Multi Response Optimization of Powder Mixed Electro Discharge Machining Using MOORA and WASPAS

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Abstract : PMEDM (powder mixed electro discharge machining) process in which a conductive powder is mixed with the die electric fluid and thus increasing the efficiency of the machining process. The present works deals with application of hybrid approach MOORA and WASPAS for obtaining the optimized results from the response parameters on H11 die steel using copper electrode by mixing chromium powder about 3gm/l to 6gm/l. The process parameter considered were powder concentration(C_p), peak current(I_p), pulse on time(T_{on}), duty cycle(DC) and gap voltage(V_g) while the response parameters considered were material removal rate(MRR), Tool wear rate(TWR), Electrode wear rate(EWR) and surface roughness(SR).

I. INTRODUCTION

EDM (electro discharge machining) also known as spark erosion machining is a versatile process used for cutting complex shapes and sizes. This is a thermo electric process involving erosion of workpiece material placed in dielectric fluid; the tool and the work piece separated by a suitable distance, known as standoff distance. **PMEDM** (powder mixed electro discharge machining), advanced machining process similar to EDM with a difference that a conductive powder is mixed with a dielectric fluid to enhance the machining process. This process is basically used for overcoming the limitations faced in EDM process, as increases the surface quality and material removal rate. Since the addition of fine conductive powder (size of used chromium powder here is <53μm) to the dielectrics decreases the insulating strength and increases the inter-electrode spacing which causes the easy removal of materials. Various characteristics of PMEDM process depends upon the powder type, it's concentration, particle size and work piece constituents .In this present work the study was done on **AISI H11 DIE STEEL** in presence of chromium powder within the dielectric considering the MRR as a beneficial criterion and TWR,EWR and SR as non-beneficial parameter. **CHAKRABORTY**[1] solved five real time manufacturing related problems using the application of MADM approach WASPAS.**AMAN**[2] et al explored the WASPAS method as a tool for studying the tribological properties of Al-Si alloy by varying percentage of Tin and Zinc. For finding the optimum value during non-traditional machining process **CHAKRABORTY**[3] et al applied the WASPAS method. **MADIC**[4] selected the suitable machining process by the MCDM approach WASPAS and obtained the relative significance by considering the pair wise comparison matrix. **GADAKH V.S**[5] reviewed total six decisions making problems for obtaining the optimum result during milling process by a new method MOORA and suggested it to be simple, easily calculative etc. **MAJUMDAR AND MAITY**[6] studied different responses of WEDM of titanium grade6 and optimised the result using hybrid approach MOORA and PCA. **CHAKRABORTY**[7] et al applied the WSAPAS method for solving eight manufacturing decision making problems and studying the effect of λ on ranking performance.

II. EXPERIMENTAL CONDITIONS

The present work is carried out on EDM for finding the optimum condition for PMEDM of H11 DIE STEEL using copper electrode using chromium powder mixed to dielectric fluid. The input parameter considered were peak current(I_p), powder concentration(C_P), pulse on time(T_{ON}),duty cycle(DC) and gap voltage(V_g) while the output parameter were material removal rate(MRR), electrode wear rate(EWR), tool wear rate(TWR) and surface roughness(SR). Considering the above parameters Taguchi based L18 orthogonal array was used. The dielectric used was commercial grade EDM oil having freezing point of 94°C and specific gravity of 0.763. The surface roughness was measured using the Taylor Hobson taly surf surface meter. The composition of work piece material:-

TABLE 1

ELEMENT OF H11 DIE STEEL.	% OF ELEMENT.
Chromium(Cr)	5%
Carbon(C)	0.35%
Silicon (Si)	1%
Manganese (Mn)	0.4%
Phosphorous(P)	0.03%
Sulphur(S)	0.02%
Molybdenum(Mo)	1.5%
Cobalt (Co)	0.01%
Copper (Cu)	0.01%
Vanadium (V)	0.45%

And rest being Fe (iron).

TABLE 2 : Taguchi based L18 experimental design with output parameter.

