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# Analysis and Experimental Study of Electrical Discharge Face Grinding on Tungsten Copper Alloy

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***ABSTRACT***
*Electrical Discharge Face Grinding (EDFG) prepare has been produced for machining materials that are hard to machine by making sparkle between face of circle shape turning device cathode and workpiece. The pivot of circle shape device cathode about vertical hub enhances material evacuation rate (MRR) and normal surface harshness (ASR) in view of compelling flushing of working hole. This paper shows the impact of information process parameters of EDFG, for example, release current, pulse on-time and pulse off-time, and grind wheel speed on MRR, TWR and ASR amid machining of Tungsten Copper. This has been finished with the assistance of a copper tool terminal with the help of Taguchi Analysis.*

**Keywords:** average surface roughness, electrical discharge face grinding, material removal rate

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## INTRODUCTION

The machining of thin and delicate material is exceptionally troublesome for assembling businesses and fast request of necessity couldn't be accomplished. Electrical release machining is worthier machine device for machining hard and fragile electrically conductive materials yet its efficiency is moderate. In past decade, analysts are concentrate on electrical discharge face grinding (EDFG) for machining these material on the grounds that there are no mechanical strengths applied on workpiece amid machining and it gives preferred exhibitions over EDM because of the turning velocity of wheel. The point of this paper is to condense a survey on EDFG prepare alongside improvements in same territory and furthermore concentrate on the future research scope in a similar range.

In EDM there are two cathodes (instrument terminal and workpiece anode) isolated by little hole (5–200 m) which is called as between terminal hole (IEG). Amid operation, electrical release happens between two little crevice cathodes in a dielectric liquid. The dielectric liquid goes about as a separator between the apparatus cathode and workpiece terminal. Dielectric liquid evacuates the little measure of warmth created by the releases, and flushes off the releases by-items from the IEG. As machining continues the centralization of particles in the crevice increments quickly. It is basic to expel the wear garbage from the crevice so that crisp dielectric enters for start releases. Lacking flushing brings about the stagnation of the dielectric, develop of machining deposit in the hole, short-circuits, bends, and low material evacuation rate (MRR), and results in the slowing down of the machining procedure.

EDM has been found to machine features in five different ways such as Sinking-EDM, Face grinding-EDM, Cutting-EDM, Milling- EDM, and Grinding-EDM [1].

Right now, Electrical discharge face grinding (EDFG) is a well known procedure utilized as a part of industry for high accuracy machining of a wide range of conductive materials. EDFG innovation is progressively being utilized as a part of hardware, pass on and form making enterprises, for face granulating of warmth treated steels and propelled materials (super combinations, earthenware production, and metal lattice composites) requiring high accuracy, complex shapes and high surface wrap up.

EDFG depends on the dissolving impact of an electric start on both the anodes utilized. EDFG is a procedure of using the expulsion marvel of electrical-release in dielectric [2], [3]. Subsequently, the anode assumes an imperative part, which influences the material evacuation rate and the apparatus wear rate.

A round empty terminal is always turned as the dielectric liquid is pumped through the cathode. The pivoting cathode helps in delivering concentricity, bringing about even wear, and aides in the flushing procedure. Since the dissolved particles are conductive, expelling them from the opening is vital to counteract shorting between the cathode and the workpiece.

The high flushing weight through the focal point of the terminal has a tendency to solidify it. Likewise, the dielectric being constrained out of the opening produces a centering impact upon the electrode [4]. With the guide of the anode direct and the flushing impacts on the cathode, EDFG can enter considerably more profound than whatever other face crushing strategy.

Generous research has been made in the previous couple of years over test investigation of EDM utilizing an electrically conductive turning apparatus electrode [5]. A few creators utilized turning EDM, alongside various flushing strategies, on various materials, and concentrated their impact on material expulsion, cathode wear, and surface roughness (SR) (Figure 1).

