COMPARATIVE ANALYSIS OF TWO DIFFERENT WIRE ELECTRODES IN A WIRE EDM MACHINING USING TOPSIS TECHNIQUE

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ABSTRACT: WEDM (Wire Electric Discharge Machining) is generally utilised to machine tough to machine metals which are electrically conductive. These machines created a significant makeover in the fabrication of small components that are hard to machine with previous non-traditional machining techniques. In the current research, experiments are performed by using two wire electrodes, they are coated copper wire electrode & Brass wire and this examination is completely depends upon the tool properties. A 0.25mm diameter electrode wire was used in the investigation and the cubes of 10mm thickness are cut on the work- piece material i.e. D2 Steel. The experiments were done by using L27 orthogonal array with six input variables at 3 different levels. The output parameters like Metal Removal Rate (MRR), Kerf Width (KW), roughness of Surface (SR) and Wear Rate of Tool (TWR) are calculated and output variables are optimized with TOPSIS technique. Pulse off Time (Toff), Pulse on time (Ton), Tension of the Wire (WT), Spark set Voltage (SV), Input current(IP) and Feed rate of Wire (WF) be chosen as the predicted variables and its outcomes are examined. The work-piece material D2 Steel of width 10 mm is being machined by two wire electrodes and table of ANOVA was obtained to find the maximum influencing factor affecting the WEDM variables. List of responses and plots of main effect are arranged to find the settings optimum and rank for the WEDM (Wire Electric Discharge Machining) parameter respectively.

KEYWORDS: TOPSIS, Ton, Toff, Kerf width, MRR, ANOVA, D2 Steel and Wire EDM.

I. INTRODUCTION

Now a day's industries are trying to go for smart materials which are having high resistance to conventional machining so advanced machining processes plays a vital role in machining these materials, So let us know one of these machines like WEDM(Wire Electrical Discharge Machining), which is a thermo-electrical method where excess part is removed by a pulse of spark between the metal and the electrode (tool) separated by a thin layer of dielectric fluid which is regularly passed forcedly in the machining zone to wash out the excess chips. To get the required complex shape and accuracy Numerically Controlled system (NC) is used. Wire Electrical Discharge Machining (WEDM) plays a major role in the manufacture of complex-shaped moulds, dies & irregular parts used in almost all industries like aerospace, automobile etc. major use of WEDM for objects having close tolerances, complex shapes, and tricky to work metals. So, to select the optimum input variables in WEDM is a principal work. The main problems occurs in this task are wire rupture, roughness of surface and short circuiting of wire.

II. LITERATURE REVIEW

Mr.Tang,S. C. Ma and L. K. Chung et.al [1] investigated on neural network system (NNS) to establish the interval of pulse settings, pulse on and off(T on&Off), current maximum, voltage on open circuit, capacitance electric and regularity of the surface. In geometrical machining, Hsue et al. [2] stated a mold that material removal rate (MRR) was built by taking the deflection of the wire. Tosun et al.[3]finds an approach of statistical in nature to establish the parameters of optimal machining for size minimum of craters of wire in WEDM. Tosun and Cogun et.al [4] studied the effects of parameters of machining on ratio of wire wear based on the wire weight loss in Wire EDM. Dongre et al. [5] considered wires of diameter scale from 25 μm to100μm to get ultra-thin wafers and lessen the kerf loss. Mohri et al. [6] investigated the electrode wear aligned with the time machining.

The outcome shows that the Electrode Wear Rate (EWR) reached an equilibrium condition. Many experimenters tried their finest level to optimize the machining values and properties of material to examine the integrity of the surface. Palaniswamy and Senthil et.al [7] examined the machinability performance of cryogenically-treated 15.5 PH stainless steel with a variety of cutting tools such as non-coated tungsten carbide, wiper geometry inserts and cryogenic treated tungsten carbide. They find that the cutting force and flank wear found to be low in case of crypto treated inserts. Also, wiper tool gives the good surface regularity while machining.

In addition, Artificial Intelligence (AI) decision-making tool called as ANFIS (adaptive neuro fuzzy inference system) was used to identify the connection between the machining force and finishing of machine surface and the results were contrast with experimental data. D.DEEPAK& B.RAJENDRABEEDU et.al [9] investigates the effects of process values on IS 5986 FE 410 STEEL by taking material removal rate as output response. Wan et al. [8] numerically examined the effect of friction on the improvement of Dead Metal Zone (DMZ). The method of Lagrangian– Eulerian was developed for simulating the machining operation and examines friction conditions effect. It was clearly found that the friction coefficient had straight taking part in the sum of profile formation on the dead metal zone. The sharp transform in coefficient of friction had a larger dead metal zone creation. The soft one and the formation of dead metal zone be found by friction coefficient values with its period length. Gadakh, V. S. et.al [10] compares different papers with multi criteria decision making technique method TOPSIS and finds that TOPSIS method was matched with the results which are derived by the past researchers, show the applicability of this process while solving various complex decision-making problems. Srikrishna S, et.al [11] Uses MCDM technique TOPSIS to get the best car for purchasing by fulfilling different requirements.[12] Sarath kumar sahoo et.al uses TOPSIS method to investigate the process parameters effects on wire edm machine performance by taking output responses as MRR, Surface Roughness, Kerf width and cutting speed. Later they developed ANOVA to find the most influencing factor on the above responses. [13] B.B. Nayak & S. S. Mahapatra et.al uses AHP based TOPSIS TECHNIQUE to find the optimized process variables in wire edm machine by taking output variables as surface roughness and kerf width. [14] T.Suresh , P.Aruneash , S.Gunasekar , B.Janakiraman et.al compares two different wire electrodes namely Brass and Zinc Coated Wire to find the performance of wire edm machine by taking the output response as MRR and also they implemented ANOVA to get the most influencing factor.

