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Review Article

A Retrospective on Literature Review of Milling Parameter Optimization using Non-Traditional Optimization Methods

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Abstract

In current trend, it is known fact that cutting conditions of material such as feed, speed and depth of cut plays an important role in the industrial sector for manufacturing process. In this critical review, it has made an attempt to identify key issues addressed by the various researchers on machining parameter optimization of milling operations. This paper highlights the unconventional optimization approaches for optimizing the cutting parameters in milling operations. Refer to the review; the limitations, advantages, and applications of each technique which is classified as an unconventional approach is observed. By reviewing it is understood that each method has its own features that perform effectively and not related to certain optimization problems. Lastly, the authors concluded about various features of non-traditional optimization methods and their applications in an effective manner and also discussed about further scope of new methods in the area of milling machine parameter optimization.

Keywords: *Milling Operations, Unconventional Techniques, Optimization, Cutting Parameters.*

1. Introduction

Over the last few decades, there is a need for selecting and implementing the most suitable cutting tool for optimum machining conditions. The selection criteria based on cutting conditions such as feed rate, cutting speed and depth of cut to optimize the machining operations in economic way have identified since long. Metal cutting is a subject in which the industrial practice has always led to the theory. The metal cutting process necessarily postdates the development of modern machine tools. Machining has become indispensable to the modern industry. It is used directly or indirectly in the manufacture of almost all the goods and services being created all over the world. Moreover, advances in the field have generally resulted from changes in practice, particularly the introduction of new tool materials. Here the authors focused on machining parameters of milling machine which is essential for production of gears, keyways, T-slots and dove tail grooves on work pieces. In order to tackle and solve the various parameters of optimization problems, the most suitable tool is optimization techniques. Actually, optimization techniques are classified into two approaches; the first is conventional and second is unconventional. These optimization techniques have been initiated to solve combinational problems by optimizing the machining parameters.

The unconventional optimization approaches had been established as a prominent technique now a day's used to solve the problem of combinational issues of cutting parameters. Based on the literature in history, it is observed that unconventional optimization techniques are available in literature by more in number such as Simulated Annealing (SA), Tabu Search (TS), Ant Colony Algorithm (ACO), Particle Swarm Optimization (PSO), Sheep Flock Heredity Algorithm (SFHA), Music Based Harmony Algorithm (MBHA), and Glow Warm Algorithm (GWA). A.V.N.L. Sharma, K. Venkatasubbaiah Addressed about an investigation into the use of Taguchi parameter design and regression analysis to predict and optimize the surface roughness and metal removal rate in turning operations using CVD cutting tool. They stated that achieving a desired level of surface quality on turning parts requires practical knowledge and skill to set up this type of operation with the given specifications and conditions. Aggarwal and Hari Singh stated that unconventional approaches are applied usefully in industrial applications for optimal selection of process variables in the area of machining. Ali R. Yildiz states that in order to demonstrate the effectiveness of the unconventional approach, a milling optimization problem was solved and the results were compared with those obtained using other well-known optimization techniques.

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Table 1: Review on machining parameters of milling using non-traditional optimization technique

