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Utilizing multiple criteria decision-making optimization methods to machine LM25Al/VC material under electro-discharge machining processes

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Abstract. In this work, sparking electro-discharge machining (EDM) process parameters are optimized by using multiple criteria decision-making (MCDM) methods. The work piece utilized for the investigation was LM25 aluminum alloy reinforced with Vanadium carbide (VC), processed through a stir casting technique. The EDM process parameters that have been considered in this work are by peak current, pulse-on-time, and pulse-off-time, with the effects of each variable and their combinations on the performance metrics of EDM like material removal rate, electrode wearing rate, and surface roughness. In this study, three MCDM methodologies were applied to evaluate EDM performance. Then, the obtained MCDM scores were compared using two different objective verification mechanisms. In this case, the VIKOR technique delivered the best-desired results relative to TOPSIS method, and factorial analyzing method. Also, the factorial method is simpler than the other methods, though it produced nearly identical results as the sophisticated MDCM method.

Keywords: Material removal rate, VIKOR, peak current, pulse-on-time

1. Introduction

The electro-discharge machining (EDM) process is a non-conventional and non-contact operation that is used in industry for high-precision products, especially in manufacturing industries such as the aerospace and automotive industries, communication, and biotechnology industries [1–3]. Most of those industries employed materials with superior properties like high corrosion and wear resistance, low cost, low weight and good strength. It is also appropriate in some high-strength and high-temperature applications. However, it is difficult to see the aforementioned properties in a single material, and to overcome these significant demands, composite materials were proposed by different researchers [4-8]. Aluminum alloys are an ideal material for different applications, like aircraft applications, cog wheels and shafts, rocket components, and regulating valve parts, while being supported by heat-refractory and hard materials.

Aluminum-vanadium carbide composites are providing superior properties which cannot be achieved by any existing monolithic or composite materials [9]. Vanadium carbide (VC) is the hard refractory material, and the cost of the reinforcement in comparison with other materials is very nominal [10]. VC particulate reinforcements help to improve the aluminum matrix in terms of hardness, heat refractory, strength, and wear resistance [11]. In fact, extremely high hardness will lead to machinability challenges. When it comes to the machining of difficult-to-machine and/or hard materials, the selection and optimization of the appropriate machining techniques are of prime importance. In addition to their unique characteristics, most modern materials need special manufacturing processes to enable them to be machined with ease [12]. EDM, a thermo-physically based material ablation technology, is a cutting-edge machining technique with a remarkable ability to machine extremely hard and brittle materials with complicated three-dimensional structures [13].

In this study, the focus is to increase material removal rate and minimize surface roughness for composite aluminum alloys with vanadium carbide (LM25Al/VC). The LM25Al/VC hybrid composite has been selected to analyze its machineability by EDM with the MCDM optimization method. The various EDM input parameters, such as peak current (I_p), pulse-on-time (t_{on}), plus-off time (t_{off}), and VC weight percentage of reinforcement materials, are considered in the analysis. It is also important to state that the influence of an increase in wt% of VC was investigated on performance characteristics during the machining of the aluminum alloy silicon composite [14]. It was found that the material erosion rate decreased, and the electrode wear increased with an increase in reinforcing quantity in the matrix phase [15]. Some researchers [16–19] have checked the feasibility of EDM in composite materials, and their results yield that the reinforcing constituents in the matrix obstruct effective sparking and reduce matrix phase erosion.

To improve the performance metrics of EDM, several sensitivity analysis and optimization approaches of the process variables were performed by previous researchers on various high-strength and harder materials [20–23]. The experimental findings indicate that positive polarity exhibited the maximum workpiece material removal rate accompanied by reduced tool erosion and surface waviness when compared to negative polarity [24]. An examination of electrically independent variables like pulse current, spark duration, and gap voltage was made for the Al7075/SiC/WS2 hybrid composite using the MCDM method. The results revealed that pulse current and discharging time had significantly varied all the performance metrics (MRR and tool erosion rate) in a linear manner with a gradual change in current levels [25]. EDM effectiveness, namely the quality of the machined holes, was measured through surface roughness and taperness. It was found that spark-off time had a large percentage contribution to hole quality metrics relative to discharge current, sparking duration, and flushing force [26]. Shao et al. [27] used dielectric fluid mixed with Al powder and conducted experiment in EDM machine, and to analyze the experimental results, response surface methodology (RSM) was used.

