To compare the output characteristics in electric discharge machining using new and re-used tool on Aluminium silicon Carbide MMC.

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Abstract— This research paper consists of impact of new tool and old tool on the response parameters like MRR, TWR, surface roughness and dimensional accuracy in electric discharge machining process. The experiments were conducted on aluminium silicon carbide (Al6061 10p SiC) MMC using copper electrodes in drill EDM machine. To meet the objective, the experiments were conducted using Taguchi method of design of experiments. The variables used during the experiments were pulse on time, pulse off time and peak current. The results obtained from all the experiments performed, revealed that there were differences in performance output of material removal rate, tool wear rate and surface roughness when tool was reused and when new tool was used. Significant difference was observed in tool wear rate but it was found insignificant in case of material removal rate when tool with recast layer was used. Surprisingly, the tool wear rate decreases in most of the cases, due to the recast layer formed on the tool. The melting property of aluminium silicon carbide (Al6061 10p SiC) contributes to the differences observed in the obtained results.

***Keywords*—Electric discharge machining (EDM), Metal matrix composite (MMC), material removal rate (MRR), Tool wear rate (TWR), recast layer (RL), surface roughness, diametrical overcut (DOC).**

I. INTRODUCTION

EDM is a controlled machining of an electrically conductive material through an electrically conductive 3-D shaped tool or wire electrode using pulsed electrical current within a dielectric medium. The material removal takes place due to melting and flushing away of the workpiece material. The flushing in EDM plays a very important role as the MRR, TWR and SR are very much dependent on the flushing system. The recast layer (RL) is formed on both the tool and the workpiece which is formed due to resolidification of unflushed molten material present at the surfaces of tool and workpiece. This layer is very different in nature from the parent material as the dielectric assimilates into the molten pool and solidifies giving entirely new composition at the surfaces of both tool and the electrode. This layer is mainly undesirable because of its different chemical composition from the parent material. For e.g. if some implant is to be machined first using EDM and then placed in body, the recast layer formed on the implant during the machining will act as a toxic layer, hence, making it necessary to remove before it is implanted into the body. It may also act as a protective layer, like for e.g. it may act as a coating on the surface which protects the material from corroding away.

In various research works in the past, the recast layer on the workpiece has always been analysed but very little work has been for analysing the effect of recast layer on tool, which has been the focus of this research work. In papers on micro edm, it was found that there has been deposition of carbonaceous layer which played a part in increasing the length of the tool after machining in very few cases of the experiments performed, pointing towards negative tool wear in the longitudinal direction.

II. METHODOLOGY

The paper aims at finding the difference in the performance characteristics of EDM when tool with and without recast layer on it is used. For this Taguchi's method of design of experiments is used in order to set the variable parameters of peak current, pulse on duration and pulse off duration at three different levels, as shown in table 1, in order to study the role of each of the input variable in affecting material removal rate (MRR), tool wear rate (TWR), surface roughness (SR) and diametrical overcut (DOC) when both tool with and without recast layer are used for the machining process. The recast layer removal is done by removing the tool tip of length 11 mm which is same as depth of the hole and also these tips are used for measuring the recast layer thickness on them. L_9 orthogonal array is selected for performing the experiments, i.e. nine experiments are performed in order to obtain and optimise the results as shown in table 2. So in total eighteen experiments are performed with nine experiments conducted using tool with no recast layer and the other one being tool with recast layer on it.

TABLE 1: PARAMETERS AND LEVELS

S. no.	Parameter	Notation	Leve l 1	Level 2	Level 3
1	Pulse on time	t_{on}	3	6	9
2	Pulse off time	t_{off}	3	6	9
3	Peak current	I_P	3	6	9

TABLE 2: EXPERIMENTAL TABLE

Experiment no.	t_{on} (µseconds)	t_{off} (µseconds)	I_P (amperes)
1	3	3	3
2	3	6	6
3	3	9	9
4	6	3	6
5	6	6	9
6	6	9	3
7	9	3	9
8	9	6	3
9	9	9	6

III. EXPERIMENTAL SETUP

The experiments are performed on Al6061 10p SiC metal matrix composite as workpiece using a copper tube as tool on fast drill ED 25 machine. The workpiece is prepared using stir casting process in which the Al6061 rods were melted and then the SiC powders of mesh size 200 was used and finally the workpiece was obtained and the surface is machined using milling operation and then the microstructure is checked in order to check the homogeneity of the workpiece as shown in figure 2. It is observed that the homogeneity is not 100% due to not so skilled labour available for the process but the strength of the aluminium got enhanced and after measuring its hardness on Rockwell hardness, it is found that it is 16RW hard.