S.No	Author	Processing	Remark
1	M.Toulei-Rad, I.M.Bidahendi	Milling	The paper describes, development and utilization of an optimization system which determines optimum machining parameters for milling
2	M.R. Soleymani Yazdi, A. Khorram	Milling	Describes the selection of optimal machining parameters (i.e., spindle speed, depth of cut and feed rate) for face milling operations was investigated in order to minimize the surface roughness and to maximize the material removal rate.
3	N. Baskar · P. Asokan	Milling	Developed the optimization procedures based on the genetic algorithm, tabu search, ant colony algorithm and particle swarm optimization algorithm were developed for the optimization of machining parameters for milling operation
4	A.Gopala Krishna and K. Mallikarjuna Rao	Milling	Describes the application of a newly developed metaheuristic, the scatter search, for optimizing the machining parameters of milling operations. An objective function based on maximizing profit is used while considering the practical constraints, such as allowable speed and feed etc
5	Sunil Kumar, and Kulvinder Garg	Milling	The paper is based on Genetic Algorithm (GA) for optimization of process parameters (e.g. feed and speed) for multi-objective, multi pass end milling. GA has been implemented using the MATLAB environment on the objective function, which is a hybrid function of cost and time, feed and speed.
6	Ali R. Yildiz	Milling	Introduced cuckoo search algorithm for process parameter optimization and compared with other metaheuristic and analyzed the performance of cuckoo search
7	Maulik B. Nagarchi, Prof. D.A. Patel	Milling	Introduced harmony search algorithm for cutting parameter optimization for face-milling and compared with other metaheuristic and analyzed the performance of it
8	Reddy Sreenivasulu	Milling	Introduced desirability function analysis (DFA), which is a useful tool for optimizing multi-response problems and the application of desirability function analysis integrated with Taguchi technique proves to be an effective tool for optimizing multi response characteristics of machining parameters during end milling of GFRP composites
9	Shivasheshadri and Arunadevi	Milling	Developed the simulation model which develops the required machining time for each operation by specifying the exact tool and machining parameters. This project focuses on the minimization of machining time of the CNC Milling machine.
10	Bharat S Patel	Milling	Investigated the optimum machining parameters that can produce significant good surface finish.

In this paper, discussion was made on unconventional approaches for optimization of cutting parameters in milling processes and highlighted the advantages, limitations and applications.

2. Review on Non Traditional Approaches for Cutting Process

In current scenario, the need for precise and fast evaluation of many production parameters are governed by the enhancement in usage of sophisticated machine tools in modern industries. It is observed that, the constant issues which are confronting the manufacturing industries are selection of efficient cutting parameters by the researchers and is the main study of many researchers still. An important key point is that the selection of the optimal machining parameters leads to high quality of machining products, reduction in cost incurred for machining and enhancement in the effectiveness of machining process. As it is known that cutbacks of machining operations are playing vital role in manufacturing sector mainly depends on optimal machining parameters in the global competition. Many researchers have been focusing on machining parameters during the last few decades. A number of approaches have been developed and employed for solving various problems on machining parameters of milling by considering various objectives.

Sonti Sreeram and A. Senthil Kumar addressed about the micro end milling with fine grained carbide end mills and studied about the influence of depth of cut on tool life. They have considered the depth of cut also one of the decision variables in optimization problem. N. Baskar, P. Asokan developed the algorithm for the optimization of machining parameters for milling operation and observed significant improvement over the handbook and the method of feasible direction.

Vaibhav and Mukund made an attempt to obtain optimal turning parameters for minimum surface roughness value by using Ant Colony Optimization (ACO) algorithm in multipass turning operation and used multiple linear regressions for formulating the relationship between the machining parameters and determining the various performance measures. Milos Madic, Danijel Markovic compared various metaheuristic algorithms for solving machining optimization problems. They have applied these metaheuristic algorithms for five benchmark case studies considered from literature and compared with the results available in the literature.

Şeref Aykut focused on how to predict the surface roughness of customized material after machining process using ANN and investigated the effects of cutting tools with the same diameters, but with different cutting edges and tool materials on average surface roughness. U. Deepak addressed about optimization of milling operation using Genetic and PSO Algorithm and these techniques are used to optimize the machining parameters like depth of cut, feed rate and cutting speed which helps in better optimization of milling.

Jalili Saffar & Razfar stated that high precision and efficient machining are an important aspect in optimizing the cutting parameters using genetic algorithm. Finally, it is concluded that optimization of machining parameters using Genetic Algorithm led to minimal machining errors. R. Saravanan and M. Sachithanandam developed the Genetic Algorithm based optimization procedure to optimize the surface grinding process using a multi-objective function model by considering ten process variables are considered in this work: wheel speed, work piece speed, depth of dressing, lead of dressing, cross-feed rate, wheel diameter, wheel width, grinding ratio, wheel bond percentage, and grain size.

