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Genetic Algorithm and Response Surface Methodology Based Optimization of Electrical Discharge Machining (EDM) Process

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Abstract : Non-conventional machining processes have proved to be a great method for the machining processes involving material removal both in small or large quantities of the material removal. The optimization of the methods of non-conventional machining is necessary for the accurate evaluation of the machining processes and also for the best possible outcome. There are various methods for the optimization of the non-conventional methods namely artificial bee colony (ABC) algorithm, genetic algorithm (GA), Taguchi method, evolutionary algorithms, dynamic algorithms, differential evolution etc. This work is mainly focused on the application of genetic algorithm and response surface methodology (RSM) for the optimization of the non-conventional machining processes.

Keywords: **Genetic Algorithm, Response Surface Methodology, Material Removal Rate, Electrical Discharge Machining.**

I. Introduction

Electrical Discharge Machining (EDM), Ultrasonic Machining (USM), Laser Beam Machining (LBM) are one of the non-conventional machining methods implemented widely. Optimization of the results obtained from the machining operations is essential for the accurate evaluation of the results and to obtain a specific and optimized result. Various combinations of the input parameters are implied to obtain the optimized result which is given a defined set of combination of the parameters. One of the most widely used unconventional method is Electrical Discharge Machining process which is mainly used for precise machining. EDM is thermo-electric unconventional method which utilizes the heat obtained from the spark generated between two electrodes which are submerged in a dielectric medium. The purpose of the using the dielectric medium is to enhance the effectiveness of the machining and to improve the quality of the surface finish. In addition, EDM does not make direct contact between the electrode and the workpiece, eliminating mechanical stresses, chatter and vibration problems during machining [1].

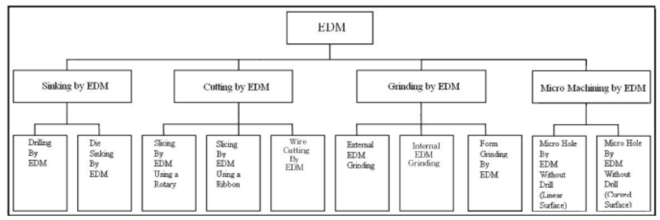

Fig. 1: Classification of the Spark Erosion Machining Processes [2].

The optimization of the result depends entirely on the input parameters like working voltage, working current, spark gap, pressure of oil, etc. control the result and the give the optimized result from the correct set of combination of the input parameters. In the EDM process electrodes are used between which the spark is generated. Today, an electrode is as small as 0.1mm can be used to make hole into curved surfaces at steep angles without drill [1]. The smaller the spark gap better the accuracy and the slower the MRR [3]. Both electrode (tool) and workpiece must be electrically conductive [4]. Various researchers have don numerous work in the field of EDM.

II. Genetic Algorithm

A genetic algorithm (GA) is a local search technique used to find approximate solutions to optimization and search problems. GA are particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection and crossover. Evolutionary algorithm (EA) is subset of evolutionary computation, a generic population-based metaheuristic optimization algorithm. An EA uses mechanisms inspired by biological evolution such as reproduction, mutation, recombination and selection [14]. Genetic algorithms are typically implemented as a computer simulation, in which a population of abstract representatives (called chromosomes) of candidate solutions (called individuals) to an optimization problem, evolves toward better solution. Compared to traditional optimization paradigms, a GA is robust, global and may be applied generally without recourse to domain-specific heuristics. It can be used not only for general optimization problems, but also in indifferent optimization problems and unconventional optimization problem [5]. So GAs are widely used for machine learning, function optimizing and system modeling [6-10]. GA is a population-based search methodology [11, 12]. Genetic Algorithm (GA) is applied for the optimization of the results obtained from response surface methodology, and MATLAB is used for the working of genetic algorithm. The Genetic Algorithm Toolbox MATLAB functions to construct a set of tools for the implementation of genetic algorithm methods. GA is one of the solver of the MATLAB that is popularly used commercially for the optimization processes in the engineering and research industries. The GA solver requires fundamental needs, most importantly the objective function and constraints corresponding to the objective function.