In real-world industry applications, many variables affect the manufacturing process. These variables can be analyzed by MCDM methods. In the same way, multi-objective approaches also have difficulties achieving many goals at the same time [28]. Various approaches, such as metaheuristics, Pareto-based strategies, and multi-model independent direction, are used to address improvement challenges. EDM process variables were optimized using different optimization techniques like Taguchi, TOPSIS, VIKOR, TLBO, RSM, and Grey relational analysis (GRA) [29, 30]. As a result, using various multi-standard methodologies may result in varied choice suggestions. However, most approaches gave some unique advantages and also had deficiencies of one sort or another. On the other hand, the choice of those models is based on the knowledge of researchers and professionals in the specific domain. In addition, the ML25Al/VC hybrid composite in the machining process is not yet fully understood due to the likely utilization of various materials for numerous non-conventional machining applications such as electrochemical machining, abrasive machining, chemical machining, etc. The problem is not only this, but also there is very few literatures among the research done on the ML25Al/VC hybrid composite. Even it's possible to say, there are no works done on the ML25Al/VC under machining processes. While we summarized the advancements in using MCDM approaches, TOPSIS and the VIKOR method are considered in this work with different weighting metrics for genuine factories and place options based on alternative ranking and instructional recorded in terms of quality from a multifaceted perspective.

2. Materials and methods

2.1 Base metal and reinforcement

In this work, the LM25Al alloy is considered the base material. To enhance the material characteristics of the LM25Al alloy, vanadium carbide is used as reinforcement, as shown in Table 1. In addition, works related to utilizing vanadium carbide-reinforced aluminum matrix composites were scarcely available; hence, it is selected as reinforcement. VC tests often include an oxide debasement. It is produced by heating vanadium oxides with carbon to roughly 1000°C. Despite being thermodynamically stable, VC transforms to V2C at temperatures over 1000°C. VC particles are extremely strong at high temperatures and have a high oxidation capability. As a result, it is used for a variety of high-temperature applications. The metal network composite used in this investigation was joined using a mix-projecting method. To combine the composite, a mix-projection arrangement comprised of an obstruction stifle heater and a hardened steel stirrer was used. The stirrer assembly consisted of a stirrer connected to a variable-speed vertical boring machine with a range of 80 to 1400 rpm through a steel shaft. The stirrer had three edges that were spaced by 120°. Within this approach, the liquid aluminum mixture (LM25Al) is liquefied at a clear temperature near 780 ºC in the silent heater (furnace), and then a warmed support material with 3% wt of VC is blended in with the liquid compound, and the mixture is mixed using the stirrer. To achieve consistent composite characteristics, the mixture was stirred at 800 rpm for 8 minutes. The improvement depends on the amount and uniformity of distribution of reinforcements, and the strength of the particle matrix boundary, and the mechanical properties of the matrix. Subsequently, to investigate the effect of 3 wt% VC in LM25Al alloy, brinell hardness as per ASTM E10 is 195±16 BNH obtained. When compared with the plain LM25Al alloy, the hardness of the synthesized composite increased up to 116%. This enhancement in hardness and strength value of LM25Al/VC is associated with the presence of VC as a load-bearing constituent in the ML25Al matrix during loading conditions. A similar phenomenon was reported in [26].

Table 1. Chimerical composition of base metals (ML25AL and VC)

Chemical composition	Cu	Mg	Si	Fe	Mn	Pb	Ni	Zn	Ti	Al
ML25 Al alloy	0.1	0.2-0.6	6.5-7.5	0.5	0.3	0	0.1	0.1	0.2	Bal.
Chemical composition of VC	Cu	Cr	Si	Fe	C	Pb	O	N	Al	V
	0.003	0.006	0.005	0.005	0.01	0.001	0.025	0.006	0.005	Bal.

