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Analysis of Bronze and Copper Bonded EDM based Grinding Process: A Comparative Study

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Abstract

The Electrical discharge machining (EDM) based diamond abrasive grinding processes are gaining additional recognition in processing of advance engineering materials due to high quality of surface and enhancement of material removal rate. Electric Discharge Diamond Face Grinding (EDDFG) is a special configuration of EDM based diamond abrasive grinding process. It is one of the hybrid machining processes, where material is removed from conductive workpiece by combined action of diamond abrasive which causes abrasion and electric spark between metal bonded wheel and conductive workpiece which causes softening and melting of workmaterial. In present work EDM based diamond abrasive grinding (i.e. EDDFG) have been used for conductingexperiments to find out the effect of machining parameters on performance characteristic viz MRR (Material removal rate), TWR (Tool wear rate) and surface roughness (R_a). Four input parameters namely pulse current, pulse-on-time, pulse-off-time and Wheel rpm were selected as input parameters. Experiments have been performed with copper and bronze bonded diamond abrasive wheel. To have a full insight of this hybrid machining process, many experiments have been performed with copper and bronze bond wheel. Further, comparative study has been performed. After analyzing the experimental results, it has been concluded that Bronze bonded wheel is better than copper bonded wheel because it provide better Material Removal Rate (MRR) at comparatively low Tool Wear Rate (TWR).

Keywords: Electric Discharge Diamond Face Grinding, High Speed Steel, Metal bonded diamond grinding wheel

1. INTRODUCTION

Improvement in Automobile sector, aircrafts, missiles etc. have resulted in development of advance engineering material which possesses higher strengths related properties. Such advanced engineering materials are titanium alloys, metal matrix composites, ceramics, super alloy and high speed steel etc. However these materials are difficult to be machined by conventional machining processes and even non- conventional machining processes. Problem with conventional processes is less strength of tool while non-conventional processes have lower productivity and limitations. Koshy et al. (1996) have studied and suggested to overcome the difficulties of conventional as well as non-conventional machining processes by suggesting hybrid machining processes (HMP).In HMPs, two or more machining processes are combined to achieve the advantages of constituent processes. In present case, study has been performed on Electro Discharge Diamond Grinding (EDDG) process which is a combination of two processes i.e. Electric Discharge machining (EDM) and conventional grinding with diamond abrasives. Grodzinskii et al. (1979) have suggested the concept of combination of EDM and diamond grinding in late eighties (1980) .Yadav et al. (2008) developed an experimental setup for Electrical Discharge Diamond Grinding (EDDG) and studied the variation of material removal rate (MRR) with current, wheel speed, pulse-on time and duty factor using HSS as workpiece. It was found that MRR increases with current, wheel speed and pulse-on-time. Singh et al. (2010) studied Electrical Discharge Diamond Face Grinding (EDDFG) with bronze bonded diamond abrasive wheel. They observed that MRR was increased and Wheel Wear Rate (WWR) was reduced as compared to Electrical Discharge Face Grinding (EDFG). Velmurugan et al. (2011) conducted Electro-Discharge machining on Al6061 based hybrid metal matrix composite and studied variation of material removal rate (MRR), tool wear rate (TWR) and surface roughness with current, pulse-on-time and flushing pressure of dielectric fluid.

In this paper, study has been performed on EDDFG using Copper bonded and Bronze bonded, diamond abrasive wheels and comparative study has been done. Experiments were conducted to study the effect of pulse current, pulse-on-time, pulse-off-time, wheel rpm and type of bonding material (Copper and Bronze) on Material Removal Rate (MRR), Tool Wear Rate (TWR) and surface finish.

2. EXPERIMENTAL DETAILS

The experiments were conducted on S 50 ZNC EDM machine. It has a capacity of 350 liters with 1HP pumping motor. Tank was filled with dielectric namely CPC Kerosene. Various other specifications are mentioned in Table 1. Experiments were conducted on High Speed Steel (HSS) workpiece having square cross section (20mm×20mm) and height (10mm). HSS was selected as workpiece material because it is advance engineering material having easy availability and not much work regarding EDDFG has been done on this material. According to EDM machine and tool holder specifications, two type of grinding wheel was designed. Both the wheel has diamond abrasives however for one wheel bonding material is Bronze while for other it is Copper. Material removal rate (MRR), Tool wear rate (TWR) and Surface Roughness R_a were the responses that were observed. Out of these responses for TWR and Surface Roughness smaller value is considered better. However for MRR larger value is better. Therefore one wants higher MRR at lower TWR and Surface Roughness. Main effect plots were plotted for each response with variation in pulse current, pulse-on-time, pulse-off-time and wheel rpm. Taguchi L9 approach for the design of experiment was selected. In order to find out the suitable range of parameters for conducting experimental study, pilot experiments were performed.