Kuraiakose and Shunmugam et.al [15] optimized Wire electric discharge machining process by taking the multiple reverting model to characterize connection in-between input and output responses and the multi-objective optimization method based on a Non-Dominated Sorting Genetic Algorithm (NSGA). [16] [17]I.HARISH[1*], SANTOSH PATRO[2]& P. SRINIVASA RAO[3] uses TOPSIS method to find the optimum values while machining with Brass and Coated wires in WEDM machine on D2 steel by taking output responses as MRR, Kerf width, Surface roughness and wear ratio of tool.

III. EXPERIMENTAL SETUP

The present work was done by using ELECTRONICAS print cut Wire EDM machine as shown in Fig.1. The major aim of the work is to find the right wire electrode from the two wire electrodes namely Brass and

Coated copper wire for machining D2 steel which is used mainly in die making, moulds and the parts which can withstand heavy loads, for this the selection of exact parameters is one of the main criteria in WEDM process.

FIG. 1: ELECTRONICA SPRINT CUT WIRE EDM MACHINE

Based on the literature review, it is found that Pulse duration is the major important factor which affects the output variables. So, in this work the input parameters namely Ton, Toff, Input current(IP), wire feed rate(WF), Spark gap set Voltage(SV) and Wire Tension(WT) are varied with three levels as shown in the Table.1 keeping flushing pressure and servo voltage as constant..

TABLE .1:

PROCESS PARAMETERS WITH THEIR LEVELS

S. No	Process parameters	Sign	L-1	L-2	L-3
1	Pulse on time (A)	T on	110	115	120
2	Pulse off time (B)	T off	30	45	60
3	Spark gap set voltage(C)	SV	15	18	21
4	Peak current (D)	IP	180	210	240
5	Wire feed. (E)	WF	2	4	6
6	Wire tension. (F)	WT	6	8	10

To find the best suited wire, the output responses were taken as Surface Roughness (SR), Material Removal Rate (MRR), Tool Wear Rate (TWR) and Kerf Width (KW). However in this work 10mm thickness cubes are cut from the work piece of D2 steel work material. Taguchi L27 orthogonal array as shown in the Table.2 was used by varying the input variables for each wire of 0.25mm dia.

TABLE .2:

TAGUCHI L27 ITERATIONS

Trail. No.	A	B	C	D	E	F
1	1	1	1	1	2	3
2	1	1	2	2	3	1
3	1	1	3	3	1	2
4	1	2	1	2	3	1
5	1	2	2	3	1	2
6	1	2	3	1	2	3
7	1	3	1	3	1	2
8	1	3	2	1	2	3
9	1	3	3	2	3	1
10	2	1	1	1	2	3
11	2	1	2	2	3	1
12	2	1	3	3	1	2
13	2	2	1	2	3	1
14	2	2	2	3	1	2
15	2	2	3	1	2	3
16	2	3	1	3	1	2
17	2	3	2	1	2	3
18	2	3	3	2	3	1
19	3	1	1	1	2	3
20	3	1	2	2	3	1
21	3	1	3	3	1	2
22	3	2	1	2	3	1
23	3	2	2	3	1	2
24	3	2	3	1	2	3
25	3	3	1	3	1	2
26	3	3	2	1	2	3
27	3	3	3	2	3	1

In this experimental operation, distilled water was used as dielectric fluid. First the experiments were done by using brass wire electrode then followed by coated copper and annealed wire electrode. Fig 3 & 4. Represents the machined work piece with cubes of 10mm thickness by using brass wire and coated wire electrode respectively. The constant input parameters and machining parameters must be carefully monitored to minimize the breakage of wire electrode. While machining, time was noted for each cube of 10mm thickness, later the Tool Wear Rate (TWR), Material Removal Rate (MRR), Surface Roughness (SR), and Kerf Width (KW) measurements were done.

