CHAPTER 1

INTRODUCTION

Due to development of mechanical industry, the demands for alloy materials having high hardness, toughness and impact resistance are increasing. Such materials are difficult to be machined by traditional machining methods. Hence, non-traditional machining methods like electrochemical machining, ultrasonic machining, Electrical Discharge Machine (EDM) etc. are applied to for such difficult to machine materials. The Wire Electrical Discharge Machine (WEDM) process is considered a unique adoption of the EDM process, where a thin wire electrode transforms electrical energy to thermal energy for cutting materials. With this process, alloy steel, conductive ceramics and aerospace materials can be machined irrespective of their hardness and toughness.

Furthermore, EDM has now become the most important widely accepted technology in manufacturing industries since many complex 3D shapes can be machined using a simple shaped tool electrode. EDM is an important ‘non-traditional manufacturing method’, developed in the late 1940s and has been accepted worldwide as a standard process for the manufacture of forming tools to produce plastics moldings, die castings, forging dies etc. New developments in the field of material science have led to new engineering metallic materials, composite materials and high-tech ceramics having good mechanical properties and thermal characteristics as well as sufficient electrical conductivity so that they can readily be machined by spark erosion. At the present time, EDM is a widespread technique used in
industry for high precision machining of all types of conductive materials such as metals, metallic alloys, graphite, or even some ceramic materials of whatsoever hardness. EDM technology is increasingly being used in tool, die and mould-making industries, for machining of heat treated tool steels and advanced materials (super alloys, ceramics, and metal matrix composites) requiring high precision, complex shapes and high surface finish.

Traditional machining technique is often based on the material removal, using tool material harder than the work material and is unable to machine them economically. EDM is based on the eroding effect of an electric spark on both the electrodes used. It is actually a process of utilizing the removal phenomenon of electrical-discharge in dielectric. Therefore, the electrode plays an important role and affects the material removal rate and the tool wear rate.

WEDM is capable of producing a fine, precise corrosion and wear resistant surface. It utilizes a continuously travelling wire electrode made of thin copper, brass or tungsten of diameter 0.05-0.30 mm which is capable of achieving very small corner radii. The wire is kept in tension using a mechanical tensioning device reducing the tendency of producing inaccurate parts. During the WEDM process, the material is eroded ahead of the wire and there is no direct contact between the work piece and the wire eliminating the mechanical stresses during machining.

1.1 PROBLEM IDENTIFICATION IN EDM AND WEDM

EDM is commonly used in tool, die and mould making industries for machining heat-treated tool steel materials. The heat treated tool steel materials fall in the difficult-to-cut material group when using conventional machining process. The high rate of electrode wear is one of the main problems in EDM. The wear ratio is defined as the volume of metal lost from
the tool divided by the volume of metal removed from the work material and
varies with the electrode and work materials used. If the rate of electrode wear
is high, it means that the material is easy to wear and not good for machining
performance. The significance of this study is to optimize the process
parameters and find the optimized combination of process parameters in EDM
and in Wire Electrical Discharge Machine (WEDM) for the advanced
machining processes in the manufacturing industries. EDM has been analyzed
for several years for improving the material removal rate and the electrode
wear rate, which are the most critical aspects of the process.

In the machining of EDM, there are a few characteristics which
influence the machining process.

The important characteristics are the Material Removal Rate
(MRR) and Electrode Wear rate (EW). These characteristics should be taken
into account when good machining performance is needed. The experimental
studies and optimization techniques of this research are to determine the
MRR, EW, surface roughness (Ra) and Rapidly Resolidified Layer Thickness
(RRLT). This would lead to a better process and product finishing. The
machining characteristics of EDM remain unclear, especially regarding the
total energy of discharge pulses and tool electrode wear, since the energy is
not only used to machine the work piece but also degrades the tool electrode.
Hence, some investigation is needed to find the best combination of process
parameters for best performance in machining using EDM and WEDM.
Generally, the summary of the literature review has revealed that the higher
MRR and the lower EW are better factors for machining process
performances. On the other hand, the WEDM performance includes material
removal rate, wire wear rate and surface finish of machined materials that can
be influenced by process parameters. Some of the process parameters have
significant influence on the EDM and WEDM performance and others have insignificant effect.

1.2 PROBLEM STATEMENT

In EDM, improper combination of process parameters may cause poor machining rate or performance. This is due to MRR characteristic though long machining process lesser material removal rate, it is a fertile effort unsuitable for production. The second problem is that it will decrease the accuracy of the product because of the influence of the Electrode Wear (EW) characteristic. The accuracy of the machined surface can be obtained when the EW is high or MRR is low. Furthermore, electrode wear imposes high costs on manufacturers to substitute the eroded complicated electrodes by new ones for die-making. In order to increase the machining efficiency, erosion of the work piece must be maximized and that of the electrode be minimized in EDM and WEDM processes.

Similarly, resolidified layer thickness formed on the work piece would dictate the surface roughness. Chiang et al (2007) concluded in his work as rapidly re solidified layer on electrical discharge machined surface exhibits continuous ridges means poor surface roughness. Hence, by minimizing the resolidified layer thickness, the surface finish would be improved. Therefore studying the effective combination of process parameters on the electrode wear rate, material removal rate, surface roughness and resolidified layer thickness would be effective to enhance the machining productivity and process reliability.