Machining is carried out on the ML25Al/VC composite using different processing conditions. The PLUS Spark EDM PS 50 ZNC series machine is used for conducting experimental work, and the line diagram of the EDM process is elucidated in Figure 1. Copper electrodes and kerosene dielectrics are used in this study. The EDM process is influenced by both electrical and non-electrical parameters such as pulse on-time (t_{on}), pulse off-time (t_{off}), flushing pressure, polarity, peak current (I_p), electrode material, pulse interval, open discharge voltage, etc. It is difficult to examine the impact of all process parameters on performance characteristics at the same time due to different constraints. Thus, major influencing electrical parameters, namely I_p, t_{on} and t_{off} were considered in this work, and these parameters showed large deviations on the output characteristics [31]. The properties of the machine were that the connected load is 5 KVA and the capacity of flush pressuring is 196 kPa. The multi-design objective methods of ANOVA factorial, TOPSIS, and VIKOR are used in this research work to optimize the experimental trials. Twenty-seven runs are formulated by the design expert software, and the number of trials is purely dependent on the number of process parameters and the three ranges selected in this research work. The range for each variable is selected based on the preliminary trial runs on the ML25Al/VC composite and the capacity of the machine. It is important to state that when discharge current levels are less than 5 amps, there is not much change in workpiece material ablation. In addition, higher levels of current greater than 20 amps are not considered in order to facilitate stable machining and maintain parameter range consistency. To achieve the optimized parameters for pulse duration and spark interval, a wide range has been chosen based on the machine capacity. The range and levels of process variables are delineated in Table 2. The three replication runs of mid-level machining parameters are to measure the repeatability of the results. Tests are carried out in a randomized way, and performance metrics, namely material ablation rate and surface roughness, are considered. In addition, different combinations of process variables and their measured responses are delineated in Table 3**.**

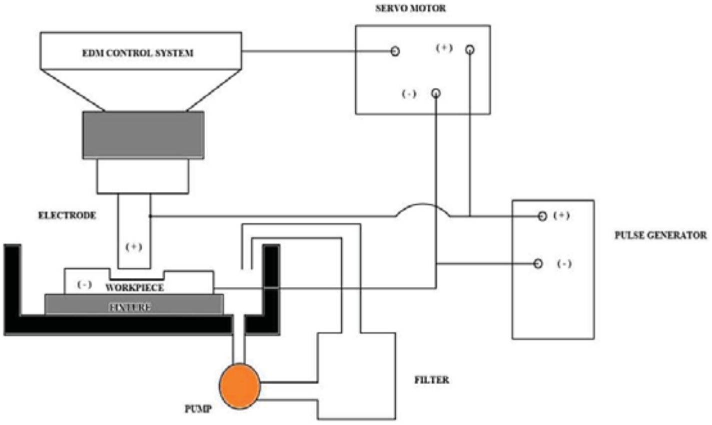

Figure 1. Schematic representation of EDM process

Table 2. Parameters and their levels

Parameters	Symbol	Level		
		-1	0	1
Pulse on time (µs)	t_{on}	100	350	500
Pulse off time (µs)	t_{off}	30	70	100
Peak current (Amps)	I_p	10	15	20

Table 3. Experimental trials and its responses

Expt. No.	Pulse on time (t_{on}) (µs)	Pulse off time (t_{off}) (µs)	Peak current (Amp)	Material removal rate (MRR) (g/min)	Surface roughness (R_a) (µm)
1	500	70	15	0.028248	4.67412
2	500	70	20	0.062556	4.256555
3	150	70	15	0.011592	4.751555

4	500	100	20	0.032388	6.11342
5	150	30	10	0.014544	4.861685
6	100	30	15	0.02454	4.431455
7	500	30	15	0.054792	3.85908
8	100	100	10	0.038892	5.26382
9	500	30	20	0.046284	3.337005
10	100	70	15	0.0183	5.176315
11	150	100	20	0.026544	4.106575
12	500	30	10	0.060648	5.32364
13	100	100	15	0.033708	5.106285
14	150	100	15	0.037692	4.596515
15	150	30	15	0.014784	5.50816
16	500	70	10	0.020928	4.99894
17	100	100	20	0.023832	4.61367
18	150	70	20	0.034224	4.62892
19	500	100	10	0.054612	4.822005
20	100	70	20	0.012696	5.205385
21	150	30	20	0.017868	4.818
22	150	100	10	0.01824	4.675
23	150	70	10	0.031824	4.29005
24	500	100	15	0.05568	4.3375
25	100	30	10	0.01314	4.7965
26	100	70	10	0.034668	5.0505
27	100	30	20	0.021144	4.671

