Parametric Optimization of Electrochemical Grinding Operation by Particle Swarm Optimization Technique

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Abstract

This paper presents the Optimization of Non-Traditional Machining (NTM) process for the Electrochemical Grinding Operation by Particle Swarm Optimization Technique. The main aim of the work is to find the optimum values of machining parameters. The Non-Traditional or Unconventional Machining Process has proved to be better than conventional machining process to a large extent.

Keywords — *Conventional Machining; Electrochemical Grinding Operation; Non-Traditional Machining; Partical Swarm Otimization; Parametric Optimization*

I. INTRODUCTION

Due to high demand of materials, like high strength temperature resistant (HSTR) alloys having high strength-to-weight ratio by the technological giants like aeronautics, nuclear reactors, automobiles etc. , the researchers in the area of material science have been developing materials having higher strength, hardness, toughness and other diverse properties [1].But these all expectation are not possible to meet by the conventional machining processes as it will affect the cost of machining and several others factors.

Here a need was felt for development of new and advanced machining processes which could accurately and easily machine the most difficult-to-machine materials, and produce intricate and accurate shapes economically. Hence in order to meet the above-mentioned requirements, a set of machining processes were developed which were collectively known as non-traditional machining (NTM) processes or unconventional machining processes. They are known as unconventional machining processes because they do not use the conventional machine tools for removal of materials from the work piece, instead they use the energy in its direct form for the removal of materials from the work piece surface [2, 3].

The NTM processes can be classified according to the type of fundamental machining energy employed [4]. Table 1 gives a classification of NTM processes based on the type of energy used, mechanism of metal removal, source of energy requirement etc.

Type of energy	Mechanism of metal removal	Transfer media	Energy source	Processes
Mechanical	Erosion	High velocity particles	Pneumatic hydraulic pressure	Abrasive jet machining, water jet machining, ultrasonic machining
Electrochemical	Ion displacement	Electrolyte	High current	Electrochemical machining, electrochemical grinding
Chemical	Ablative relation	Reactive environment	Corrosive agent	Chemical machining
Thermo-electric	Fusion	Hot gases	Ionized materials	Ion-beam machining, plasma arc machining.
		Electrons	High voltage	Electric discharge machining
	Vaporization	Radiation	Amplified light	Laser beam machining
		Ion stream	Ionized materials	Plasma arc machining

Table 1 Classification of NTM processes

Electrochemical Grinding

Electrochemical grinding (ECG) process combines electrolyte activity with physical removal of material by means of charged grinding wheels. ECG facilitates the production of stress free parts without heat or mechanical grinding, which eliminates the need for secondary machining operations. ECG generates very little or no heat that can distort delicate components. ECG can be used to process any conductive material that is electrochemically reactive.

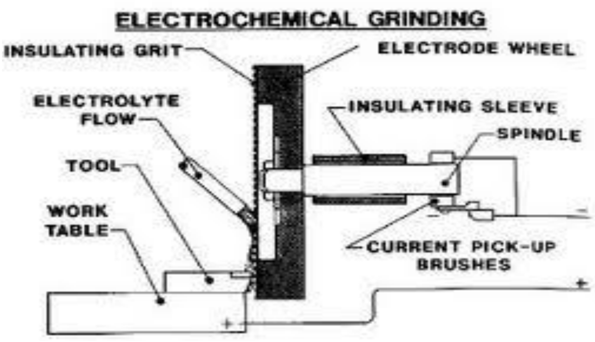

Figure 1 Schematic Diagram of an Electrochemical Grinding Process [46]

II. NEED FOR PARAMETRIC OPTIMIZATION FOR NON-TRADITIONAL MACHINING PROCESSES

- In order to make proper use of the machining process, it is very important to understand that
  - i) the NTM processes can never replace the conventional machining processes, they can only compliment them, and
  - ii) a particular NTM process which is suitable under a certain machining condition might not be suitable under other conditions.

So, it is important to find out the optimal parametric conditions under which the NTM machining processes will be able to perform their best.

- It has been found out that selection of the optimal parametric conditions for an NTM process is vital because it affects the economics of that machining process.
- It is very important to find out the optimal process parameters of these machining processes to use them efficiently and achieve a high degree of dimensional accuracy.
- Due to unavailability of a suitable technological performance equation, it is very difficult to implement the optimized parametric conditions. In such circumstances, a large number of experiments has to be conducted in order to establish an empirical performance equation for each operating environment and work material combination for a given machining operation.

The needs for parametric optimization of NTM processes have been discussed in the previous section. The parametric optimization of an NTM process is undertaken in mainly two stages, i.e.

a) mathematical modelling of the optimization problem taking into consideration the relationship between the process parameters and performance measures (responses), and

b) Optimization of the mathematical model in order to determine the optimal or near optimal value of the performance measures and corresponding combination of the process parameters.