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Table 1: Specification of EDM machine

Machining unit	S 50 (ZNC)
Tank Size (mm)	900×550×375
Table Size (mm)	600×400
Long Cross Travel (mm)	350×2×25
Vertical Filter	14", 10 micron
Quill (mm)	250
Maximum height of the workpiece(mm)	350
Maximum weight of work piece (kg)	550
Maximum Electrode weight (kg)	35
Parallelism of Table Surface with travel	0.02

Table 2: Specification of Grinding Wheel

Abrasive	Diamond
Concentration	75%
Grit number	Medium (In between coarse and fine)
Grade	M(Medium)
Bonding Material	Bronze, Copper
Depth of Abrasive	10 mm
Wheel Diameter	35 mm
Holding length	35 mm
Holding Dia.	6 mm

3. EXPERIMENTAL DATA OBTAINED

A number of pilot experiments were conducted in order to obtain the suitable range of machining process parameters as given in Table 3. Whole set of experiment was conducted twice, firstly by Copper bonded grinding wheel then by Bronze bonded grinding wheel. The data obtained through experimentation is shown in Table 4.

Table 3: Machining parameters and their levels

Input parameters	Level I	Level II	Level III
Pulse current (A)	3	6	9
Pulse-on-time (μs)	30	60	90
Pulse-off-time (μs)	15	45	90
Wheel speed (rpm)	600	800	1000

4 RESULTS AND DISCUSSION

Following responses were observed: material removal rate(MRR), Tool wear rate(TWR) and Surface Roughness $R_{a.}$

4.1 Effect ofinput parameters on MRR

The effect of input parameters on MRR with both type of wheel (Bronze and Copper) is shown in Fig. 1 and Fig. 2 respectively.

It is observed that with increase in pulse current MRR increases because the spark energy increases with increase of the current.

Due to this, more amount of material is melted and softened. The molten material is flushed away during pulse-off-time while the soften material is removed by diamond particles during grinding process resulting increased MRR. Also for both kind of wheel (Bronze and Copper), with increase in pulse-on-time, MRR increases because an increase of pulse-on-time means longer time for the particular spark discharge. Hence, the same amount of heat energy is transmitted into workpiece for a longer time. Due to this, more material is melted and softened as a result of which MRR increases.

Table 4: Experimental Data Obtained

S. No	Pulse current (A)	Pulse-on-Time (μs)	Pulse-off-Time (μs)	Wheel rpm	MRR (g/min)	TWR (g/min)	R_a(μm)
For Copper Bonded Grinding Wheel							
1	3	30	15	600	0.00065	0.0027	2.21
2	3	60	45	800	0.00055	0.0055	2.61
3	3	90	90	1000	0.00535	0.0103	2.74
4	6	30	45	1000	0.00185	0.0055	2.99
5	6	60	90	600	0.0012	0.0074	3.2
6	6	90	15	800	0.00405	0.0558	3.4
7	9	30	90	800	0.0056	0.01115	3.8
8	9	60	15	1000	0.00685	0.0405	3.66
9	9	90	45	600	0.00625	0.04025	4.04
For Bronze Bonded Grinding Wheel							
1	3	30	15	600	0.00125	0.00395	2.7
2	3	60	45	800	0.00275	0.0053	3.35
3	3	90	90	1000	0.0017	0.0108	3.4
4	6	30	45	1000	0.0062	0.0067	3.36
5	6	60	90	600	0.00465	0.00995	3.64
6	6	90	15	800	0.00817	0.04213	3.85
7	9	30	90	800	0.00574	0.00483	4.55
8	9	60	15	1000	0.01265	0.0274	4.01
9	9	90	45	600	0.0107	0.03275	4.55