The machinability of the process is calculated by determining material ablation rate, surface unevenness and electrode erosion rate. The formula used for measuring MRR

$$\mathrm{MRR} = \frac{\mathrm{W_{in}} - \mathrm{W_{fi}}}{\mathrm{M_t}}\ (\mathrm{gm/min}) \tag{1}$$

Where w_{in} is weight of the workpiece before machining, w_{fi} is weight of the workpiece after machining and $\mathrm{M_t}$ is machining time. The rate of material removal from the LM25Al/VC is calculated for each combination of parameters by considering loss in weight of the workpiece with respect to time taken to create a through hole. In this work, TOPSIS and the VIKOR are considered for further optimization and developing the models.

3. Multi criteria decision making techniques

3.1. TOPSIS

TOPSIS, known as technique for order of preference by similarity to ideal solution, is a multi-criteria decision analysis method. It compares a set of alternatives based on a pre-specified criterion. The various steps in performing the TOPSIS method are as follows:

Stage 1: Development of choice framework that comprising of all the data about the traits and the options of the interaction. Here, the potential options are addressed in line (i =1, 2......, m) and all credits connecting with every one of the choices are portrayed in the section (j =1, 2......, n).

Stage 2: Get the normalization choice framework utilizing the formulae given underneath: where, x_{ij} is the standardize choice. The normalized decision matrix grid can be addressed.

$$\bar{X}_{ij} = \frac{\mathrm{Xij}}{\sqrt{\sum_{i=1}^{n}(\mathrm{X_{ij}})^2}} \tag{2}$$

Stage 3: Acquire the weighted standardized choice network by assigning the heaviness of each. Property as: $\{w_j, j = 1, 2,......,n\}$. It very well may be resolved utilizing the formulae given below

$$Wij = w_j * \bar{X}_{ij} \text{ , where } w_j \text{ is assigned value} \tag{3}$$

Stage 4: Decide the best (positive ideal) and most terrible (negative ideal) depending on the objective function.

Stage 5: Decide the partition measure for every elective utilizing the below relation

$$\leftthreetimes^{+} = Max\ (Wij)_{i=1}^{n},\quad \leftthreetimes^{-} = Min\ (Wij)_{i=1\ldots}^{n},\quad \text{For beneficiaries} \tag{4}$$

$$\leftthreetimes^{+} = Min\ (Wij)_{i=1}^{n},\quad \leftthreetimes^{-} = Max\ (Wij)_{i=1\ldots}^{n},\quad \text{For non beneficiaries} \tag{5}$$

Stage 6: Get relative closeness to the ideal arrangement utilizing the formulae given as Equation (5).

$$(s^{+}, s^{-}) = \sum_{j=1}^{n}\sqrt{(Wij - \leftthreetimes^{\pm})^2 + (Wij - \leftthreetimes^{\pm})^2} \tag{6}$$

Stage 7: Assign and positioning to all the overall closeness esteem in sliding request. Biggest or the smallest relative closeness esteem assigned as great execution of the other option as given in Equation (6) and results generated in Table 4.

$$P_i = \left(\frac{S^{-}}{S^{+}+S^{-}}\right) \tag{7}$$

3.2. VIKOR

VIKOR means multi-criteria optimization and comprising solutions. The VIKOR technique focuses on positioning and picking an ideal substitute from a set of options and gives a compromise answer for an issue with clashing measures, hence coming to a last arrangement. It is a powerful apparatus for the advancement of machining activity, which comprises different reactions [32]. The proposed technique contains the accompanying advances:

Step 1: The different results obtained during the trial and error first and foremost changed over to a choice grid. In this step, all the criteria and output parameters are normalized irrespective of their units, and the values of the criteria lie between 0 and 1 by using Equation (2). And then determine the best and worst value, like ${X_{ij}}^{+} = \max(X_{ij})$ and ${X_{ij}}^{-} = \min(X_{ij})$.