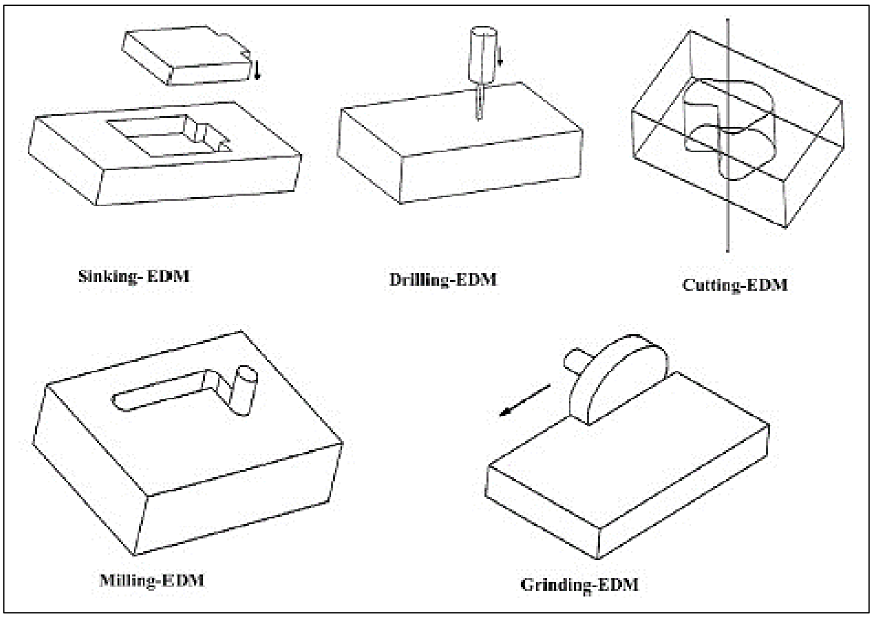



***Fig. 1.*** *Type of EDM.*

Mohan et al. [4] have broken down the impact of EDM parameters, in particular, extremity, current, terminal material, beat length, and revolution of cathode on MRR, TWR, and SR esteem in EDM of Al-Sic MMC with 20 and 25 vol% Sic.

Fujun et al. [5] dissected machining of non-circle framework with revolving anode and built up movement laws for machining turning work pieces. On the premise of examination of the movement laws, PC recreation of machining non-circle by rotational EDM utilizing the built up scientific models as the reproduction models, a program is produced to mimic the way toward machining complex bended surface by turning EDM in the genuine machining framework. Running reproduction program, we can examine the procedure and the movement laws specifically of machining complex bended surface in the genuine arrangement of machining non-circle and locate the perfect parameters to make the machining framework best. Along these lines we can significantly expand the efficiency and enhance the work-piece quality.

Rahman et al [6] goes for improving the info parameters with respect to the device wear rate in EDM. The apparatus being copper tungsten, and the workpiece being Ti-6Al-4V. The parameters being enhanced are pinnacle current, beat on time and heartbeat off time. It was found that TWR diminishes with increment of heartbeat on time and heartbeat off time and at a present an incentive between 10A to 25A.

Singh et al [7] worked towards streamlining electrical release confront granulating of metal grid composites. Work was finished with a strong copper cathode, with the info parameters: release current, circular segment on time and apparatus speed. The information parameters were improved in order to get most extreme material expulsion rate and least instrument wear rate. The consequences of EDFG were contrasted and EDM. It was found that EDM on MMC had a slower MRR, however the TWR was more in EDFG.

Hascalık et al. [8] concentrated the impacts of the utilization of various terminals, to be specific graphite, copper and aluminum in EDM on the Ti-6Al-4V composite. The procedure parameters were heartbeat current and heartbeat term. The outcomes were measured with filtering electron microscopy (SEM), X-beam diffraction (XRD), vitality dispersive spectrograph (EDS) and hardness investigation tests. The test comes about uncover that surface breaking can be wiped out in Al and Graphite, however not in Copper anode. Graphite anode gives the most astounding MRR, then copper, then aluminum. Graphite has the least TWR. aluminum terminal has most minimal SR.

