CHAPTER 8

CONCLUSION AND SUGGESTIONS FOR FURTHER STUDY

In this chapter, the thesis of the research is summarized. The originality of the research and its specific contribution to the drilling of blind holes using EDM are highlighted. In addition, the essential findings of this research are clearly presented.

The research on the drilling of blind holes in EDM using conventional copper solid electrode and multichannel electrodes was carried out to meet the performance requirements. However, to exploit full potential of EDM, a thorough research is needed to improve the material removal, electrode wear and surface roughness by optimizing the various parameters of EDM process. Machining of blind holes using multichannel electrodes are economical compared to conventional copper solid electrode in an EDM. This research aims to alleviate the problem of flushing of debris and improving MRR by using multichannel electrodes having array of holes.

Keeping this in view, commercially available die sinking EDM machine was used to carry out a thorough research for achieving the suitable control of EDM process parameters to meet the blind hole machining requirements for Al-SiC metal matrix composite. The objective of taking up this research is to identify simple and economical way of obtaining the optimized process parameters, so that the MRR as well as the accuracy can be improved.
8.1 RESEARCH CONTRIBUTIONS

The main objective of this research is to increase the MRR by improving the flushing condition in blind hole drilling using multichannel electrodes in the EDM. Additionally, optimum machining parameters in the view of maximizing the MRR (mg/min) and minimizing EWR (mg/min) and SR (µm) using EDM are found out.

ANOVA was performed to find out the significance of the various machining parameters. ANOVA indicates that pulse on time is the most influencing parameter corresponding to quality characteristics of MRR. The current also plays a substantial role in the variation of MRR. Current is the most significant parameter and polarity is the significant parameter corresponding to quality characteristics of EWR. Similarly, pulse on time is the most influencing parameter corresponding to quality characteristics of SR. Negative polarity of work piece provides better MRR values whereas positive polarity provides lower SR. Also positive polarity of work piece results in lower EWR. The electrical parameters more significantly affect the EDM machining process than the non-electrical parameter (i.e., dielectric pressure).

Experiment results confirm that the effect of blind hole drilling by EDM with multichannel electrodes results in higher MRR whereas EWR is higher in comparison with the conventional solid electrode. In case of SR, there is no significant change. Multichannel electrode with the array of 1.5mm channels performed best considering the MRR. Use of this electrode results increased MRR of 294.78 mg/min whereas for the conventional solid electrode the MRR is only 234.94 mg/min in the optimum conditions. Thus an improvement in MRR of 25.47% is achieved. Correspondingly, the EWR for this multichannel electrode is 19.62 mg/min while for the solid electrode it is 11.66 mg/min, resulting in 40.6% increase.
Taguchi method of robust design was applied for optimizing response process parameter for EDM of Al-SiC MMC using solid electrode and multichannel electrodes. Results obtained from Taguchi methods closely match with ANOVA.

- Optimum values and corresponding machining conditions of response parameters viz., MRR, EWR and SR are predicted using Taguchi’s robust design method.

- The optimum machining conditions for the solid electrode are A2-B3-C3-D1-E3 (polarity negative, current 12 A, pulse on time 600 µs, pulse off time 20 µs and dielectric pressure 0.075 MPa) for MRR, A1-B1-C3-D1-E1 (polarity positive, current 4 A, pulse on time 600 µs, pulse off time 20 µs and dielectric pressure 0.025 MPa) for EWR and A1-B1-C1-D3-E1 (polarity positive, current 4 A, pulse on time 200 µs, pulse off time 60 µs and dielectric pressure 0.025 MPa) for SR. The optimum values for MRR, EWR and SR are 261.82 mg/min, 0.67 mg/min and 2.92 µm respectively.

- The optimum machining conditions for the 1 mm MCE are A2-B3-C3-D2-E3 (polarity negative, current 12 A, pulse on time 600 µs, pulse off time 40 µs and dielectric pressure 0.075 MPa) for MRR, A1-B1-C3-D2-E2 (polarity positive, current 4 A, pulse on time 600 µs, pulse off time 40 µs and dielectric pressure 0.05 MPa) for EWR and A1-B1-C1-D2-E3 (polarity positive, current 4 A, pulse on time 200 µs, pulse off time 40 µs and dielectric pressure 0.075 MPa) for SR. The optimum values for MRR, EWR and SR are 261.45 mg/min, 1.15 mg/min and 3.18 µm respectively.

- The optimum machining conditions for the 1.5 mm MCE are A2-B3-C3-D1-E1 (polarity negative, current 12 A, pulse on time 600 µs, pulse off time 20 µs and dielectric pressure 0.025 MPa) for MRR,
A1-B1-C3-D3-E2 (polarity positive, current 4A, pulse on time 600µs, pulse off time 60µs and dielectric pressure 0.05 MPa) for EWR and A1-B1-C1-D2-E3 (polarity positive, current 4A, pulse on time 200µs, pulse off time 40µs and dielectric pressure 0.075 MPa) for SR. The optimum values for MRR, EWR and SR are 322.85 mg/min, 1.69 mg/min and 3.29 µm respectively.

- The optimum machining conditions for the 2 mm MCE are A2-B3-C3-D1-E1 (polarity negative, current 12A, pulse on time 600µs, pulse off time 20µs and dielectric pressure 0.025 MPa) for MRR, A1-B1-C3-D3-E1 (polarity positive, current 4A, pulse on time 600µs, pulse off time 60µs and dielectric pressure 0.025 MPa) for EWR and A1-B1-C1-D1-E3 (polarity positive, current 4A, pulse on time 200µs, pulse off time 20µs and dielectric pressure 0.075 MPa) for SR. The optimum values for MRR, EWR and SR are 309.31 mg/min, 2.18 mg/min and 3.01 µm respectively.

