Optimization of Machining Parameters for Turning Using Genetic Algorithm

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Abstract –
Optimization of machining parameters is an important research area for achievement of higher productivity and high-quality products to retain and improve market share in the current competitive scenario. This project aims at multi-objective optimization of turning process on C45 grade medium carbon steel for an optimal parametric combination to provide the minimum surface roughness (Ra) with the maximum material-removal rate (MRR) using the Genetic Algorithms. Turning parameters considered are cutting speed, feed rate and depth of cut.
Eighteen experimental runs based on Taguchi's L18 orthogonal array were performed followed by the Response Surface method (RSM) to model the problem. The significance of chosen parameters on overall quality characteristics of the cutting process has been also analyzed by Response Surface method (RSM). Genetic algorithm is used to optimize the multi-response optimization problem. The optimal parameter values obtained during the study have been validated by confirmation experiment

1. INTRODUCTION

Machining is a process designed to change the size, shape, and surface of a material through removal of materials that could be achieved by straining the material to fracture or by thermal evaporation. Offers important benefits such as excellent dimensional tolerances, External and internal geometrical features, Surface finish and Economical if small quantities despite of the limitations that include Material waste, Time consuming, Energy, capital and labor intensive.

Turning: Turning is a machining process used to make cylindrical parts, where the cutting tool moves in a linear fashion while the work piece rotates. Commonly performed with a lathe, turning reduces the diameter of a work piece, typically to a specified dimension, and produces a smooth part finish. A turning center is a lathe with a computer numerical control.

Computer numerical controlled (CNC) lathes are rapidly replacing the older production lathes (multispindle, etc.) due to their ease of setting, operation, repeatability and accuracy. They are designed to use modern carbide tooling and fully use modern processes. The part may be designed and the tool paths programmed by the CAD/CAM process or manually by the programmer, and the resulting file uploaded to the machine, and once set and trialled the machine will continue to turn out parts under the occasional supervision of an operator.

The machine is controlled electronically via a computer menu style interface, the program may be modified and displayed at the machine, along with a simulated view of the process. The setter/operator needs a high level of skill to perform the 7 process, however the knowledge base is broader compared to the older production machines where intimate knowledge of each machine was considered essential. These machines are often set and operated by the same person, where the operator will supervise a small number of machines (cell).

OBJECTIVE OF THE WORK:

The objective of the present work is to determine the optimum cutting parameters and also which factor has major influence on C45 steel during CNC Turning. RSM is used to determine the effect of factors on each response variable and to create a model for each response variable. Further fuzzy goal programming is used to convert a multiobjectve optimization problem to a single objective optimization problem. Finally genetic algorithm is used to optimize the values of response variables and determine the corresponding values of design variables.

2.Genetic Algorithms:

Genetic Algorithms (GAs) are adaptive heuristic search algorithm based on the evolutionary ideas of natural selection and genetics. As such they represent an intelligent exploitation of a random search used to solve optimization problems. Although randomized, GAs are by no means random, instead they exploit historical information to direct the search into the region of better performance within the search space. The basic techniques of the GAs are designed to simulate processes in natural systems necessary for evolution, specially those follow the principles first laid down by Charles Darwin of "survival of the fittest.". Since in nature, competition among individuals for scanty resources results in the fittest individuals dominating over the weaker ones

Overview of Genetic Algorithm:

GAs simulates the survival of the fittest among individuals over consecutive generation for solving a problem.

Each generation consists of a population of 22 character strings that are analogous to the chromosome that we see in our DNA. Each individual represents a point in a search space and a possible solution.

The individuals in the population are then made to go through a process of evolution. GAs are based on an analogy with the genetic structure and behaviour of chromosomes within a population of individuals using the following foundations: Individuals in a population compete for resources and mates.

3.METHODOLOGY:

Reducing production cost and achieving desired quality of product is never fulfilled and continuous research work is being done to determine the optimal cutting parameters to achieve the above goals.

In turning process material removal rate (MRR) is considered as the factor that directly affects the rate of production, hence there by cost. Minimizing Surface roughness (Ra) is the most important technical requirement for achieving the desired surface quality which affects the functional behavior of a mechanical component.

Both MRR and surface roughness are influenced by various factors like cutting speed, feed, depth of cut and nose radius of tool and their levels.

