ABSTRACT

The present day's requirement of the industries is to produce good quality products at the minimum cost and in the shortest possible time. The quality of the products made in industries is largely influenced by the material properties and these properties, in turn, are dependent on the input process parameters. Thus, a good control on quality and cost of the product can be achieved by choosing the appropriate process. Hence, it is essential to have adequate knowledge of effect of input process parameters on the performance characteristics of the process.

Stiff market competition, scientific and engineering advances along with continuously growing demand for improved product performance has led to the development of an ever growing variety and quality of materials such as carbides, ceramics, composites, semiconductors, variety of glass, diamond, etc. These advanced exotic engineering materials have wide range of applications in various fields of engineering such as die and moulded parts, automobile, electronics, avionics, communication and medicine. These newly developed materials have high strength and stiffness at elevated temperatures, extreme hardness, high brittleness, high strength to weight ratio, high corrosion and oxidation resistance, and chemical inertness. Although such properties result in superior product performance; nevertheless, it is difficult to machine these materials by conventional methods. This situation has given a new impetus to the development of non-traditional machining processes since early 1940s, where in material is removed by mechanical means (USM, AJM, WJM), thermal erosion (EDM,
LBM, EBM), anodic dissolution (ECM), chemical reaction or combination of two or more than two processes called hybrid machining (EDAG, ECSM).

The Electrical Discharge Machining (EDM) works on the principle of erosion of metals by spark discharges. The EDM is one of the most accurate manufacturing processes available for creating simple or complex shapes and the geometries within parts and assemblies of extremely hard materials (fragile) that are difficult to machine using conventional methods, as it works using electrical energy turned to thermal energy rather than cutting.

The basis of controlling the sink electrical discharge machining (sink-EDM) process mostly relies on empirical methods largely due to the stochastic nature of the sparking phenomenon involving both electrical and non-electrical process parameters. Thus the performance of sink-EDM process is commonly evaluated in terms of Material Removal Rate (MRR); Tool Wear Rate (TWR), Surface Finish (SF) and accuracy. However, in present research work process performance is evaluated in terms of Material Removal Rate (MRR) and Tool Wear Rate (TWR).

A detailed literature survey is carried out on the sink-EDM input process parameters. The gaps in the literature have been identified and the objectives of the present work have been set. It is also identified that adequate knowledge of effect of tool taper angle and tool shape with size factor consideration is very much essential to evaluate the performance characteristics in sink-EDM process, as the tool wear also adversely affect the accuracy of the machining features.
Simulation models of those real world systems may themselves be complex and expensive to construct. Therefore, simple mathematical models that approximate the outputs from simulation models are often constructed to clarify the system input-output relationships. These mathematical models, which can be polynomial forms fitted, using least squares regression, can help engineers to make system design decisions.

Statistically designed experiments are outstanding in comparison with the conventional engineering experimental approach of varying one variable at a time. The most important advantage of statistical Design of Experiment (DOE) lies in the fact that several variables are simultaneously studied for a more complete insight into the combined effect of the factors on the response under investigation. The experiments usually involve a large number of variables. The well-planned statistically designed experiment requires a less number of experiments compared to the conventional engineering experimental approach.

Statistical Design of Experiment (DOE) refers to the process of planning the experiment, so that an appropriate set of data can be collected and analyzed using the statistical methods for drawing inferences on the input-output relationships. It is an efficient technique to estimate the effect of several variables simultaneously. Each experimental design will contain a group of experimental runs. Optimizing a product or process design means determining the best architecture, levels of control factors and tolerances. The Design of Experiment (DOE) combined with the Response Surface Methodology (RSM) is a powerful statistical tool to develop the input-output
relationships. The Response Surface Methodology (RSM) is an empirical modelling approach using polynomials as the local approximations to the true input-output relationships.

Thus the principal objective of the research work is decided to carryout Response Surface Methodology (RSM) based investigations into the effect of tool taper angle and tool shapes such as triangular, square, rectangular and circular with size factor consideration along with other process parameters like discharge current, pulse on-time, pulse off-time, tool area and tool taper angle. The RSM based mathematical models of Material Removal Rate (MRR) and Tool Wear Rate (TWR) have been developed using the data obtained through Central Composite Design (CCD). The Analysis of Variance (ANOVA) was performed along with Fisher's statistical test (F-test) to verify the lack-of-fit and adequacy of the developed mathematical models for the desired confidence interval. The ANOVA table includes sum of squares (SS), degrees of freedom (DF) and mean square (MS). In ANOVA, the contributions for SS is from the first order terms (linear), the second order terms (square), the interaction terms, lack of fit and the residual error. The lack of fit component is the deviation of the response from the fitted surface, whereas the residual error is obtained from the replicated points at the center. The MS are obtained by dividing the SS of each of the sources of variation by the respective DF. The p-value is the smallest level of significance at which the data are significant. The Fisher's variance ratio (F-ratio) is the ratio of the MS of the lack of fit to the MS of the pure experimental error. As per the ANOVA technique, the model developed is adequate within the confidence interval if the calculated value of F-ratio of
lack of fit to pure error does not exceed the standard tabulated value of $F$-ratio and the $F$-values of model should be more than the $F$-critical for a confidence interval. Further, the confirmation tests were performed to ascertain the accuracy of the developed models.

The entire research work is experiment oriented and the conclusions are drawn based on graphical analysis of experimental results. The research work carried out reveals that the findings are encouraging in establishing the effect of tool taper angle and tool shapes such as triangular, square, rectangular and circular with size factor consideration along with other process parameters like discharge current, pulse on-time, pulse off-time, tool area and tool taper angle on sink-EDM process performance characteristics. The results of this investigation can be adopted in deciding the optimal values of input process parameters along with tool taper angle and tool shapes for obtaining required performance characteristics in sink-EDM process.

LAYOUT OF THE THESIS

The thesis consists of six chapters. CHAPTER 1 starts with general introduction, History, development and Basic principles of EDM process. Evolution of a single spark in the EDM process is illustrated.

CHAPTER 2 Gives an overview and literature review for finding scope for the present study. The objectives of the present thesis have been set, based on the gaps identified in the literature.
CHAPTER 3 describes the modelling tools and techniques used in the present study. The principle of conventional statistical regression analysis has been explained.

CHAPTER 4 The mathematical modelling of sink-EDM process parameters has been dealt. Input-output relationships have been determined using the conventional statistical regression analysis for investigating the effect of tool shapes such as triangular, square, rectangular and circular with size factor consideration.

CHAPTERS 5 deals with mathematical modelling of process parameters for investigating the effect of tool taper angle with size factor consideration in sink-EDM process.

CHAPTER 6 presents conclusions made from the present study. The scope for future work is also stated in this chapter.