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Parametric Optimization of Process Parameters on Surface Integrity in WEDM of Al-2024 Metal Matrix Composite using Taguchi Approach

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Abstract: The of ratio low weight to strength desires to special applications of automobile and components of aerospace which found new scope for advanced studies on "Metal Matrix Composites (MMCs)". In the present research optimization of WEDM process parameters viz,. "Voltage (V), discharge current (I_p), pulse on Time (T_{on}) and pulse off Time (T_{off}) "are carried out to minimize "the White Layer Thickness (WLT)" and "Surface Crack Density (SCD)" of Al-2024 reinforced with volume fraction of 10% TiC_p and 10% B_4C_p separately by Taguchi method and design of experiments. The array of standard L_{18} orthogonal has elected for experiments design. The results have gotten from the experimental runs have analyzed via. using "Minitab 16 Software". The process parameters which effecting on WLT and SCD have found by ANOVA for S/N ratios. In this experimental study, it has noticed that WLT and SCD have mainly affected by all process parameters except T_{off} has little effect on the SCD. The identical values of the response parameters have calculated by mathematical formulae and promoted by carry out validation experimentation. The values of confirmation tests, all being found to be quite satisfactory (2.660% in the worst case), prove the efficacy and reliability of the suggested approach.

Key words: WEDM, MMCs, Taguchi method, ANOVA, surface integrity, Iraq

INTRODUCTION

In many industries (medical, electronics, automobile and aerospace) are used "Metal Matrix Composites (MMCs)". Their superior mechanical properties such as the ratio of strength to weight and high thermal conductivity are made MMCs widely used. A matrix, the reinforcement element and the interface mainly manipulate the desirable properties. Particulates, fibers or whiskers of hard ceramic reinforcements such as Silicon Carbide (SiC), Boroncarbide (B_4C), Titanium Carbide (TiC) can be used to manufacture those composites by adding into a base matrix element asalloys of aluminum, magnesium or titanium (Satheesh *et al*., 2013). Many challenges are faced the present manufacturing industries from these advanced materials because of these hard and difficult to machine, demand high precision, surface quality that led to increasing the machining cost (Vishwakarma *et al*., 2012). New processes and techniques with development tools and advanced methodology must be used to stand upthese challenges (Shrivastava and Sarathe, 2014). Classic machining as (turning, milling and drilling, etc.) are displayed ineffective in the machining of advanced materials, since, it is produceda poor removal rate of material, excessive tool wear and higher surface roughness (Pandey and Singh, 2010).

Specifications appropriate machining processesmust be selected to manufacturing parts. From the varied non-traditional machining processes available, "Electrical Discharge Machining (EDM)" is widely carried outto exceed the difficult to machine materials. "Wire EDM (WEDM)" is a special form of EDM which used a continuous moving conductive wire electrode (Singh and Kumar, 2012). A large number of parameters needed for a complex WEDM machining process. The machining performance measurement can be effected by any few differences in one of the process parameters (Khaja *et al*., 2015). The surface machined by WEDM IS included several defects on Heat Affected Zone (HAZ) as stated by Yan and Chien (2007). Therefore, WEDM is produced a tensile stresses at the surface and just below it, a superficial "white layer" is formed with it at the same time (Han *et al*., 2007). The "recast layer" is defined as the melt of material by electric sparks and re-solidified on the surface without being evictedor taken off by flushing (Fukuzawa *et al*., 2009). During "pulse-off time", rapid cooling is happened because of part of the molten metal re-solidified and quenched. This rapid cycle of heating and cooling is due to a surface crack on the recast layer (Dewangan *et al*., 2015). One of the main interests in the "MMC machining" is the surface safety of the finished part or components to obtain better quality to the higher extent. Therefore, the estimate of surface safety "(white layer thickness and surface crack density)" will be contribution for better "MMCs machining process".

The detailed of literature survey is showed that, the available researches are spotted on machining of traditional materials as steel, brass, titanium, etc. There are no published works concentrated on surface safety, especially, WLT and SCD in the machining of MMCs. Therefore, this study aims to fill the gap in the present literature with respect to the processing of MMCs with WEDM. In particular, WEDM experiments were conducted on Al-2024 reinforced with volume fraction of 10% B_4C on the one hand and 10% TiC on the other hand to determine the best parametric settings for each of the minimum WLT and SCD with the help of ANOVA and S/N ratios.

MATERIALS AND METHODS

Experimental procedure

Materials selection: The recent development and end applications is based on material selection which it is one of the important processes for any search. Two specimens Al-2024 reinforced with volume fraction of 10% TiC on the one hand and 10% B_4C on the other hand as MMCs of hardness 133.9 and 121 HV, respectively at load 100 g were considered for the present investigation. MMCs were prepared using stir casting technique with dimensions 100×100×50 mm. The chemical composition of Aluminum alloy (Al-2024) is shown in Table 1 and the microstructure of specimens for MMCs are shown in the Fig. 1.

Machining conducted: The machining is conducted on the 5 axis ACRA-W-A430 CNC wire cut machine. A wire of brass (0.25 mm) diameter is used as the cutting tool. The distilled water is used as dielectric medium. The responses are selected for experimentation thickness of white layer and surface crack density. Response characteristics are given in Table 2.