Khan [9] concentrated the impacts on MRR and TWR on aluminum and mild steel workpieces utilizing both copper and metal cathodes. He found that most astounding wear apportion was when EDM was being finished by metal cathode on steel. The most elevated MRR was when EDM was being performed on aluminum by metal terminal. The MRR was most minimal when copper cathodes were being utilized on steel. Be that as it may, the TWR of copper is not exactly of the metal cathode.

Govindan et al. [10] utilized the gas as a dielectric to perform EDFG on Stainless Steel 304 by a Copper Electrode. This was a dry EDFG prepare. In conclusion, it was set up that the TWR was close to zero and MRR was higher than when a fluid dielectric is utilized. In any case, because of warm anxieties and the ensnared gasses numerous miniaturized scale splits were framed.

Chattopadhyay et al. [11] created observational model for three parameters and three levels for turning EDM. In light of model they have accomplished close outcomes in further experimentation. The workpiece was EN-8 (steel) and device utilized was copper. Some observational formulae were produced to assess MRR, TWR and SR. They likewise found that amplifying MRR and accomplishing most ideal SR is not at the same time at one blend of control parameters settings.

## EDFG SETUP

The EDFG connection has been utilized on Press-mach Spark Generator Machine Tool, Model A25. The setup has been outlined keeping in view the central instrument of the procedure and essential practical prerequisites of various parts. The EDFG setup comprises of electrically conductive pivoting anode (copper), engine, shaft, V-belt, and bearing. Shaft is a turning component of the connection and is held between the two heading. At one side of the pole, the copper instrument terminal is mounted, and another side V-pulley is mounted for pivot. Outline of the pole requires the choice of some information parameters like material, engine power, and engine RPM. Here, steel (Cu-steel) shaft of 15mm breadth is utilized. An engine of 3 kW and 3,000 RPM is utilized (Figure 2).

***Fig. 2.*** *EDFG setup.*

The V-belt is utilized to transmit control from driver to driven pulley. The belt is given a specific measure of starting pressure to evade slip. The V-belt has a trapezoidal cross- segment, with the goal that it contacts the side of pulley too. Belt of width 10mm and thickness of 5 mm is chosen. Bearing is utilized to bolster development of the pole. It allows a relative movement between the contact surfaces of the individuals while conveying the heap. Determination of the bearing needs the heaviness of the pole, device terminal, and pulley. The engine is another essential piece of the connection and is situated on the 170mm × 60mm vertical level plate. The engine is utilized to drive the pole of connection with the assistance of belt.

In our EDFG connection, smooth power transmission is required in light of the fact that variance in the speed influences the start, and most extreme time of persistent operation is up to 10-15 hrs. As indicated by these parameters, a solitary stage engine of 3kW is chosen, which is fit to give the speed to the pole in the scope of 500–3,000RPM. Copper too anode is mounted on the pole with the assistance of neckline. In the EDFG procedure, instrument pivot is required, and crevice between both anodes ought to be steady amid machining.

The manufactured connection had been supplanted by unique device holder of bite the dust sinking EDM. The EDFG get together is in part dunked in dielectric with in dielectric tank. The manometers have been utilized to gauge dielectric weight. The wires are the leads for both instrument terminal and workpiece cathode. The wires from the engine were associated with the yield terminal of auto transformer. The dielectric liquid utilized as a part of the examination was Spark Erosion Oil 25.