Run	C_P	I_P	T_{ON}	DC	V_g	Avg MRR	Avg TWR	Avg EWR	Avg SR
1	0	3	100	7	30	2.564	0.017	0.671	3.8
2	0	3	100	7	40	2.649	0.019	0.735	4.1
3	0	6	150	8	30	4.529	0.027	0.611	4.87
4	0	6	150	8	40	5.470	0.030	0.561	5.45
5	0	9	200	9	30	9.401	0.389	4.143	6.5
6	0	9	200	9	40	10.256	0.486	4.747	7.47
7	3	3	150	9	30	2.735	0.008	0.3	2.86
8	3	3	150	9	40	3.076	0.009	0.318	3.14
9	3	6	200	7	30	6.666	0.017	0.257	4.07
10	3	6	200	7	40	7.222	0.01	0.146	4.56
11	3	9	100	8	30	8.511	0.045	0.529	5.2
12	3	9	100	8	40	11.829	0.057	0.489	5.63
13	6	3	200	8	30	6.239	0.004	0.076	2.4
14	6	3	200	8	40	7.435	0.003	0.046	2.84
15	6	6	100	9	30	12.820	0.003	0.026	3.12
16	6	6	100	9	40	13.076	0.007	0.054	3.36
17	6	9	150	7	30	16.153	0.034	0.214	4.07
18	6	9	150	7	40	16.692	0.042	0.256	4.68

III. METHODOLOGY

In the present study, the machining is done on H11 die steel with copper electrode with powder mixed EDM using a combined MCDM approach MOORA and WASPAS.

A. MOORA(MULTI-OBJECTIVE OPTIMIZATION ON THE BASIS OF RATIO ANALYSIS)

This method was proposed by Brauers and Zavadaskas in 2006, suggesting MOORA to be a one folded method and is used for optimizing together two or more contrary objectives subjected to certain constraints. This method is easy for use and for calculation purpose and the results obtained were same as that obtained by the previous researchers, which prove its compatibility, flexibility etc.

The step involved in this method includes:

Step1: DETERMINATION OF PROBLEM:

The first step is to understand the problem and classify the required alternatives and their characteristics.

Step2: FORMATION OF DECISION MATRIX:

In this step, the decision matrix is prepared representing the performance characteristics with respect to different variables.

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & \cdots & x_{2n} \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ \cdots & \cdots & \cdots & \cdots & \cdots \\ x_{m1} & x_{m2} & \cdots & \cdots & x_{mn} \end{bmatrix}$$

Here, x_{ij} = performance measure of i^{th} alternative on j^{th} attribute, m=number of alternatives, and n=number of attributes.

Step3: NORMALIZATION OF DECISION MATRIX:

The third step involves the normalization of decision matrix in which the decision matrix is normalized making its dimensionless so that every component can be compared. The normalization of decision matrix can be defined as the ratio of performance measures of i_{th} alternative to j_{th} attribute to the square root sum of the squares of performance measures of i_{th} alternative to j_{th} attribute, as given:

$$x^*_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}},$$

Here, x^*_{ij} =normalized value of i^{th} alternative on j^{th} criterion which lies between 0 and 1.

Step4: OVERALL ASSESSMENT VALUE EVALUATION:

The overall assessment value is done to attain the optimum value of the response parameters. For this the beneficial criterion are added while subtracted for non-beneficial criterion. This is given by:

$$z_i = \sum_{j=1}^{g} x^*_{ij} - \sum_{j=g+1}^{n} x^*_{ij} .$$

It is observed that few attributes are more influential than others, thus for overcoming this, the attributes were multiplied by its corresponding weight, and is given by:

$$z_i = \sum_{j=1}^{g} w_j x_{ij}^* - \sum_{j=g+1}^{n} w_j x_{ij}^*$$

Where, w_j = weight of j^{th} criterion.

Step5: ASSIGNING RANKING TO OVERALL ASSESSMENT VALUE.

After finding the overall assessment values, the ranking is provided to determine the optimum value; the highest ranking is the best alternative while the lowest ranking corresponds to the worst alternative.

TABLE 3. : Normalization of decision matrix.