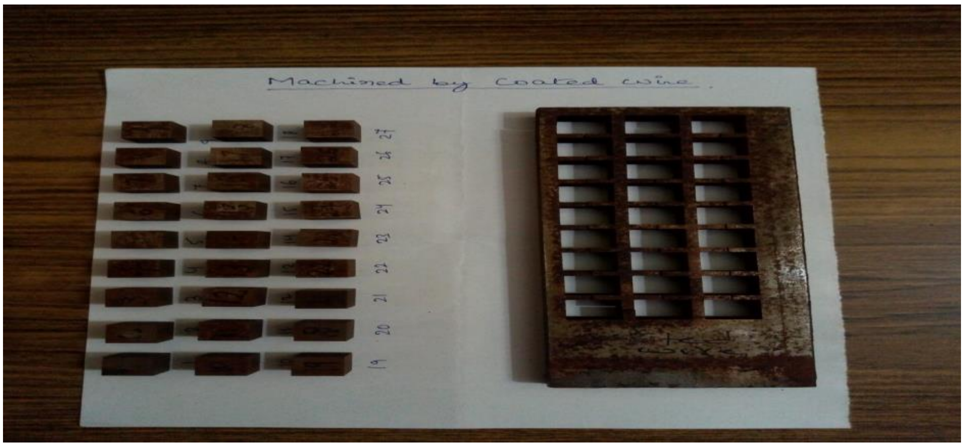

FIG. 2: MACHINED WORK PIECES OF D2 STEEL BY USING COATED COPPER WIRE

FIG. 3: MACHINED WORK PIECES OF D2 STEEL BY USING ANNEALED COPPER WIRE

MRR is known as the rate of material removal from the work piece while machining. It depends on Kerf width, total cutting length, thickness of the work piece (cube) and time. The kerf width is the width of the metal wasted while machining operation; it is measured by using profile projector. Later, Surface roughness and wire wear ratio was measures by using surface roughness measuring machine and wire diameter was measured by using screw gauge to measure ratio of wire wear which is a ratio between diameter change of the wire to diameter original as shown in the FIG. 5 and 6 respectively.

FIG. 4: SURFACE ROUGHNESS MEASURING TOOL

FIG. 5: SCREW GAUGE WHILE MEASURING WIRE DIAMETER

IV. DATA ANALYSIS BY EXPERIMENTALVALUES

Total 27 experiments were conducted for each wire electrode and the response variables like material removal rate, Kerf width, surface roughness and tool wear ratio was calculated as we said earlier. All the values are noted by varying the process parameters according to the levels which we have taken to get more MRR, less Kerf width, less tool wear rate and better surface roughness these values are tabulated below in Table 3.

TABLE. 3:

RESULTS FOR MRR, KERF WIDTH, TWR AND SR FOR TWO WIRE ELECTRODES

S.No	Coated copper electrode				Brass electrode			
	MRR	KW	TWR	SR	MRR	KW	TWR	SR
1	0.111	0.394	0.04	1.9	0.058	0.264	0.02	1.6
2	0.114	0.38	0.06	2.38	0.058	0.27	0.08	1.6
3	0.104	0.383	0.084	1.88	0.056	0.277	0.008	1.73
4	0.135	0.331	0.04	3.43	0.086	0.252	0.016	2.32
5	0.097	0.311	0.06	2.87	0.099	0.262	0.036	2.69
6	0.131	0.285	0.048	2.93	0.096	0.266	0.04	2.81
7	0.064	0.267	0.056	1.85	0.046	0.26	0.02	1.72
8	0.055	0.23	0.02	1.68	0.044	0.258	0.028	1.77
9	0.051	0.208	0.016	1.72	0.043	0.264	0.072	1.71
10	0.161	0.429	0.1	2.97	0.098	0.284	0.048	3.22
11	0.191	0.41	0.02	3.32	0.089	0.262	0.056	3.17
12	0.150	0.39	0.1	2.66	0.082	0.248	0.048	2.49
13	0.172	0.352	0.06	3.89	0.1	0.216	0.032	3.12
14	0.168	0.307	0.08	3.81	0.063	0.241	0.036	2.21
15	0.179	0.286	0.06	3.29	0.116	0.222	0.04	2.84
16	0.108	0.302	0.048	2.81	0.061	0.238	0.032	2.78
17	0.101	0.294	0.04	2.41	0.057	0.233	0.04	2.36

18	0.096	0.28	0.04	2.29	0.055	0.232	0.076	1.87
19	0.196	0.391	0.088	4.27	0.135	0.33	0.08	4.07
20	0.154	0.388	0.076	4.1	0.121	0.312	0.036	3.64
21	0.196	0.382	0.12	3.91	0.135	0.337	0.084	3.64
22	0.178	0.37	0.04	3.46	0.127	0.28	0.036	4.19
23	0.207	0.349	0.08	3.24	0.141	0.289	0.12	5.01
24	0.181	0.347	0.1	3.46	0.154	0.289	0.12	4.76
25	0.164	0.341	0.08	3.33	0.106	0.29	0.12	3.76
26	0.172	0.347	0.072	3.07	0.095	0.297	0.1	3.59
27	0.169	0.352	0.06	2.99	0.1	0.291	0.12	3.02

V. OPTIMIZATION USING TOPSIS METHOD

TOPSIS is one of the MCDM(Multi Criteria Decision Making technique) which was proposed by Yoon (1980) and Hwang and Yoon (1981), to solve Multiple Criterion problems depends on the principle that the taken alternative must contain the nearest Euclidian distance to the Positive Ideal Solution (PIS) and the longest to the Negative Ideal Solution (NIS). It is a easy and helpful technique to solve MCDM problems by giving rankings to the alternatives according to the ideal solution.