## EXPERIMENTATION

First, preliminary experiments were conducted using a copper rotating tool electrode. The spark and machined surface was clearly observed. The experimentation was successfully conducted using EDFG setup. Current, pulse on-time, pulse off-time and tool rotations per minute (RPM) are the process parameters of EDFG process. The operating conditions were selected as control factors. An exhaustive pilot experimentation is done to decide the parameter range for machining of Tungsten copper. The control factors (or input parameters) taken are the current (3–7 A), pulse on-time (100–200 μs), pulse off-time (50–90 μs) and wheel speed (725-

925RPM). The effect of various input parameters such as tool RPM, pulse on-time and current were experimentally observed on output parameters such as MRR, TWR and ASR. Tungsten copper was the cylindrical workpiece material for experimentation. The composition of Tungsten copper is 75% Tungsten and 25% copper. Copper tungsten alloy properties (Table 1).
Chart is given below:

***Table 1.*** *Results of confirmation test and their comparison with the results.*

| Composition | Density (gr/cc) | Bend Strength (MPa) | Hardness (Kgf/mm2) |
|---|---|---|---|
| W75 Cu25 | 14.5 | 706 | 195 |

The electrode was rotated and sunk simultaneously to generate cylindrical profile on workpiece. A digital contact tachometer was used to measure the wheel RPM of rotating electrode. The wheel RPM was adjustable with the help of the autotransformer. The experiments were conducted for fixed time period, i.e., 15 min for set of experiments.

Reduction in the weight of the workpiece was calculated by obtaining weight difference before and after machining using electronic digital weight balance. The electronic digital weight balance is used to measure the weight of the workpiece. It has a weighing range of 0–100 g with a least count of 0.1mg. MRR was calculated for each cutting condition using the formula:

$$\mathrm{MRR} = \frac{(W_i - W_f) \times 1000}{\rho \times t} \mathrm{mm}^3/\mathrm{min}$$

Where, Wi is initial weight of workpiece in g (before machining), Wf is final weight of workpiece in g (after machining), t is machining time in minutes, and is density of workpiece in g/cm$^3$. ASR was measured using Digital Portable Surface Roughness Tester. The workpiece clamped within the device.

Taguchi's design was the basis of the flow of the experiment. This method is based on Orthogonal arrays and helps determine the optimal settings in which to conduct the experiment.

Orthogonal arrays assist in providing a minimum number of experiments and also the Signal-to-noise ratio (S/N ratio) which are the log function of the desired output, this helps in analyzing data and for the prediction of optimum results.

The 3 S/N ratios for optimization are (n being the MSNR):
1. Smaller the better –
n = - 10 log10(mean sum of squares)
2. Larger the better –
n = - 10 log10(reciprocal of the mean sum of squares)
3. Nominal is best –
n = - 10 log10(mean sum of squares/variance)

## RESULTS AND DISCUSSION

The ranking shown Table 2 shows the relative contribution of the factors on multiple quality characteristics. For MRR, the calculations for the S/N ratio have been done based on 'Larger the Better' model (Table 3).

***Table 2.*** *Results of SN ratio for MRR.*

| Level | Current | Ton | Toff | Speed |
|---|---|---|---|---|
| 1 | -49.32 | -46.83 | -44.83 | -43.87 |
| 2 | -45.54 | -45.75 | -44.32 | -44.59 |
| 3 | -38.86 | -41.15 | -44.59 | -45.27 |
| Delta | 10.46 | 5.68 | 0.51 | 1.4 |
| Rank | 1 | 2 | 4 | 3 |