Ali R. Yildiz introduced a new optimization algorithm, called the cuckoo search algorithm (CS) algorithm for solving manufacturing optimization problems. Author found significant improvement with the Cukoo Search compared to the feasible direction method, ant colony algorithm, immune algorithm, hybrid particle swarm, hybrid immune algorithm, genetic algorithm and handbook recommendations

M.Toulei-Rad, I.M.Bidahendi focused on efficient utilization machine tools which is issued for manufacturing firms for many years. They found significant improvement in machining efficiency over the handbook recommendations. N. Baskar P.Ashokan studied the different unconventional optimization techniques such as GA, CACO, TS and PSO algorithm for the optimization of machining parameters in milling operations. They found significant improvement is obtained by the above techniques in comparison to the results by the handbook and the method of feasible direction. A.Gopala Krishna and K. Mallikarjuna Rao stated that the search mechanisms used in Scatter Search result in optimization procedures with the ability to escape local optimum points. They discussed that the highly promising outcome of this study suggests that SS can be a very useful tool for optimization of machining conditions. Similar to other metaheuristics, such as simulated annealing and genetic algorithms, SS is a generalized optimization methodology for machining optimization problems, since it has no restrictive assumptions about the objective function and constraint set. The table 1 discusses the Review on machining parameters of milling using nontraditional optimization techniques.

3. Latest Optimization Techniques

In investigation world of computational intelligence, there are so many latest techniques for optimization include simulated annealing, particle swarm method, scatter search technique, genetic algorithm, sheep flock heredity algorithm, etc.

3.1 Simulated annealing

Simulated Annealing (SA) is one of the earliest methods for derivative-free optimization such as Tabu Search (TS). Annealing is the metallurgical process of heating up a solid and then cooling slowly until it crystallizes. Atoms of this material have high energies at very high temperatures. This gives the atoms a great deal of freedom in their ability to restructure themselves. As the temperature is reduced the energy of these atoms decreases, until a state of minimum energy is achieved. In an optimization context Simulated Annealing seeks to emulate this process. SA begins at a very high temperature where the input values are allowed to assume a great range of variation. As the algorithm progresses temperature is allowed to fall. This restricts the degree to which inputs are allowed to vary. This often leads the algorithm to a better solution, just as a metal achieves a better crystal structure through the actual annealing process.

Methodology

Simulated Annealing implementation

Application of the SA algorithm requires definition of:

a) Initial population;
b) Initial temperature;
c) Perturbation mechanism;
d) Objective function;
e) Cooling schedule;
f) Terminating criterion.

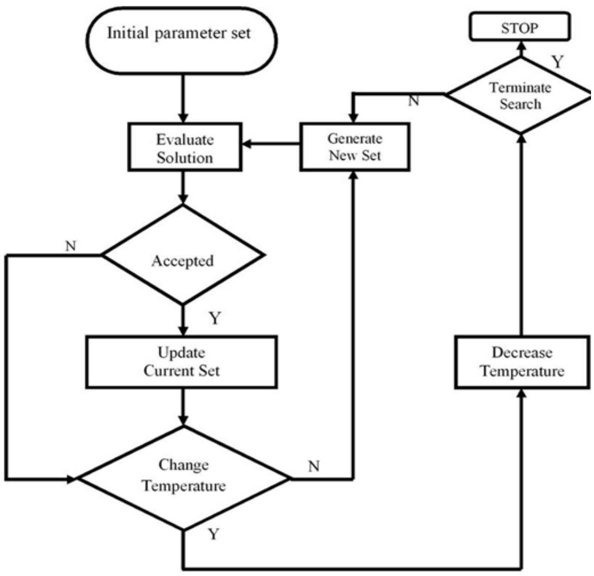

Fig 1: Flow chart of simulated annealing

The main feature of SA algorithm is the ability to avoid being trapped in local minima. This is done letting the algorithm as shown in figure 1 to accept not only better solutions but also worse solutions with a given probability. This means that the algorithm must be tuned in order to maximize its performance.