The following steps will give us a brief idea about TOPSIS method to get the best solution among the number of alternatives:

Step I: First, create the decision matrix (DM)to start the TOPSIS method.

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$$DM = \begin{matrix} & C_1 & C_2 & \cdots & C_n \\ L_1 & x_{11} & x_{12} & \cdots & x_{1n} \\ L_2 & x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ L_m & x_{m1} & x_{m2} & \cdots & x_{mn} \end{matrix} \text{----------- (1)}$$

Where i = criterion index (i = 1 . . . m), m = no. of prospective sites.

j =alternative index (j= 1 . . . n), C1, C2…, Cn = criteria.

L_1, L_2…, L_n=Different locations.

Step II: As another step indicates the relative execution of the produced different designsto create the normalized deign matrix (NDM).

$$NDM = R_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x^2{}_{ij}}} \text{----------- (2)}$$

Step III: Later, find the weighted decision matrix which will be obtained by multiplying the NDM with random weights. These weights were commenced by AHP(Analytical Hierarchy Process) method.

$$V= V_{ij} = W_j \times R_{ij} \text{--------- (3)}$$

Step IV: Find the PIS and NIS, by using equation (4)&(5) below

$$PIS = A^+ = \{ V_1^+, V_2^+ \ldots, V_n^+ \}, \text{ where: } V_j^+ = \{(\max_i (V_{ij}) \text{ if } j \in J); (\min_i V_{ij} \text{ if } j \in J') \} \quad \text{------------ (4)}$$

$$NIS = A^- = \{ V_1^-, V_2^- \ldots, V_n^- \}, \text{ where: } V_j^- = \{(\min_i (V_{ij}) \text{ if } j \in J); (\max_i V_{ij} \text{ if } j \in J') \} \quad \text{------------ (5)}$$

Where, J =Beneficial attributes and J'= Non-beneficial attributes.

Step V: Now, compute separation distance of every alternative from the ideal and non- ideal solution.

$$S^+ = \sqrt{\sum_{j=1}^{n} (V^+_j - V_{ij})^2} \quad i = 1, \ldots, m \quad \text{--------- (6)}$$

$$S^- = \sqrt{\sum_{j=1}^{n} (V^-_j - V_{ij})^2} \quad i = 1, \ldots, m \quad \text{--------- (7)}$$

Where, i = criterion and j = alternative.

Step VI: Finally, calculate the relative closeness of each alternative to the ideal solution by using below equation (8).

$C_i = Si^- / (Si^+ + Si^-), 0 \leq C_i \leq 1$ --------- (8)

Step VII: Rankings will be given to each alternative according to their respective C_i value by taking the highest value of C_i as the first rank and it is the best alternative and alternative having the lowest C_i value will be the worst alternative.

VI. RESULTS AND DICUSSIONS

6.1 TOPSIS Results for all three wire electrodes:

Total 27 experiments for each wire namely Brass wire and Coated copper wire electrodes were done to figure out the effects of input parameters process in WEDM(wire electric discharge machining) on multiple criterions like kerf width, Metal Removal Rate, roughness of the surface and ratio of wire wear. TOPSIS method results for the two wires was tabulated below in Table .4 by taking weights as W_{MRR}= 0.509, WKW= 0.173, W_{WWR}= 0.224and WSR = 0.0912 where as these weights are calculated by using AHP method.

Table .4: TOPSIS results for two wire electrodes

Exp no	Ci+ for Brass wire	RANK	Ci+ for Coated wire	RANK
1	0.413356093	17	0.456333689	18
2	0.254926233	26	0.440382736	19
3	0.431794996	15	0.406323543	21
4	0.542541755	11	0.522829995	17
5	0.574348003	8	0.349586243	24
6	0.549080171	10	0.526023846	16
7	0.377068851	22	0.304583107	27
8	0.357253756	24	0.326788713	25
9	0.235198191	27	0.324259882	26
10	0.538918532	12	0.614904683	13
11	0.463773594	13	0.751992315	2
12	0.447064346	14	0.585442496	14
13	0.591129707	7	0.65740391	10
14	0.389963842	20	0.642862432	12