Selection of the process parameters and their levels: The parameters of process and their levels are given in Table 3 were selected based on some preliminary experimental and considering the range limitation of WEDM machine.

Selection of the orthogonal array: In this experiment, the L_{18} orthogonal array is meet the requirements of the experiment as itis a small mixed 2 and 3 level array (Phadke, 1995). The experimentation is carried out as per the L_{18} orthogonal array that are shown in Table 4.

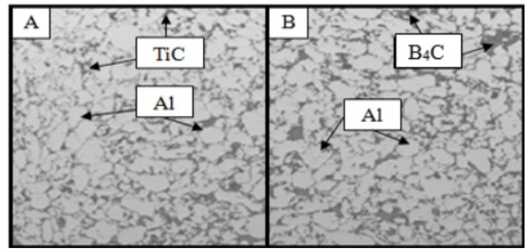

Fig. 1: Microstructure of specimens; A: Al-2024+10% TiC_P and B: Al2024+10% B_4C_P

Table 1: Chemical composition of aluminum alloy

Material	Si	Fe	Cu	Mn	Ti	Mg	V	Cr	Al
Weight%	0.058	0.126	4.21	0.55	0.052	1.67	0.007	0.0055	Rem.

Table 2: Response characteristics

Response names	Response	Units
White Layer Thickness (WLT)	Smaller is better	μm
Surface Crack Density (SCD)	Smaller is better	μm/μm^2

Table 3: Process parameters and their levels

		Levels		
Parameters	Units	1	2	3
Voltage (V)	Vol.	75	100	----
Current (I_p)	A	11	13	15
Pulse on Time (T_{on})	μsec	110	120	130
Pulse off Time (T_{off})	μsec	40	50	60

Response measurement: In the present study, the white layer forming and surface cracks are characterized the integrity or safety of surface by. The white layer forming is inspected in the form of White Layer Thickness (WLT) while the Surface Crack Density (SCD) are quantified the surface cracks. The techniques of measurement for these output responses is described briefly in the following section.

White layer thickness: The recast or white layer is measured of, after WEDM operations, the top surface of each specimen is ground successively with the emery papers of up to (2500), followed by polishing with a slurry of Alumina (Al_2O_3) and finally, is washed with acetone fluid under a standard procedure for metallographies observation. Scanning Electron Microscopy (SEM) (with model: Inspect S50) with a magnification (500X) is used to characterize the surface of specimen with five different locations of each specimen. The images of SEM are used to determine the thickness of White Layer (WLT).

Surface crack density: The surface cracks density is measured by using the side (machining) morphology of surface which studied using same SEM at a magnification

Table 4: Design of experiments L_{18} ($2^1 3^3$) array

Expt. No.	V (V)	I_p (A)	T_{on} (μsec)	T_{off} (μsec)	Expt. No.	V (Vol.)	I_p (A)	T_{on} (μsec)	T_{off} (μsec)
01	75	11	110	40	10	100	11	110	60
02	75	11	120	50	11	100	11	120	40
03	75	11	130	60	12	100	11	130	50
04	75	13	110	40	13	100	13	110	50
05	75	13	120	50	14	100	13	120	60
06	75	13	130	60	15	100	13	130	40
07	75	15	110	50	16	100	15	110	60
08	75	15	120	60	17	100	15	120	40
09	75	15	130	40	18	100	15	130	50

Table 5: Results for WLT and SCD

	WLT		SCD		SN ratio for WLT		SN ratio for SCD	
Expt. No.	Al2024+10% TiC_P	Al2024+10% B_4C_P	Al2024+10% TiC_P	Al2024+10% B_4C_P	Al2024 +10% TiC_P	Al2024+10% B_4C_P	Al2024+10% TiC_P	Al2024+10% B_4C_P
01	6.791	7.475	0.0626	0.0818	-16.6387	-17.4722	24.0685	21.7449
02	8.600	10.990	0.0421	0.0561	-18.6900	-20.8200	27.5144	25.0207
03	8.836	9.065	0.0748	0.1026	-18.9251	-19.1474	22.5220	19.7771
04	9.370	10.465	0.0482	0.0508	-19.4348	-20.3948	26.3391	25.8827
05	11.870	15.400	0.0324	0.0314	-21.4890	-23.7504	29.7891	30.0614
06	12.190	12.690	0.0576	0.0707	-21.7201	-22.0692	24.7916	23.0116
07	10.580	12.870	0.0172	0.0222	-20.4897	-22.1916	35.2894	33.0729
08	11.700	16.380	0.0100	0.0126	-21.3637	-24.2863	40.0000	37.9926
09	19.066	17.360	0.0173	0.0207	-25.6052	-24.7910	35.2391	33.6806
10	7.346	9.333	0.0426	0.0532	-17.3210	-19.4004	27.4118	25.4818
11	12.438	15.810	0.0358	0.0451	-21.8950	-23.9786	28.9223	26.9165
12	12.834	17.185	0.0673	0.0831	-22.1672	-24.7030	23.4397	21.6080
13	12.367	14.910	0.0318	0.0284	-21.8453	-23.4696	29.9515	30.9336
14	13.200	19.662	0.0291	0.0281	-22.4115	-25.8726	30.7221	31.0259
15	18.870	23.741	0.0508	0.0526	-25.5154	-27.5100	25.8827	25.5803
16	12.195	15.866	0.0098	0.0125	-21.7236	-24.0093	40.1755	38.0618
17	20.647	26.890	0.0093	0.0112	-26.2971	-28.5918	40.6303	39.0156
18	21.300	29.215	0.0182	0.0214	-26.5676	-29.3121	34.7986	33.3917

(1000X). Randomly five sample areas are elected on each specimen and thencracks length are measured by using software "(PDF X-change viewer)". The average crack length on each specimen re divided by the area of each micrograph (12400 μm^2) to get the "SCD".