Step 2: Standardize the choice of lattice amounts somewhere in the range of 0 and 1. The information standardization is done utilizing the accompanying conditions. The normalized choice grid can be composed as an underneath formulation

$${Y_i}^{+} = \sum_{j=1}^{n} W_j \left[(X_{ij})_{max} - (X_{ij})\right] / \left[(X_{ij})_{max} - (X_{ij})_{min}\right], \quad \text{for beneficial attribute} \tag{8}$$

$${Y_i}^{-} = \sum_{j=1}^{n} W_j \left[(X)_{ij} - (X_{ij})_{min}\right] / \left[(X_{ij})_{max} - (X_{ij})_{min}\right], \text{non beneficial attribute} \tag{9}$$

Step 3: Register the gainful (ideal) and non-valuable (non-ideal) arrangements. These qualities can be determined utilizing the conditions indicated underneath.

$$R_i = Max^n of \left\{w_j \left[\left|(X_{ij})_{max} - (X_{ij})\right|\right] / \left[(X_{ij})_{max} - (X_{ij})_{min}\right]\right\} \tag{10}$$

Decide the utility measure and the lament measure by utilizing the accompanying conditions. Toward the end, the VIKOR file utilizes the condition given underneath (Equation (11)). Where is signifies the VIKOR file esteem i = 1, 2,..., m; likewise, addresses the heaviness of the most extreme gathering utility (in this work, v is 0.5).

$$\mathrm{Q_i} = \frac{\mathrm{v}((\mathrm{Y_i} - \mathrm{Y_{i-min}}))}{((\mathrm{Y_{i-max}} - \mathrm{Y_{i-min}}))} + (1 - \mathrm{v})\left(\left(\frac{((\mathrm{R_i} - \mathrm{R_{i-min}}))}{((\mathrm{R_{i-max}} - \mathrm{R_{i-min}}))}\right)\right) \tag{11}$$

Here $\mathrm{Y_{i-max}}$ is the maximum value of $\mathrm{Y_i}$, and $\mathrm{Y_{i-min}}$ the minimum value of $\mathrm{Y_i}$; $\mathrm{R_{i-max}}$ is the maximum value of $\mathrm{R_i}$, and $\mathrm{R_{i-min}}$ is the minimum value of $\mathrm{R_i}$.

Step 4: Ranking the acceptance choice with the cases, where case 1: $Q(a2) - Q(a1) \geq 1/(j-1)$ (acceptance advantage depending on the objective faction preference) and case 2: acceptance stability, likewise $\mathrm{Q_j}$ is ranking by Y_i and/or R_i with $v \geq 0.5$ in light of VIKOR file Q_i.The option with the biggest Q_i esteem is considered in this work as the best arrangement and result generated in Table 5.

Table 4. Optimization of EDM parameters using TOPSIS optimization technique

Exp. No.	Normalized decision matrix		Weighted normalized		Si+ (Ideal the best)	Si- (Ideal the worst)	Pi	Rank
1	0.15605	0.18815	0.11704	0.04704	0.14279	0.07052	0.3305	14
2	0.34559	0.17134	0.25919	0.04284	0.00925	0.21199	0.9587	27
3	0.06404	0.19127	0.04803	0.04782	0.21164	0.01371	0.0608	2
4	0.17893	0.24609	0.13419	0.06152	0.12808	0.08616	0.4021	16
5	0.08035	0.19570	0.06026	0.04893	0.19952	0.01756	0.0808	5
6	0.13557	0.17838	0.10168	0.04460	0.15790	0.05625	0.2626	12
7	0.30270	0.15534	0.22702	0.03884	0.03260	0.18042	0.8469	24
8	0.21486	0.21189	0.16114	0.05297	0.09995	0.11344	0.5316	21
9	0.25569	0.13433	0.19177	0.03358	0.06742	0.14643	0.6847	22
10	0.10110	0.20837	0.07582	0.05209	0.18430	0.02935	0.1373	7
11	0.14664	0.16531	0.10998	0.04133	0.14941	0.06516	0.3036	13
12	0.33505	0.21430	0.25129	0.05357	0.02150	0.20341	0.9044	26
13	0.18622	0.20555	0.13966	0.05139	0.12085	0.09219	0.4327	17
14	0.20823	0.18503	0.15617	0.04626	0.10380	0.10921	0.5127	20
15	0.08167	0.22173	0.06126	0.05543	0.19914	0.01456	0.0681	4
16	0.11562	0.20123	0.08671	0.05031	0.17329	0.04028	0.1885	9
17	0.13166	0.18572	0.09874	0.04643	0.16096	0.05291	0.2474	11
18	0.18907	0.18633	0.14180	0.04658	0.11811	0.09495	0.4456	18
19	0.30170	0.19410	0.22628	0.04853	0.03615	0.17872	0.8317	23
20	0.07014	0.20954	0.05260	0.05238	0.20744	0.01022	0.0469	1