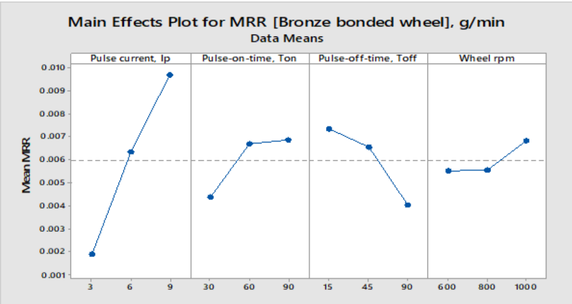

Fig. 1: Effect of input parameters on MRR for bronze bonded diamond wheel

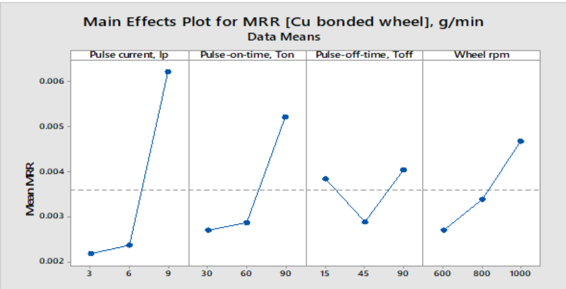

Fig. 2: Effect of input parameters on MRR for Copper bonded diamond wheel

For Copper wheel at low pulse-off-time MRR decreases but at higher value of pulse-off-time i.e. 45µs to 90µs, MRR increases. However in case of Bronze wheel with increase in pulse-off-time, there is a decrease in MRR value due to less time available for sufficient melting of workpiece. With increase in Wheel rpm, MRR increases for both types of wheel. This is due to fact that the flushing efficiency enhances with increase of the wheel rpm, thus the molten material is completely removed and no recast layer is formed. This phenomenon leads to increase of the MRR. It was observed that MRR obtained with Bronze wheel (0.006g/min) is about 71.4% greater than that obtained with Cu wheel (0.0035g/min). This is due to high strength of Bronze material compare to Copper material. Moreover it can also be seen that with increase in pulse-off-time, MRRwith Cu bonded wheel first decreases and then increases. However in case of Bronze bonded wheel it only decreases.

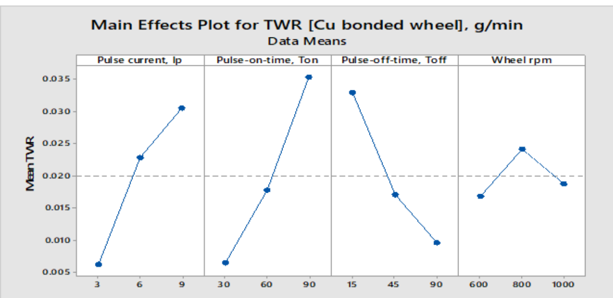

Fig. 3: Effect of input parameters on TWRfor Copper bonded diamond wheel

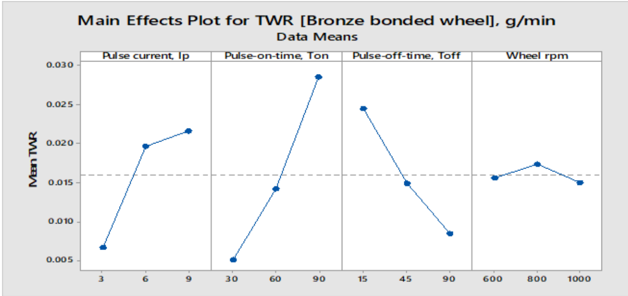

Fig. 4: Effect of input parameters on TWRfor Bronze bonded diamond wheel

4.2 Effect ofinput parameters on TWR

The effect of input parameters on tool wear rate (TWR) of copper and bronze bonded diamond wheel is shown in Fig. 3 and Fig. 4 respectively. It is observed that with increase in pulse current TWR increases because the spark energy increases with increase of the current. Due to this, more amount of material is melted from the tool also. Also with increase in pulse-on-time TWR increases because an increase of pulse-on-time means longer time for the particular spark discharge. Hence, the same amount of heat energy is transmitted into tool for a longer time.However with increase in pulse-off-time there is a decrease in TWR value due to less time available for melting of tool. Also with increase in Wheel rpm, TWR first increases due to fact that the flushing efficiency enhances with increases of the wheel rpm, thus the molten material is completely removed and no recast layer is formed on tool. However at very high rpm (≥800) there is decrease in TWR due to spark break. TWR for bronze wheel (0.016g/min) is found about 20% less than that observed in Cu wheel (0.02g/min).

