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Optimization the machining parameters by using VIKOR and Entropy Weight method during EDM process of Al–18% SiCp Metal matrix composite

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A B S T R A C T

The objective of this paper is to optimize the process parameters by combined approach of VIKOR and Entropy weight measurement method during Electrical discharge machining (EDM) process of Al-18wt.%SiC$_p$ metal matrix composite (MMC). The central composite design (CCD) method is considered to evaluate the effect of three process parameters; namely pulse on time (T_{on}), peak current (I_p) and flushing pressure (F_p) on the responses like material removal rate (MRR), tool wear rate (TWR), Radial over cut (ROC) and surface roughness (R_a). The Entropy weight measurement method evaluates the individual weights of each response and, using VIKOR method, the multi-objective responses are optimized to get a single numerical index known as VIKOR Index. Then the Analysis of Variance (ANOVA) technique is used to determine the significance of the process parameters on the VIKOR Index. Finally, the result of the VIKOR Indexed is validated by conformation test using the liner mathematical model equation develop by responses surface methodology to identify the effectiveness of the proposed method.

1. Introduction

Recently, metal matrix composite (MMC) materials are used for different applications in the manufacturing sector. The Aluminium-SiC is one of the MMC materials, which are used mostly in the industries like automotive, aerospace, defence, sports, electrical appliance and electronics industries, etc. Generally Aluminium-alloy is a light weight, high resistance, resistance to chemical degradation and low density material. When Aluminium alloy materials are reinforced with Silicon carbide (SiC) particles to form the Aluminium-SiC MMC material it increases the physical, mechanical and thermal property, in terms of lower to weight ratio, than other conventional material (Fard et al., 2013; Muthukrishnan et al., 2011). Machining of Aluminium-SiC based MMC by conventional method is an interesting problem because at the time of machining the SiC ceramic particles embedded inside the MMC which are very difficult to machining due to its high strength, inherent brittleness, and low fracture toughness. To overcome this type problem significant amount of Non-traditional machining

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process are available but in this study electrical discharge machining process is used for these experiments (Ji et al., 2012; Puhan et al. 2013). Electric discharge machining is the most widely used non-traditional machining process. In this process all the materials, conventional and composite materials, are machined with a good electrical conductor irrespective the mechanical properties of the materials. This process is based on the principle of thermoelectric energy. As per the principle at the time of spark discharge the temperature reaches approximately 12,000^{0}C between the work-piece and tool in the electrolyte fluid medium. The material is removed from the work-piece by a series of electric spark discharge between the both electrodes (work piece and tool) within a fraction of micro-second. Due to this spark discharge the material is removed by melting and vaporization from both the electrodes and erodes the surface in the shape of tool on the work piece (Laxman & Raj., 2014; Rao et al., 2011).

1.1. Literature survey

In the past many researchers have attempted different types of methodologies to improve the machining characteristics during EDM of Al-SiC_p composite material. Hung et al. (1994) explained the cast Al-SiC_p MMC as a superior mechanical property over the unreinforced alloys. Also they studied the effect of process parameter on MRR, recast layer, and surface finish of this cast MMC during EDM. Bhuyan et al. (2014) stated that Al-SiC metal matrix composites offer high specific strength and good resistances than other conventional metals did. Also they explained that MRR, TWR and R_a are greatly influenced by the Peak current during EDM process. Dhar et al. (2007) proposed Taguchi L_{27} method to study the effect of pulse current, pulse duration and gap voltage on the responses like MRR, TWR, ROC and Ra during EDM of Al–4Cu–6Si alloy with 10 wt.% SiC MMC. Also ANOVA technique and mathematical model were used to optimize the process parameters. Pradhan and Biswas (2010) used central composite design (CCD) method to investigate the effect of peak current, pulse on time, pulse off time and discharge voltage on the surface roughness during EDM of AISI D2 steel materials. Khalid et al. (2011) optimized the process parameter such as current, pulse on time and pulse off time over the three outputs MRR, TWR and R_a by using Fuzzy logic Evolutionary Strategies and concluded that proposed methodology could be a benchmark to solve the multi-objective problems. Sivasankar and jeyapal. (2012) optimized the machining performance such as MRR, TWR, weight wear ratio, taper angle by using entropy based grey relation analysis during EDM of hot pressed ZrB_2. Majhi et al. (2014) used Grey relational analysis and Entropy measurement method to investigated the effect of input parameter such as pulse on time, pulse off time, discharge current on the machining performance like MRR, TWR and R_a of AISI D2 tool steel method during EDM. Koyee et al. (2013) used VIKOR method to optimize the cutting speed, feed rate and depth of cut on the responses like surface roughness, specific cutting energy, cutting power and resultant cutting forces during turning of super duplex EN 14410, standard duplex EN 14462 and austenitic EN 14404 stainless steels. Tong et al. (2007) used Taguchi and VIKOR method to optimize the quality improvement Techniques in an industry and ranking the quality loss control factor to minimize the loss in that product. Raman et al. (2013) optimized the cutting parameter on MRR and R_a during CNC turning by using VIKOR and AHP method. Kaoser et al. (2014) suggested VIKOR and AHP method in a multi criteria decision making during electroplating of different material in an industry. Lakshmanan and kumar (2013) developed a statistical mathematical model by using response surface methodology (RSM) for the response MRR using the input parameters such as pulse on time, pulse off time, pulse current and voltage. To analyze the input parameter ANOVA technique was used during machining of EN-31 by EDM. Kumar and Mohit (2013) used Taguchi L_{27} orthogonal array and ANOVA technique to optimize the process parameters of Al-15%SiCduring EDM.