ACTION PLAN:

1.Selection of process parameters and their levels

2. Selection of quality characteristics of reach response variable

3. Taguchi Design of Experiments

4. Experimentation as per Taguchi DOE

5. Analysis of various process parameters and their contribution on optimum values of response parameter and modeling.

6. Optimization of response parameters and determination of respective process parameters individually using genetic algorithm.

7. Conversion of multi-objective into single objective function to obtain optimal process parameters for Both MRR and Surface roughness using Fuzzy goal programming.

8. Multi –objective Optimization of the response parameters and determination of respective process parameters using genetic algorithm.

9. Determining the results at optimum conditions.

10. Confirmation of experiments.

Selection of process parameters and their levels:

Table 4.1: Controlled parameters for turning on CNC lathe

Parameters	Levels 1	Level 2	Level 3
Spindle speed (RPM)	2500	3000	3500
Feed (mm/rev)	0.1	0.15	0.2
Depth of cut (mm)	0.4	0.8	1.2
Nose radius (mm)	0.4	0.8	-

4.Selection of quality characteristics of each response variable:

► Material Removal Rate (MRR): Productivity is greatly influenced by material removal rate in any machining operation. Hence the quality requirement for Material Removal Rate (MRR) in "Higher the Better" Material Removal Rate (MRR) is defined as the ratio of volume of material removed to the cutting time. It is given by $Volume$ of $material\ removed$

▶ MRR = *cutting time Inital volume* of work *piece*−*final volume* of work *piece*/*cutting time* .

▶ Surface Roughness: The quality of machined surface is characterized by the accuracy of its manufacture with respect to the dimensions specified by the designer. Every machining operation leaves characteristic evidence on the machined surface. This evidence in the form of finely spaced micro irregularities left by the cutting tool. Each type of cutting tool leaves its own individual pattern which therefore can be identified. This pattern is known as surface finish or surface roughness

Factors affecting surface roughness:

The major variables which affect the surface roughness are

▶ 1. Cutting speed

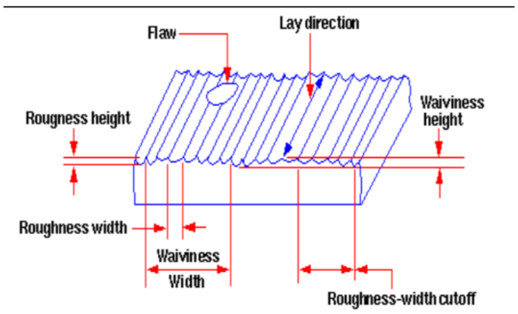
▶ 2. Feed

▶ 3. Depth of cut.

▶ 4. Tool geometry

▶ 5. Tool material

▶ 6. Type of machine tool



Surface characteristics(Courtesy, ANSI B46.1 - 1962)

Table 4.3 Orthogonal array L18 ($3^3.2^1$) of the experimental runs

Runs	Nose radius	Spindle speed	feed	depth of cut
1	0.4	2500	0.1	0.4
2	0.4	2500	0.15	0.8
3	0.4	2500	0.2	1.2
4	0.4	3000	0.1	0.4
5	0.4	3000	0.15	0.8
6	0.4	3000	0.2	1.2
7	0.4	3500	0.1	0.8
8	0.4	3500	0.15	1.2
9	0.4	3500	0.2	0.4
10	0.8	2500	0.1	1.2
11	0.8	2500	0.15	0.4
12	0.8	2500	0.2	0.8
13	0.8	3000	0.1	0.8
14	0.8	3000	0.15	1.2
15	0.8	3000	0.2	0.4
16	0.8	3500	0.1	1.2
17	0.8	3500	0.15	0.4
18	0.8	3500	0.2	0.8

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5.EXPERIMENTAL SETUP:

▶ Experimental setup: Experimental research was performed on MORI SEIKI CNC lathe machine.

▶ Selection of work piece material: Test samples were medium carbon steel bars of grade C45 with 32 mm in diameter and 100 mm in length.

