welding current (I)= 185 ampere
Arc voltage (V)= 24 Vols
Root gaps (Rg)= 3 mm
The evaluated results have been shown depicted in Table. 10 and shown by fig. 2

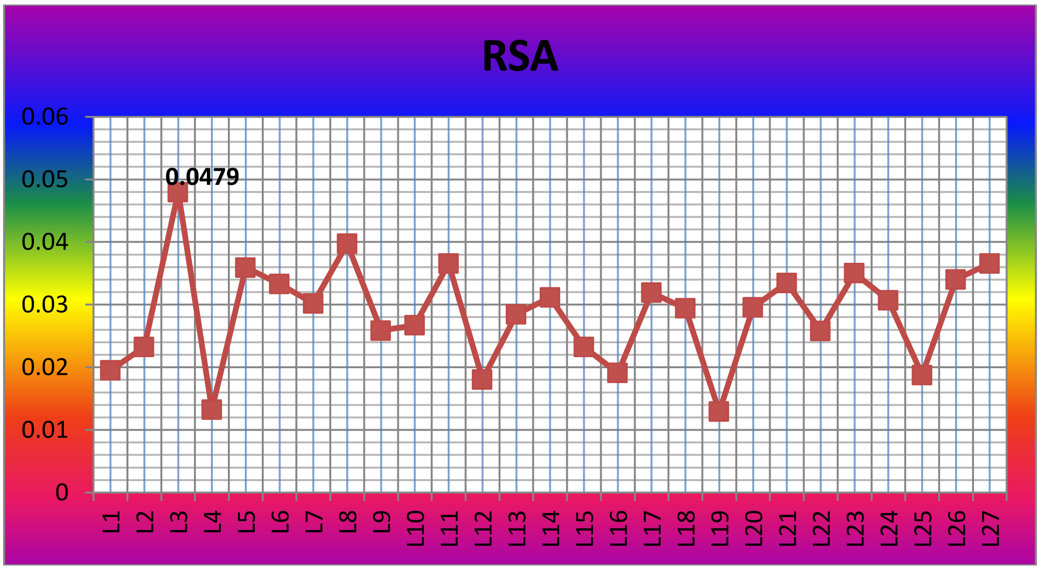

Fig: 2. The optimum parametric setting among parameters in TIG welding process, obtained by RSA techniques by line chart

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