The copper tool of outer diameter 3mm and inner diameter 1mm is used for performing the experiments. The tool was available with the machine and only hollow tools can be used in this machine of diameter 0.3 to 3mm as the mode of flushing in this machine is injection flushing i.e. the dielectric which is tap water in this case goes through the hollow space in the tube to the electrode gap where machining takes place. The use of tap water as dielectric is justified as its use brings in faster MRR and poor SR, i.e. if the surface roughness is no priority at all, the use of water as dielectric is completely justified. For the purpose of checking the recast layer on tool, the tool tips are cut using wire cutter leading to a fresh new tip for next machining operation.

During machining, the time of machining is noted down along with the change in length of the tool before and after machining in order to calculate the MRR and TWR. To check the surface roughness of the holes drilled, wire EDM operation was used for cutting the holes across the diameter and hence, exposing the surface of the holes. The surface roughness was measured using Mitutoyo surftest machine. And finally to check the geometrical accuracy of the holes drilled, i.e. to check the diametrical overcut of the holes, stereo-zoom microscope is used to check the diameter of the holes drilled by drawing circle around the periphery of the hole drilled.

IV. RESULTS AND DISCUSSIONS

The machining of the workpiece is done under same set of conditions for both, tool having recast layer on it and not having recast layer on it making it two sets of nine experiments

1. MRR analysis

The MRR is calculated as dividing the weight of workpiece before and after the machining, with the number of holes drilled and time taken per hole drilled as shown in equation 1

$$MRR = \frac{(W1 - W2)}{n \times ti}$$

Where,

MRR_i = MRR of that of i^{th} experiment

W_1 = weight of the workpiece before machining

W_2 = weight of the workpiece after machining

n = number of holes drilled

t_i = machining time for i^{th} experiment.

The values of MRR are noted down in table 3 when fresh new tool is used and when previously used tool is used. The values are obtained in milligram per second and also percentage increase in MRR due to RL on tool is also presented in table 3.

TABLE 3: MRR VALUES USING NEW AND USED TOOL TIP

Experiment number	**MRR (mg/s) when using**		**Percentage increase in MRR when new tool tip is used**
	New tool	Used tool	
1	1.7	1.6	5.882353
2	2.1	1.9	9.52381
3	0.9	0.7	22.22222
4	5.9	5.7	3.389831
5	10.9	14.5	-33.0275
6	1.5	1.3	13.33333
7	28.0	27.9	0.357143
8	2.8	3.0	-7.14286
9	9.8	8.7	11.22449

The graphical comparison of values of MRR obtained under the two set of conditions is shown in figure 2.

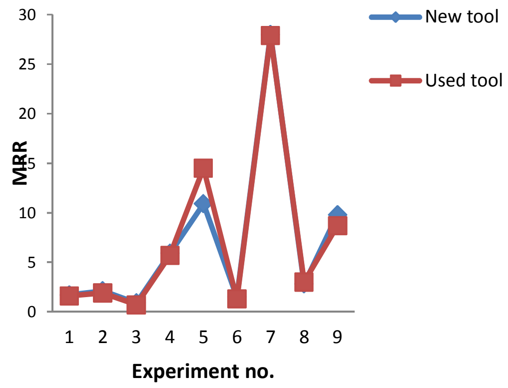

FIGURE 2: COMPARISON OF MRR WHEN USING USED TOOL AND NEW TOOL.

From both table 3 and figure 2, it can be observed that there is very small difference between the MRR obtained for new and old tool tip. The maximum differences that can be observed are in experiment nos. 3and 5 where increase in MRR is 22% and the decrease is 33% respectively due to the recast layer on tool. Hence, one can say that using a new tool tip will have very less impact on the MRR.