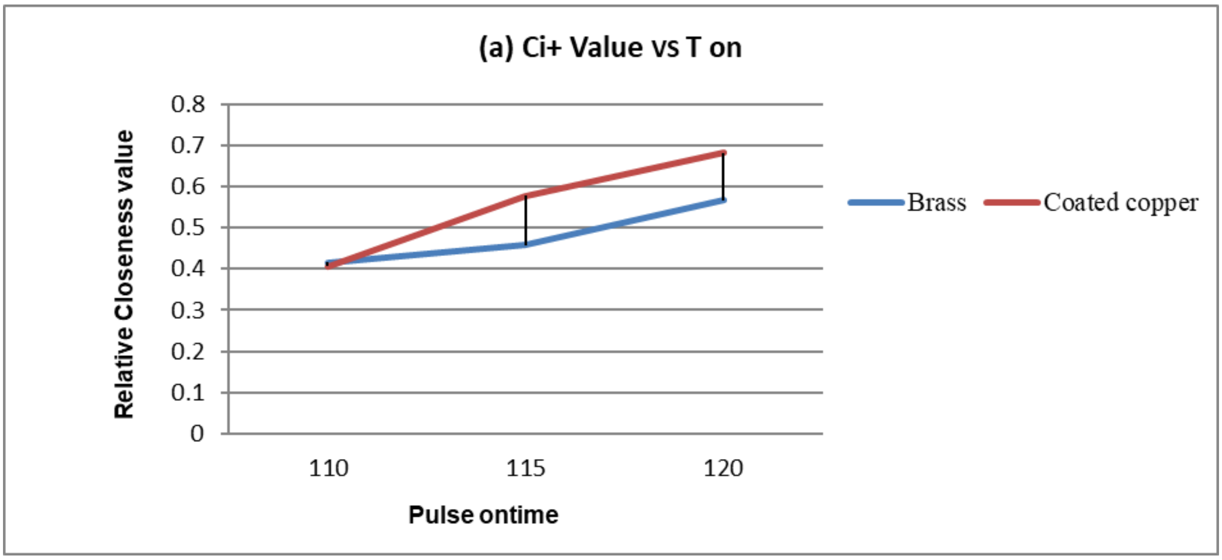
15	0.674803958	3	0.73052128	3
16	0.389599697	21	0.415192595	20
17	0.361059538	23	0.403698693	22
18	0.256029135	25	0.390778603	23
19	0.643391881	4	0.681570388	8
20	0.699807367	2	0.561274128	15
21	0.634876259	5	0.680993629	9
22	**0.735815104**	**1**	0.707766233	4
23	0.568798679	9	**0.774366407**	**1**
24	0.604160161	6	0.68763599	7
25	0.424079204	16	0.64498633	11
26	0.391043762	19	0.69772841	5
27	0.396248498	18	0.695871077	6

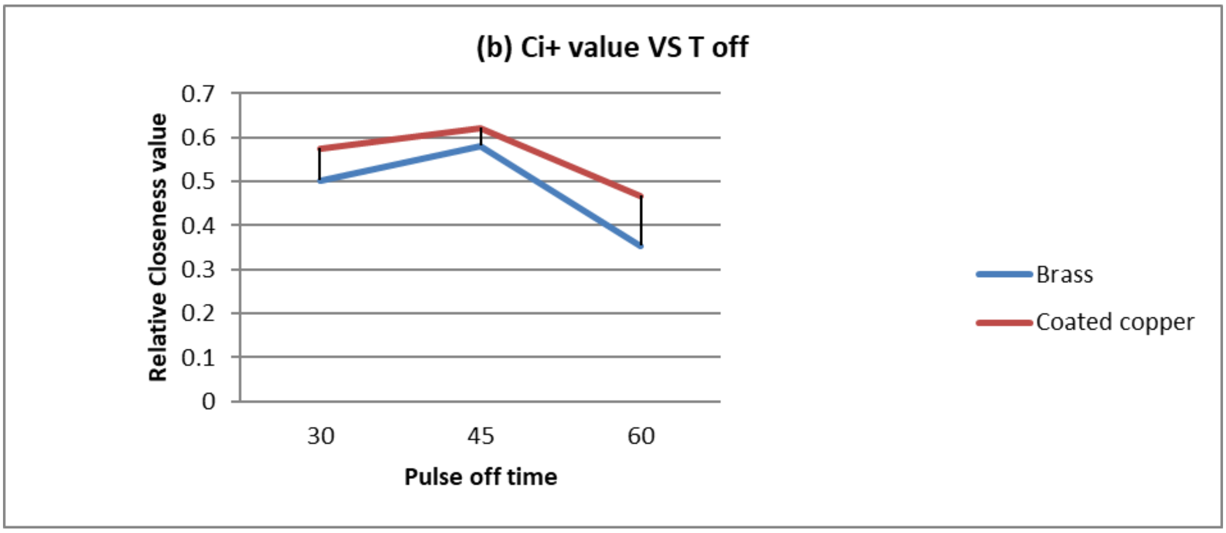
From Table 4, it is observed that the best option/rank for Coated copper wire electrode at 23rd run (Ton 120, Toff 45, SV 18, IP 240, WF 2, WT 8) and for Brass wire electrode at 22nd run (Ton 120, Toff 45, SV 15, IP 210, WF 6, WT 6) as shown in table 5 below.