Based on the above literature review, this paper is focused to optimize the process parameter by VIKOR and entropy weight measurement method during EDM of Al-18%SiC_p MMC. The objective is to obtain single numerical Index known as VIKOR index and optimal level of process parameter setting for the complex multi characteristics machining. As well as ANOVA technique is used to know the significance of the relative combination of the parameters on the VIKOR index result. Mathematical model is also developed based on response surface methodology. Also the microstructure of the surface is studied by FESEM before and after machining under the specific process parameter.

2. Experimental procedures

2.1 Fabrication of composites materials

The materials are prepared by using commercial pure aluminium with purity of 98 % and SiC particle with the average grain size is 0.0228 mm. The composite materials are fabricated by using stir casting method on the basis of 18% weight fraction of SiC and remaining weight as aluminium alloy. In this process the molten aluminium and SiC are aggregated at 400 rpm to get uniformly distributed of the SiC in aluminium alloy to obtain the sample piece material. The original size of the specimen is prepared approximately 40 mm in diameter and length approximately 360 mm. Fig. 1 shows the field emission scanning electron microscope (FESEM) surface textures of Al-18%SiC_p MMC after casting. The figure describes that at the time of fabrication of Al-SiC_p MMC the Al-alloy is easily melt near about temperature 740^0C but the SiC does not melt at that temperature because its melting point is near about 2730^0C. But at that temperature SiC particles decomposing with the parent material which produces free carbon and that carbon deposition arises black colour on the Al-SiC_p MMC surface (Hu et al., 2013; Srinivasa et al., 2014).

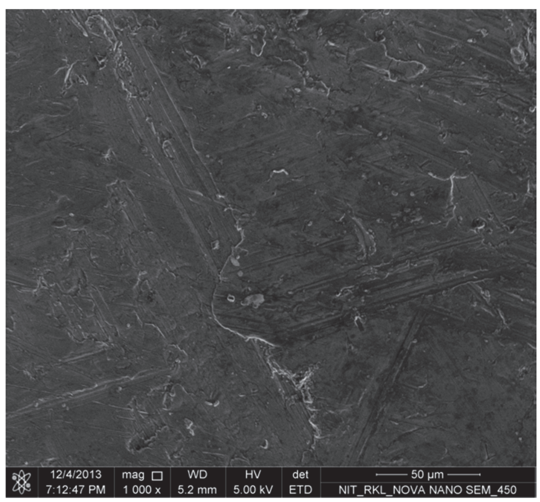

Fig. 1. FESEM of the Al-18%SiC_p MMC after casting

2.2 Design of experiment

The experiment is followed by Central Composite Design (CCD) method by running 20 experiments. To run the experiments, three process parameters are considered; i.e. Pulse on time (T_{on}) in Microsecond (μs), Peak current (I_p) in Ampere (A) and Flushing pressure (F_p) in Kg/cm^2. Based on the literature survey and CCD method, the ranges of the parameters are selected with different levels as shown in the Table 1.