21	0.09871	0.19394	0.07403	0.04849	0.18576	0.02909	0.1353	6
22	0.10077	0.18819	0.07557	0.04705	0.18411	0.03112	0.1445	8
23	0.17581	0.17269	0.13186	0.04317	0.12769	0.08581	0.4019	15
24	0.30760	0.17460	0.23070	0.04365	0.03022	0.18354	0.8586	25
25	0.07259	0.19308	0.05444	0.04827	0.20527	0.01472	0.0669	3
26	0.19152	0.20330	0.14364	0.05083	0.11683	0.09621	0.4516	19
27	0.11681	0.18803	0.08761	0.04701	0.17211	0.04216	0.1967	10

Table 5. Optimization of parameters utilizing VIKOR optimization technique

Exp. No.	Normalized decision matrix		Weight standardization		Y_i (Utility solution)	R_i (Regret solution)	Q_i	Rank
1	0.15605	0.18815	0.50489	0.12040	0.62529	0.50489	0.64742	14
2	0.34559	0.17134	0.00000	0.08280	0.08280	0.08280	0.00000	1
3	0.06404	0.19127	0.75000	0.12737	0.87737	0.75000	0.98497	26
4	0.17893	0.24609	0.44396	0.25000	0.69396	0.44396	0.64368	13
5	0.08035	0.19570	0.70656	0.13729	0.84385	0.70656	0.93196	23
6	0.13557	0.17838	0.55945	0.09855	0.65800	0.55945	0.70828	12
7	0.30270	0.15534	0.11426	0.04701	0.16127	0.11426	0.07147	2
8	0.21486	0.21189	0.34825	0.17350	0.52174	0.34825	0.46684	8
9	0.25569	0.13433	0.23946	0.00000	0.23946	0.23946	0.21302	6
10	0.10110	0.20837	0.65128	0.16562	0.81690	0.65128	0.87409	22
11	0.14664	0.16531	0.52996	0.06930	0.59926	0.52996	0.65033	15
12	0.33505	0.21430	0.02808	0.17889	0.20696	0.17889	0.14779	5
13	0.18622	0.20555	0.42453	0.15931	0.58385	0.42453	0.56192	16
14	0.20823	0.18503	0.36591	0.11341	0.47932	0.36591	0.45418	7
15	0.08167	0.22173	0.70303	0.19550	0.89853	0.70303	0.96268	25
16	0.11562	0.20123	0.61261	0.14965	0.76226	0.61261	0.81175	19
17	0.13166	0.18572	0.56987	0.11496	0.68483	0.56987	0.73247	17
18	0.18907	0.18633	0.41694	0.11633	0.53327	0.41694	0.52535	9
19	0.30170	0.19410	0.11691	0.13372	0.25062	0.13372	0.14059	4
20	0.07014	0.20954	0.73375	0.16824	0.90199	0.73375	0.98782	27
21	0.09871	0.19394	0.65764	0.13336	0.79100	0.65764	0.86304	21
22	0.10077	0.18819	0.65217	0.12048	0.77265	0.65217	0.84774	20
23	0.17581	0.17269	0.45226	0.08582	0.53808	0.45226	0.55476	11
24	0.30760	0.17460	0.10119	0.09009	0.19128	0.10119	0.07999	3
25	0.07259	0.19308	0.72722	0.13142	0.85864	0.72722	0.95647	24
26	0.19152	0.20330	0.41041	0.15429	0.56470	0.41041	0.53964	10
27	0.11681	0.18803	0.60943	0.12012	0.72955	0.60943	0.78941	18

The result obtained from the VIKOR optimization technique and portrayed in Table 5 fulfills the first acceptable advantage criteria from the file Q_i. Thus, VIKOR is a useful tool in MADM, mainly in situations where the decision-maker is not able or does not know in what way to express preference at the beginning of system design.