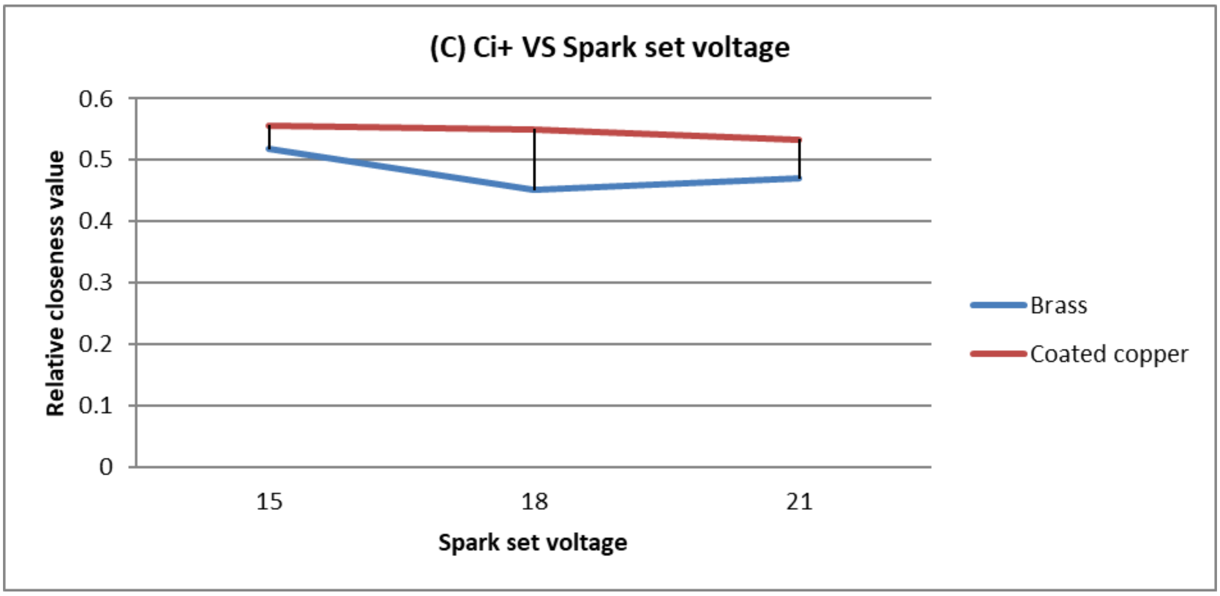
Table. 5: Comparison table for two wire electrodes

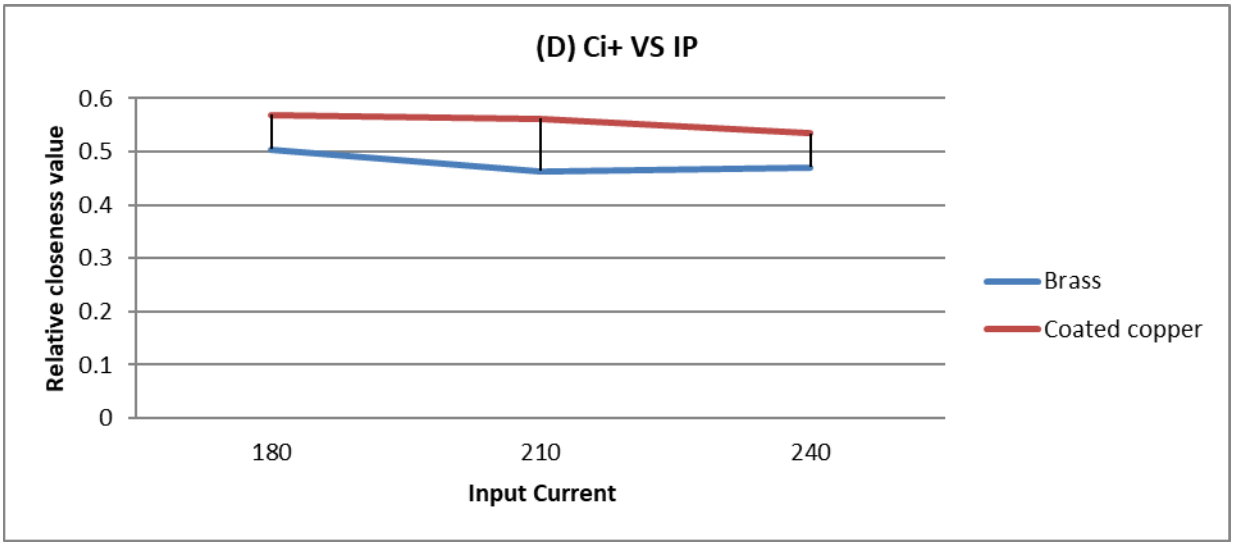
S. No	Wire type	Optimized readings	SR	WWR	MRR	Kerf Width
1	Coated copper	120- 45-18-240-2-8	3.24	0.08	0.207	0.349
2	Brass	120-45-15-210-6- 6	4.19	0.036	0.127	0.28

