Conclusions & Future Scope

The investigations into WEDM process for exploring the possibility of improvement in its process efficiency by using cryogenically treated wire electrodes have led to useful results. The important conclusions are shown in this chapter and also present the scope for future work that may be helpful to the manufacturers of wire electrodes, the users and the researchers engaged in WEDM technology.

7.1 Conclusions

Effect of six process parameters namely tool electrode (A), peak current (B), pulse-on time (C), pulse-off time (D), wire feed (E) and wire tension (F) are studied on two machining characteristics namely Material Removal Rate (MRR) and Surface Roughness (SR) using Taguchi’s design of experiment technique. The optimal set of process parameters are predicted and confirmed for each machining characteristic.

Following conclusions are made in the present experimental and analytical work within the range of test conditions employed.

1. The maximum S/N ratio obtained for higher material removal rate (MRR) for phase I is 19.03 dB [at parametric settings cryogenic tool electrode, Ip: 12 A, T_{on}: 115\mu s, T_{off}: 60, WF: 4 m/min, WT: 9 N] as compared to that obtained during phase II, which is 17.70 dB [at parametric settings normal tool electrode, Ip: 12 A, T_{on}: 125\mu s, T_{off}: 60 \mu s, WF: 4 m/min, WT: 7 N]. The MRR is found to increase with cryogenic treated tool electrode for the WEDM process.

2. Surface roughness increases with an increase in peak current settings from 10 A to 14 A. This is due to the higher discharge energy that is generates a large amount of heat and melted and vaporised the localised work material causing large craters on the work material surface.

3. Tool electrode, peak current and pulse on time are the most significant parameters at 95% confidence interval (p \leq 0.05), and are ranked at 1 and 2 for the phase I. In the case of diffused tool electrode (Phase II), the pulse on time is the most significant parameter and is ranked at 1.

4. Improvement of about 10.26% and 1.98% in material removal rate and surface roughness are noticed respectively while using zinc coated tool electrode, as compared with diffused tool electrode for the rectangular slit.
5. Improvement of about 13.86% and 28.12% in MRR and SR are noticed respectively while using zinc coated tool electrode as compared to diffused tool electrode for V slit.

6. The SEM analysis of the machined surface shows complicated crater-shaped irregularities created by the normal tool electrode. Lesser micro-crack concentration and reduction in recast layer thickness is observed on the surface machined with cryogenic treated tool electrode.

7. The use of cryogenically treated wire electrode in WEDM for machining of Inconel 625 enhances the MRR. Less time is required for processing of the same amount of work piece material. The superior surface finish of machined work piece also obtained with cryogenically treated wire electrodes as compared with normal wire electrode.

8. The SEM images of work piece surfaces processed by cryogenic treated wire electrode in WEDM suggests that surfaces are more uniform and smooth than produced with normal wire electrode in WEDM.

9. The experimental results indicate that the behaviour of response characteristics (MRR, SR) in WEDM depends upon the wire electrode and machine based parameters.

10. In the present research, the parametric optimization of process parameters with cryogenic treated wire electrodes in WEDM indicates that the optimal settings of experimental results suggested by Taguchi’s method lie well within the predicted range.

11. The electrical conductivity of normal zinc coated and diffused tool electrode are enhanced with cryogenic treatment. Cryogenic treatment improved the conductivity to 22.22% and 13.79% respectively, as compared to normal wire electrode.

12. EDS analysis depicts that during the machining, few elements of work piece material composition are deposited on the tool electrode surface and vice versa effect is observed.

13. Cryogenically treated wire electrode appreciably enhance the responses i.e. material removal rate and surface roughness as compared to normal tool electrode. Refine grains, less crater size, uniform surface are obtained by cryogenically treated tool electrode.
14. Type of wire, current, pulse on time and pulse off time significantly affects (at 95% confidence interval) the MRR and SR. Wire feed and wire tension don’t show any noticeable effect on MRR and SR.

7.2 Limitations of the Research

The methodology of the study has the following limitations:

1. The present research work is related to the machining of conductive material only. The machining of cryogenically treated wire on non-conductive electrodes is not considered in the present study.

2. The study is limited to the statistical analysis and modelling of selected performance characteristics, like MRR and SR only.

3. The wire electrodes other than zinc coated wire and diffused wire are not considered for the present study.

4. Thermal stress analysis in the work piece is not investigated in the present research work.

7.3 Scope of Future Work

Based on present investigations, future work is suggested as mentioned below:

1. The possible use of cryogenic treated wire electrode for non-conductive and composite materials (Ceramic, fiberglass etc.) can also be investigated.

2. The experimental study/theoretical analysis of surface modification/surface integrity of work piece surfaces processed by cryogenic treated wire electrode in WEDM can be taken as future work.

3. The cryogenic treatment of composite and micro-wires for WEDM could be explored in future research work.

4. Surface defects such as recast layer, un-machined surface area etc. have a strong influence on machining performance. Therefore, a deep investigation of these surface defects is required.
7.4 Concluding Remarks

From the research work, it is concluded that the cryogenically treated tool electrode enhances the MRR and provides better surface finish when compared to normal tool electrode. The accuracy of tool electrode is improved owing to the reduction in grain size with cryogenic treatment. The parametric optimization of process parameters with cryogenic treated and normal tool electrode is conducted, so that WEDM process efficiency could be effectively enhanced in industrial setups. Few limitations of the study are summarized. Some of the issues for future work are proposed so that these could be taken up by the researchers for further research work.