Run	DECISION MATRIX				NORMALIZED VALUES			
	Avg MRR	Avg TWR	Avg EWR	Avg SR	Avg MRR	Avg TWR	Avg EWR	Avg SR
1	2.564	0.017	0.671	3.8	0.065072	0.026926	0.10317311	0.197507
2	2.649	0.019	0.735	4.1	0.067229	0.030094	0.11301377	0.213099
3	4.529	0.027	0.611	4.87	0.114942	0.042765	0.0939475	0.25312
4	5.470	0.030	0.561	5.45	0.138823	0.047517	0.08625949	0.283266
5	9.401	0.389	4.143	6.5	0.238588	0.616137	0.63702863	0.33784
6	10.256	0.486	4.747	7.47	0.260287	0.769775	0.72989981	0.388257
7	2.735	0.008	0.3	2.86	0.069412	0.012671	0.04612807	0.14865
8	3.076	0.009	0.318	3.14	0.078066	0.014255	0.04889575	0.163203
9	6.666	0.017	0.257	4.07	0.169177	0.026926	0.03951638	0.21154
10	7.222	0.01	0.146	4.56	0.183287	0.015839	0.02244899	0.237008
11	8.511	0.045	0.529	5.2	0.216001	0.071275	0.08133916	0.270272
12	11.829	0.057	0.489	5.63	0.300208	0.090282	0.07518875	0.292622
13	6.239	0.004	0.076	2.4	0.15834	0.006336	0.01168578	0.124741
14	7.435	0.003	0.046	2.84	0.188693	0.004752	0.00707297	0.14761
15	12.820	0.003	0.026	3.12	0.325359	0.004752	0.00399777	0.162163
16	13.076	0.007	0.054	3.36	0.331856	0.011087	0.00830305	0.174638
17	16.153	0.034	0.214	4.07	0.409947	0.053853	0.03290469	0.21154
18	16.692	0.042	0.256	4.68	0.423627	0.066524	0.03936262	0.243245

TABLE 4. : Overall assessment values.

Run	Avg MRR	Avg TWR	Avg EWR	Avg SR	Z_i	Z_i considering wt.w_j=1/4	RANKING
1	0.065072	0.026926	0.10317311	0.197507	-0.26253	-0.06563	13
2	0.067229	0.030094	0.11301377	0.213099	-0.28898	-0.07224	16
3	0.114942	0.042765	0.0939475	0.25312	-0.27489	-0.06872	14
4	0.138823	0.047517	0.08625949	0.283266	-0.27822	-0.06955	15
5	0.238588	0.616137	0.63702863	0.33784	-1.35242	-0.3381	17
6	0.260287	0.769775	0.72989981	0.388257	-1.62764	-0.40691	18
7	0.069412	0.012671	0.04612807	0.14865	-0.13804	-0.03451	9
8	0.078066	0.014255	0.04889575	0.163203	-0.14829	-0.03707	10
9	0.169177	0.026926	0.03951638	0.21154	-0.10881	-0.0272	8
10	0.183287	0.015839	0.02244899	0.237008	-0.09201	-0.023	7
11	0.216001	0.071275	0.08133916	0.270272	-0.20689	-0.05172	12
12	0.300208	0.090282	0.07518875	0.292622	-0.15788	-0.03947	11
13	0.15834	0.006336	0.01168578	0.124741	0.015577	0.003894	6
14	0.188693	0.004752	0.00707297	0.14761	0.029258	0.007315	5
15	0.325359	0.004752	0.00399777	0.162163	0.154446	0.038612	1
16	0.331856	0.011087	0.00830305	0.174638	0.137828	0.034457	2
17	0.409947	0.053853	0.03290469	0.21154	0.11165	0.027912	3
18	0.423627	0.066524	0.03936262	0.243245	0.074495	0.018624	4

B. WASPAS (Weighted Aggregated Sum Product Assessment).

WASPAS is the combined form of two different methods i.e.WSM (weighted sum model) and WPM (weighted product model). This is a type of MCDM approach used when optimization is to be done between several characteristics. The step involved includes;

Step 1:-DECISION MATRIX FORMATION.