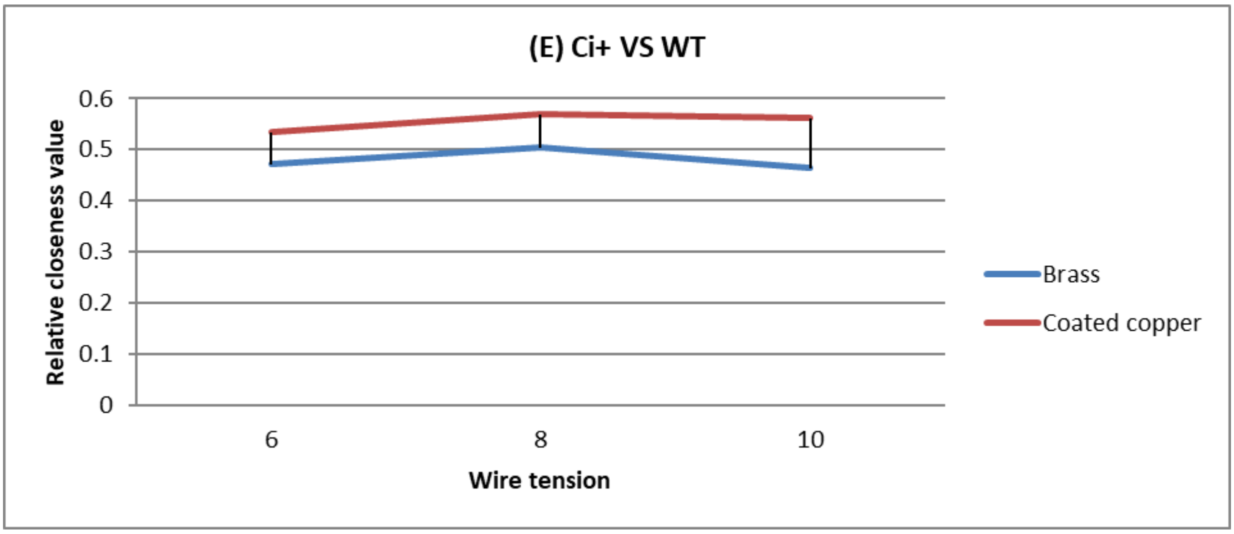
Fig. 6 represents graphical view for the main effects plot diagram by taking Relative closeness value on one side and input variables on other side for two wire electrodes.




(b) Ci+ value VS T off
Relative Closeness value
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
30
45
60
Pulse off time
Brass
Coated copper


(C) Ci+ VS Spark set voltage
Relative closeness value
0.6
0.5
0.4
0.3
0.2
0.1
0
15
18
21
Spark set voltage
Brass
Coated copper


(D) Ci+ VS IP
Relative closeness value
0.6
0.5
0.4
0.3
0.2
0.1
0
180
210
240
Input Current
Brass
Coated copper



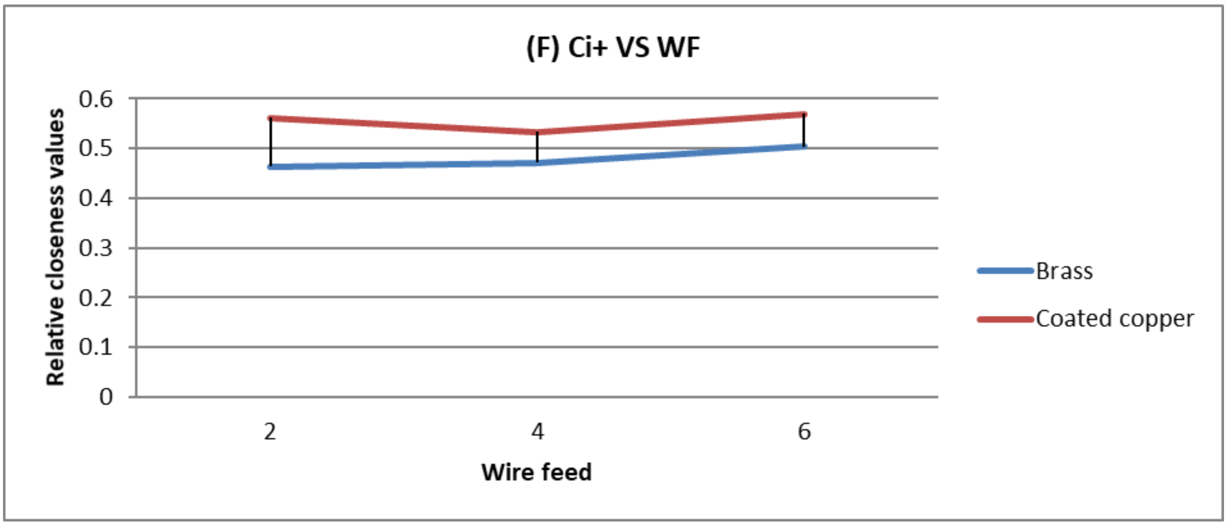


FIG. 6: GRAPHICAL REPRESENTATION OF RELATIVE CLOSENESS VALUE VS INPUT VARIABLES FOR TWO WIRES.