1.3 SCOPE OF THE RESEARCH

Research works have been conducted by different research scholars on EDM and WEDM with an aim to improve the selection of various
combinations of process parameters to get the required optimized responses. Process parameters refer to electrical parameters on EDM i.e. polarity, pulse on time, peak current, pulse off time, spark gap, electrode gap, pulse waveform, pulse interval and peak voltage. The scope should be limited only on peak current, pulse on time and pulse off time in most research works as the above said three electrical parameters are directly related with energy input, which is to be minimized, to achieve the required conditions like better material removal rate, low electrode wear rate and fine surface finish to avoid post processing. Similarly, some of the physical parameters like size and type of electrode in the case of EDM and size, wire tension and type of wire electrode in WEDM, type of dielectric fluid and its rate of flow are the other sets of parameters to be considered, as they involve cost.

Among the non-traditional methods of material removal processes, EDM and WEDM have drawn a great deal of researcher’s attention because of their broad industrial applications. These processes are well-suited for machining of casting and forging dies, powder metallurgy and injection moulds, and aerospace parts.

From the literature survey of 105 journals published between 1977 and 2012, it is concluded that a lot of scope exists for further improvement.

Different techniques have been adopted by the research scholars to optimize the combination of process parameters. Varied techniques used in EDM and WEDM processes are Response surface methodology, Taguchi method, Artificial neural network, Particle swarm optimization technique and Genetic algorithm.

In the above said techniques, different methodologies and softwares are used to formulate a combination of process parameters to conduct the
experiments and analyzed to find the optimized combination of process parameters to get the required responses.

In this research work, Response Surface Methodology (RSM) is extensively discussed to develop design matrix for conducting the experiment. Moreover, statistical software is used to develop mathematical modeling and ANOVA is used to conduct the significant test and plot relevant graph to optimize the process parameters.

Scanning Electron Microscope (SEM) analysis has been conducted to study the surface characteristics which would be useful to decide the need of post-processing.

1.4 OBJECTIVES OF THE PRESENT RESEARCH WORK

The main objective of this research is to select the new work piece material and its suitability for the EDM and WEDM processes.

A detailed literature survey has been prepared to justify the selection of T90Mn2W50Cr45 cold tool steel material alternate for the conventionally used hard tool steel AISI series and composite materials. Cold work tool steel is essentially high carbon steel, which contain relatively low alloy additions of tungsten, manganese, chromium and molybdenum. These alloy additions increase hardenability, permitting oil quenching with less distortion than with W series. In contrast to the steel, the metal matrices composites are higher cost of materials, relatively immature technology, complex fabrication and limited service expertise.

The objectives of this research work for the EDM process are summarized as follows:
Important and more effective electrical process parameters (Peak current, pulse on time and pulse off time) have been selected and other physical parameters viz., dielectric fluid and size of the electrode also have been identified.

Working ranges and levels of each EDM process parameters has been selected with respect to the specifications of EDM on which experiments are carried out.

For EDM process, three process parameters are considered as three factors with five level factorial designs using central composite rotatable design to develop a design matrix comprising 20 experiments.

20 experiments are conducted with different combination of process parameters and experimental responses are observed.

Mathematical model for each individual response has been developed from a combination of process parameters and experimental observations

The adequacy of the model is checked by means of the analysis of variance (ANOVA) technique and the effect of the three process parameters on the particular response has been plotted. Similarly, for other two parameters, the same procedure has been followed and the effect of those three process parameters on the other two responses have been plotted.

To study the surface characteristics of the work piece, SEM analysis have been done.
The above said objectives are carried out to predict the significance of each process parameter.

Artificial Neural Network (ANN) model is used to predict all the responses viz., electrode wear, material removal rate, surface roughness and resolidified layer thickness.

For the WEDM process along with three electrical process parameters, wire tension is also considered as the fourth process parameters. Hence the WEDM process has four factors with 5 level factorial design comprising 31 experiments.

Same procedures as said in the EDM process are followed to predict the significance of those four process parameters.

1.5 ORGANIZATION OF THESIS

Chapter 1 consists of a brief Introduction about the EDM and WEDM machines and their importance in the present manufacturing industries. New work piece, identification of problem and problem statement are also stated. Scope of the research and objectives of the present research work are set out.

Structure and organization of the proposed thesis are framed in it. Hence, this chapter gives the guidelines for the strategy to complete this research work.

In Chapter 2, a detailed literature survey has been reported, in which various international journal articles are grouped in different categories like EDM and WEDM process. Based on the different combination of process parameters, literature review has been given in Chapter 2. Journals related to
different techniques like RSM, Taguchi method, ANN and Genetic Algorithm and method parameters which have been optimized are discussed.

Chapter 3 covers a brief introduction about the experimental set up in EDM and WEDM. Here, a detailed discussion about the work piece material, electrode material, process parameters and responses have been reported separately for EDM and WEDM.

In Chapter 4, Response Surface Methodology has been explained in detail viz., selection of important process parameters and required responses, development of design matrix to set the numbers of experiments with different combination of process parameters for EDM. After conducting the experiments, the responses for different experiments are tabulated for EDM. Here network training and testing methods using ANN technique and observation values for EDM process are tabulated. In Chapter 5, Observational details for WEDM process using RSM and ANN techniques are tabulated.

Chapter 6 covers a detailed discussion about the effect of combination of different process parameters on each response. From the discussion, optimized combination of process parameters for the required response is found out. Also surface characteristics of the work pieces are analyzed using Scanning Electron Microscope for the EDM process. Analysis using ANN techniques for the EDM process is also discussed. In Chapter 7, the above said discussion is carried out for the WEDM process.

Chapter 8 contains the summary of the research conducted in this thesis. Also, some of the salient outcomes are given in the conclusion and suggestions for future work on the related topics have been enumerated.