The first step involves the formation of decision matrix as shown below:-

Y= $(y_{ij})_{m*n}$, where, y_{ij}=performance of ith alternative with respect to jth criterion m=number of alternatives n=number of evaluation criteria

Step 2:-NORMALIZATION OF PERFORMANCE MEASURES.

In this step the performance measures or the different characteristics are normalized with the aim of making every component dimensionless for easy comparison and is done by the following method shown below:-

For beneficial criterion or maximizing the performance measure:-

$$\bar{y}_{ij}=\frac{y_{ij}}{max_i y_{ij}}$$

While for non-beneficial or minimizing the performance measure:-

$$\bar{y}_{ij}=\frac{min_i y_{ij}}{y_{ij}}$$

Step 3:-APPLICATION OF WSM AND WPM FOR OPTIMUM CONDITION.

This step is the main step as it helps to find the optimum condition from the performance measure and is given by:-

$$R_i^{(1)} = \sum_{j=1}^{n} \bar{y}_{ij} w_j$$

$R_i^{(2)} = \prod_{j=1}^{n} (\bar{y}_{ij})^{w_j}$, respectively.

For more accurate result the ithalternative is given by the formula shown below:-

$$R_i = 0.5R_i^{(1)} + 0.5R_i^{(2)} = 0.5\sum_{j=1}^{n} \bar{y}_{ij} w_j + 0.5\prod_{j=1}^{n} (\bar{y}_{ij})^{w_j}$$

Where, wj=weight of jth criterion=1/4 as all the responses are given equal weightage

From the result, the optimized value is obtained from the ranking done as the highest ranking corresponds to the best optimized alternative.

TABLE 5 : Normalization of decision matrix through WASPAS.

Run	DECISION MATRIX.				NORMALIZED VALUES.			
	Avg MRR	Avg TWR	Avg EWR	Avg SR	Avg MRR	Avg TWR	Avg EWR	Avg SR
1	2.564	0.017	0.671	3.8	0.153607	0.176471	0.038748	0.631579
2	2.649	0.019	0.735	4.1	0.158699	0.157895	0.035374	0.585366
3	4.529	0.027	0.611	4.87	0.271328	0.111111	0.042553	0.492813
4	5.470	0.030	0.561	5.45	0.327702	0.1	0.046346	0.440367
5	9.401	0.389	4.143	6.5	0.563204	0.007712	0.006276	0.369231
6	10.256	0.486	4.747	7.47	0.614426	0.006173	0.005477	0.321285
7	2.735	0.008	0.3	2.86	0.163851	0.375	0.086667	0.839161
8	3.076	0.009	0.318	3.14	0.18428	0.333333	0.081761	0.764331
9	6.666	0.017	0.257	4.07	0.399353	0.176471	0.101167	0.589681
10	7.222	0.01	0.146	4.56	0.432662	0.3	0.178082	0.526316
11	8.511	0.045	0.529	5.2	0.509885	0.066667	0.049149	0.461538
12	11.829	0.057	0.489	5.63	0.708663	0.052632	0.05317	0.426288
13	6.239	0.004	0.076	2.4	0.373772	0.75	0.342105	1
14	7.435	0.003	0.046	2.84	0.445423	1	0.565217	0.84507
15	12.820	0.003	0.026	3.12	0.768033	1	1	0.769231
16	13.076	0.007	0.054	3.36	0.783369	0.428571	0.481481	0.714286
17	16.153	0.034	0.214	4.07	0.967709	0.088235	0.121495	0.589681
18	16.692	0.042	0.256	4.68	1	0.071429	0.101563	0.512821

TABLE 6 : Overall assessment value through WASPAS.

