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# Influence of Processes Parameters of Al 6063/$ZnSio_{4p}$ Metal Matrix Composite on WEDM using Response Surface Methodology(RSM)

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**ABSRACT**

*In this paper, an attempt has been made to machine Al 6063/ ZrSiO4(p) metal matrix composite using wire electric discharge machining. The objective is to investigate the influence of process parameters namely pulse on time, pulse off time, peak current and servo voltage on dimensional deviation . A Box-Behnken design approach of response surface methodology (RSM) is used to plan and analyze the experiments. The mathematical relationships between WEDM input process parameters and response parameter are established to determine optimal values of cutting rate mathematically. The Analysis of variance (ANOVA) and F-test are performed to obtain statistically significant process parameters. The generated optimal process conditions have been verified by conducting confirmation experiments and predicted results have been found to be in good agreement with experimental findings.*

***KEY WORDS :***

## 1. INTRODUCTON

Metal Matrix Composites (MMC's) have proven to be important advanced materials that serve as alternatives to many conventional materials, particularly when light-weight and high strength components are needed such as in the automotive, aerospace, defense and other industries. MMCs have found many successful industrial applications in recent past as high-technology materials due to their exceptional properties such as high strength-to-weight ratio, high toughness and lower value of coefficient of thermal expansion, light weight and capability of operating at elevated temperatures .They also exhibit greater resistance to corrosion, oxidation and wear.

WEDM is a spark erosion process used to produce complex two and three dimensional shapes through electrically conductive work pieces. A power supply delivers high-frequency pulses of electricity to the wire and the work piece and material is removed as a result of high energy discharge subjected on the work piece. WEDM has become an important non-traditional machining process, widely used in the aerospace, nuclear and automotive industries.

## 2. LITERATURE REVIEW

Al 6063/ ZrSiO4(p) MMC's are widely used materials in many engineering applications due to their improved properties but very few research efforts are made and published on the combined effect of process parameters on the performance of WEDM process in machining of Al 6063/ ZrSiO4(p) MMC. Al 6063/ ZrSiO4(p) MMC is selected as work piece material because it meets a wide range of applications including wearresistant components, cutting tools, punches, engine parts, high temperature applications, medical and biomedical purposes etc. Table 1 shows the chemical composition of 6063 Aluminium alloy used as the base metal. In the present work, an attempt has been made to optimize process parameters of WEDM for machining of MMC using Response Surface Methodology and in particular Box-Behnken Designs to develop an empirical relationship between different process parameters namely Pulse on time (TON), Pulse off time (TOFF), Peak Current (IP) and Servo Voltage (SV) and output response namely dimensional deviation (DD).

The ANOVA is applied to identify the significance of the process parameters. Thereafter, Optimization of cutting rate is performed using desirability approach. A plate of rectangular shape (110mm x 80mm x 11mm) having 5% $ZrSiO_4$ particles (by weight) as reinforcement is prepared by stir casting process.

Chemical composition of Al 6063 alloy

| Element | Al | Si | Fe | Cu | Mn | Mg | Cr | Zn | Ti | Other |
|---|---|---|---|---|---|---|---|---|---|---|
| Composition % wt | 97.5 | 0.6 | 0.35 | 0.1 | 0.1 | 0.9 | 0.1 | 0.1 | 0.1 | 0.15 |

## 3. DESIGN OF EXPERIMENTS

The present work utilizes four varying input process parameters viz. Pulse on time (TON), Pulse off time (TOFF), Peak Current (IP) and Servo Voltage (SV) to investigate their effects on dimensional deviation (DD) during machining of Al 6063/ $ZrSiO_{4(p)}$ MMC. The ranges of input parameters are selected on the basis of literature review and pilot study conducted by using one factor at a time approach. The selected process parameters along with their levels are listed in Table 2.

| Parameters | Units | Level | | | Fixed parameters |
|---|---|---|---|---|---|
| | | I | II | III | |
| Pulse on time(Ton) | mu | 112 | 116 | 120 | Wire feed |
| Pulse off time(Toff) | mu | 50 | 55 | 60 | Water pressure |
| Peak current (IP) | Amp | 120 | 150 | 180 | Wire tension |
| Servo voltage(SV) | Volts | 50 | 65 | 80 | Serve feed |

Present work utilizes, Box-Behnken experimental design approach as it plans experiments within identified search space (assuming a=1). Four control factors are considered at three levels, therefore 29 experiments needed to be performed .