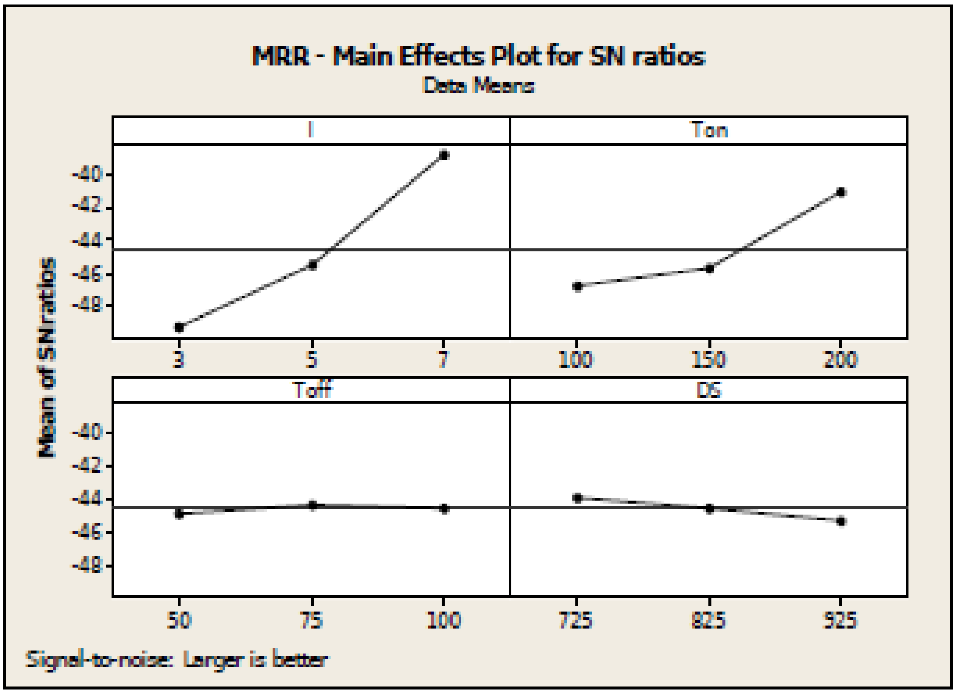
 

ANOVA for Signal to Noise Ratios for MRR

***Table 3.*** *Results of ANOVA for MRR.*

| Source | DF | Seq SS | Adj SS | Adj MS | P |
|---|---|---|---|---|---|
| I | 2 | 168.289 | 168.289 | 84.1443 | 74% |
| Ton | 2 | 54.583 | 54.583 | 27.2916 | 24% |
| Toff | 2 | 0.393 | 0.393 | 0.1964 | 0% |
| DS | 2 | 2.929 | 2.929 | 1.4643 | 1% |
| Total | 8 | 226.193 | | | |

Now as per above results the optimum settings for the MRR are as below:
Optimal combo: A3B3C2D1
Also on these settings the optimum output is represented as below:
Y.opt = 0.018893
From Table 3 the P shows the percentage contribution that the peak current (I) has the most effect on the material removal rate i.e. 74%. The graphical representation of factor effect on the quality characteristic MRR at different levels is shown.




The optimum levels of different control factors for MRR obtained are peak current at level 3 (7A), pulse on time at level 3 (200 μs), pulse off time at level 3 (100 μs) and drill speed at level 1 (725 RPM). For TWR, the calculations for the S/N ratio have been done based on ‘Smaller the Better’ model (Tables 4, 5).

***Table 4.*** *Results of SN ratio for TWR.*

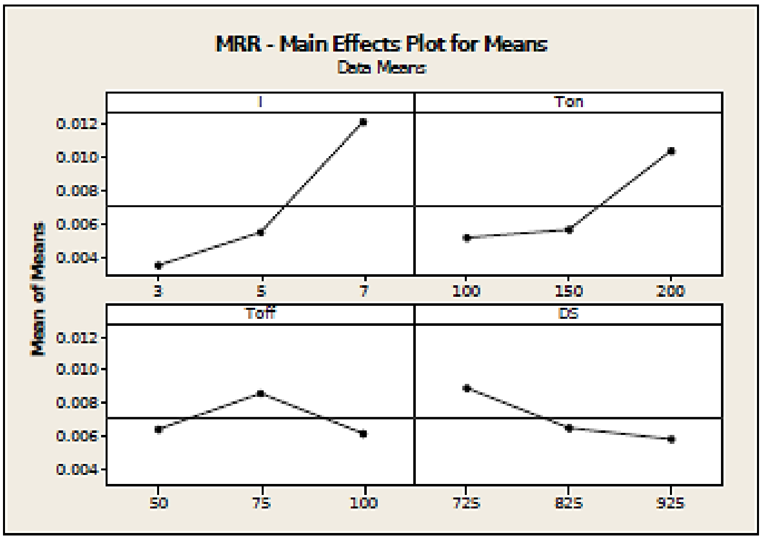
| Level | Current | Ton | Toff | Speed |
|---|---|---|---|---|
| 1 | 53.84 | 51.41 | 49.52 | 48.88 |
| 2 | 49.45 | 49.77 | 49.71 | 49.15 |
| 3 | 44.76 | 46.87 | 48.82 | 50.02 |
| Delta | 9.09 | 4.54 | 0.89 | 1.14 |
| Rank | 1 | 2 | 4 | 3 |

