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Optimization of Material Removal Rate in Electric Discharge Machine

Manish Kumar
Mechanical Department
Dr. MCSIEM, Lucknow
manish.kit@gmail.comed

Ravendra Singh
Mechanical Department
Rama University, Kanpur, U.P.
ravendra.cngh@gmail.com

Ravi Prakash Vishvakarma
Electrical Department
Rama University, Kanpur, U.P.
ravendra.cngh@gmail.com

Abstract- **Productivity and quality are two important aspects have become great concerns in today's competitive global market. Every production/manufacturing unit mainly focuses on these areas in relation to the process as well as product developed. Electrical discharge machining (EDM) process, even now it is an experience process, wherein still the selected parameters are often far from the maximum, and at the same time selecting optimization parameters is costly and time consuming.**

Material Removal Rate (MRR) during the process has been considered as productivity estimate with the aim to maximize it. With an intention of maximizing mrr is been taken as most important output parameter. Objective function is obtained by Mat lab. Then objective function is optimized using Mat lab technique. The model is shown to be effective; MRR improved using optimized machining parameters.

Key words: Electrical discharge machining (EDM Material removal rate (MRR); Mat lab, Mild Steel Specimen.

1. INTRODUCTION

Optimization is a mathematical results and numerical methods for finding and identifying the best candidate from a collection of alternatives without having to explicitly enumerate and evaluate all possible alternatives. The process of optimization lies at the root of engineering, since the classical function of the engineering is to design new, better, more efficient and less expensive systems as well as to devise plans and procedures for the improved operation of existing systems [1]. The power of optimization methods to determine the best case without actually testing all possible cases come through the use of a modest level of mathematics and at the cost of performing iterative numerical calculations using clearly defined logical procedures or algorithms implanted on computing machines. The development of optimization methodology will therefore require some facility with basic vector-matrix manipulations, a bit of linear algebra and calculations, and some element of real analysis. We use mathematical concepts and constructions not simply to add rigor to the proceedings.

Some other work has been already done over the optimization techniques in production engineering. Joopelli, V [3] tried to optimize the moving trajectories of electrode of EDM. Gradient based methods have been used to optimize the single objective function variable. A moving frame reference has also been used to locate the tool electrode at any instant along its traversed trajectories.

Cao and Yang carried out an experiment, and then they have used artificial neural network (ANN) and genetic algorithm (GA) together to establish the parameter optimization model. An ANN model which adapts Levenberg-Marquardt algorithm has been setup to make an equation between input and output parameters. Output parameters such as surface roughness and Material removal rate are then optimized using Genetic algorithm. This model is shown effective and values obtained are much optimized one.

Lee et al. have done experiment and found that the results of MRR and surface roughness increases with the values of pulse current but after certain value SR and MRR reduce because of expansion of electric plasma. Surface crack density is affected by pulse current while the crack opening is influenced by the pulse on duration.

Jain V. K. [4] analyzed the problem by using a simple optimization algorithm by keeping other objective functions unaffected and the results are concluded to give the suitable operating variable value selection on the basis of output obtained. The operating working voltage and the pulse interval plays an important role in obtaining the required surface finish. The flow movement of the dielectric fluid controls the homogeneous surface characteristics in the entire EDM controlled region. Kahng, C. H [5].

Kee. P. [6] specified an integrated approach for jointly solving process selection, machining parameter selection, and tolerance design problems to avoid inconsistent and infeasible decision. L.C. Lim, H.H. Lu [7] specified the basic thumb rules for the analysis of surface features of Electro discharge machining process.

Pandit, S. M [10] stated the critical factors affecting the performance of the Electro Discharge machining process when the work piece material is Cemented carbide. A suitable hard alloy material is selected as electrode tool material. And the dielectric fluid is given turbulent flow in and around the EDM region. The operating variables like Pulse duration, Discharge Current, Operating voltage, Pulse Interval time and heat dissipation rate differ in operating ranges considerably as compared to electro discharge machining of Steel alloys. However, it has been claimed that consistency and repeatability of the machine towards maintaining the minimum deviation in the operating conditions helps a lot in the Machining accuracy in the process. Spedding, T.A. [11] used the concept of conformal transformation of the operating characteristic variables. The variables are parameterized and the parametric representation of the metal removal rate, surface roughness has been mapped onto parametric surface. The surface characteristics of the wire-Cut EDM process have been analyzed for the sensitivity of the operating variables. The dependencies of the decision variable on each other are represented and a computation algorithm has been proposed to evaluate the mapped point for specified surface characteristics onto parametric plane. Spedding, T.A. and Wang, Z.Q. [12] considered the theoretical aspects of the modeling of the wire-Cut EDM process. The interpretation of output variables variations has been carried out for the wire Cut EDM process and the suggested ranges of the input variables are given for a desired set of output variables in terms of metal removal rate and power consumption etc. Smyers, S., Guha, A. [13] stated a practical approach for Machining the Beryllium Copper alloys as work piece by Electro Discharge Machining process. Methods have been suggested for obtaining the desired level of surface characteristics by using this EDM method. Wang W.M. [14] stated that spark gap and the controlling parameters for a sensitive EDM process layout can be controlled in number of ways. A feedback system with real time stability analysis and process monitoring through digital modern sensors and transducers can give an efficient responding mechanism for the EDM process control. An artificial neural network was developed for EDM. The relationships between the operating intermediate processes along with decision variables have been framed. The performance Index evaluated by using this method helps in analyzing the adverse and positive gradient effects of the variation in the Metal removal rate, the surface roughness and the power consumption by the machine. Zhang, B. [15] calculated the effect of motion and turbulence level in the dielectric material during various stages of the electro-discharge machining process. The effect of the selection of dielectric fluid has also been analyzed for a given set of electrode tool and material combination.

