DETERMINATION OF OPTIMAL CUTTING CONDITIONS USING DESIGN OF EXPERIMENTS AND OPTIMIZATION TECHNIQUES

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***Abstract*— In machining operations, achieving desired surface quality features of the machined product, is really a challenging job. Because, these quality features are highly correlated and are expected to be influenced directly or indirectly by the direct effect of process parameters or their interactive effects (i.e. on process environment). However, the extents of significant influence of the process parameters are different for different responses. Therefore, optimization of surface roughness is a multi-factor, multi-objective optimization problem. Therefore, to solve such a multi-objective optimization problem, it is felt necessary to identify the optimal parametric combination, following which all objectives could be optimized simultaneously. In the present work, Design of Experiment (DOE) with Design of Expect software, Mini Tab & optimized using genetic algorithm by MAT Lab and Particle Swarm Optimization (PSO) by "C" program in straight turning operation. Collected data related to surface roughness have been utilized for optimiation. Due to complexity of this machining optimization problem, a genetic algorithm (GA) and Particle Swarm Optimization (PSO) are applied to resolve the problem and the results obtained from GA and PSO are compared.**

***Keywords*— Machining Operation (turning); Surface Roughness; Lathes Machines and Mathematical Model.**

I. INTRODUCTION

Surface roughness has received serious attention for many years. It has formulated an important design feature in many situations such as parts subject to fatigue loads, precision fits, fastener holes, and aesthetic requirements. In addition to tolerances, surface roughness imposes one of the most critical constraints for the selection of machines and cutting parameters in process planning. A considerable number of studies have investigated the general effects of the speed, feed, and depth of cut on the surface roughness.

To improve the efficiency of these turning processes, it is necessary to have a complete process understanding and model. To this end, a great deal of research has been performed in order to quantify the effect of various hard turning process parameters to surface quality. These factors can be divided into a) setup variables, b) tool variables, and c) work piece variables.

II. LITERATURE SURVEY

Parametric Analysis and Optimization of Cutting Parameters for Turning Operations based on Taguchi Method was found **S.S.Mahapatra Amar Patnaik Prabina Ku. Patnaik (1)**.

On-line optimization of the turning using an inverse process neurocontroller, Transactions of ASME was found **R. Azouzi, M. Guillot (2).**

Surface roughness prediction models for fine turning were found **A. Mital, M. Mehta (3).**

Optimal selection of process parameters for turning operations in a CAPP system was found **V. S. R. Prasad (4).**

Determination of optimal subdivision of depth of cut in multi-pass turning with constraints was found **R. Gupta (5).**

III. PROBLEM DISCRIPTION

To find the optimum machining parameters in order to get the minimum surface roughness. Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) are used to do this and the results are compared.

We have taken 14 samples of turning operation in finishing cut the values of the speed, feed and depth of cut and their respective surface roughness. The value obtained in this by varying three parameter are taken in design of expect V-8 software to obtain an equation. In the response surface methodology the linear and second order polynomials were fitted to the experimental data for obtaining regression equations.

And then using Particle Swarm Optimization (PSO) algorithm we can obtain the optimization value by using C-program and similarly optimized using genetic algorithm by MAT Lab.

IV. EXPERIMENTAL PART

The present study has been done through the following plan of experiment.

a) Checking and preparing the Centre Lathe ready for performing the machining operation.

b) Cutting ***S45C*** bars by power saw and performing initial turning operation in Lathe to get desired dimension (of diameter 59 mm and length 100mm) of the work pieces.

c) Performing straight turning operation on specimens in various cutting environments involving various combinations of process control parameters like: spindle speed, feed and depth of cut.

d) Measuring surface roughness and surface profile with the help of a portable stylus-type profilometer, Talysurf (Taylor Hobson, Surtronic 3+, UK)

CUTTING TOOL:

Tungsten carbide with the grade of P-10

Tungsten carbide also called cemented carbide, hard metal. There are 2 compounds of tungsten and carbon, WC and tungsten semi carbide.