ANOVA for Signal to Noise Ratios for TWR

***Table 5.*** *Results of ANOVA for TWR.*

| Source | DF | Seq SS | Adj SS | Adj MS | P |
|---|---|---|---|---|---|
| I | 2 | 123.861 | 123.861 | 61.9307 | 78 % |
| Ton | 2 | 31.787 | 31.787 | 15.8937 | 20 % |
| Toff | 2 | 1.305 | 1.305 | 0.6527 | 1% |
| DS | 2 | 2.145 | 2.145 | 1.0724 | 1% |
| Total | 8 | 159.099 | | | |

Now as per above results the optimum settings for the TWR are as below:
Optimal combo – A1B1C2D3
Also on these settings the optimum output is represented as below:
Y. optimal = 0.000936




The optimum levels of different control factors for TWR obtained are peak current at level 1 (3A), pulse on time at level 1 (100 µs), pulse off time at level 2 (75 µs) and drill speed at level 3 (925 RPM) (Tables 6–9). For ASR, the calculations for the S/N ratio have been done based on 'Smaller the Better' mode.

***Table 6.*** *Results of SN ratio for ASR.*

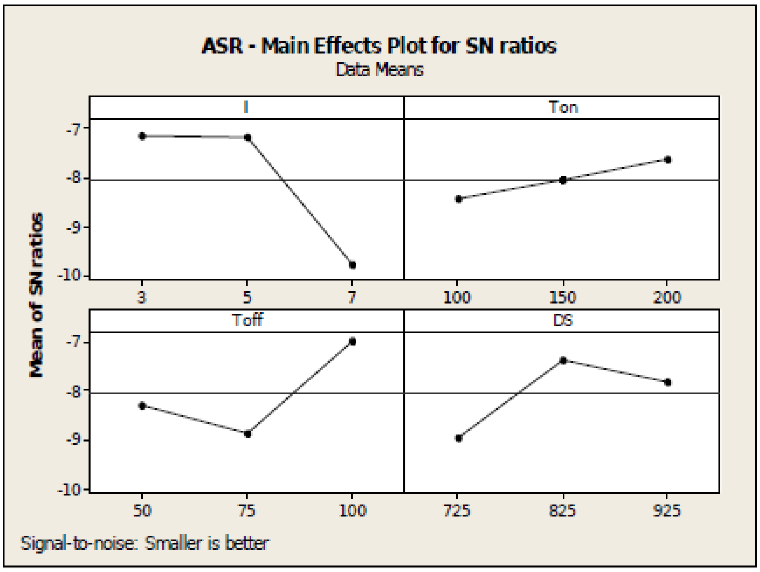
| Level | Current | Ton | Toff | Speed |
|---|---|---|---|---|
| 1 | -7.144 | -8.451 | -8.281 | -8.964 |
| 2 | -7.176 | -8.038 | -8.854 | -7.352 |
| 3 | -9.797 | -7.627 | -6.982 | -7.8 |
| Delta | 2.653 | 0.824 | 1.873 | 1.612 |
| Rank | 1 | 4 | 2 | 3 |

ANOVA for ASR

***Table 7.*** *Results of ANOVA for ASR.*

| Source | DF | Seq SS | Adj SS | Adj MS | P |
|---|---|---|---|---|---|
| I | 2 | 13.907 | 13.9057 | 6.95285 | 57% |
| Ton | 2 | 1.0174 | 1.0174 | 0.50869 | 4% |
| Toff | 2 | 5.5226 | 5.5226 | 2.7613 | 22% |
| DS | 2 | 4.1548 | 4.1548 | 2.07738 | 17% |
| Total | 8 | 24.600 | | | |

From this it shows that the peak current (I) has the most effect on the material removal rate. The graphical representation of factor effect on the quality characteristic ASR at different levels is shown.