From Fig. 6(a) it is stated that the Relative closeness value amplify with the Pulse on time(Ton)increase for the coated copper wire and Brass wire. It is due to the energy release of the channel plasma amplifies due to which increase of the spark efficiency results and so we obtain superior values of Relative closeness value. By the Fig. 6(b) the Relative closeness value decreases with an increases in pulse off time for the two wires, this is due to the spark concentration is decreased.

6.2. ANOVA (Analysis of Variance) results for Relative closeness value:

Analysis of Variance (ANOVA) is a tool vital which evaluates effects of each process input variables on the output variables. The value of Probability (P) is supposed to be important if the value is < 0.05.

6.2.1. ANOVA for two wires:

Table 6 & 7 represents the ANOVA (Analysis of Variance) results of coated wire and Brass wire electrodes respectively. From these tables, we can clearly say that Pulse on time(T ON)is the most effecting factor for coated wire followed by Pulse off time(T OFF) and Pulse off time(T OFF) is the most effecting factor for Brass wires followed by Pulse on(T ON) time for the output responses.

Table 6: ANOVA Results for Coated Copper wire electrode

PARAMETERS	DOF	SS	MS	%
T ON	2	0.346908	0.173454	58.98
T OFF	2	0.113845	0.056922	19.36
SV	2	0.004241	0.002120	0.72
Input current	2	0.006291	0.003146	1.07
Wire Tension	2	0.006291	0.003146	1.07
Wire Runoff	2	0.006291	0.003146	1.07
Error	14	0.104248	0.007446	17.72
Total	26	0.588115		100

Table 7: ANOVA Results for Brass wire electrode

PARAMETERS	DOF	SS	MS	%
T ON	2	90.110044	0.055022	21.92
T OFF	2	0.239399	0.119699	47.68
SV	2	0.020897	0.010448	4.16
Input current	2	0.008142	0.004071	1.62
Wire Tension	2	0.008142	0.004071	1.62
Wire Runoff	2	0.008142	0.004071	1.62
Error	14	0.107324	0.007666	21.38
Total	26	0.50209		100

6.3. Response table for Relative closeness value:

Response table gives the ranks for each process input variables. Table 8 & 9 represents the response table of coated wire electrode and Brass wire electrode. From these response tables it is observed that pulse on time (T ON) is the important input parameter affecting the responses followed by pulse off time (T OFF), spark set voltage, Input current, wire tension and wire feed rate for Coated wire electrode and Pulse off time (T OFF) is the important input parameter affecting the responses followed by pulse on time(T ON), spark set voltage, Input current, wire tension and wire feed rate for Brass wire electrode

Table 8: Response Table of C_i^+ mean values for coated copper electrode

Level	ON Pulse	OFF Pulse	SV	IP	Wire Tension	Wire Runoff
1	0.406346	0.575469	**0.556175**	**0.569467**	0.533815	0.561395
2	0.576977	**0.622111**	0.549853	0.561395	**0.569467**	0.533815
3	**0.68135**	0.467099	0.533815	0.533815	0.561395	**0.569467**
Delta	0.275009	0.155012	0.022359	0.035652	0.035652	0.035652
Rank	1	2	6	3	3	3

Table 9: Response Table of C_i^+ mean values for Brass electrode

Level	ON Pulse	OFF Pulse	SV	IP	Wire Tension	Wire Runoff
1	0.4151	0.5031	**0.5173**	**0.5037**	0.4708	0.4639
2	0.4569	**0.5812**	0.4512	0.4639	**0.5037**	0.4708
3	**0.5665**	0.3542	0.4699	0.4708	0.4639	**0.5037**
Delta	0.1514	0.227	0.0661	0.0397	0.0397	0.0397
Rank	2	1	3	5	5	5

VII. CONCLUSION

This paper presents a comparative study between two wire electrodes by taking the identical input variables & output responses and their effects in Wire Electric Discharge Machining. Based on the present research, the following conclusions were drawn:

1. The results of the experiments established the soundness of the utilized TOPSIS Technique for establishing the machining performance and optimizing the machining input values in Wire EDM process.

2. By considering ANOVA, on time Pulse (Ton) and off time Pulse (Toff) are important factors that affect outputs for coated copper wire and Brass wire electrodes.

3. The effects of variations are examined for the coated wire copper and Brass wire electrode with the varying variables process. The Relative closeness value amplifies with the Pulse on time increase for two wire electrodes is because the released energy of the plasma channel increases which results in the amplification of the spark efficiency, so we obtain higher values of Relative closeness value.

4. From the analysis it confirms that coated copper wire electrode gives a better surface quality than brass wire electrodes and at the same time wire breaking chances are also higher in coated copper compared to brass wire electrodes.

5. By the results obtained for tool wear ratio, we can say that TWR is less in brass wire electrode compared to coated wire electrodes.

6. From the experimental analysis we can also conclude that coated copper wire electrode gives better MRR than brass wire for machining D2 steel.

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