Experimental results and S/N ratios: The results of experiments for thickness of white layer and density of surface crack by varying the selected control parameters as per L_{18} orthogonal array are shown in Table 4. The S/N ratios worked out by using Minitab 16 Software are also tabulated in Table 5.

RESULTS AND DISCUSSION

All observations of results are transformed into "S/N ratio" and results for S/N ratios of have been analyzed by ANOVA method to find the significance of various control parameters and their bestlevel. The analysis and graphical presentations are made using "Minitab 16 Software". Themost significant parameters affecting the selected response variable and their best level value are determined. The optimal design for each of the response parameters have been decided and confirmedby conducting a confirmation test.

Analysis of Variance (ANOVA) for S/N ratios of WLT: The S/N ratio is combinedmany of repetitions into one value and is indicated to theamount of variation present. The S/N ratios are calculated to specify the major contributing factors which caused variation in theWLT. Type response of WLT is "Smaller is better" which is given by:

$$(S/N)_{SB} = -10\log(MSD)_{SB} \quad (1)$$

$$(MSD)_{SB} = \frac{1}{n}\sum_{i=1}^{n}(y_i^2) \quad (2)$$

Where:

$(MSD)_{SB}$ = Mean Square Deviation for Smaller-the-Better response
y = Value of response variable
n = The number of observations in the experiments

Table 6: Analysis of variance for SN ratios of WLT

Materials	Source	df	Seq. SS	Adj. SS	Adj. MS	F-values	p-values	Contribution (%)	Remarks
Al2024+10% TiC_P	V (V)	1	25.413	25.413	25.4127	218.64	0.000	17.68328	S
	Ip (A)	2	59.543	59.543	29.7716	256.15	0.000	41.43217	S
	Ton (μsec)	2	45.382	45.382	22.6909	195.23	0.000	31.57843	S
	Toff (μsec)	2	12.212	12.212	6.1061	52.54	0.000	8.497551	S
	Residual error	10	1.162	1.162	0.1162			0.808562	
	Total	17	143.712					100.00000	
Al2024+10% B_4C_P	V (V)	1	56.621	56.621	56.6212	488.17	0.000	31.75834	S
	Ip (A)	2	65.292	65.292	32.6460	281.46	0.000	36.62185	S
	Ton (μsec)	2	46.600	46.600	23.3000	200.88	0.000	26.13763	S
	Toff (μsec)	2	8.614	8.614	4.3069	37.13	0.000	4.831536	S
	Residual error	10	1.160	1.160	0.1160			0.650636	
	Total	17	178.287					100.00000	

S = 0.3409, R^2 = 99.2%, R^2 (adj) = 98.6%; S = 0.3406, R^2 = 99.3%, R^2 (adj) = 98.9%

Table 6 is shown the results of ANOVA for "S/N ratio of WLT" at 95% confidence interval. Discharge current (I_p) is spotted to be the most considerable factor affecting the WLT which is followed by "pulse on time (T_{on})", Voltage (V) and pulse off Time (T_{off}) for Al2024+10% TiC_P whereas (I_p) is the most considerable factor which is followed by (V), (T_{on}) and T_{off} for Al2024+10% B_4C_P according to F test. The percentage contribution of each of the control parameter is calculated by the following equation:

$$\begin{aligned}&\text{Contribution of control factor} = \\ &[\text{SS (respective factor)} / \text{SS (total)}]\times 100\%\end{aligned} \quad (3)$$

The percentage contribution of each of the control parameters under study for WLT is shown by a bar chart in Fig. 2. It can be seen that for Al2024+10% TiC_P, Fig. 2 (a), discharge current contributes significantly (41.43217%), followed by pulse on time (31.57843%), voltage (17.68328%) and pulse off time (8.497551%). While arranging the control parameters was different for Al2024+10% B_4C_P, Fig. 2b, discharge current contributes significantly (36.62185%), followed by voltage (31.75834 %), "pulse on time" (26.13763%) and "pulse off time" (4.831536 %).

The main effects are ploted for S/N ratios of WLT for two composite materials (Al2024+10% TiC_P and Al2024+10% B_4C_P) are shown in Fig. 3 and 4. Figure 3 is shown that with the increase in "Voltage (V), discharge current (I_p) and pulse on Time (T_{on})", S/N ratio decreasing. The S/N ratio is increased with an increasing in "pulse off Time (T_{off})" as well.

As can be observed from in Fig. 4, S/N ratio is decreased with an increasing in voltage and discharge current. However, a steep decrease in S/N ratio is observed from a pulse on time of 110-120 μsec then decreased slightly with an increase from 120-130 μsec. Further, it is observed that, S/N ratio reduced slightly with an increasing in "Pulse off time" of 40-50 μsec then noticeable increase from 50-60 μsec.