▶ C45 grade steel: C45 grade steel is medium carbon steel offering moderate tensile strengths. The material is capable of through hardening by quenching and tempering on limited 39 sections but can also be flame or induction hardened to Hrc 55.This grade is most commonly supplied in an untreated or normalized condition and is available in several variations (denoted by additional letters) which offer slight modifications of chemical composition. Machinability similar to that of mild steel can be expected, however weldability is reduced.

Selection of tool:

▶ Selection of tool: Experiments were carried out by the two external machining turning tool with the holder mark DDJNL 3225P15 and the tungsten carbide insert under wet cutting conditions. The tool nose radii are 0.4 mm and 0.8 mm

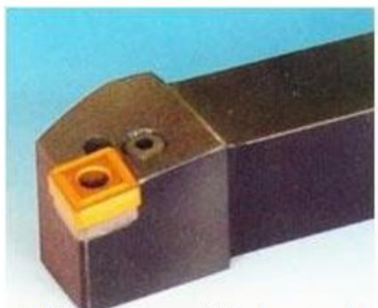

Fig. 5.2 Tungsten carbide insert with tool holder

6.Experimental procedure:

Total 18 number of experiments based on Taguchi's design of experiments discussed earlier to investigate the effect of Nose radius, Spindle speed, Feed and Depth of cut on Material Removal Rate and surface roughness on C45grade medium carbon steel which is machined by CNC lathe using single point cutting tool. The work piece is fixed in the three jaw chuck and the insert is also fixed to tool holder properly. Tool is fixed in the tool holder. Program was set as per the parameters chosen and wet machining was completed on 18 number of work pieces according to the plan.

TESTING PROCEDURE: The following parameters were measured during and after experimentation.

▶ Mater Removal Rate: It is the volume of material removed during time of cutting. It was found by the following procedure. (i) Initial diameter(D1)and length(L) in mm of work piece is measured with vernier caliper before machining. (ii) The time for machining or cutting time(T)in sec is measured with the help of a stopwatch 42 (iii) The final diameter(D2) in mm after machining is measured. (iv) Material removal rate is found using the formula M.R.R= $(d_1^2-d_2^2)L/T$

Surface Roughness: A portable surface roughness tester was used in th present investigation. It consists of a stylus through which one can calculate the surface roughness value by moving the stylus front and back on the machined surface. Three readings were obtained on at different places on the machined surface and the average of all is considered.

Mitutoyo SJ-301 Surface roughness tester used for measurement.

7.RESULTS AND DISCUSSION:

Table 6.2: Responses for MRR and surface roughness

Runs	Nose radius	Spindle speed	feed	depth of cut	Ra	MRR
1	0. 4	2500	0.1	0.4	0.79	9.95
2	0.4	2500	0.15	0.8	1.76	29.86
3	0.4	2500	0.2	1.2	2.73	59.72
4	0.4	3000	0.1	0.4	0.95	11.94
5	0.4	3000	0.15	0.8	1.75	35.83
6	0.4	3000	0.2	1.2	2.60	71.66
7	0.4	3500	0.1	0.8	0.95	27.86
8	0.4	3500	0.15	1.2	1.77	62.70
9	0.4	3500	0.2	0.4	2.56	27.86
10	0.8	2500	0.1	1.2	0.52	29.86
11	0.8	2500	0.15	0.4	0.77	14.93
12	0.8	2500	0.2	0.8	1.42	39.81
13	0.8	3000	0.1	0.8	0.73	23.88
14	0.8	3000	0.15	1.2	1.04	53.74
15	0.8	3000	0.2	0.4	1.47	23.88
16	0.8	3500	0.1	1.2	0.81	41.80
17	0.8	3500	0.15	0.4	1.18	20.90
18	0.8	3500	0.2	0.8	1.52	55.73

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1. The effect of feed is more on surface roughness than any other parameters considered.
2. It is also found that there is significant effect of interference by nose radius and spindle speed as well as nose radius and feed.
3. Value of Ra increases with increase in nose radius.
4. At higher feeds surface roughness decrease with depth of cut to some extent and then increases