Table 1
Process parameter and their levels

	Machining parameter Levels				
	-1.682	-1	0	1	1.682
Pulse on time (T_{on})	116	150	200	250	284
Peak current (I_p)	3.2	10	20	30	36.8
Flushing pressure (F_p)	0.164	0.3	0.5	0.7	0.836

2.3 Experimental method & Results

A series of experiments are carried out by Electrical Discharge machining of model MIC-432CS CNC manufactured by ECOWIN at Central Institute of Plastic Engineering And Technology, Patia, Bhubaneswar. The work pieces materials are Al-18%SiC_p MMC with individual dimensions of each work piece 40 mm in diameter and 10 mm in thickness. The tools are made of Copper electrode with the average diameter 25.4 mm. The depth of machining of each work piece is carried out 2 mm and the machining time is recorded in the timer of EDM. The weight of the work piece and tools are measured by using electronic "METLERPM 200" digital weight measurement instrument and the diameters of tool and hole are measured by "PROFILE PROJECTOR". The surface roughness R_a is measured by "MITUTOYO" Surface roughness tester. The following mathematical relations are used for evaluation of responses such as Material removal rate (MRR), Tool wear rate (TWR) and Radial over cut (ROC) as shown in below.

$$MRR = \frac{W_b - W_a}{t}\, mg/min$$

where W_b = Weight of work piece before machining (mg), W_a = Weight of work piece after machining (mg) and t =Machining time in (min).

$$TWR = \frac{T_b - T_a}{t}\, mg/min,$$

where T_b= Weight of tool piece before machining (mg), T_a= Weight of tool piece after machining (mg), t = Machining time (min).

$$ROC = \frac{d_t - d_h}{2}\, mm$$

where d_t= Tool diameter before machining (mm) d_h = Hole diameter after machining (mm). The experiments results with their un-code arrangement of the process parameter by CCD method are shown in Table 2.

Table 2

Design of experimental and results

Experiment No.	Pulse on time(µS)	Peak current(A)	Flushing pressure(Kg/cm^2)	MRR (mg/min)	TWR (mg/min)	ROC (mm)	R_a (micron)
1	150	10.0	0.300	265.530	11.780	0.064	8.301
2	250	10.0	0.300	333.900	0.770	0.116	10.406
3	150	30.0	0.300	1313.250	14.684	0.081	16.521
4	250	30.0	0.300	1290.580	9.700	0.077	24.342
5	150	10.0	0.700	128.360	0.391	0.012	8.680
6	250	10.0	0.700	1065.940	0.698	0.058	13.149
7	150	30.0	0.700	1367.000	15.918	0.092	16.844
8	250	30.0	0.700	1340.780	14.513	0.083	22.489
9	116	20.0	0.500	884.000	14.599	0.055	7.468
10	284	20.0	0.500	1116.590	4.078	0.087	20.056
11	200	3.2	0.500	162.400	0.678	0.044	6.083
12	200	36.8	0.500	1759.000	21.687	0.091	23.404
13	200	20.0	0.164	680.580	12.000	0.087	14.989
14	200	20.0	0.836	1035.000	7.977	0.046	16.737
15	200	20.0	0.500	754.687	7.952	0.073	16.101
16	200	20.0	0.500	750.590	6.032	0.073	15.858
17	200	20.0	0.500	745.791	7.632	0.075	15.850
18	200	20.0	0.500	784.843	8.827	0.075	15.981
19	200	20.0	0.500	754.423	7.632	0.074	15.729
20	200	20.0	0.500	764.670	7.632	0.072	15.796

Fig. 2 shows the FESEM of erode surfaces at the condition T_{on} = 250 µS, I_p =10 Amp and F_p = 0.700 Kg/cm^2 during EDM. In this Figure there are large number of voids, micro holes, gas bubbles and micro crackers appearing on the surface during EDM. This type of morphological defects is due to at the time of machining a high tensile stress is developed because of an extremely high energy discharge in the area between electrodes to form a plasma phase. Due this phase a temperature is raised in between work piece and the tool to form a molten stage on the machining surfaces. When this machining surface is contact with the air and flushing of dielectric result to from various types of surface texture on the surface at the time of solidification of molten droplets.(Muller & Monaghan, 2001; Velmurugan et al., 2011).