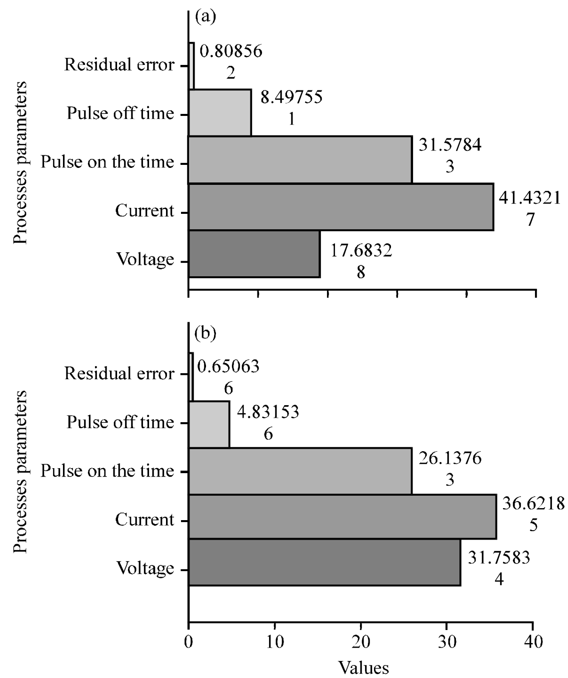

Fig. 2: Percentage contribution of control parameters for WLT: a) Al2024+10%TiC_P and b) Al2024+10% B_4C_P

Lastly, it can be observed that out of the two metal matrix composite, Al2024+10% B_4C_P has a larger S/N ratio compared to Al2024+10% TiC_P. Figure 5a, b shows the white layer thickness at experiment No. 16, Table 5 (V = 100 V, Ip = 15 A, T_{on}: 100 μsec, T_{off} = 60 μsec) of the two MMCs. The white layer thickness of Al2024+10% B_4C_P (Fig. 5b) is nearly 1.3 more than Al2024+10% TiC_P (Fig. 5a) because the more hardness of the first MMC (Al2024+10% TiC_P) compared to the second MMC (Al2024+10% B_4C_P).

Analysis of Variance (ANOVA) for S/N ratios of SCD: The S/N ratios is calculated to specify the major contributing factors that caused variation in the SCD.