II. Electric Discharge Machining

Electrical Discharge Machining (EDM) is a controlled metal-removal process that is used to remove metal by means of electric spark erosion. In this process an electric spark is used as the cutting tool to cut (erode) the work piece to produce the finished part to the desired shape. The metal-removal process is performed by applying a pulsating (ON/OFF) electrical charge of high-frequency current through the electrode to the work piece. This removes (erodes) very tiny pieces of metal from the work-piece at a controlled rate.

A. EDM Process

EDM spark erosion is the same as having an electrical short that burns a small hole in a piece of metal it contacts. With the EDM process both the work-piece material and the electrode material must be conductors of electricity. The EDM process can be used in two different ways:

1. A reshaped or formed electrode (tool), usually made from graphite or copper, is shaped to the form of the cavity it is to reproduce. The formed electrode is fed vertically down and the reverse shape of the electrode is eroded (burned) into the solid work piece.

2. A continuous-travelling vertical-wire electrode, the diameter of a small needle or less, is controlled by the computer to follow a programmed path to erode or cut a narrow slot through the work piece to produce the required shape.

B. Principle of operation

We know that whenever an arc is caused by an accidental short circuit, pitting erosion occurs on the surface of the shorted material. EDM also works on the same principle of erosion by arcing. It involves the controlled erosion of electrically conducting materials by rapid and repetitive discharge of spark between the electrode tool and work piece (hence the name spark erosion) the tool is usually made the cathode and the work piece made the anode. The work piece and tool separated by a small gap and termed as the spark gap. The spark gap ranges from 0.005 mm to 0.05mm depending upon the cutting action required and the current density, this spark gap is either flooded or immersed in a dielectric fluid, the spark discharge is produced by the controlled pulsing and direct current. The frequency ranges from a few hundred to several thousand kilohertz with the application of a suitable voltage across the anode and cathode, electrons are the emitted from the cathode and cause the ionization of the fluid in the spark gap, when more electrons are collected in the gap, the resistance drops causing an electric spark to jump between the work and the tool gap. The spark causes a focused stream of electrons to move with a high velocity and acceleration from the cathode toward the anode, thus creating high compression shock waves .such shock waves result in local rise in temperature to the order of about 10,000 c and cause melting of the metal. The forces of electric and magnetic fields caused by the spark produced a tensile force and tear off particles of molten and soften metal from the work piece, Thereby resulting in the metal and carried away by the flowing dielectric fluid.

Work piece and the tool are separated by the dielectric fluid in a container. The dielectric breaks down when a proper DC voltage (50-450) V is applied across the anode and the cathode, and electrons are emitted from the cathode and the gap is ionized, thereby causing electrical discharge and machining operation. The electro-magnetic field cause compressive forces to act on the cathode thus metal removal from the tool is much slower than the work piece .the duration of the electric pulse is about 0.001 seconds, hence the whole cycle of sparking and metal removal take place in a few microseconds. The particles of the metal so removed are driven away by the flowing dielectric fluid .the current density and the power density used is the order of 10,000a/cm2 and 500mw/cm2 respectively.

C. Parameters affecting EDM process

A number of controlling variables play an important role in the entire Electric Discharge machining process. A few of them are: (i) Pulse duration (ii). Pulse interval time (iii). Discharge current (iv). Erosion diameter (v). Erosion depth The few process parameters which are useful in analyzing the EDM process accuracy and efficiency are as below: (i). Metal removal rate (ii). Electrode wears (iii). Surface Roughness (iv). Power consumption by the Machine.

D. Experimental Procedure

The metal removal was carried out using SPARKONIX based electric discharge machining. In the experiment a copper electrode was used and mild steel was used as work-piece material. In the experiment a copper electrode with 29.2 mm diameter was used. All experiment was carried out with same electrode and kerosene oil was used as dielectric fluid. A direct current up-to 35 A was used for various readings. For calculating more accurate result six readings were carried out.