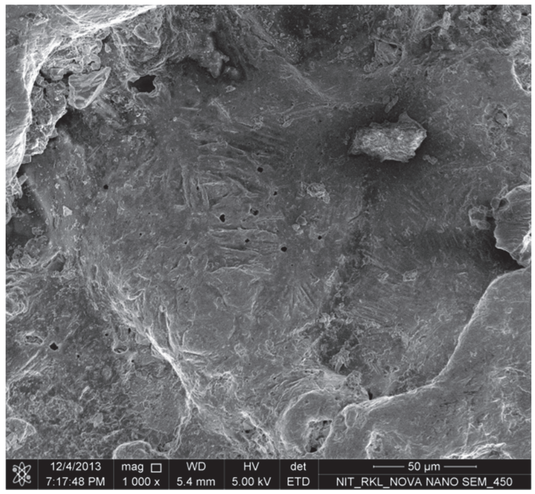

Fig. 2. FESEM of the Al-18%SiC_p MMC after Machining

3. Methodology

3.1. Entropy weight Measurement Method

The Entropy weight measurement method determines the weight of each individual response parameters without any consideration of the decision of the decision maker. The basic concept of entropy weight measurement is that higher weight index value is more useful than smaller index value. In this paper, the following steps are used to evaluate the weight index of each response (Sivasankar et al., 2013; Majhi et al.,2014; Li et al., 2011),

Step-I: First step is covert the process parameter and the responses into 'm' alternatives, from 'n' attributes. Here the 'm' alternatives are T_{ON}, I_p, F_p and the 'n' attributes are MRR, TWR, ROC, R_a.

Step-II: The experimental results are changed in the form of Decision matrix i.e. $D[x_{ij}]_{m\times n}$ where '*D*' is the Decision matrix and x_{ij} is the j^{th} attributes results of the i^{th} alternatives. The decision matrix can be expressed as

$$D=\begin{bmatrix} x_{11} & x_{12} & . & . & . & x_{1n} \\ x_{21} & x_{22} & . & . & . & x_{23} \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ . & . & . & . & . & . \\ x_{m1} & x_{m2} & . & . & . & x_{mn} \end{bmatrix}$$

where $i=1, 2\ldots m$ & $j=1, 2,\ldots.n$

Step-III: The decision matrix is normalized by beneficial attribute (i.e. maximum values), and non-beneficial attribute (i.e. minimum values).The Normalized matrix is calculated by the following mathematical equation.

$$r_{ij} = \frac{x_{ij} - min(x_{ij})}{max(x_{ij}) - min(x_{ij})}, \tag{1}$$

$$r_{ij} = \frac{max(x_{ij}) - x_{ij}}{max(x_{ij}) - min(x_{ij})}, \tag{2}$$

i=1, 2…m & j=1, 2…n

Step-IV After normalization put the value of r_{ij} in the equation (3) to get ‘M’

$$M = (r_{ij})_{mxn} \tag{3}$$

Then find $T = (T_{ij})_{mxn}$

$$T_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}}. \tag{4}$$

Step-V Calculation of entropy index (‘e_j’)

The entropy of *‘j^{th}’ index* is evaluated by the following relation.

$$e_j = -\frac{1}{lnm}\sum_{i=1}^{m} T_{ij} lnT_{ij}. \tag{5}$$

Step-VI Entropy weight (w_j) of the j^{th} index is determined by

$$w_j = \frac{1 - e_j}{n - \sum_{j=1}^{n} e_{ij}}. \tag{6}$$

3.2 VIKOR method (Vise Kriterijumska Optimizacija Kompromisno Resenje)

The VIKOR method was first introduced by Zeleny, in the year 1982. It is a Serbian name full pronounces as Vlse Kriterijumska Optimizacija Kompromisno Resenje. This method is applicable to multi criteria decision making in a complex decision making problem. The basic thought of this VIKOR method is multi-criteria optimization and compromise the solution for finding a final solution. Basically it is an aggregated statistical procedure to find the solution close to ideal and negative ideal solution. This method is focused on ranking the set of alternatives from the different problems criteria that help the decision makers reach a final solution. The best optimal solution is the result corresponding to smallest VIKOR indexed value. To calculate the VIKOR Index the following steps are used as per the previously selected researcher method. (Tong et al., 2007; Kumar et al., 2013; Li & Wang, 2012; Sayadi et al., 2009)

Step 1. Normalize the decision matrix,

The Normalized matrix may be defined as

$$f = (f_{ij})_{mxn} \tag{7}$$

where

$$f = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{8}$$

$i = 1,2, \ldots, m$; $j = 1, 2, \ldots, n$; and x_{ij} is the corresponding value of the j^{th} attribute.