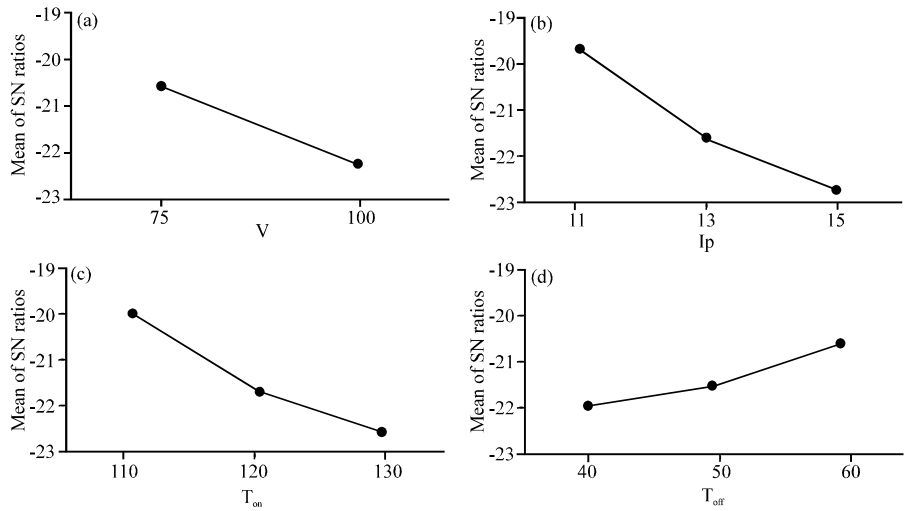

Fig. 3: Main effects plot for S/N ratios of WLT for Al2024+10% TiC_P

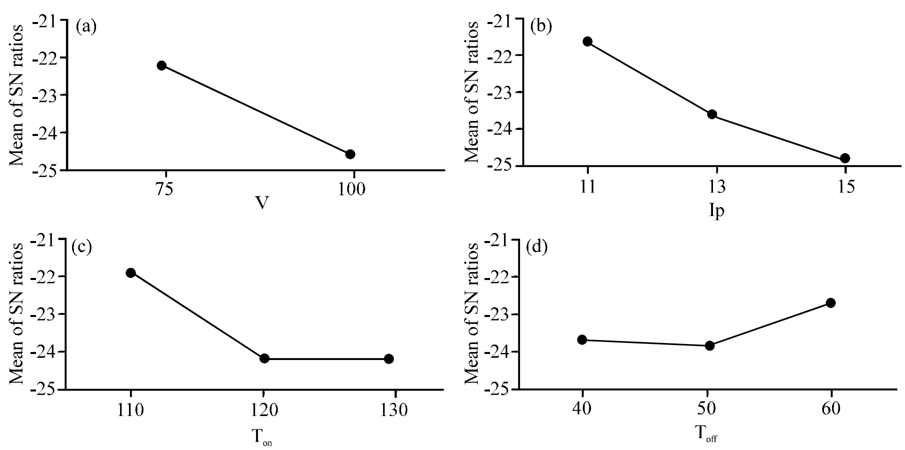

Fig. 4: Main effects plot for S/N ratios of WLT for Al2024+10% B_4C_P

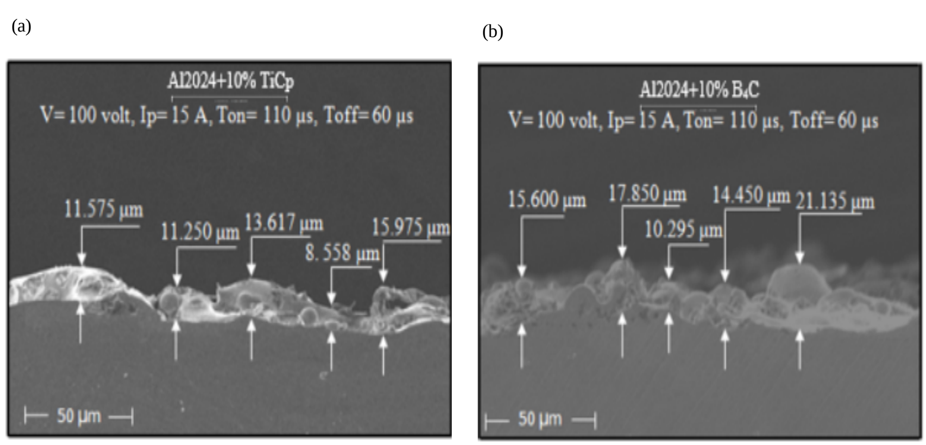

Fig. 5: SEM snap WLT atprocess parameters ($V = 100$ V, $I_p = 15$ A, $T_{on} = 100$ µsec; $T_{off} = 60$ µsec) of a) Al2024+10% TiC_P and b) Al2024+10% B_4C_P

Table 7: Analysis of variance for SN ratios of SCD

Material	Source	df	Seq. SS	Adj. SS	Adj. MS	F-values	p-values	Contribution (%)	Remarks
Al2024+10% TiC_P	V (V)	1	14.909	14.909	14.909	15.58	0.003	2.492677	S
	Ip (A)	2	491.455	491.455	245.727	256.81	0.000	82.16772	S
	Ton (μsec)	2	79.728	79.728	39.864	41.66	0.000	13.32994	S
	Toff (μsec)	2	2.452	2.452	1.226	1.28	0.320	0.409957	NS
	Residual error	10	9.568	9.568	0.957			1.5997	
	Total	17	598.112					100.00000	
Al2024+10% B_4C_P	V (V)	1	26.331	26.331	26.331	17.10	0.002	4.300954	S
	Ip (A)	2	478.995	478.995	239.497	155.55	0.000	78.23993	S
	Ton (μsec)	2	90.957	90.957	45.478	29.54	0.000	14.85708	S
	Toff (μsec)	2	0.533	0.533	0.267	0.17	0.843	0.087061	NS
	Residual error	10	15.397	15.397	1.540			2.514974	
	Total	17	612.213					100.00000	

S: Significant factor; NS: Non-Significant; S = 0.9782, R^2 = 98.4%, R^2 (adj) = 97.3%; S = 1.241, R^2 = 97.5%, R^2 (adj) = 95.7%

Type response SCD is _g Smaller is better_h which is given by Eq. 1 and 2. Table 7 is shown the results of ANOVA for S/N ratio of SCD at 95% confidence interval. Discharge current (I_p) is observed to be the most considerable factor affecting the SCD which followed by the "pulse on time (T_{on})" and Voltage (V) for two metal matrix composite (Al2024+10% TiC_P and Al2024+10% B_4C_P) according to F test. The remaining "pulse off time (T_{off})" is non-significant to affect the SCD.

The percentage contribution of each of the control parameters under study for SCD is shown by a bar chart in Fig. 6. It can be seen that for Al2024+10% TiC_P, Fig. 6 a, discharge current contributes significantly (82.16772%), followed by pulse on time (13.32994%), voltage (2.492677%) and pulse off time (0.409957%). Arranging the control parameters is similar for Al2024+10% B_4C_P Fig. 6 b, discharge current contributes significantly (78.23993%), followed by pulse on time (14.85708%), voltage (4.300954%) and pulse off time (0.087061%).

The main effects plot for S/N ratios of SCD is shown in Fig. 6 and 7. Both MMC_S have the same behavior. Although, Al2024+10% B_4C_P has a larger S/N ratio than Al2024+10% TiC_p. Figure 8 shows that with increase in voltage, S/N ratio increases. As can be shown from the graph, S/N ratio increasing slightly with an increase discharge current from 11-13A. However, a steep increase in S/N ratio can be observed from a discharge current of 13-15A. The S/N ratio is increased with an increasing in |pulse on time" from 110-120 μsec then drop significantly from 120-130 μsec. Further increase the S/N ratios are almost non-existent with increasing pulse off time.