3.2 Genetic Algorithm

Genetic Algorithms are computerized search and optimization algorithms based on the mechanics of natural genetics and natural selection. They operate on the principle of "The survival of the fittest", where weak individuals die before reproducing, while stronger ones live longer and bear many offspring and breed children, who often inherit the qualities that enabled their parents to survive. The reproduced children are in most cases stronger than their parents. Figure 2 illustrate the genetic algorithm.

Genetic Algorithm Operates Through the Following Stages

- Creation of a "Population" of Chromosomes
- Evaluation of each chromosome
- Selection of "best" chromosomes
- Genetic manipulation to create the new population of chromosomes

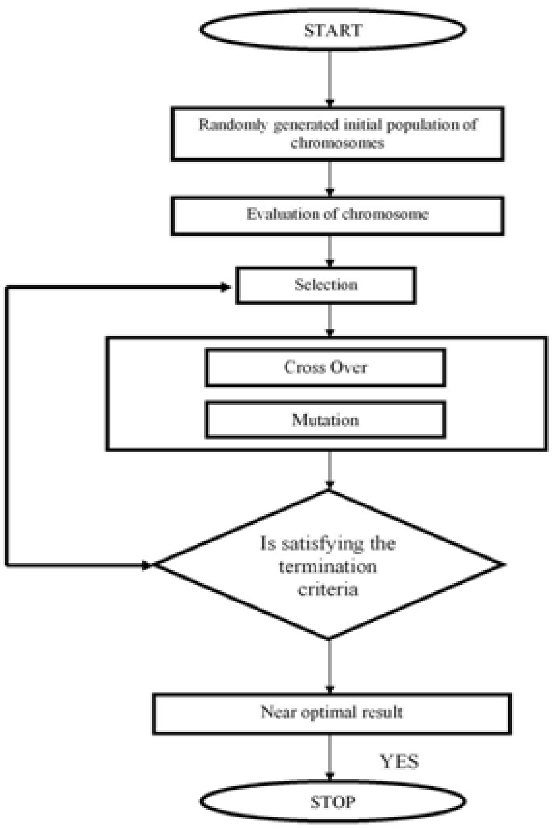

Fig 2: Flow chart of Genetic Algorithm

3.3 Particle Swarm Optimization

Particle swarm optimization (PSO) is one of the global optimization algorithms that works with a few of the control parameters used in the design update behavior. Particle swarm optimization (PSO) is a population-based stochastic optimization technique modeled on the social behaviors observed in animals or insects, e.g., bird flocking, fish schooling, and animal herding. Particle swarm optimization (PSO) is an evolutionary computation technique mimicking the behavior of flying birds and their means of information exchange. In PSO a number of particles are moved in the search space through a systematic approach. The figure 3 represents PSO flow chart.