Step 2 Determination of ideal and negative-ideal solutions

The ideal (best) solution represented by f^* and the negative ideal (Worst) solution represented by f^- are determined as follows:

$$f^* = \{(max\ f_{ij}\ /\ j \in J) \text{ OR } (min\ f_{ij}\ /\ j \in J')\}, \tag{9}$$

$$f^- = \{(min\ f_{ij}\ /\ j \in J) \text{ OR } (max\ f_{ij}\ /\ j \in J')\}, \tag{10}$$

where J = {j= 1, 2…..n}, f_{ij} if desired responses is large
J'= {j= 1, 2…..n}, f_{ij} if desired responses is small.

Step 3 Calculation of utility measure and regret measure

The utility measure and the regret measure for each result are calculated by the following equation

$$S_i = \sum_{j=1}^{n} w_j \frac{\left(f^* - f_{ij}\right)}{\left(f_j^* - f_j^-\right)}, \tag{11}$$

$$R_i = \max_{j} \left[w_j \frac{\left(f^* - f_{ij}\right)}{\left(f_j^* - f_j^-\right)} \right], \tag{12}$$

where S_i is the utility measure, R_i is the regret measure and w_j is the corresponding weight of the j^{th} attribute. In this paper the individual weight are calculated by entropy weight measurement method.

Step 4 Calculation of VIKOR index

The VIKOR index is calculated as the following relation.

$$Q_i = v\left[\frac{\left(S_i - S^*\right)}{\left(S^- - S^*\right)}\right] + (1-v)\left[\frac{\left(R_i - R^*\right)}{\left(R^- - R^*\right)}\right], \tag{13}$$

where Q_i is the VIKOR Index or multi-performance characteristics index (MPCI) of the i^{th} result of the alternatives and v is the maximum weight of the group utility in general v=0.5

$S^- = \max_i S_i$, $S^* = \min_i S_i$, $R^- = \max_i R_i$, $R^* = \min_i R_i$

Step 5 Rank the order

To rank the alternatives decease value of the VIKOR index is consider and the smallest value is the highest rank order.

Step 6 Propose as a compromise solution of the consider weights of the given alternative. The alternative A^1 is considered as first highest rank by the measure Q (minimum) and A^2 is the second highest in the ranking order of the VIKOR index list.

If the following two condition are satisfied

a. *Acceptable advantage*

$$Q\left(A^2\right)-Q\left(A^1\right) \geq DQ = \frac{1}{(m-1)}, \tag{14}$$

where *m* is the number of alternatives

b. Acceptable stability in decision making

Alternative A^1 is the best ranked by S or / and R. This compromise solution is stable within the decision making process, which could be the strategy of maximum group utility (when v > 0.5 is needed), or "by consensus" (when v≈0.5) or "with veto" (when v < 0.5). If one of the conditions is not satisfied, then the set of compromise solutions is proposed by,

This consists of:

I. the Alternatives A^1 and A^2 if only second (b) condition is not satisfied
II. Alternatives A^1, A^2,……… A^n first (a) condition is not satisfied A^n is calculated by the following relation

$$Q\ \left(A^n\right)-Q\ \left(A^1\right)\ <\ DQ \text{ for maximum } n \tag{15}$$

Step 7

From the above the best rank when the Q value is minimum. The main objective is rank the list of experimental result and compromises the solution with their advantage rate. A smaller the VIKOR Index is the better result for the multi responses problem.

4.2 Response surface Methodology

Response surface methodology (RSM) is a technique to build the machining characteristics into a mathematical and statistical numerical equation. The primary objective is to make a relationship between the response and the cores spending process parameters. The relationship between the machining characteristics is commonly represented by a function
(ϕ). The functional relation can be representing as

$$\mathrm{R} = \varphi(\mathrm{x}_1,\cdots,\mathrm{x}_\mathrm{n}), \tag{16}$$

where R is defined as the response and $x_1, x_2, \cdots, x_n$ are the *input* process parameters. In RSM the relationship between the process parameter and responses is represented by the fitted second order polynomial regression model in the form of quadratic equation. The quadratic model equation for the three input process parameter is written as

$$R = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_4 x_1^2 + \beta_5 x_2^2 + \beta_6 x_3^2 + \beta_7 x_1 x_2 + \beta_8 x_1 \times x_3 + \beta_9 x_2 x_3 \quad (17)$$

where β_0 is a constant and $\beta_1, \beta_2, \beta_3$ are the coefficients of linear effect of the input variables, x_1, x_2, x_3 respectively. Moreover, $\beta_4, \beta_5, \beta_6$ are the coefficients of the square effects of input parameters associated with x_1^2, x_2^2, x_3^2, respectively. Similarly the $\beta_7, \beta_8, \beta_9$ are the coefficients of liner by liner interactions of x_1 and x_2, x_1 and x_3 and x_2 and x_3 respectively. The coefficients are found by an appropriate method such as the least square method or Minitab Software (Velmurugan et al., 2011; Shandilya et al., 2012)