TABLE I. MATERIAL REMOVAL RATE AT VARIOUS VALUES OF CURRENT & TIME

SN	Current (ampere)	Time (min)	Depth of cut (mm)	MRR
1	0.049	20	0.5	6.01
2	0.0907	16	0.5	6.89
3	0.1423	13	0.5	7.5456
4	0.1920	11	0.5	7.9125
5	0.2231	10	0.5	8.0470
6	0.3012	8	0.5	8.1388

Initially the lower surface was made parallel to the bed of the EDM machine. After measuring the thickness all around the diameter to the electrode fixed the electrode into the chuck. After that the level was checked to avoid some manual error during fixing the electrode.

Initially thickness of the copper electrode = 15 mm. Finally calculated thickness of electrode = 14 mm (approximate) So, average wear-out of the electrode = (15-14)/6 = 0.166666 mm.

Similarly, to know about a relationship between time and material removal rate the graph between then was drawn in figure 2. The graph indicates that material removal rate is also directly related to the current density. As the current density increases material removal rate also increases in the same proportion.

III. RESULTS ANALYSIS AND DISCUSSIONS

A. Effect of current on mrr:

Material removal rate increases with increase in current density. As current density increases material removal rate also increases. From table 1 as current density increases from 0.049 ampere to 0.09 ampere material removal rate increases from 6.01 to 6.89 mm3/ minute. The graph between material removal rate and current shown in fig 1.

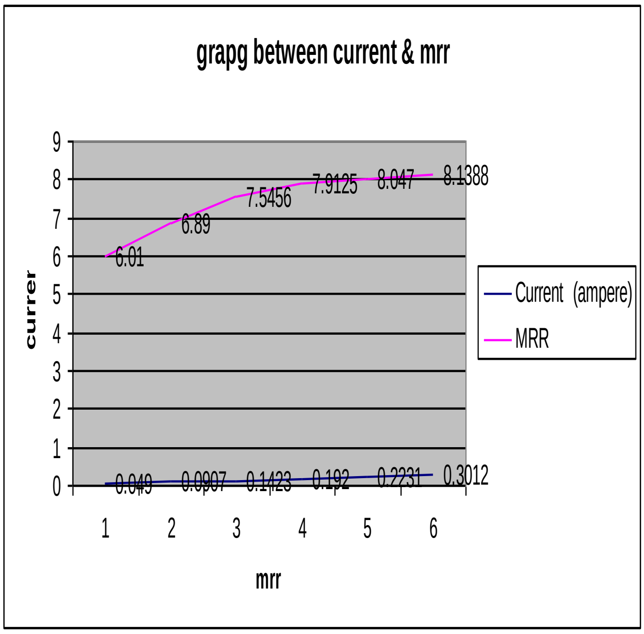

Fig 1: Graph between material removal rate and current

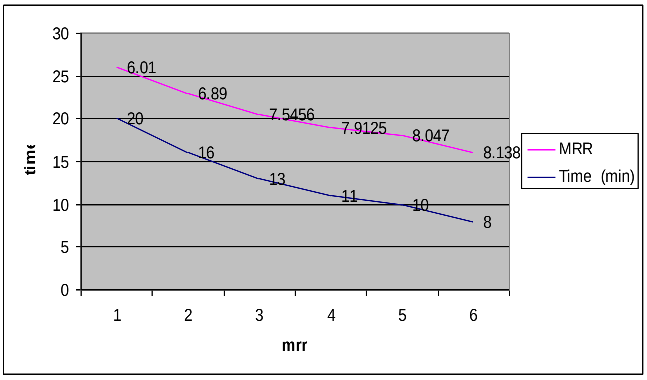

Fig 2: Graph between material removal rate and time

Material removal rate increases with decrease in time. As time decrease material removal rate also increases. From table 1 as time decrease from 20 min to 18 min material removal rate increases from 6.01 to 6.89 mm3/ minute. The graph between material removal rate and time shown in fig 2

B. Optimization analysis

On comparison the calculated values by optimization process & by the experimental values it is clear that both the values are not exactly equal but are nearly equal to each other.

On measuring the MRR by mat lab method & by analyzing it comes out not exactly the same but both are nearly to each other.

IV. Conclusion And Future Scope

The present method adopted to solve the optimization problem of EDM process is simple enough and is flexible in selection of objective functions and the constraints for such machining processes. At any stage, the dominance factor of the input variables and output variables contained in the constraints and objective functions can be computed.

During the solution of the problem, it has been found that the results obtained by this approach show their convergence towards the exact solutions obtained by optimization of objective functions. However, the absolute values of the objective function differ significantly for their absolute values under max-max or min-min condition. Even though a number of numerical optimization tools in the workbench of the software's are available now a days, such optimization methods are contributing a lot for optimization of machining processes due to their localized flexible nature of the constraints and the interchangeable objective functions. A list of suggested proposals of work which can be carried out beyond the scope of this work is as below.

1. A number of other non-traditional machining methods are available for advanced manufacturing. This method or algorithm may be used for getting the optimized results of the respective processes.

2. The approach can be used for the probabilistic sensitivity analysis of the manufacturing processes including EDM process. This work will give a symbolic justification of the effect of external and internal system variables on the accuracy of surfaces.

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