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OPTIMIZATION OF CUTTING PARAMETERS IN MULTIPASS TURNING OPERATION USING ANT COLONY ALGORITHM

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Abstract

In this paper, attempt is made to obtain optimum turning parameters for minimum surface roughness value by using Ant Colony Optimization (ACO) algorithm in multipass turning operation. The cutting process has roughing and finishing stage. Also the relationship between the parameters and the performance measures were determined using multiple linear regression, this mathematical model is used to determine optimal parameters. The experimental results shows that the proposed technique is both effective and efficient.

Index Terms: *Key Ant colony algorithm, Pheromone, Optimization, Turning, cutting parameters.*

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1. INTRODUCTION

Metal cutting is one of the important and widely used manufacturing processes in engineering industries. In the study of metal cutting focus is set on the features of tools, input work materials, and machine parameter settings. These factors influence the process efficiency and output quality. A considerable improvement in process efficiency may result the great advantage in collective economics of industry.[7]

The selection of optimal cutting parameters is a very important issue for every machining process in order to enhance the quality of machining products, to reduce the machining costs and to increase the production rate. Due to machining costs of Numerical Control a machine (NC), there is an economic need to operate NC machines as efficiently as possible in order to obtain the required pay back. In workshop practice, cutting parameters are selected from machining databases or specialized handbooks, but they don't consider economic aspects of machining. The cutting conditions set by such practices are too far from optimal. Therefore, a mathematical approach has received much attention as a method for obtaining optimized machining parameters.[4,5,10]

The cutting parameters must be so selected that the machine is utilized to the maximum possible extent. Therefore developing a mathematical model to obtain optimum parameters will become essential.

In contest of survival, the quality of product plays an vital role. To achieve best quality with minimum cost it is very essential that machining parameters which are to be used must be optimized prior. Keeping in view, in this attempt we tried to obtain optimum cutting parameters like cutting speed, feed rate and depth of cut which gives minimum surface roughness value. For this we used Ant colony algorithm.

2. LITERATURE REVIEW

Many researchers focused their research on optimization of cutting parameters in machining. W.H. Yang used three cutting parameters; speed, feed and depth of cut for achieving quality surface finish and improve tool life and using Taguchi technique for optimization of cutting parameters obtained the optimum result.[5] K. Vijayumar also find the optimum cutting parameters for multipass turning to produce component at minimum production cost. for their research they used ACO tool. [2] Researchers compared their result with the result obtained by other technique such as GA, PSO, etc. and found that the result obtained by ACO are good as compared to other. Though Yi-Chi Wang is not agree with the result and conclusion of Mr. Vijaykumar and he criticized the same showing that the result obtained are wrong for single pass operation.[3] Ersan Aslan work for to get the minimum tool flank wear using Taguchi technique. M. Milfelner worked on reduction of cutting force in ball end milling using genetic equation. [7] Researcher has experimentally proved that the setting of optimum parameter during the machining will increases the tool life. [6]

3. EXPERIMENTAL PROCEDURE:

3.1 Experiment and material

The goal of this experimental work was to investigate the effects of cutting parameters on surface roughness, and to establish a correlation between them. In order for this, cutting speed, feed rate and depth of cut were chosen as process parameters.

The work material was Oil Hardened Non shrinkable Steel (OHNS) steel in the form round bars of 50 mm diameter and 100 mm length. The chemical composition of the work material is given in the Table1. The OHNS steel is used in industries for producing Gauges, Plug Gauges, Punches, Ring Gauges, Thread Gauges, Weighing Machine Pivots etc

The turning operation is carried by using the water as a coolant on CNC Turning Centre of make LMW Machine Tool Division having Spindle speed range, rpm: 45-4300 and
Feed range: 1-20m/min. The cutting tool used was CNMG 120408 TF IC907 ISCAR

Three levels were specified for each process parameter as given in the Table 2. The parameters levels were chosen within the range recommended by the cutting tool manufacturer. In each run same amount of the material is removed from the work material. Turning operation is as carried on the cutting length of 70 mm and the diameter is reduced from 50 to 44 mm in subsequent number of passes.