4.3 Effect of input parameters on surface roughness (R_a)

Here also similar trends were observed for both kind of wheel.The effect of input parameters on surface roughness obtained for copper and bronze is shown in Fig. 5 and Fig. 6 respectively. R_a value increases with high rate with increase of pulse current. At higher current more volume of material is melted and formed larger size of craters after ejection. Due to this, the protrusion height of the abrasive particles become ineffective to remove the crater marks smoothly resulting in increase of R_a. Also with increase in pulse-on-time, Surface Roughness (R_a) increases. The reason is that with increases of pulse-on-time, the bigger size craters are formed on workpiece surface after ejection of the

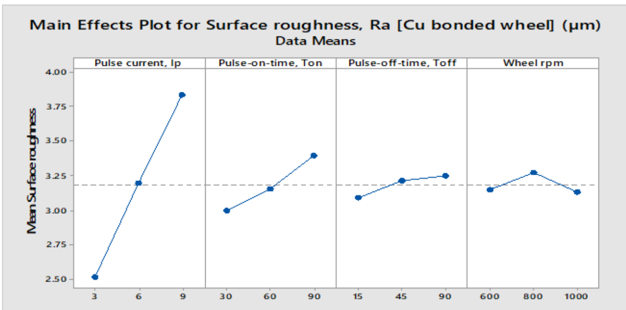

Fig. 5: Effect of input parameters on surface roughness (R_a) for copper bonded diamond wheel

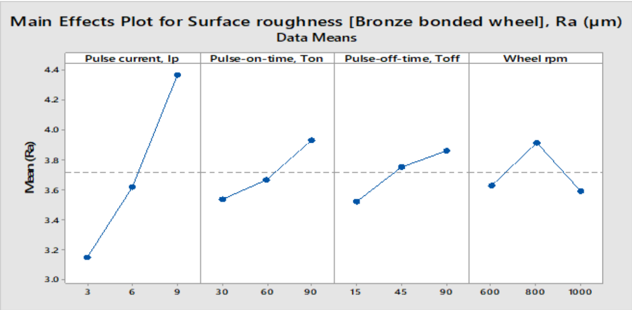

Fig. 6: Effect of input parameters on surface roughness (R_a) for Bronze bonded diamond wheel

molten materials resulting in increased Ra value. It may be also possible that the protrusion heights of abrasive particles become ineffective to smoothly machine the crater marks on workpiece surface due to the formation of the bigger size craters, as a result of which R_a value increases. Also with increase in pulse-off-time, surface roughness (R_a) increases. This is due to fact that large volume of fresh dielectric enters into gap with an increase of the pulse-off-time, this causes quenching effect and workpiece become harder. Due to which the abrasive particles start blunting during grinding process as a result of which R_a value increases. However in case of rpm, at lower rpm range (600-800) surface roughness increases due to corresponding increase in flushing action and diamond abrasive grinding. However at very high rpm range (≥800), Surface Roughness decreases due to spark breaking. Surface Roughness for Bronze Wheel (3.7 µm) found 15.63% greater than that found in copper bonded wheel (3.2 µm).

5 CONCLUSIONS

From the comparative study of bronze and copper bonded diamond face grinding process following conclusions are obtained:

- i MRR increases with pulse current, pulse on time and rpm. Further it decreases with pulse-off-time for both the copper and bronze bonded diamond wheels.
- ii In case of Copper bonded wheel MRR first increases and then decreases with pulse-on-time, whereas in case of Bronze bonded wheel it only decreases.
- iii MRR obtained with Bronze wheel is found about 71.4% greater than that obtained with copper bonded wheel.
- iv For both the wheels, TWR increases with increase in pulse current and pulse-on-time, while it decreases with pulse off time.
- v TWR for bronze wheel is found about 20% less than that of copper bonded wheel.
- vi It is observed that surface roughness increases with increase in pulse current, pulse-on-time and pulse-off-time. Further, surface roughness first increases and then decreases with increase in rpm.
- vii Surface roughness with Bronze bonded Wheel is found about 15.63% greater than that with Copper bonded wheel.
- viii So, it can be concluded that it is better to select bronze bonded diamond grinding wheel instead of copper bonded wheel because greater MRR is obtained with comparatively less tool wear in case of bronze bonded wheel. Moreover Surface Roughness was almost comparable.

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