## 4. RESULT AND DISCUSSIONS

The experiments are performed on a four axis Electronica Sprintcut 734 CNC Wire Cut Machine .A diffused brass wire of 0.25mm diameter is used as tool material and deionized water is used as dielectric to machine 6063 Aluminium based MMC. A 8mm x 8mm rectangular cut is taken on the work piece.

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| S.NO | Ton | T off | IP | SV | DD |
|---|---|---|---|---|---|
| 1 | 112 | 50 | 150 | 65 | 115 |
| 2 | 120 | 50 | 150 | 65 | 460 |
| 3 | 112 | 60 | 150 | 65 | 110 |
| 4 | 120 | 60 | 150 | 65 | 440 |
| 5 | 116 | 55 | 120 | 50 | 255 |
| 6 | 116 | 55 | 180 | 50 | 425 |
| 7 | 116 | 55 | 120 | 80 | 225 |
| 8 | 116 | 55 | 180 | 80 | 415 |
| 9 | 112 | 55 | 150 | 50 | 135 |
| 10 | 120 | 55 | 150 | 50 | 480 |
| 11 | 112 | 55 | 150 | 80 | 85 |
| 12 | 120 | 55 | 150 | 80 | 470 |
| 13 | 116 | 50 | 120 | 65 | 190 |
| 14 | 116 | 60 | 120 | 65 | 270 |
| 15 | 116 | 50 | 180 | 65 | 440 |
| 16 | 116 | 60 | 180 | 65 | 410 |
| 17 | 112 | 55 | 120 | 65 | 77 |
| 18 | 120 | 55 | 120 | 65 | 390 |
| 19 | 112 | 55 | 180 | 65 | 170 |
| 20 | 120 | 55 | 180 | 65 | 490 |
| 21 | 116 | 50 | 150 | 50 | 430 |
| 22 | 116 | 60 | 150 | 50 | 380 |
| 23 | 116 | 50 | 150 | 80 | 415 |
| 24 | 116 | 60 | 150 | 80 | 350 |
| 25 | 116 | 55 | 150 | 65 | 360 |
| 26 | 116 | 55 | 150 | 65 | 340 |
| 27 | 116 | 55 | 150 | 65 | 315 |
| 28 | 116 | 55 | 150 | 65 | 310 |
| 29 | 116 | 55 | 150 | 65 | 297 |

Following equation represents the relation between dimensional deviation and control factors which is obtained by multiple regression technique. Backward elimination process is used to eliminate the non-significant factors to fit the quadratic model for cutting rate.

Regression Equation

DD = 315.6 - 187.2 Ton_112 + 34.83 Ton_116 + 152.4 Ton_120 + 14.6 Toff_50 - 14.17 Toff_55 - 0.4 Toff_60 - 82.0 IP_120 + 6.91 IP_150 + 75.1 IP_180 + 21.5 SV_50 - 18.76 SV_65 - 2.7 SV_80

Table 4. ANOVA for response surface of reduced quadratic model of dimensional deviation .

Analysis of Variance (ANOVA )

| SOURCE | DF | Adj SS | AdjSS | F-value | P-value |
|---|---|---|---|---|---|
| Ton | 2 | 363823 | 181912 | 170.44 | 0.000 |
| Toff | 2 | 3606 | 1803 | 1.69 | 0.210 |
| IP | 2 | 74801 | 37401 | 35.04 | 0.000 |
| SV | 2 | 6886 | 3443 | 3.23 | 0.061 |
| Error | 20 | 21347 | 1067 | | |
| Lack of fit | 16 | 18789 | 1174 | 1.84 | 0.294 |
| Pure error | 4 | 2557 | 639 | | |
| Total | 28 | 476470 | - | | |