Table 6.3: Analysis of Ra using RSM

Term	Coef	SE Coef	T	P
Constant	-2.948	1.325	-2.225	0.09
A	-0.59	0.7687	-0.767	0.486
B	0.0009	0.0008	1.167	0.308
C	28.588	5.8096	4.921	0.008
D	1.0445	0.6092	1.715	0.162
B*B	0	0	-0.859	0.439
C*C	13.536	13.524	1.001	0.374
D*D	-0.094	0.2113	-0.444	0.68
A*B	0.0007	0.0002	3.495	0.025
A*C	-21.46	2.5555	-8.396	0.001
A*D	-0.079	0.3194	-0.249	0.816
B*C	-0.002	0.001	-2.286	0.084
B*D	-2E-04	0.0001	-1.834	0.141
C*D	-0.513	1.7153	-0.299	0.78

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Surface plots of Surface roughness:

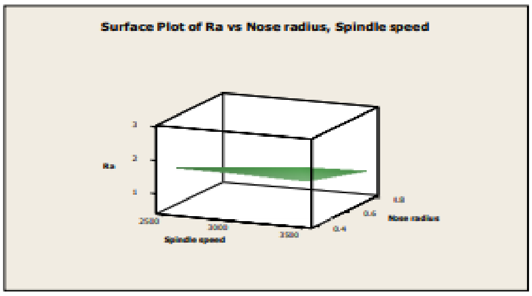

Fig 6.1 Surface plot of Ra vs Nose radius and spindle speed.

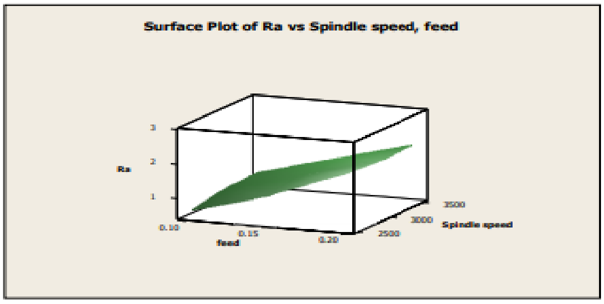

Fig 6.2 Surface plot of Ra vs Feed and spindle speed.

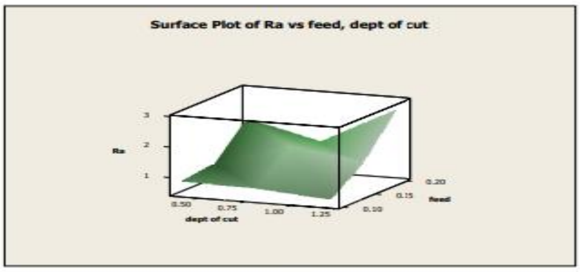

Fig 6.3 Surface plot of Ra vs Feed and Depth of cut

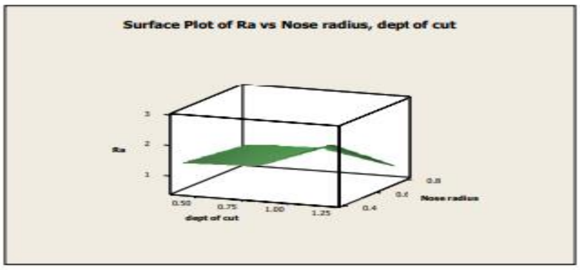

Fig 6.4 Surface plot of Ra vs Nose radius and depth of cut

Analysis of MRR:

Table 6.4: Analysis of MRR

Term	Coef	SE Coef	T	P
Constant	22.969	8.579	2.677	0.055
A	6.045	4.977	1.215	0.291
B	-0.005	0.0051	-0.982	0.382
C	-279.4	37.617	-7.427	0.002
D	-34.35	3.9442	-8.708	0.001
B*B	0	0	-1.29	0.267
C*C	-70.82	87.563	-0.809	0.464
D*D	-1.107	1.3682	-0.809	0.464
A*B	-0.002	0.0013	-1.791	0.148
A*C	30.945	16.547	1.87	0.135
A*D	-3.868	2.0684	-1.87	0.135
B*C	0.093	0.0067	13.894	0
B*D	0.013	0.0008	15.879	0
C*D	294.78	11.106	26.541	0

Surface plots of Material Removal Rate:

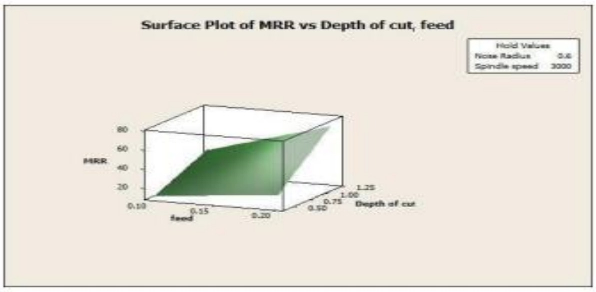

Fig 6.7 Surface plot of MRR vs Depth of cut and feed

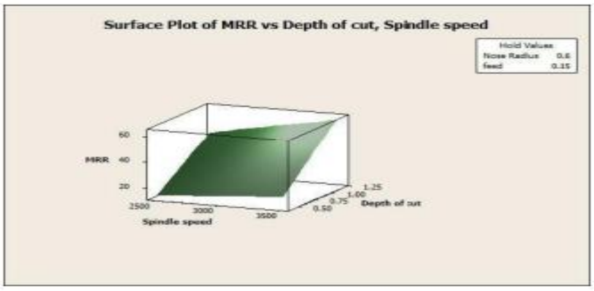

Fig 6.8 Surface plot of MRR vs Depth of cut and Spindle speed

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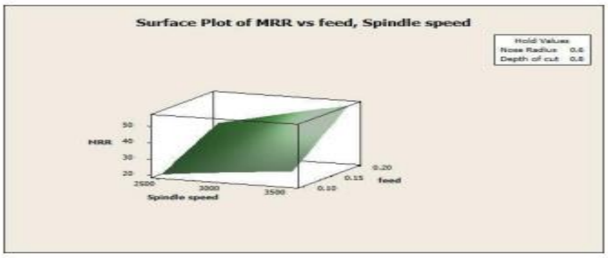

Fig 6.9 Surface plot of MRR vs spindle speed and feed

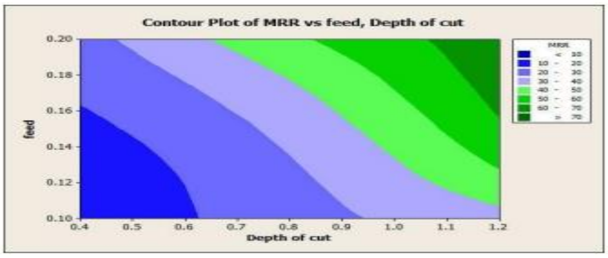

Fig 6.10 Contour plot of MRR vs Depth of cut and feed

Table 6.7 Values of parameters for Ra and MRR at optimum conditions

Nose radius	Spindle speed	feed	depth of cut	Ra	MRR
0.8	1900	0.1	0.1	0.2315	8.42832
0.8	3500	0.2	1.2	2.914956	94.8722

Table 6.6 Optimum values of Ra and MRR after multi-objective optimization

Nose radius	Spindle speed	Feed	Depth of cut	**Ra**	**MRR**
0.8	2007.286	0.101	0.355	**0.491**	**13.374**

Results:

Optimum conditions provide the best performance based on the data obtained from the experiments and various methods used for optimization.

1. Surface Roughness

a. Nose radius : 0.8 mm

b. b. Spindle speed : 1900 RPM

c. c. Feed : 0.1 mm

d. d. Depth of cut :0.1 mm

2. Material removal rate

a. Nose radius : 0.8 mm b. Spindle speed : 3500 RPM c. Feed : 0.2 mm d. Depth of cut : 1.2 mm

3. Surface Roughness and Material removal rate a. Nose radius : 0.8 mm b. Spindle speed : 2007 RPM c. Feed : 0.1 mm d. Depth of cut : 0.49 mm

CONCLUSIONS:

Based on the results obtained and discussion made in the previous chapters the following conclusions were made

1. The effect of feed is more on surface roughness than any other parameters considered.

2. It is also found that there is significant effect of interference by nose radius and spindle speed as well as nose radius and feed.

3. Value of Ra increases with increase in nose radius.

4. At higher feeds surface roughness decrease with depth of cut to some extent and then increases.

5. MRR increases with spindle speed, feed and depth of cut. But depth of cut has highest influence on MRR than any other followed by feed and there is considerable effect of interaction among cutting speed, feed and depth of cut.

6. By using genetic algorithm as optimization technique the optimum values arrived not confined to local optima. Results were obtained to global optima

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