WORKPICE MATERIAL:

S45C OR Equivalent Alloy (1045)

Surface roughness. Particle Swarm Optimization (PSO) and Genetic Algorithm (GA) are used to do this and the results are compared.

TABLE I: COMPOSITION

METALS	**COMPOSITION**	
	MIN	**MAX**
Carbon	0.42	0.48
Silicon	0.15	0.35
Manganese	0.60	0.90
Phosphorus	max0.03	
Sulphur	max0.035	
IRON	REMAINING	

TABLE 4.1: PROCESS VARIABLES AND THEIR LIMITS

Variables		**Values of different levels**		
Designation	**Description**	**Low (-1)**	**Medium (0)**	**High (+1)**
D	Depth of cut (mm)	0.6	1.00	1.60
F	Feed rate (mm/rev)	.08	0.2	0.32
V	Cutting speed (m/min)	135	210	285

Measuring Surface Roughness:

Roughness measurement has been done using a portable stylus-type profilometer, Talysurf (Taylor Hobson, Surtronic 3+, UK).

Experiments have been carried out using Taguchi’s L27 Orthogonal Array (OA) experimental design which consists of 27 combinations of spindle speed, longitudinal feed rate and depth of cut. By obtain Taguchi’s L27 Orthogonal Array the experiment have be conducted and the value of the particular feed, speed and depth of cut are given below has been done through the following plan of experiment.

TABLE -4.2 EXPERIMENTAL RESULTS

S.no	**Cutting speed**	**Feed rate**	**Depth of cut**	**Surface Roughness**
	m/min	**mm/rev**	**mm**	**µm**
1	135	.08	0.6	2.086
2	135	.08	1	2.338
3	135	.08	1.6	2.522
4	135	.2	0.6	4.326
5	135	.2	1	4.714
6	135	.2	1.6	5.044
7	135	.32	0.6	6.887
8	135	.32	1	7.2362
9	135	.32	1.6	7.788
10	210	.08	0.6	3.414
11	210	.08	1	3.618
12	210	.08	1.6	3.773
13	210	.2	0.6	5.966
14	210	.2	1	6.1983
15	210	.2	1.6	6.363
16	210	.32	0.6	8.041
17	210	.32	1	8.197
18	210	.32	1.6	8.303

V. EXPERIMENTAL RESULTS AND ANALYSIS

The experimental results are presented in Table given below For the purpose of developing the mathematical model; both the data for the machining responses and factors were logarithmically transformed. Using these sets of data, the parameters for the mathematical models were determined using the multiple regression method and the significance of the models and the parameters were then analyses using analysis of variance. In this work, a commercially available statistical software package DOE was used for the computation of regression and statistical analysis of the constants and parameters. The procedure PROC REG from this package was used to compute values of the mathematical models and to carry out the analysis of variance for the models developed. In the following sections, the significance of each model developed will be discussed.

The experimental value were obtain form the experiment is given the following table 5.1 and 5.2 and by using above software's the mathematical equation is obtain in term of speed, feed and depth of cut for the surface roughness.

USING DESIGN-EXPECT SOFTWARE SURFACE ROUGHNESS (Ra)

TABLE 5.1 ANOVA FOR RESPONSE SURFACE QUADRATIC MODE

	Sum of Squares	**DoF**	**Mean**	**F**	**p-value**	
Source				**Value**	**Prob >F**	
Model	110.48	9	12.2	561.25	< 0.001	**Significant**
A-A	15.68	1	15.68	717.07	< 0.001	
B-B	18.69	1	18.69	854.57	< 0.001	
C-C	0.72	1	0.72	33.09	< 0.001	
AB	0.889	1	0.889	40.66	< 0.001	
AC	0.182	1	0.182	8.352	0.102	
BC	4.18E-05	1	4.18E-05	0.0019	0.9	
A^2	0.437	1	0.437	19.9	0.003	
B^2	73.3	1	73.37	3354.6	< 0.001	
C^2	0.0019	1	0.0019	0.087	0.77	
Residual	0.37	17	0.021			
Total	110.86	26				