During WEDM, increasing temperature of the sparking zone is due to the workpiece material to melt during "pulse-ontime". During "pulse-off time", part of the molten metal is obtainedre-solidified and quenched caused rapid cooling. The rmalresidual stress generated are caused rapid heating and cooling cycle which resulted surface cracks in the recast layer (Lee and Li, 2003; Rao *et al.*, 2008). Figure 9a, b is described SEM images of surface cracks formed on the surfaces machined at

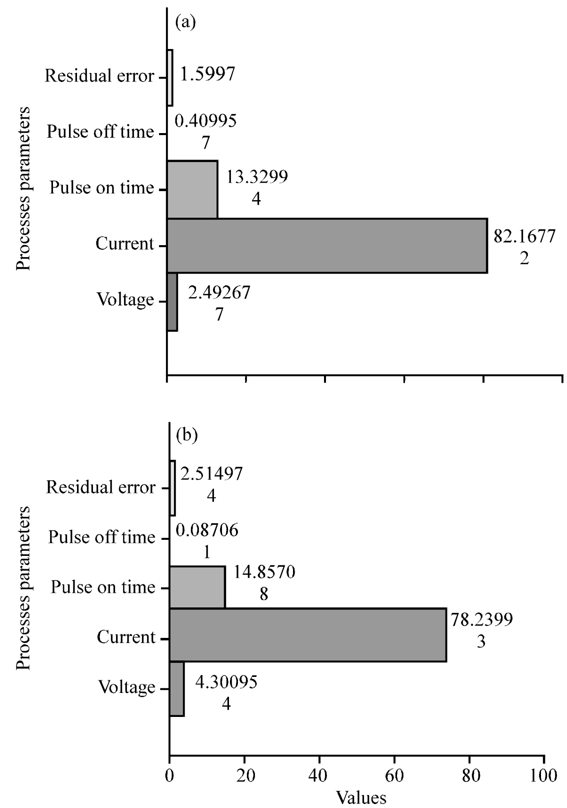

Fig. 6: Percentage contribution of control parameters for SCD: a) Al2024+10%TiC_P and b) Al2024+10% B_4C_P

experiment No. 16, Table 5 (V = 100 V, Ip = 15 A, T_{on}: 100 μsec, T_{off} = 60 μsec) of the two MMC_S (A: Al2024+10% TiC_P, B: Al2024+10% B_4C_P). The SCD of Al2024+10% B_4C_P (Fig. 5b) is nearly 1.27 more than Al2024+10% TiC_P (Fig. 5a). At the first MMCs, WLT is highand the induced stress is obtained more severe (Vishwakarma *et al.*, 2012) resulting in anincreasing in SCD.

Optimization of wedm process parameters: The mean of S/N ratios of all factors are calculated by S/N ratio values of WLT and SCD and shown in Table 8 and 9.