Now as per above results the optimum settings for the ASR are as below:
Combo = A1B3C3D2
Also on these settings the optimum output is represented as below:
Y.optimal = 1.706

The optimum levels of different control factors for ASR obtained are peak current at level 1 (3A), pulse on time at level 3 (200 μs), pulse off time at level 3 (100 μs) and drill speed at level 2 (825 RPM).

## CONFIRMATION TESTS

The confirmation experiment is the final step of design of experiment process. The purpose of experimental test is to validate the conclusions during the analysis phase. The confirmation experiment is performed by conducting a test with specific combinations of the factors and levels previously evaluated. In this study, after determining the optimum conditions and predicting the response under these conditions, a new experiment was designed and conducted with the optimum levels of the machining parameters. After conducting the experiment, we have to verify the improvement of the performance characteristic. The confirmation run results using optimal machining parameters are shown in Table 8. The experimental results confirmed the validity of the used Taguchi method for improving the machining performance optimizing the machining parameters. The MRR is greatly improved by using this approach (Table 9).

Rotating or EDFG

***Table 8.*** *Optimal parameters for respective quality characteristics.*

| Process Parameters | I | Ton | Toff | DS | |
|---|---|---|---|---|---|
| Level No. | 3 | 3 | 2 | 1 | MRR = 0.01889 |
| | 1 | 1 | 2 | 3 | TWR = 0.00093 |
| | 1 | 3 | 3 | 2 | ASR = 1.706 |

***Table 9.*** *Results of confirmation test and their comparison with the results.*

| Quality Characteristics | Optimal Setting | Predicted & Confirmed Results | | |
|---|---|---|---|---|
| | | Predicted Value | Experimental Value | % Error |
| MRR | A3B3C2D1 | 0.018893 | 0.019802 | 4.811306 |
| TWR | A1B1C2D3 | 0.000936 | 0.000977 | 4.380342 |
| ASR | A1B3C3D2 | 1.706000 | 1.742000 | 2.110199 |

From the analysis of confirmation results, it can be seen that the calculated error is minute. The errors between the calculated and experimental values are 4.81%, 4.38% and 2.11%, for MRR, TWR and ASR, respectively. The new experimental setup developed to increase the material removal rate of the hard materials has been investigated for the analysis of various factors influencing the performance characteristics, following the Taguchi method of experimental design. It has been successfully applied for finding out the relative contributions of various factors such as current, wheel speed, pulse-on time and duty factor on MRR, TWR and ASR and for finding out the optimum factor level combinations. Based on the experimental results, conclusions are drawn as follows:

(1) Electrical discharge face grinding EDFG experiments indicate that MRR, TWR and ASR increase with increasing current, wheel speed, and pulse on time.
(2) The most significant factor affecting the EDFG robustness have been identified as current and pulse on time.
(3) The following factor settings have been identified to yield the best combination of process variables for MRR: current-level 3 (7A), pulse off time level 2 (75 µs), pulse-on time- level 3 (200 µs) wheel speed-level 1 (725 RPM).
(4) The following factor settings have been identified to yield the best combination of process variables for TWR: current-level 1 (3A), pulse off time level 1 (75 µs), pulse-on time- level 2 (100 µs) wheel speed-level 3 (925 RPM).
(5) The following factor settings have been identified to yield the best combination of process variables for ASR: current-level 1 (3A), pulse off time level 3 (95 µs), pulse-on time- level 3 (200 µs) wheel speed-level 2 (825 RPM).
(6) Experimental as well as predicted S/N ratios at optimum level are nearly equal to each other and therefore confirm the success of the experiment.
(7) The experimental results confirmed the validity of the used Taguchi method for enhancing the machining performance and optimizing the machining parameters in EDFG.

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