4. Result and discussion

The objective of this work is to estimate the optimized electrical discharge machining (EDM) parameters for maximum productivity and minimum surface integrity using the combined TOPSIS and VIKOR methods. The effect of three process parameters, namely pulse on time (t_{on}), pulse off time (t_{off}), and peak current (I_p), on responses such as *MRR* and R_a have been considered. The optimal conditions of the analysis were determined using the values obtained from TOPSIS and the VIKOR method, a multi-criteria decision-making method which determines the ranking list based on the particular measure of closeness to the ideal solution. From the design expert software analysis, it is found that the I_p=10Amp, t_{on}=150µs, t_{off} = 30 µs provides the lowest values for TOPSIS, and the I_p=15Amp, t_{on}=500 µs, t_{off}=30 µs provides the lowest values for VIKOR optimization techniques. The results were confirmed by conducting a conformation test and found to be comparable with the experimental results, as shown in Table 6**.** The findings of the study provide valuable information regarding TOPSIS and VIKOR optimization techniques, the responses, and confirm a higher *MRR* and minimum R_a. The VIKOR method provides a better compromise solution based on maximum *MRR* utility and minimum regret when compared with the TOPSIS method. However, it turns out that both the task of indicating the best alternative and ranking a set of decision options have similar results, but to a very limited extent, they are different, as shown in Table 6 in terms of errors.

Table 6. Conformation test as per the TOPIS and VIKOR Indexes

Predictor index	level of main effect for closeness solution	Predicted results	Experimental results for *MRR*	%Error
TOPSIS	I_p = 10 Amp, t_{on} = 150 µs, t_{off} = 30µs	0.0444861	0.014544	2.99421
VIKOR	I_p = 15 Amp, t_{on}= 500 µs, t_{off} = 30 µs	0.06220563	0.0547992	0.740643

In this work, optimization criteria are attempted for TOPSIS and VIKOR in design expert software to maximize MRR and minimize R_a. The dependent parametric condition with maximum composite desirability is viewed as the optimal level of parameters, as shown in Figure 2. As per the obtained results, I_p is the most vital parameter, followed by t_{on}. In this study, the obtained ideal parameter levels are I_p = 20 Amp, t_{on}=500 µs, and t_{off}=30 µs with desirability value of 0.553 and it is depicted in Figure 2. The combination of process parameters showing highest value of composite desirability are noted as the optimized parameter levels. Moreover, there is no significant rule that the composite desirability value ought to be near 1 [33]. It purely indicates how far the maximum and minimum values of the measured performances are from the optimized value of the responses.