4. Results and Discussion

The study is approached by a combine effect of Entropy weight measurement and VIKOR methods. To evaluate the entropy weight measurement the decision matrix $D_{m\times n}$ is represented by the experimental results as shown in Table 2. To evaluate the weight of the each experiment by entropy weight measurement method, the normalized matrix is solved by considering the minimum requirement attributes by Eq. (1) and maximum attributes by Eq. (2). The TWR, ROC and R_a are considered as non-beneficial (i.e. minimum attribute values) while MRR is considered as beneficial attribute (i.e. maximum attribute values). After the normalization of matrix, the individual relative weighted of the responses is evaluated using Eq. (3) to Eq. (6).The weights of the each response are shown in Table 3.

Table 3
Weight of each response

Experiment	MRR	TWR	ROC	R_a
1	0.245	0.245	0.251	0.258
2	0.244	0.260	0.243	0.254
3	0.256	0.246	0.249	0.249
4	0.256	0.250	0.250	0.244
5	0.237	0.256	0.256	0.251
6	0.248	0.257	0.248	0.248
7	0.257	0.245	0.248	0.250
8	0.257	0.247	0.250	0.246
9	0.248	0.243	0.251	0.258
10	0.252	0.255	0.247	0.245
11	0.239	0.256	0.249	0.257
12	0.265	0.242	0.249	0.245
13	0.250	0.249	0.250	0.252
14	0.250	0.250	0.253	0.247
15	0.249	0.251	0.250	0.249
16	0.249	0.253	0.249	0.249
17	0.249	0.252	0.250	0.250
18	0.250	0.251	0.250	0.250
19	0.249	0.251	0.250	0.250
20	0.249	0.251	0.250	0.250

The VIKOR method is used for optimizing the multi objective problem for that reason again the decision matrix normalized by Eq. (8). Now the performance of individual normalized response matrix is analyzed with the best (f^*) by Eq. (9) and worst (f^-) values by Eq. (10). For the response MRR, TWR, ROC, R_a the best values are 0.409, 0.003, 0.035, 0.516 and the worst values are 0.030, 10.087, 0.346 and 8.263, respectively. The value of S_i (utility measure) and R_i (Regret measure) is by Eq. (11) and Eq. (12), respectively. The maximum, minimum utility measure are $S^- = 0.661$, $S^* = 0.255$ and for regret measure is $R^{-} = 0.250$, $R^{*} = 0.110$, respectively. The VIKOR Index (Q_i) is evaluated based on the Eq. (13) and ranked according to the lowest value of Q_i as shown in Table 4.

Table 4
VIKOR Index (Q_i) scores and Rank Order.

Experiment .No	Q_i	Rank Order
1	0.633	16
2	0.762	18
3	0.445	10
4	0.840	19
5	0.456	11
6	0.028	1
7	0.587	15
8	0.736	17
9	0.210	3
10	0.486	12
11	0.512	13
12	0.972	20
13	0.565	14
14	0.108	2
15	0.379	7
16	0.357	4
17	0.383	8
18	0.384	9
19	0.371	6
20	0.360	5

To check the stable position and advantage over other experimental result, the acceptable advantage condition is applied by using the Eq. (14) as on step 6. From the Table 4 it is found that $Q(A^1)$ and $Q(A^2)$ are the first Index and the second Index, respectively. The corresponding VIKOR index values are 0.108 and 0.028, respectively. As per the first acceptable condition the values of $DQ = \frac{1}{(m-1)}$ is 0.052.Therefore $Q(A^2) - Q(A^1)$ (0.108-0.028=0.080) is always greater than DQ and condition is acceptable.