3.2 Design of experiment

The three levels were specified foe each of the factors as indicated in Table 2. The orthogonal array chosen was L9 which has 9 rows corresponding to the number of parameter conditions. This array has eight degrees of freedom and it can handle three-level design parameters. Each cutting parameter is assigned to a column, nine cutting-parameter combinations being available. Therefore, only nine experiments are required to study the entire parameter space using the L9 orthogonal array. The experimental layout for the three cutting parameters using the L9 orthogonal array is shown in Table 3. One test was performed for each combination resulting in a total of 9 tests. (no replication). Also a random order was determined for running the test.

Table 1: Chemical Composition of OHNS

C	Si	Mg	Cr	Tungsten	Vanadium
0.9 to 1.0 %	0.3 to 0.5%	0.7 to 0.8%	0.5 to 0.6%	0.5 to 0.6 %	1.0 %

Table 2. Levels of process parameter

Process Parameter	Level-1	Level-2	Level-3
Feed Rate (mm/rev)	0.1	0.15	0.2
Cutting Speed (m/min)	150	200	250
Depth of Cut (mm)	0.5	1	1.5

Table 2 : L9 orthogonal array (design of experiment to conduct the experiment)

Experiment No.	Cutting Parameter Level		
	Cutting Speed	Feed Rate	Depth of cut
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

4. EXPERIMENTAL RESULTS AND DATA ANALYSIS

The plan of the experiment was developed to obtain value of surface finish which is used to develop mathematical model to predict the surface finish for intermediate values of cutting speed(v), feed rate (f) and depth of cut (d) inside the constrained limits. Table 4 illustrates the experimental results for surface finish. Surface finish is measured by using the surface tester, Surftest- SJ 210 of make Mitutoya. Sampling length for measurement is 0.8 mm, Cut of length : 0.8 x 5 = 4 mm and Probe velocity : 0.5 mm/sec. The method followed for the measurement is as per the ISO 1997.

5. MATHEMATICAL MODEL DEVELOPMENT:

The relationship between the factors and the performance measure was modeled by multiple linear regression. At the time of model development the effect of interaction of cutting parameters such as cutting speed-depth of cut (vd), cutting speed-feed rate (vf) and feed rate – depth of cut (fd) are also considered. The regression equations obtained was as follows:

Ra = 8.11 - 0.0217 v - 25.9 f - 6.37 d + 0.0563 vf + 0.0153 vd + 19.4 fd

$$R^2 = 99.8\%$$

This equation gives the expected value of surface roughness (Ra) for any combination of factor levels provided that the levels are within the ranges in Table2

R2-values for the regression equation is high enough to obtain reliable estimates.

We have used the same mathematical model in our analysis for finding minimum surface roughness value.

Table 4: Surface Roughness value (Ra)

Run No.	Cutting Speed (m/min)	Feed (mm/rev)	Depth of cut (mm)	Average Surface Roughness Ra (μm)
1	150	0.1	0.5	2.053
2	150	0.15	1	1.08
3	150	0.2	1.5	1.064
4	200	0.1	1	0.898
5	200	0.15	1.5	1.009
6	200	0.2	0.5	1.127
7	250	0.1	1.5	0.594
8	250	0.15	0.5	1.115
9	250	0.2	1	1.638

5. OPTIMIZATION PROBLEM:

Objective Variable:
For this analysis we considered main three machining parameters as objective variable i.e. Cutting speed (V), Feed rate (f) and Depth of cut (d).