2. TWR analysis

The tool wear is calculated as rate of change of tool length for each machining. The z-coordinate of tool is noted down before and after the machining and then the difference is divided by the machining time and the TWR is calculated in mm/min. The values for TWR are shown in table 4

The graphical representation showing the difference in TWR when new tool used tool are used is shown in figure 3. It can be observed from both table 4 and figure 3 that there are significant differences in TWR due to deposits obtained on the same tool when used again and again. In six cases out of nine there is a decrease in TWR and the decrease is mainly near 45% in these cases and in three cases there is increase in TWR, out of which only one has increase of 50% in TWR

TABLE 4: TWR VALUES USING NEW AND USED TOOL

Experiment no.	TWR (mm/min)		Percentage decrease in TWR (%)
	New Tool	Used Tool	
1	0.672	0.350	47.91667
2	0.839	0.466	44.45769
3	0.404	0.132	67.32673
4	3.090	3.706	-19.9353
5	3.334	3.880	-16.3767
6	0.428	0.355	17.05607
7	3.420	5.140	-50.2924
8	1.130	0.581	48.58407
9	2.400	1.034	56.91667

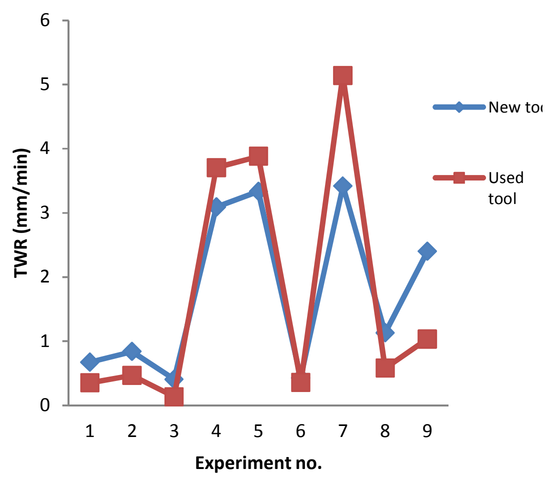

FIGURE 3: VARIATION IN TWR NEW TOOL AND USED TOOL

The decrease in TWR is bit unexpected because the recast layer that is formed on the tool is mainly a composition of oxides of copper and debris from the workpiece as water, when used as dielectric forms oxides as the recast layer. The breakdown of oxide layer of copper should happen faster than the copper layer itself but this is not the case observed in 6 out of 9 cases discussed above probably because of the phenomenon occurring during the machining that the aluminium alloy melts first and then the SiC particles are pushed out of the matrix, which seep into the molten pool of copper along with the water and thus forming a matrix composite in the recast layer where the copper oxide is acting as the matrix and the SiC powder is acting as the reinforcement leading to strengthening of the layer and hence, the breakdown of layer is slower than the parent metal copper. Hence, for this reason at lower values of pulse on time and peak current, the TWR decreases whereas it increases when the pulse on time and peak current are high when the copper oxide fails to hold the temperature and pressure as good as copper itself created in the plasma channel.

3. Surface roughness analysis

The surfaces roughness of the holes drilled using both tool with recast layer and without recast layer were measured and recorded in table 5. The recast layer on tool is a rough surface both on frontal part and lateral part. Where it is highly concentrated at the frontal part, it is also present on the lateral surface of the tool but cannot be easily distinguished or observed. One section of the lateral surface always have recast layer on it which is the portion which conducts during rotation.