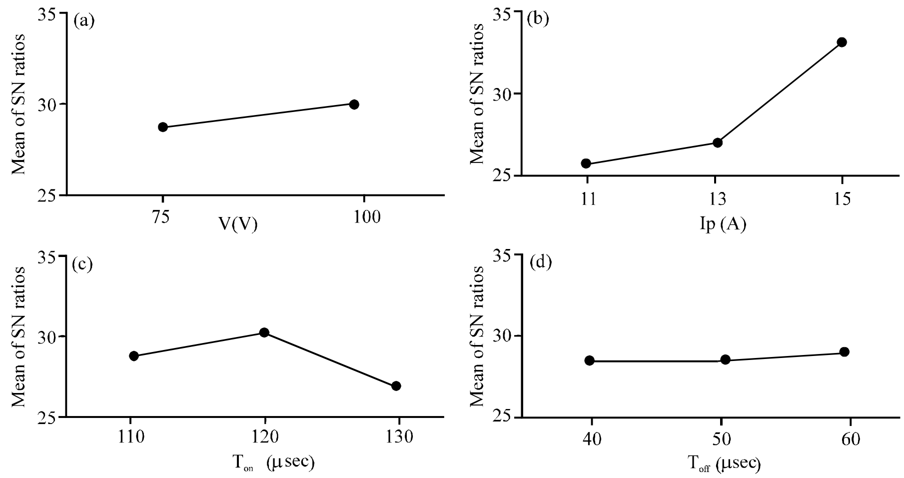

Fig. 7: Main effects plot for S/N ratios of SCD forAl2024+10% TiCP

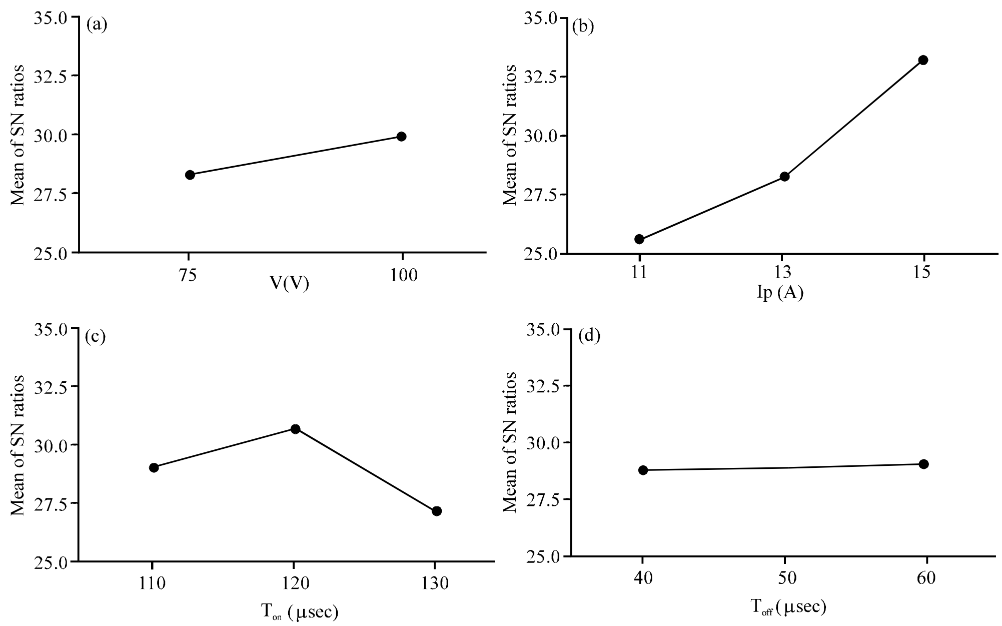

Fig. 8: Main effects plot for S/N ratios of SCD for Al2024+10% B_4C_P

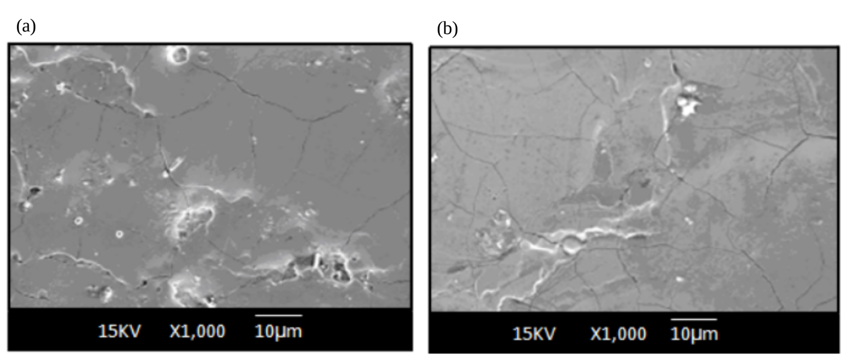

Fig. 9: SEM snap SCD at process parameters (V = 100 V, I_p = 15 A, T_{on}: 100 µsec, T_{off} = 60 µsec) of a): Al2024+10% TiC_P and b) Al2024+10% B_4C_P

Table 8: Response table for signal to noise ratios of WLT and SCD

		WLT				SCD			
Materials	Level	V	I_p	T_{on}	T_{off}	V	I_p	T_{on}	T_{off}
Al2024+10% TiC_P	1	-20.48	-19.27	-19.58	-22.56	29.51	25.65	30.54	30.18
	2	-22.86	-22.07	-22.02	-21.87	31.33	27.91	32.93	30.13
	3		-23.67	-23.42	-20.58		37.69	27.78	30.94
	Delta	2.38	4.40	3.84	1.99	1.82	12.04	5.15	0.81
	Rank	3	1	2	4	3	1	2	4
Al2024+10% B_4C_P	1	-21.66	-20.92	-21.16	-23.79	27.80	23.42	29.20	28.80
	2	-25.21	-23.84	-24.55	-24.04	30.22	27.75	31.67	29.01
	3		-25.53	-24.59	-22.46		35.87	26.17	29.23
	Delta	3.55	4.61	3.43	1.58	2.42	12.44	5.50	0.42
	Rank	2	1	3	4	3	1	2	4

Table 9: Optimal value of WLT and SCD

	Optimal value	
Materials	WLT	SCD
Al2024+10%TiC_P	5.554	0.00827
Al2024+10% B_4C_P	6.240	0.01006

Table 10: Results of the confirmation experiment for WLT and SCD

	Optimal machining parameter							
	WLT					SCD		
Materials	Level	Pred.	Exp.	Error (%)	Level	Pred.	Exp.	Error (%)
Al2024+10% TiC_P	A_1	5.554	5.414	2.520	A_2	0.00827	0.00805	2.660
	B_1				B_3			
Al2024+10% B_4C_P	C_1				C_2			
	D_3				D_3			

In optimization, we use the S/N ratio as the objective function to be maximized (Phadke, 1995). To conclude the discussion, for minimum WLT and SCD, the level value with a higher S/N ratio of each of the control parameters under study should be selected at this stage. Thus, for WLT of two composite materials alow voltage of 75 V, low discharge current of 11 A, low "pulse on time" of 110 µsec and high "pulse off time" of 60 µsec. Thus, it can be concluded that, the optimum combination for WLT is A_1 B_1 C_1 D_3.

For SCDof two composite materials (Al2024+10% TiC_P and Al2024+10% B_4C_P), higher voltage of 100 V, higher discharge current of 13 A, moderate "pulse on time" of 120 µsec and higher "pulse off time" of 60 µsec. Thus, it can be concluded that, the optimum combination for SCD is A_2 B_3 C_2 D_3.