III. PARTICLE SWARM OPTIMIZATION TECHNIQUE

Kennedy and Eberhart [13] defined swarm as a population of interactive elements or agents who are able to optimize some global objective through collaborative search in space. Figure 1 shows a pictorial representation of the simple scheme of a swarm. There are various optimization techniques that have been developed using this concept of swarm intelligence, e.g. ACO, ABC and PSO. The concept of PSO algorithm is discussed below.

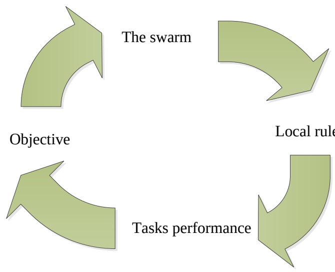

Figure 2 Scheme of a Swarm

The PSO algorithm was first introduced by Kennedy and Eberhart [13, 16-21]. PSO is based on the social behavior of animals and birds. It is influenced by the social behavior in a flock of birds, school of fishes and a group of people. In PSO, the group is also known as swarm. It is a population-based stochastic optimization process. The swarm consists of number of individuals called the particles. These particles fly in a n-dimensional space.

In PSO algorithm, the flight trajectory of a particle is influenced by the trajectory of neighborhood particles as well as the flight experience of the particle itself. Each particle is treated as a point in the n-dimensional space. Each particle keeps information of its best coordinates in the problem space.

IV. METHODOLOGY

The whole process in the project takes place according to the flow chart shown below. This gives the overall method used in the project.

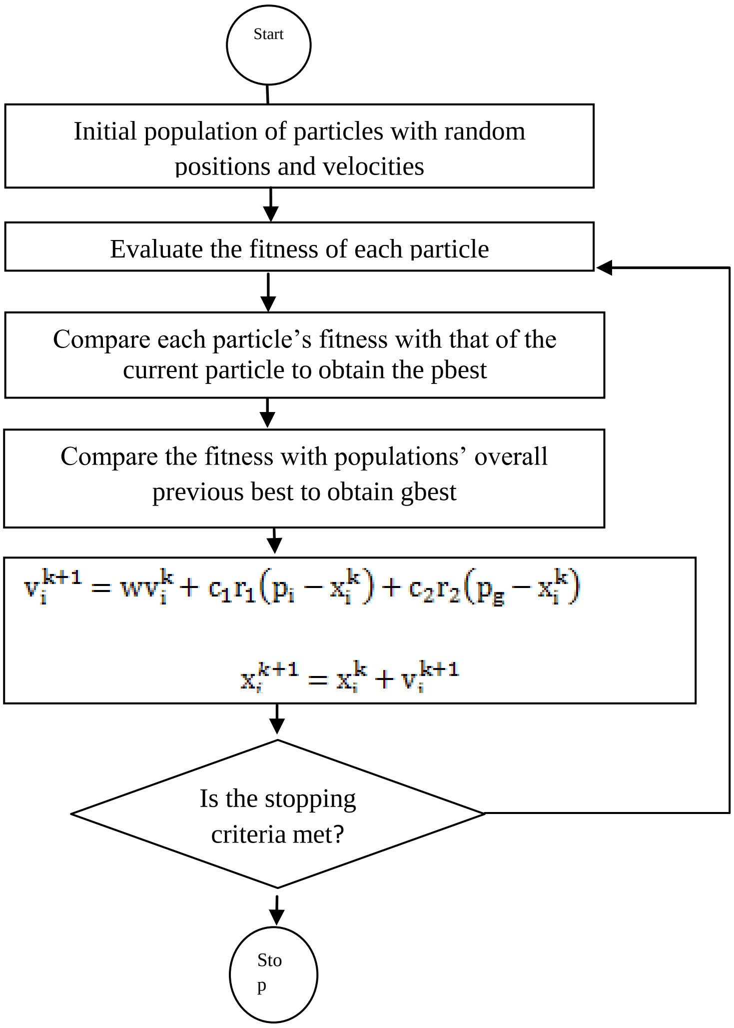

Figure 3 Flowchart for PSO Algorithm [20]

V. RESULT

Using the above methodology, we have found the following results for the single objective and multi-response optimization of ECG process.