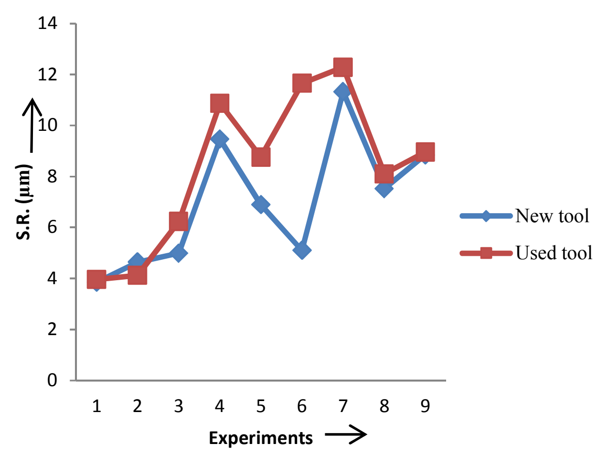

FIGURE 4: GRAPHICAL COMPARISON OF SR USING NEW TOOL AND USED TOOL

TABLE 5: SR VALUES USING NEW TOOL AND USED TOOL

Experiment no.	Surface roughness (S.R.) (in µm)		Percentage decrease in SR due to RL on tool
	New tool	Used tool	
1	3.85	3.96	-2.8571429
2	4.64	4.12	11.206897
3	4.99	6.23	-24.849699
4	9.46	10.87	-14.904863
5	6.89	8.76	-27.140784
6	5.1	11.65	-128.43137
7	11.32	12.28	-8.4805654
8	7.52	8.10	-7.712766
9	8.84	8.96	-1.3574661

The graphical comparison of both the set of results are shown in figure 4, showing significant amount of variation mainly depicting undesirable effects on surface roughness due to recast layer on tool.

4. Diametrical Overcut Analysis

The tool with recast layer on it, not just had different composition at the tip but also is geometrically different from the original tool tip, i.e. the tool tip is generally bit tapered due to the previous machining performed on it resulting in lateral wear and hence a tapered tool tip. So table 6 shows the results for DOC obtained using tool with recast layer and tool without recast layer.

TABLE 6: DOC OBTAINED FROM NEW TOOL AND USED TOOL

Experiment no.	DOC (mm)		Percentage decrease in doc (%)
	New tool	Used tool	
1	0.36	0.27	25
2	0.5	0.33	34
3	0.38	0.35	7.89
4	0.5	0.35	30
5	0.5	0.39	22
6	0.36	0.3	16.67
7	0.67	0.4	40.29
8	0.43	0.3	30.23
9	0.46	0.38	17.39

The graphical comparison of the same is also shown in figure 5, and the DOC is measured in mm. From both table 6 and graph 5, it can be observed that the DOC is very less when tool with recast layer is used, but it cannot solely be the reason for decrease in DOC as the geometrical aspects also needs to be taken into consideration as initially the hole drilled by them is of diameter less than 3mm which during the complete machining increases in diameter. Although the DOC is less in tool with recast layer but the results should also be compared with tool with tapered tip having no recast layer to know the actual impact of tool recast layer on DOC of the holes drilled.

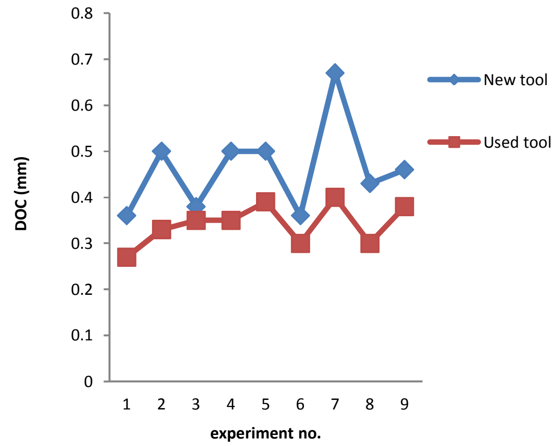

FIGURE 5: GRAPHICAL COMPARISON OF DOC OBTAINED FROM NEW TOOL AND USED TOOL.

V. CONCLUSIONS

1. There is no significant difference observed between the MRR obtained for new and used tool.
2. But there is significant difference observed between TWR of the new and used tool. It was expected that the recast layer formed on the used tool would weaken the tool material and hence produce faster TWR, but because of seeping of SiC powder into the tool recast layer gives the tool strength to resist wear.
3. The reused tool has significant effect on DOC, as it is decreased by upto 40% suggesting that that if holes of high accuracy needs to be drilled, the new tool should always first be used on a dummy workpiece.
4. The recast layer on tool is affecting the surface finish of the workpiece by upto 120% when compare with the new tool which has no recast layer deposits on it.
5. Upon removal of tool tip by the length equal to the depth of the hole drilled, changes in the output are clearly observed.

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