After evaluating the optimal parameter settings, used the "Taguchi approach" to predict and prove the enhancement of quality properties via. combination of the optimal parametric which is not available in L_{18} array under study. Hence, the theoretical optimum value of WLT and SCD have to be calculated. The estimated S/N ratio is used the optimal level of the design parameters are calculated. The optimal value of S/N ratio is given by Eq. 4:

$$n_{opt} = n_m + \sum_{i=1}^{a} n_i - n_m \quad (4)$$

Where:

n_m = The total mean S/N ratio
n_i = The mean S/N ratio at optimum level
a = The numberof main design parameters

which is affected quality characteristic. Based on Eq. 4, the estimated multi-response signal to noise ratio is obtained. For Al2024+10% TiC_P:

- n_{opt}=-21.6722+(-20.48+21.6722)+(-19.27+21.6722)+(-19.58+ 21.6722)+(-20.58+21.6722)
- n_{opt} = Optimal value of S/N ratio = -14.8934

The corresponding value of WLT is given by Eq. 5:

$$y^2 = 10^{\frac{-n_{opt}}{10}} \quad (5)$$

thus, y^2 = 30.8560, y_{opt} = 5.554. In the same method for all responses which are tabulated in Table 9.

Confirmation test: A confirmation test is performed by setting the control parameters as per the optimum levels achieved. The experimental result is obtained for the WLT is 5.414 and 6.105 whereas for the SCD 0.00805 and 0.00991 of Al2024+10% TiC_P and Al2024+10% B_4C_P, respectively. Thus, the experimental value agrees reasonably well with the prediction as shown in Table 10.

The maximum errorof the predicted result from experimental result is about 2.520% and 2.162 for WLT and 2.660 and 1.491 for SCD. Hence, the experimental result is emphasized the optimization of WLT and SCD by Taguchi approach and the resulting model is appeared be ableto predicting WLT and SCD.

CONCLUSION

The WLTof Al2024+10% TiC_P is mainly affected by "the discharge current (I_p)" followed by "pulse on Time (T_{on})", voltage and "pulse off Time (T_{off})" whereas (I_p) was the most significant factor, followed by (V), (T_{on}) and T_{off} for Al2024+10% B_4C_P. The SCDof two MMC_S is mainly affected by "the discharge current (I_p)" followed by "pulse on Time (T_{on})" and voltage, "pulse off Time (T_{off})" has no effect. The optimum combination for WLT of two MMC_S can be achieved with V of (75 V), I_p of (11 A), T_{on} of (110 μsec) and T_{off} of (60 μsec). The optimum combination for SCD of two MMC_S can be achieved with Vof (100 V), I_p of (15 A), T_{on} of 120 μsec and T_{off} of (60 μsec). Comparison of the values experimental and predicted of the WLT and SCD is shown a good agreement is achieved between them.

The methodology of optimization suggested is a strong process and offered to scientific researcher's as well manufacturing metal working a useful optimization method for different combinations of the MMC_S as a workpiece and the brass wire as an electrode.

REFERENCES

Dewangan, S., S. Gangopadhyay and C.K. Biswas, 2015. Study of surface integrity and dimensional accuracy in EDM using Fuzzy TOPSIS and sensitivity analysis. Meas., 63: 364-376.

Fukuzawa, Y., N. Mohri, H. Gotoh and T.A.N.I. Takayuki, 2009. Three-dimensional machining of insulating ceramics materials with electrical discharge machining. Trans. Nonferrous Met. Soc. China, 19: 150-156.

Han, F., J. Zhang and I. Soichiro, 2007. Corner error simulation of rough cutting in wire EDM. Precis. Eng., 31: 331-336.

Khaja, M., R. Kumar and V. Singh, 2015. Modeling and optimization of WEDM process parameters on machining of AISI D2 steel using Response Surface Methodology (RSM). Intl. J. Adv. Res. Eng. Sci. Technol., 2: 49-53.

Lee, S.H. and X. Li, 2003. Study of the surface integrity of the machined workpiece in the EDM of tungsten carbide. J. Mater. Process. Technol., 139: 315-321.

Pandey, A. and S. Singh, 2010. Current research trends in variants of electrical discharge machining: A review. Intl. J. Eng. Sci. Technol., 2: 2172-2191.

Phadke, M.S., 1995. Quality Engineering using Robust Design. Prentice Hall, Upper Saddle River, New Jersey, USA.,.

Rao, G.K.M., S. Satyanarayana and M. Praveen, 2008. Influence of machining parameters on electric discharge machining of maraging steels: An experimental investigation. Proceedings of the World Congress on Engineering (WCE'08) Vol. 2, July 2-4, 2008, Imperial College London, London, England, UK., ISBN:978-988-17012-3-7, pp: 1-6.

Satheesh, J., T. Pasha, Harish and T. Madhusudhan, 2013. Optimal machining conditions for turning of AlSiC metal matrix composites using ANOVA. Intl. J. Innovative Res. Sci. Eng. Technol., 2: 6171-6176.

Shrivastava, S.M. and A.K. Sarathe, 2014. Influence of process parameters and electrode shape configuration on material removal rate, surface roughness and electrode wear in die sinking EDM. Intl. J. Emerging Technol. Adv. Eng., 4: 138-145.

Singh, J. and V. Kumar, 2012. Investigation on the material removal mechanism and the thermal aspects in the electrical discharge machining process. Intl. J. Eng. Technol., 2: 1503-1507.

Vishwakarma, M., V. Parashar and V.K. Khare, 2012. Advancement in electric discharge machining on metal matrix composite materials in recent: A review. Intl. J. Sci. Res. Publ., 2: 86-93.

Yan, M.T. and H.T. Chien, 2007. Monitoring and control of the micro wire-EDM process. Intl. J. Mach. Tools Manuf., 47: 148-157.