- For MRR, the optimum process parameter values correspond to higher energy level whereas for EWR and SR the optimum process parameter values correspond to lower energy level. It is also observed that the increase in optimum values of MRR also leads to increase in EWR. The wear in multichannel electrodes is more because of reduction in the material at the cross sectional area, compared to the solid electrode.

- Further, the optimum process parameter combinations for MRR, EWR and SR are different from the combinations used in the L18. This fact emphasises the need for optimization process.

- Confirmations experiments were conducted for these predicted optimum machining conditions.
• The optimum and experimental values were compared and the errors obtained are within the permitted levels.

The use of the orthogonal array with grey relational analysis to optimize the EDM process with the multiple performance characteristics has been reported. A grey relational analysis of the experimental results of material removal rate, electrode wear rate and surface roughness can convert optimization of the multiple performance characteristics into optimization of a single performance characteristic called the grey relational grade. As a result, optimization of the complicated multiple performance characteristics can be greatly simplified through this approach. It is shown that the performance characteristics of the EDM process such as material removal rate, electrode wear rate and surface roughness are improved together by using the method proposed by this study. Various values of weights of MRR, EWR and SR can be selected with suitable values of distinguishing coefficient. The results obtained will provide a comprehensive summary of the multi-objective optimization of the EDM process parameters.

By this approach, there is improvement in responses comparing the initial and the optimum conditions. For solid electrode, MRR, EWR and SR improve from 34.12 mg/min, 1.48 mg/min and 5.38 µm to 37.23 mg/min, 1.36 mg/min and 3.47 µm respectively. For 1 mm MCE, MRR, EWR and SR improve from 40.23 mg/min, 2.05 mg/min and 5.11 µm to 44.18 mg/min, 2.03 mg/min and 4.72 µm respectively. For 1.5 mm MCE, MRR, EWR and SR improve from 44.90 mg/min, 3.19 mg/min and 5.93 µm to 76.76 mg/min, 1.89 mg/min and 3.88 µm respectively. For 2 mm MCE, MRR, EWR and SR improve from 42.35 mg/min, 4.71 mg/min and 5.19 µm to 62.13 mg/min, 4.21 mg/min and 4.04 µm respectively.
Improvement in grey relational grade for solid electrode, 1 mm MCE, 1.5 mm MCE and 2 mm MCE are 0.0944, 0.0300, 0.1485 and 0.0585 respectively. It is observed that for the 1.5 mm MCE, the improvement in MRR and grey relational grade is maximum.

Conducting experiments for all the machining combinations is time consuming and costly affair. ANN provides a means for predicting the response variables for all the different machining combinations i.e., full factorial results of 162 combinations. The predicted responses of the ANN model are in very good agreement with the experimental values. This method is also tested for its prediction potentials for non-experimental patterns to confirm the suitability of the ANN model. Further, with predicted results of ANN, the optimum condition for each of the MRR, EWR and SR can be readily found out.

The optimum ANN predictions for MRR, EWR and SR for the solid electrode are 235 mg/min, 0.83 mg/min and 3.06 µm respectively; for the 1 mm MCE 242.07 mg/min, 1.05 mg/min and 3.13µm respectively; for the 1.5 mm MCE 303.5 mg/min, 1.79 mg/min and 3.73µm respectively and for the 2 mm MCE 280.55 mg/min, 1.32 mg/min and 3.00µm respectively.

It is observed that 1.5 mm MCE has the best predicted MRR. It should be noted that the optimum machining parameters are different for each of the responses viz., MRR, EWR and SR.

The research evaluates the feasibility of machining of 6061Al-SiCp by EDM using conventional solid and multichannel copper electrodes. Based on the results presented herein, the following can be concluded.
Experiment results confirm that the effect of blind hole drilling by EDM with multichannel electrodes resulted in higher MRR although EWR is higher in comparison with the conventional solid electrode. In case of SR, there is no significant change. Multichannel electrode with the array of 1.5mm channels performed best considering the MRR.

Optimization of performance characteristics is carried out using S/N ratio for MRR, EWR and SR. Confirmation experiments were conducted and the results are compared. The resulting error is within the acceptable limit.

Grey relational analysis was carried out to obtain multi-objective optimization. Confirmation experiments were conducted and the results are shown.

ANN based model was developed to predict MRR, EWR and SR. A multilayer feed forward network and generalized regression neural network configurations were found suitable for training the network. The predicted responses of the ANN model were in very good agreement with the experimental values.

8.2 SUGGESTIONS FOR FURTHER RESEARCH

Various composite materials and conventional materials which are difficult to machine can be considered for work material. For tool material, tellurium or chromium copper, copper tungsten, brass, aluminium alloy, graphite (Non-metallic), copper-graphite (combined metallic and non-metallic), copper on moulded plastics and copper on ceramics can be used. Rotary motion to electrode (which leads to elimination of $T_2$ and $T_3$ in eqn
3.1), vibratory motion and combination of vibro-rotary motion can be given to electrode.

Electrode design such as number of channels, diameter of the channels and depth of channels can be varied. Transformer oil, Silicon oil, deionized water, abrasive powder mixed dielectric fluids can be considered. Flushing type can be varied as injection flushing and reciprocating electrode flushing.

A knowledge base can be developed by generating a number of data (response parameters) by varying the above all, leading to the formation of an expert system.