III. Response Surface Methodology

Response Surface Methodology (RSM) explores the relationships between several explanatory variables and one or more response variables. The main idea of RSM is to use a sequence of designed experiments to obtain an optimal response [15]. RSM can be employed to maximize the production of a special substance by optimization of operational factors. RSM properties include:

1. Orthogonality
2. Rotatability
3. Uniformity [15]

IV. Proposed Approach

There are basically nine parameters in genetic algorithm toolbox that has to be specified or chosen as per the requirement of the optimization function. The parameters are population size, fitness scaling function, selection function, elite count, crossover fraction, mutation function, crossover function, migration function, and hybrid function.

Population

The population option specifies the type of population that has to be implemented in the optimization process.

Fitness scaling function

The scaling function converts raw fitness scores returned by the fitness function to values in a range that is suitable for the selection function. The rank of an individual is its position in the sorted scores. The rank of the fittest individual is 1, the next fittest is 2, and so on.

Selection function

The selection function chooses parents for the next generation based on their scaled values from the fitness scaling function. Ignored with integer constraints.

Elite count

It specifies the number of individuals that are guaranteed to survive to the next generation. Elite count is set to be a positive integer less than or equal to the population size.

Crossover fraction

"*Crossover fraction"* specifies the fraction of the next generation that crossover produces. Mutation produces the remaining individuals in the next generation.

Mutation function

Mutation functions make small random changes in the individuals in the population, which provide genetic diversity and enable the genetic algorithm to search a broader space. Ignored with integer constraints.

Crossover function

Crossover combines two individuals, or parents, to form a new individual, or child, for the next generation. Ignored with integer constraints [16].

Migration function

Migration is the movement of individuals between subpopulations, which the algorithm creates if you set Population size to be a vector of length greater than 1. Every so often, the best individuals from one subpopulation replace the worst individuals in another subpopulation. It can be controlled by three parameters viz. Direction, fraction and interval [17].

Hybrid function

Hybrid function enables you to specify another minimization function that runs after the genetic algorithm terminates. Not available with integer constraints [18].

V. Fitness function

Fitness function directs to the objective function which is required to optimize. Fitness function is also called as objective function which is the fundamental element of the genetic algorithm toolbox. Fitness function works on the principle of the "survival of the fittest". This is the function that is to be minimize or maximize. The working of the genetic algorithm basically involves the gaining of the optimum solution from the given set of input data.

Fig.2: Experimental setup of a wire EDM [13].

VI. Analysis of Data

The setting of the set of the input data can be done by any combination building software. In order for the analysis of the result, analysis method like ANOVA analysis can be utilized. Analysis of Variance (ANOVA) is a collection of statistical models used to analyze the differences among group means and their associated procedures [19]. It provides a statistical test of whether or not the means of several groups are equal. ANOVA is a technique for testing hypothesis. It is also a very useful tool for obtaining estimates if various parameters involved in the two models. The basic principle underlying the technique is that the total variation in the dependent variable is broken into one which is attributed to some specific causes is known as the variation between the samples and the one which attributed to chance is called the variations within the samples.

VII. Results and Discussions

The optimization of the Electrical Discharge Machining process has been studied with the method of Genetic Algorithm (GA) and Response Surface Methodology (RSM). It is also studied that to obtain the optimum result there should be the implementation of correct set of combination of input parameters. The method of EDM is advantageous because it is used for fine machining and working. Genetic Algorithm is an important tool for the optimization of the process.

VIII. Conclusion

This paper deals with the approach of optimization of Electrical Discharge Machining process using the method of Genetic Algorithm and Response Surface Methodology. The main aim of the process of optimization is to obtain an optimum solution i.e. output that is the result having the best set of combination of the input data. The total output dependency is based on the correct optimization of the correct set of data.

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