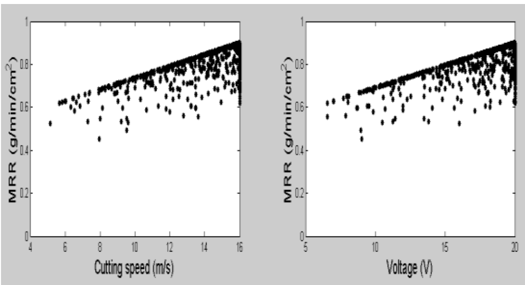

Figure 4 Variations of MRR with Respect to Different ECG Process Parameters

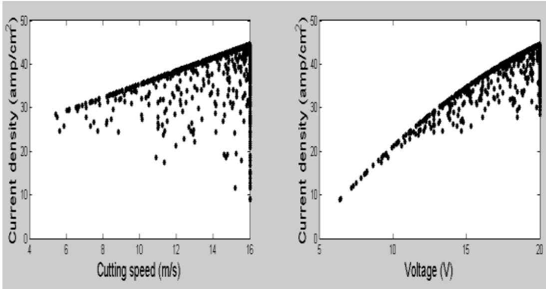

Figure 5 Variations of Current Density with Respect to Different ECG Process Parameters

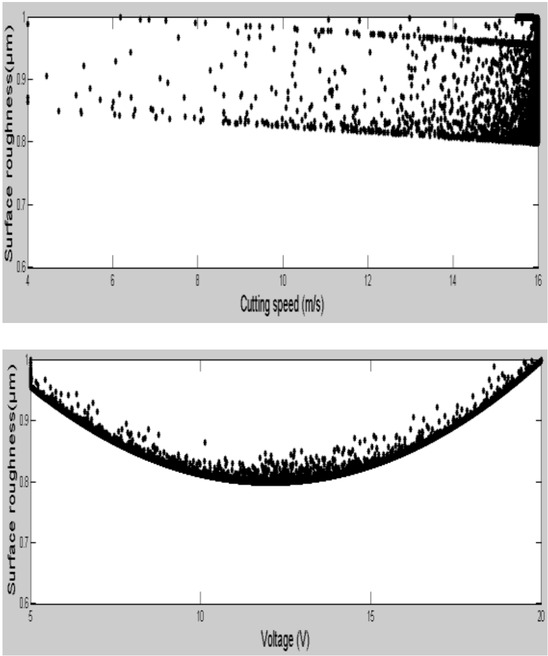

Figure 6 Variations of Surface Roughness with Respect to Different ECG Process Parameters

Figures clearly reveal the variations of surface roughness with cutting speed and voltage. It is observed from the figure that an increase in cutting speed would cause the surface roughness to decrease. This figure also exhibits that surface roughness would decrease with increase in voltage up to a certain level and then it would start to increase with further increase in voltage.

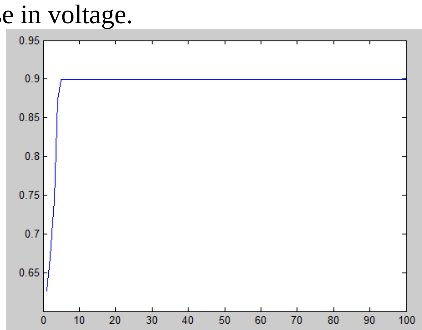

Figure 7 Convergence of PSO algorithm for MRR

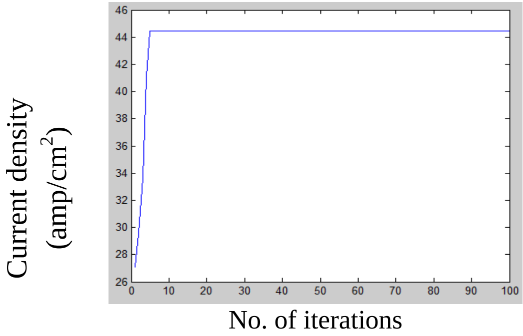

Figure 8 Convergence of PSO Algorithm for Current Density

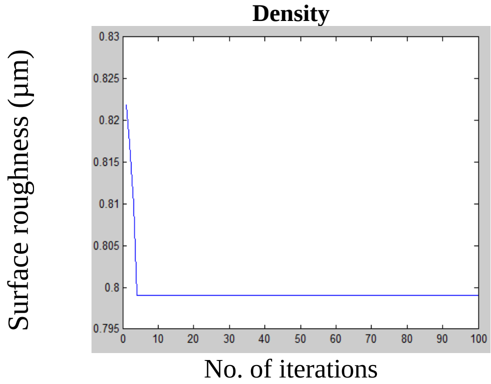

Figure 9 Convergence of PSO Algorithm for Surface Roughness

VI. CONCLUSION

From the above results, we have following conclusions.

Process parameters	PSO algorithm		
	MRR (g/min/cm^2)	Current density (amp/cm^2)	R_a (μm)
Cutting speed (m/s)	16	16	16
Voltage (V)	20	20	12.0487
Optimal value	0.89908	44.4763	0.798

Table 2 Results of Single Objective Optim Ization for ECG Process

Process parameters and objective function	Results obtained by Puri and Banerjee [47]	PSO algorithm
Cutting speed (m/s)	16	16.8806
Voltage (V)	12	12.9476
MRR (g/min/cm^2)	0.7607	0.7759
Current density (amp/cm^2)		26.9698
R_a (μm)	0.8	0.7975
Z_2		-0.173371

Table 3 Comparative Results of Multi-Response Optimization of ECG Process

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