Objective function:
Our aim is to obtain the cutting parameters for minimum surface roughness value. So, the required objective function is
Min. Ra = f(V, f, d)

Constraints:
Optimum results are obtained under the constraints of :
Vmax > V > Vmin
fmax > f > fmin
dmax > d > dmin

6. ANT COLONY OPTIMIZATION METHODOLOGY

Ant colony optimization is a new approach to solve complex optimization problem. It is a population based technique. This technique is based on behaviour of real ants. Researcher are surprised by seeing that the ability of the almost blind ants in establishing the shortest route from their nest to food source and back. These ants depart a chemical on their path which is called as 'Pheromone'. This pheromone is a communication media between the ants. Real ants follow the route which has more pheromone deposition.

Many researchers tried this algorithm to solve engineering problem. Basically it is suitably used for traveling salesman routine problem. Its use is not limited to that only but can be used for solving other engineering problem also. ACO was presented as an effective optimization procedure by introducing bi-level search procedure called local and global search.

6.1 Steps followed in ACO.
The proposed ant colony algorithm for optimization of cutting conditions in multi-pass turning is shown as scheme in Figure 2. The distribution of ants is shown in Figure 1.

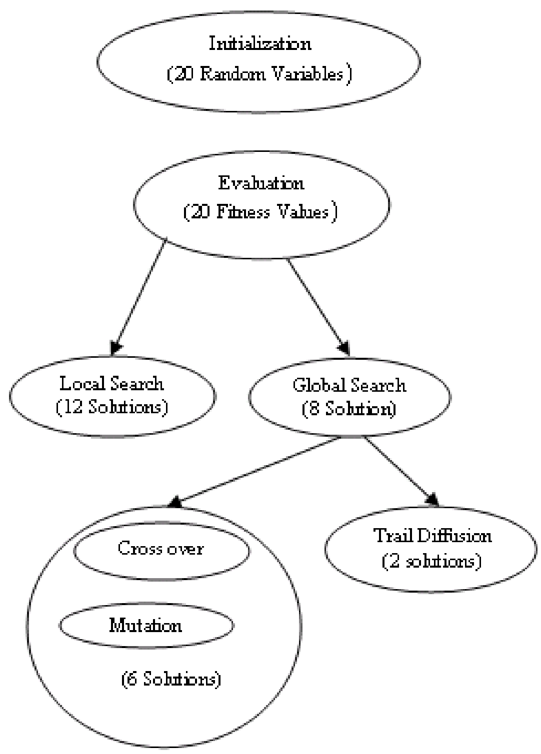

Fig. 1 Artificial Ant Distribution

The proposed ACO algorithm for optimization of cutting parameters with objective of minimizing surface roughness value will go through the following steps.

6.1 Step 1: Initial Solution:

In first step 20 solutions are generated randomly, with the values that lie within the given constraints. After this these 20 solutions are arranged in ascending order. The region which has lower roughness value is referred as superior solution, while region having larger roughness values is called inferior solutions.

6.2 Step 2 Global Search:

Global search is applied on only inferior solutions. Following three operators are to be performed on the randomly generated solutions.
a. Cross over
b. Mutation
c. Trail diffusion

6.2.1 Cross over

Cross over is divided in three sections. Firstly generate two random numbers and select the initial solution form superior region corresponding to these random numbers. These solutions are noted as parent1 and parent2. Secondly generate another integer random number and according to it the position of digit in solutions of parent1 and parent2 are interchanged to get child1 and child2. In last section of crossover the solution of child1 and child2 are decoded and its fitness value is assessed. The solution which has closer fitness value will replace the inferior solution.

6.2.2 Mutation.

In this step also the inferior solution obtained after cross over is repaired. Randomly adding or subtracting a value to each variable of the newly create solution in the inferior region with a suitably defined mutation probability.