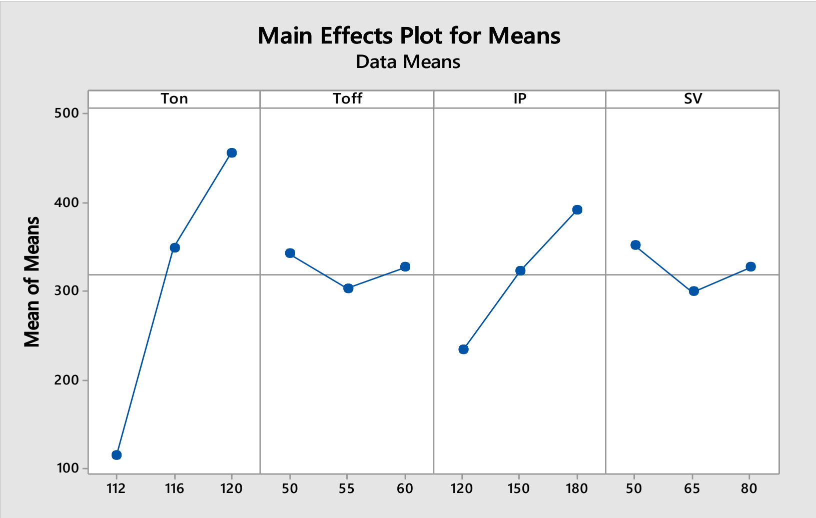


Fig 2: Main effects plots for means

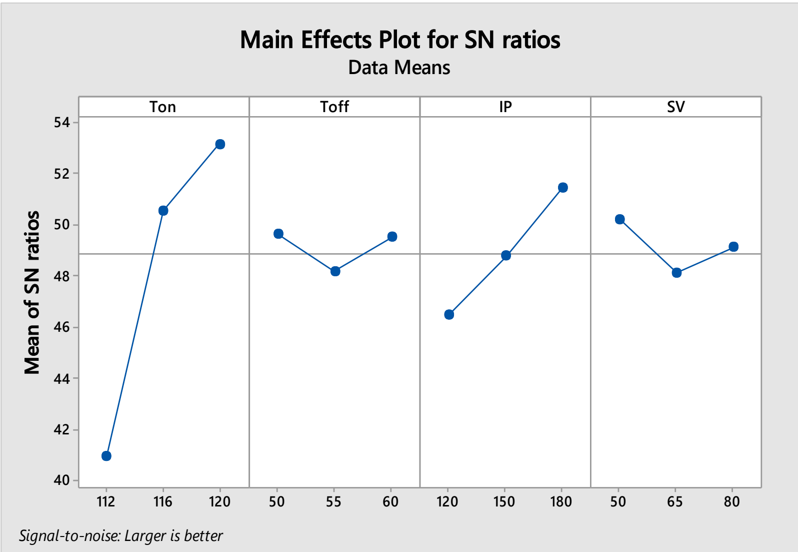


Fig 3 : Main effects plots SN ratios

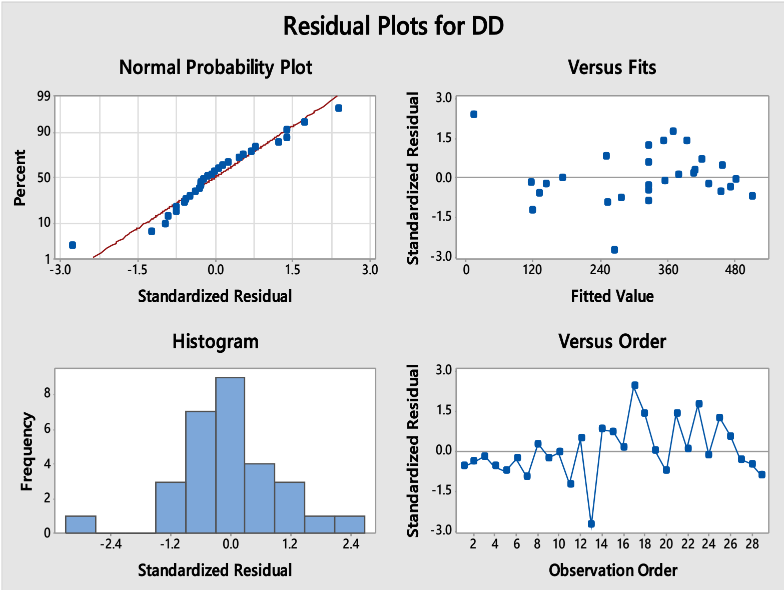


Fig 4: Residual  plots for dimensional deviation

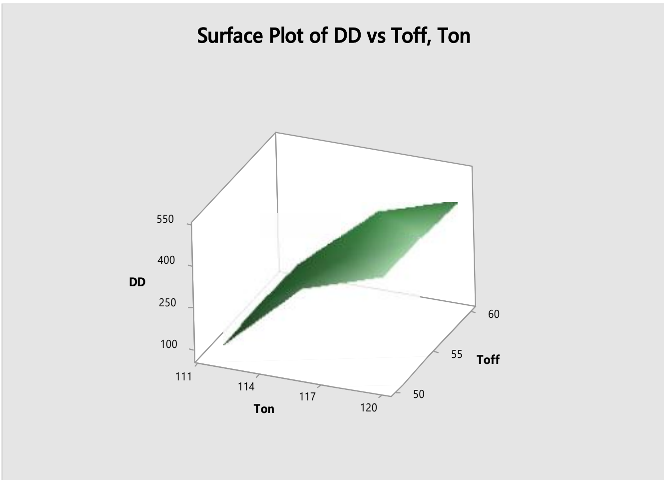


Fig 5 : Surface  plots for DD Vs  Toff , Ton

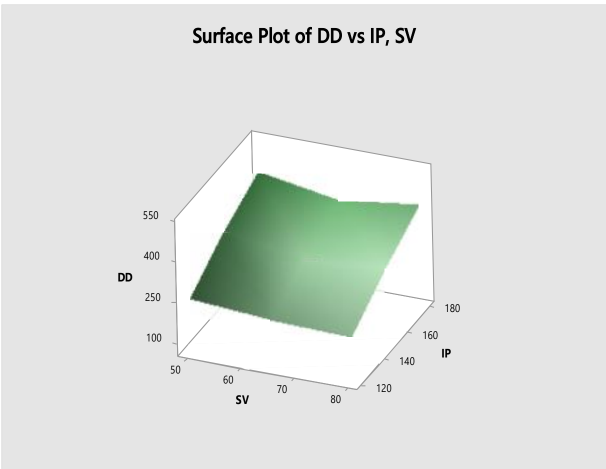


Fig  6 : Surface  plots for DD Vs  IP,SV

Fig 2 , fig 3 and fig 4 shows main effect plots , SN ratio and residual plots for dimensional deviation .It indicates the main effects also follow the same trends as exhibited by interactions. Dimensional deviation is found to increase with increase in Ton and IP and decrease with increase in Toff and SV . Fig 5 shows the surface plots of TON and TOFF on DD. It clearly shows that DD attains a peak value at higher value of TON and at a lower value of TOFF. This is because a high value of TON and corresponding lower value of TOFF, causes spark to occur for longer duration which leads to higher energy discharge causing faster and greater erosion of material. It also shows that DD attains a minimum value at low value of TON and high value of TOFF. Fig 6 explains the interaction of IP and SV on DD which shows that DD decreases at higher value of TOFF and at a higher value of SV. This is because a high value of TOFF and corresponding higher value of SV causes spark

## 5. CONCLUSION

Present work explore the WEDM of Al 6063/ $ZrSiO_4$(p) metal matrix composites. The quadratic models for cutting rate is developed to correlate the effects of process parameters namely pulse on time, pulse off time, peak current and servo voltage with dimensional deviation . An experimental plan of the Box-Behnken based on the RSM was applied to perform the experimentation work. Optimization of cutting rate is carried out using desirability approach. From this study, following conclusions are drawn. Main effect of pulse on time, pulse off time, peak current and servo voltage and interaction effect of pulse on time and pulse off time, pulse on time and peak current, pulse on time and servo voltage, pulse off time and peak current, pulse off time and servo voltage and interaction effect of peak current and servo voltage found to be significant from the ANOVA of cutting rate. It was found experimentally that increasing the pulse on time and peak current, the cutting rate increases, whereas increasing the pulse off time and servo voltage decreases the cutting rate. The higher discharge energy associated with the increased pulse on time, peak current and lesser pulse off time and servo voltage leads to more powerful explosions which increases the cutting rate. The effect of production of crates is more pronounced on the surface of the machined work piece when peak current is increased to a high level and servo voltage is kept at lower level.

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