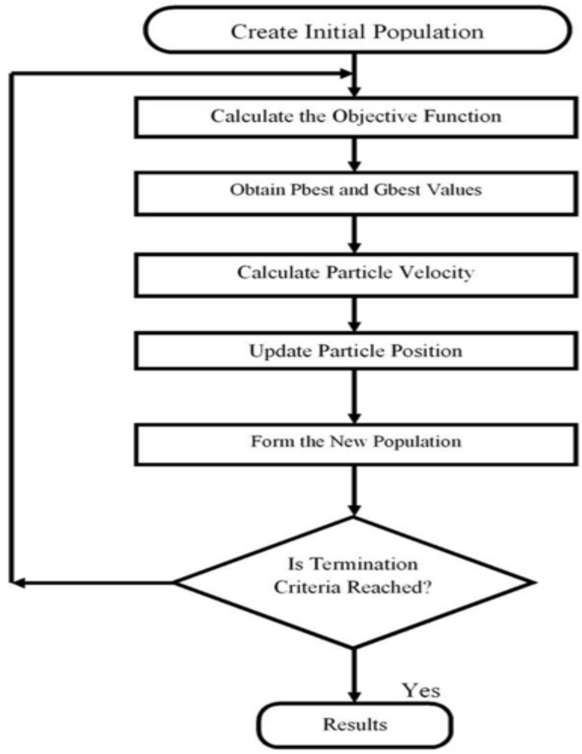

Fig 3: Flow chart of PSO

3.4 Scatter Search Algorithm

Scatter search (SS) was first introduced by Glover (1977) as a heuristic for integer programming. In the original proposal, solutions are purposely (i.e., non-randomly) generated to take account of characteristics in various parts of the solution space. The orientation of SS is to explore systematically relative to a set of reference points that typically consist of good solutions obtained by prior problem solving efforts, where the criteria for "good" are not restricted to objective function values. In this way, SS shares with other evolutionary methods the philosophy of operating on a set of solutions rather than on a single solution at a time. The figure 4 shows Scatter Search Algorithm.

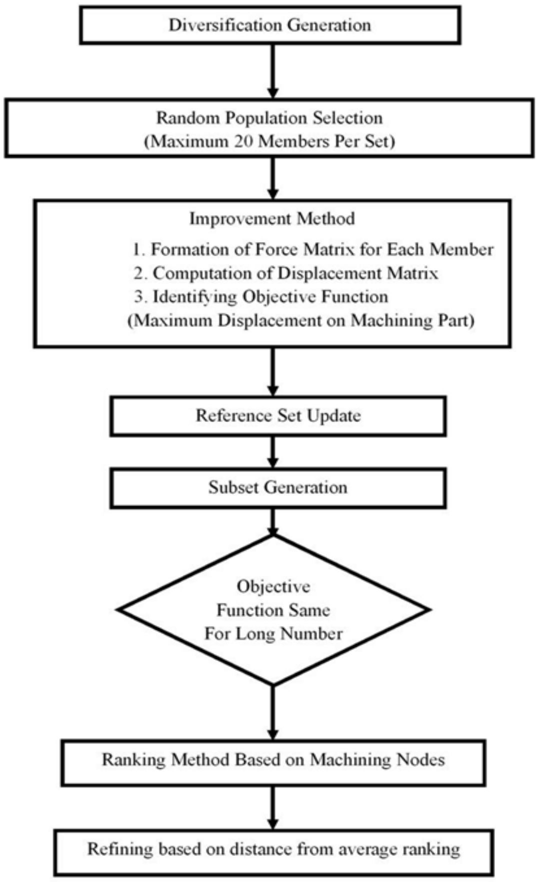

Fig 4: Flow chart of Scatter search method

3.5 Sheep Flock Heredity Algorithm

A Sheep flock algorithm was developed by Kim and Ahn . Normally, sheep in an each flock are living within their own flock under the control of shepherds. So, the genetic inheritance only occurs within the flock in other words, some special characteristics in one flock develop only within the flock by heredity, and the sheep with high fitness characteristics of their environment breed in the flock. Assume there are two flocks occasionally mixed with the other flocks. The characteristics of the sheep in neighboring flocks can be inherent to the sheep in this flock. In the field, the flock of the sheep, which has better characteristics of the field environment, breeds most.

The natural evolution phenomenon of flocks can be corresponded to the genetic operations of this type of string. For this kind of string, we can define two kinds of operations.

- Normal genetic operations between strings.
- Genetic operations between sub-strings within one string. In SFHA, special string structure and hierarchical genetic operations (crossover and mutation) are introduced. They are (a) sub-chromosome level genetic operation and (b) chromosome (global) level genetic operation. This hierarchical operation is referred to as "multi-stage-genetic operation".

Conclusion

This paper has discussed five optimization techniques that are classified as a non-conventional technique during machining which are, SA, GA, PSO, SSM and SFHM.

1. Methodology and procedure of each technique have been discussed in relation to milling. This literature specified that various traditional machining optimization techniques like the Lagrange's method, geometric programming, goal programming, dynamic programming etc. have been successfully applied in the past for optimizing the various turning process variables are not effective.
2. Genetic algorithm, scatter search, Particle swarm method, sheep flock heredity method, etc. are the latest optimization techniques that are being applied successfully in industrial applications for optimal selection of process variables in the area of machining.
3. A review of literature on optimization techniques has revealed that there are, in particular, successful industrial applications for optimal settings of process variables.

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