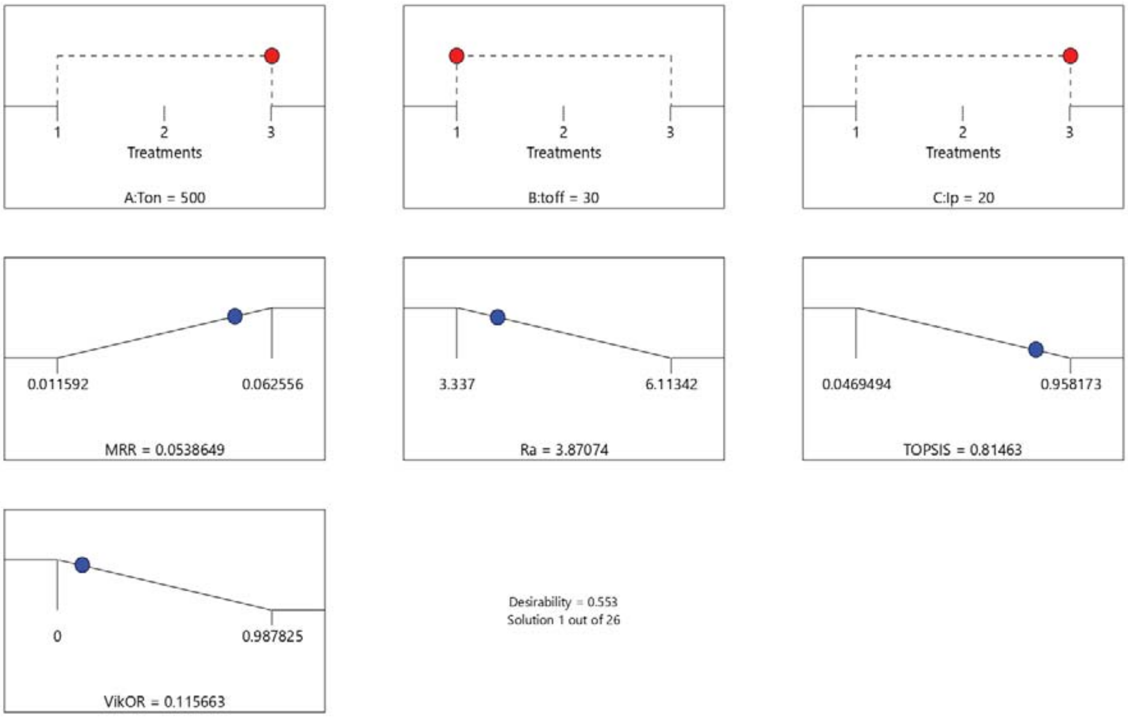

Figure 2. Optimized parameter levels for maximum MRR and minimum R_a

4.1. Factorial modelling and conformation

To assess performance characteristics for the EDM of LM25Al/VC, confirmation tests for the optimum parameters with their levels are done in Table 6. In the same way, factorial methods are used to build the machining characteristics into a mathematical and statistical numeric equation. The primary objective is to establish a relationship between the response and the spending process parameters.

$$TOPSIS = 0.3901 - 0.1264t_{on(1)} - 0.1508t_{on(2)} - 0.0294t_{off(1)} - 0.0544t_{off(2)} + 0.0101I_{p1} - 0.0001I_{p2} - 0.0590t_{on(1)}{*}t_{off(1)} - 0.1151t_{on(2)}{*}t_{off(1)} + 0.0026t_{on(1)} * t_{off(2)} + 0.1179t_{on(2)} * t_{off(2)} + 0.0762{*}t_{on(1)}{*}I_{p1} - 0.0403t_{on(2)} * I_{p1} + 0.0139t_{on(1)}{*}I_{p2} - 0.0254t_{on(2)}{*}I_{p2} \tag{12}$$

$$VIKOR = 0.5981 + 0.1372t_{on(1)} + 0.1547t_{on(2)} + 0.0291t_{off(1)} + 0.0604t_{off(2)} + 0.0017I_{p1} - 0.0042I_{p2} + 0.0538t_{on(1)}{*}t_{off(1)} + 0.1374t_{on(2)}{*}t_{off(1)} + 0.0049t_{on(1)} * t_{off(2)} - 0.1248t_{on(2)} * t_{off(2)} - 0.0826{*}t_{on(1)}{*}I_{p1} + 0.0237t_{on(2)} * I_{p1} - 0.0163t_{on(1)}{*}I_{p2} + 0.052t_{on(2)}{*}I_{p2} + 0.0500t_{off(1)} * I_{p1} - 0.0247t_{off(2)} * I_{p1} \tag{13}$$

The equation contains all factor main effects and all factor-by-factor interactions to make predictions about the response for given levels of each factor. In this work, the high levels of the factors are designated by 2, and the low levels are assigned as 1 with a subscript in the equations.

5. Conclusion

In this work, the EDM process parameters are analyzed to machine the LM25 AL/VC composite material. Increasing I_p and t_{on} have produced a higher *MRR* and medium surface roughness. It has been indicated that I_p is the most crucial input parameter, followed by t_{on}. Using the VIKOR and TOPSIS techniques, the degree of impact of machining variables on the response parameters *MRR* and R_a have been analyzed. The prime conclusions are that TOPSIS and VIKOR can be used to find the ideal solution of EDM input parameters to machine LM25AL/VC composite material. The ideal solutions obtained at I_p=10 Amp, t_{on}= 150 µs, t_{off} = 30 µs provide the lowest values for TOPSIS, and the I_p = 15 Amp, t_{on}= 500 µs, t_{off} = 30 µs provide the lowest values for VIKOR optimization techniques. The models are valid with experimental results for selected responses. Therefore, VIKOR and TPOSIS can be used as prediction tools for EDM processes.

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