TABLE 5.2 ANALYSIS OF VARIANCE (ANOVA) FOR SURFACE ROUGHNESS

Actor	**Coeffic Estima**	**Df**	**Stand Error**	**95% CI Low**	**95% CI High**	**VIF**
Interce	3.68	1	0.077	3.51811	3.8431	
A-A	0.93	1	0.034	0.86275	1.0103	1.0
B-B	-1.02	1	0.034	-1.09618	-0.948	1.0
C-C	0.20	1	0.034	0.127008	0.2741	1.0
AB	0.27	1	0.042	0.18219	0.3623	1
AC	-0.12	1	0.042	-0.21206	-0.033	1.0
BC	-0.00	1	0.042	-0.09134	0.0876	1.0
A^2	-0.26	1	0.060	-0.39735	-0.142	1
B^2	3.49	1	0.060	3.369696	3.6244	1
C^2	-0.01	1	0.063	-0.15227	0.1148	1.0

Final Equation in Terms of Coded Factors:

$$Ra = + 6.184 + 0.9711 * A + 2.2593 * B + 0.1811 * C - 0.1991 * A * B - 0.0989 * A * C - 0.0018 * B * C - 0.2677 * A2 - 0.21277 * B2 - 0.06667 * C2$$

Final Equation in Terms of Actual Factors:

$$Ra = -5.257 + 0.0402 * A + 29.4195 * B + 1.50896 * C - 0.0221 * A * B - 0.0016637 * A * C - 0.0311 * B * C\ 4.8\,e{-5} * A2 - 14.776 * B2 - 0.266666 * C2$$

VI. *OPTIMIZATION OF CUTTING PARAMETERS*

A.PARTICLE SWARM OPTIMIZATION (PSO)

In recent years, the collective behavior of large numbers of moving cooperative agents, frequently called particles, has proven to be useful in the fields of optimization and control.

The collection of these particles is called a swarm and its application is referred to as swarm intelligence. The power of swarm intelligence is that simple behavior on the local level can result in useful, often more complex, and behavior on the global level. Even if the individual agents are too simple for the label 'intelligent', the swarm often does manifest intelligent behavior. The global behavior of the swarm is difficult to predict based on the local dynamics of the particles

B. GENETIC ALGORITHM

Machining optimization problem requires a robust search method (Robustness means numerical stability and ability to find a solution for a wide range of algorithmic parameters), which runs well in complex situations. The genetic algorithm **(GA)** approach has been selected firstly because their behavior is robust and so far efficient and secondly more and more attention is being is drawn to GA in a variety of disciplines. Evolution program started in the sixties when a group of biologists used digital computers to simulate genetic systems.

VII. CONCLUSIONS

GENETIC ALGORITHM

A neural network is created based on experimental values is used instead of mathematical models and optimized machining parameters are found using Genetic algorithm.

By training the network using single objective function and using genetic algorithm optimum speed, feed and depth of cut are evaluated and the corresponding values of objective functions for corresponding speed feed and depth of cut are found and the results are as follows.

1. By optimization of surface Roughness

Optimum speed = 145.405 m/min
Optimum feed = 0.0876 mm/rev
Optimum depth = 0.6057 mm
Minimized surface roughness =2.494 µm

PARTICLE SWARM OPTIMIZATION

By obtained equation form the design of expect software and written particle swarm optimization in c-language the program obtain the corresponding value of objective function for corresponding speed feed and depth of cut are found and the results are as follows.

2. By optimization of surface Roughness

Optimum speed = 145m/min
Optimum feed = 0 .08 mm/rev
Optimum depth = 0.6 mm
Minimized surface roughness =3.199 µm

Based on the conducted experiments and accomplished analysis, the following conclusions can be made:

1. The speed and feed rate are the most significant factors in surface roughness model.
2. All types of lathe machines have been used to produce continuous finished profiles. A continuous finished profile has many types of operations such as turning. To model the machining process, several important operational constraints have been considered. These constraints were taken to account in order to make the model more realistic. A model of the process has been formulated with non-traditional algorithms; GA and PSO have been employed to find the optimal machining parameters for the continuous profile. GA produces better results.

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