4.1. Optimal level of Selection and Analysis of Variance (ANOVA)

To find the optimal level of selection the main effects parameter is evaluated on the basis of each individual level result of VIKOR Index as shown in Table 5. The best level for each factor is identified by the lowest VIKOR Index. From the table it is found that the level corresponding to lowest VIKOR Index is T_{on} level 1, I_p level 3, and F_p level 5 with their corresponding values are T_{on}=0.210, I_p=0.363 and F_p=0.108, respectively. Based on the lowest level result the corresponding process parameter for that level Ton=116 µS, I_p=20 amp and F_p=0.836 Kg/cm^2 are the optimized process parameter for this multi-character machining. Also the table shows the difference between the maximum and minimum level value and their ranking among the process parameter for this selective model.

Table 5
Main effects factor on VIKOR level

Parameter	Level 1	Level 2	Level 3	Level 4	Level 5	Max-Min	Rank
T_{on}	0.210	0.530	0.439	0.592	0.486	0.382	3
I_p	0.512	0.470	0.363	0.652	0.972	0.608	1
F_p	0.565	0.670	0.441	0.452	0.108	0.562	2

The result of ANOVA test on the VIKOR Index result is shown in Table 6. From the table it is analyzed that if the ‘P’ value is less than 0.05 then the linear, square, interaction of the process parameter are significant and 95% confidences level. The R^2 and Adj R^2 are indicating the measure result goodness of fit for the model. If it is close to unity the experimental result is better and fit for the model. The value of R^2 and Adj R^2 are for MRR 96.57%, 93.49%, for TWR 95.34%,91.15% , ROC 98.62%, 97.39% for R_a 98.26%, 96.69% and for Q_i 95.16%, 90.81%, respectively. From the R^2 and Adj R^2 result it is analyzed that the developed model is statistically considerable (Sahoo et al., 2013; Shandilya et al., 2012).

Table 6
ANOVA of VIKOR Index

Source	DF	SeqSS	AdjSS	Adj MS	F	P	Remark
Linear	3	0.39977	0.397524	0.132508	26.15	0.000	Significant
Square	3	0.31490	0.314904	0.14968	20.71	0.000	Significant
Interaction	3	0.28220	0.2882201	0.094067	18.56	0.000	Significant
Residual Error	10	0.05068	0.0050678	0.005068			
Total	19	1.04756					

6. Conformation Test

To verify the model the experiment is again analyzed by conformation test. The predicated value of the conformation test is obtained from the quadratic mathematical equation by using RSM. Based on the RSM using the quadratic Eq. (17) the VIKOR Index result is represented by

$$Qi = 1.41816 + 0.00057Ton - 0.11985Ip + 0.11729Fp + 0.0000Ton^2 + 0.00148Ip^2 + 0.10160Fp^2 + 0.00021Ton * Ip - 0.01004Ton * Fp + 0.05936Ip * Fp \quad (18)$$

For the conformity test the overall percentage of error with its experiments value and predicted values is evaluated by considering the Eq. (18) with the corresponding process parameter of the lowest main effects factor of the VIKOR Index level. The conformity test result with its overall percentage is shown in Table 7.

Table 7
Conformation test as per the VIKOR Index

Numerical Index	Lowest main effective level of VIKOR Index.	Predicted results	Experimental results	% Error
VIKOR Index	T_{on}=116 µS I_p=20 Amp. F_p=0.836 Kg/cm^2	0.354	0.343	3.107

7. Conclusion

- In this study the experiment is followed by CCD method with pulse on time, peak current and flushing pressure as an input parameter and the output are MRR, TWR, ROC and R_a.
- To optimize the machining characteristics the VIKOR and Entropy weight measurement method have been used to determine the optimal machining condition during EDM of Al-18% SiC_p MMC. In this attempt the single numerical index has been evaluated known as VIKOR Index.
- From the main effect table the corresponding process parameter for the lowest level of VIKOR

Index is the optimized machining parameter setting for this chosen model. It is found that the peak current is the most effective parameter among the other process parameter.

- The ANOVA is carried out and it has been found that all the machining characteristics during linear, square and interaction of process parameter are significant. Also from the ANOVA analysis the selected model is more than 95% confidence level.
- Finally, the conformation test is carried out by using the developed mathematical equation by RSM. It is found from the test that the estimated optimum parameter machining condition produce best possible result with a minimum error near about 3.1%.
- Hence this study is simple and success-fully optimized the multi machining problem in both the researchers and industries to solving the robust problem for any type of machining.

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