Run	Avg MRR	Avg TWR	Avg EWR	Avg SR	$R_i^{(1)}$	$R_i^{(2)}$	R_i
1	0.153607	0.176471	0.038748	0.631579	0.250101	0.160487	0.205294
2	0.158699	0.157895	0.035374	0.585366	0.234333	0.150926	0.19263
3	0.271328	0.111111	0.042553	0.492813	0.229451	0.158568	0.19401
4	0.327702	0.1	0.046346	0.440367	0.228604	0.160815	0.194709

5	0.563204	0.007712	0.006276	0.369231	0.236606	0.056325	0.146465
6	0.614426	0.006173	0.005477	0.321285	0.23684	0.050828	0.143834
7	0.163851	0.375	0.086667	0.839161	0.36617	0.25855	0.31236
8	0.18428	0.333333	0.081761	0.764331	0.340926	0.248912	0.294919
9	0.399353	0.176471	0.101167	0.589681	0.316668	0.254637	0.285652
10	0.432662	0.3	0.178082	0.526316	0.359265	0.332112	0.345688
11	0.509885	0.066667	0.049149	0.461538	0.27181	0.166639	0.219224
12	0.708663	0.052632	0.05317	0.426288	0.310188	0.170515	0.240352
13	0.373772	0.75	0.342105	1	0.616469	0.556489	0.586479
14	0.445423	1	0.565217	0.84507	0.713928	0.679157	0.696542
15	0.768033	1	1	0.769231	0.884316	0.876716	0.880516
16	0.783369	0.428571	0.481481	0.714286	0.601927	0.582922	0.592424
17	0.967709	0.088235	0.121495	0.589681	0.44178	0.279667	0.360723
18	1	0.071429	0.101563	0.512821	0.421453	0.246969	0.334211

TABLE 7 : Ranking for obtaining optimized value.

Run	R_i	RANKING
1	0.205294	13
2	0.19263	16
3	0.19401	15
4	0.194709	14
5	0.146465	17
6	0.143834	18
7	0.31236	8
8	0.294919	9
9	0.285652	10
10	0.345688	6
11	0.219224	12
12	0.240352	11
13	0.586479	4
14	0.696542	2
15	0.880516	1
16	0.592424	3
17	0.360723	5
18	0.334211	7

IV. CONCLUSION

The present work dealt with the PMEDM operation on H11 die steel by addition of chromium powder to the die electric. The goal intended was maximising the MRR (the beneficial criterion) and minimising TWR, EWR, and SR (the non-beneficial criterions). For obtaining the best optimum solution to the input parameters powder concentration (C_p), peak current (I_p), pulse on time (T_{on}), duty cycle (DC) and gap voltage (V_g), two MCDM approaches MOORA and WASPAS were applied. The optimal setting parameters as obtained from MOORA and WASPAS was 6gm/l powder concentration (C_P), 6 ampere peak current (I_P), 100 µs pulse on time (T_{on}), 90%duty cycle (DC) and 30 volt gap voltage (V_g).Thus the application of MOORA and WASPAS as a decision making tool proved to be satisfactory in result and can be applied for industrial purpose.

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REFERENCES

[1] Shankarchakraborty, Application of the WASPAS method as the multi criterion decision making tool.

[2] Aman, Arindam Bharadwaj, Satyam Singh, Dhritiman Das and Shantanu Chakraborty, Study and optimization of the mechanical and tribological properties of Al-Si alloy with varying percentage of Tin and Zinc,ICMMRE 2017.

[3] Shankar Chakraborty, Orchi Bhattacharyya, Edmunds kazimieraszavadskas, jurgita Antucheviciene, Application of WASPAS method as an optimization tool in non traditional machining process, Information technology and control-2015.

[4] Madic M., Gecevska V., Radovanovic M., and Petkovic D. Multi criteria economic analysis of machining processes using the WASPAS method, journal of production engineering, vol.17, 2014.

[5] Gadakh V.S Parametric optimization of milling process using MOORA method, journal of material science vol.1, no.4 (2011), ISSN-0976-4259.

[6] Himadri Majumdar and Kalipada Maity, Optimization of machining condition through WEDM on Ti grade 6 using hybrid approach MOORA coupled with PCA, journal of advanced machining system vol.6 (2)-2017, page (81-99).

[7] Shankar chakra borty, Edmunds kazimieras zavadskas, Application of WASPAS method in manufacturing decision making, journal of informatica, vol.25 (2014), page (1-20).