6.2.3 Trail Diffusion.

It is another element in global search. This is applied on inferior solutions which were yet not considered for crossover or mutation. Here two parents are selected at random from superior solutions obtained child can have either

1. the value of corresponding variable from the first parent
2. the corresponding value of the variable from second parent
3 or a combination arrived from a weighted average of the above

$$X_{child} = \alpha \,.X_i(parent1) + (1-\alpha).X_i(parent2)$$

Where α is uniform random number between 0 -1

6.3 Step -3 . Local Search :

In ACO local ants select a region with a probability ,

$$P_i(t) = \frac{\tau_i(t)}{\sum \tau_k(t)}$$

Where i is the region index and $\tau_i(k)$ is the pheromone trail on region i at time t. After selecting the region ant moves through a short distance (finite random increment). If the fitness is improved, the new solutions are updated to the current region. Correspondingly the regions position vector is updated.
In continuous algorithm, the pheromone values are decreased after each iteration by:

$$\tau_i(t+1) = \rho\, \tau_i(t)$$

where ρ is the evaporation rate which is assumed to be 0.2 on trial basis and $\tau_i(t)$ is the trail associated with solution at time t.

7. RESULT:

To solve the Ant colony algorithm a program is prepared in Mat-LAB by attempting the steps in flowchart as shown in Fig1.
The final optimum result is obtained after 500 iterations which is shown in Table 5. The final number of iterations is decided by trial and error method and the program will give constant result for 500 iterations.

Table 5: Optimum cutting parameters and surface roughness value.

No. of Iteration	Cutting Speed (m/min)	Feed rate (mm/rev)	doc - d (mm)	Ra Value
500	150	0.1032	1.4677	0.0114

8. DISCUSSION:

Generally in machining it is considered that the better surface finish is obtained at high cutting speed with minimum feed and depth of cut. Result obtained by ACO algorithm for minimization of surface roughness value shows that the minimum Ra values is obtained at minimum cutting speed with minimum feed and high depth of cut. This result shows controversy with general consideration regarding speed and depth of cut. This may be interpreted as, for finish cut if we have major depth of cut it will remove any projection completely remain in rough cut and we have best surface finish.

9. CONCLUSION:

In this work, non-conventional method of optimization ACO was studied. ACO is used to find optimum cutting parameters in turning operation.

ACO is problem independent so that it can be easily modified to optimize this turning operation under various conditions.
It can obtain a near- optimal solution in an extremely large solution space within a reasonable time.

It requires less number of iteration to reach to optimal solution.
It can be used for other machining process like milling, drilling etc.

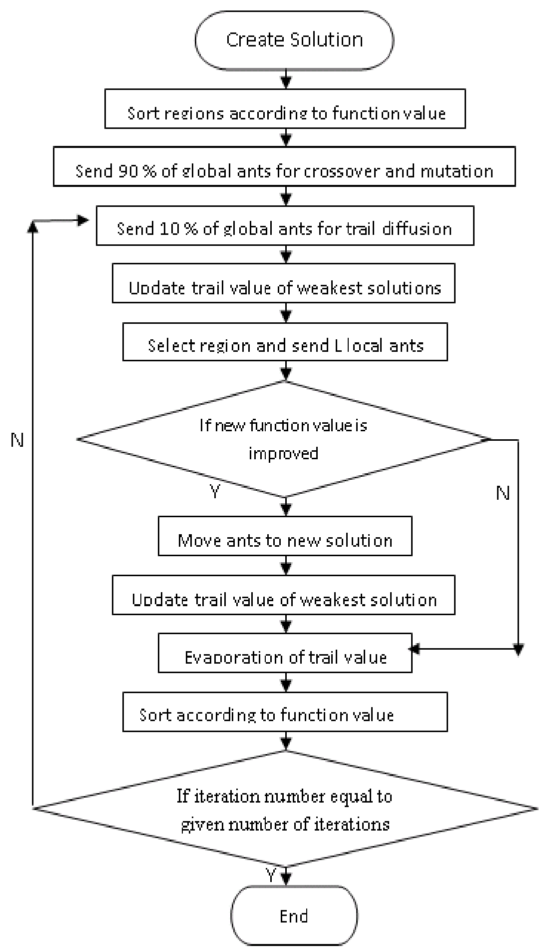

Fig.2 Flow chart for the ant colony algorithm.

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