ABSTRACT

In the present trend, new fabrication methods for producing miniaturized components are gaining popularity due to the recent advancements in Micro-Electro Mechanical Systems (MEMS). Micro machining differs from the traditional machining with small size tool, resolution of x-y and z stages also optical microscope to observe the cutting status. Micro-machine tool industry has made prominent growth in its manufacturing capabilities in the last decade but still micro-machine tools are not utilized to their full potential. This limitation is a result of the failure to run the machine tools at their optimum operating conditions. Since the micro-end milling and micro-WEDG processes are widely used, most important operations in the electronics, automobile, air-craft, medical, defense and other industries, these two micro-machining operations are considered in this research work. Now-a-days, statistical techniques play a vital role for modeling, simulation and optimization of micro-machining processes, due to accuracy and less computation time. In micro end milling and micro-WEDG processes, the material removal rate and surface roughness are important aspects, which require attention from industry personnel as well as in Research and development. Hence, an attempt has been made to predict the best combination of micro-end milling process and micro-WEDG process parameters for achieving the better output of single and multiple quality characteristics using the statistical techniques like Taguchi method, Pareto ANOVA, Taguchi’s Quality Loss Function (TQLF), Principal Component Analysis (PCA) and Response surface methodologies (RSM).
This research work analyses the effect of micro-end milling parameters such as spindle speed, feed rate and depth of cut on material removal rate and surface roughness. Initially single response optimization of the process parameters of micro-end milling process is carried out using Taguchi method and Pareto ANOVA method. Based on experimental results it is concluded that the optimal parameters for single response in micro-end milling process using Taguchi approach and Pareto ANOVA for data analysis draw same conclusion.

However, most cases in industrial products present multiple response problems. This problem can easily be augmented with the use of Taguchi’s Quality Loss Function (TQLF) and a powerful multivariate statistical method called Principal Component Analysis (PCA). In this work, TQLF and PCA methodology are proposed for the multiple-response optimization problem. The optimum micro-end milling parameters are determined using TQLF for the multiple-response to achieve maximum MRR and minimum $R_a$. The weighting ratio for the two responses in micro-end milling is set as 1:1 (i.e., each characteristic has equal importance) as assumed in Taguchi quality loss function. But in actual manufacturing environment it is not possible to predict the weighting ratio. Hence, in this experimental work PCA technique is used for the prediction of multiple-responses in micro-end milling process. The predicted value of multiple response performance index $(Z)$ which is calculated by using additive model. The closeness between measured value and predicted value of multiple response performance index $(Z)$ shows good prediction accuracy.
However the Taguchi technique and PCA technique will give optimized parameters in discrete form. Now-a-days MEMS technology is employed in micro-machining processes. So it is also possible to control the value of micromachining parameters in terms of non-discrete values. In this study, response surface methodology for the optimization of machining parameters has been suggested. Response Surface Methodology (RSM) is a collection of statistical and mathematical techniques useful for developing, improving and optimizing process. Statistical models have been developed for the MRR and $R_a$ using central composite design with three level factors. The optimum machining parameters are determined using these models for the multiple-response to achieve maximum MRR and minimum $R_a$. Further the developed models from multiple response optimizations, the optimum machining conditions are predicted and the optimized machining parameters are used for the confirmation of experiments for validation and it is observed that the percentages of error for MRR and $R_a$ are showing good agreement with the predicted responses.

Also this experimental work analyses the effect of micro-wire EDG process parameters such as feed rate, capacitance and voltage on material removal rate and surface roughness. Based on experimental results it is concluded that the optimal parameters for single response in micro-end milling process using Taguchi approach and Pareto ANOVA for data analysis leads to similar conclusion. Also in this study, the significant factors and its interaction effects are identified using Taguchi quality loss function for the multiple response of micro-WEDG process. The optimum machining
parameters are determined using Taguchi MRSN technique for the multiple-response to achieve maximum MRR and minimum $R_a$. Also in this research work, the optimum machining parameters are determined using multiple response performance index value for the multiple-response to achieve maximum MRR and minimum $R_a$. Based on the experimental result it is concluded that, the TQLF and PCA is suitable for the above said problem. The predicted value of multiple response performance index ($Z$) which is calculated by using additive model. The measured value of multiple response performance index ($Z$) which shows the good prediction accuracy.

Also in this work, response surface methodology for the optimization of micro machining parameters is recommended. Statistical models have been developed for the MRR and $R_a$ using central composite design with three level factors. The optimum machining parameters are determined using these models for the multiple-response to achieve maximum MRR and minimum $R_a$. Optimized machining parameters obtained from multi response optimization were used in verification experiments. The percentage of error for MRR and $R_a$ shows good prediction accuracy. Among the various methods for optimization of micro-machining processes used in this research work, the Response surface methodology is proved to be more reliable than the other statistical techniques.