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Experimental Investigation and Analysis of Optimum Cutting Parameters for AISI1042 Using CVD Tool in Turning Operation

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Abstract
The paper envisages the study to optimize the effects of process variables on surface roughness, and MRR of AISI 1042 (EN 41B) work material using CVD coated tool. In the present investigation the influence of spindle speed, feed rate, and depth of cut were studied as process parameters. The experiments have been conducted using full factorial design in the design of experiments (DOE) on a conventional lathe(PSGA141). A Model has been developed using regression technique and the optimal cutting parameters for minimum surface roughness, and maximum MRR were obtained using Taguchi technique. To predict the surface roughness, an Artificial Neural Network (ANN) model was designed through back propagation network using MATLAB 7.1 software for the data obtained. Comparison of the experimental data and ANN results show that there is no significant difference and ANN was used confidently. The results obtained, conclude that ANN is reliable and accurate for solving the cutting parameter optimization. The contribution of various process parameters on response variables have been found by using ANOVA technique. Finally optimization is done by using Particle swarm optimization (PSO).

Keywords: AISI No1042 alloy steel, CVD tool, DOE,ANN, Taguchi technique.

Introduction

Increased in Productivity and machined part quality characteristics are the main hinderness of metal based industry. Surface finish is the prime requirement of the customer satisfaction and also productivity which fulfills the customer demand. For this purpose, quality of the product should be well with in customer satisfaction and also productivity should be high. In addition to the quality of the product, the material removal rate (MRR) is also an important characteristic in machining operation and high MRR is always desirable. To ensure the cost of the final finished product, power consumption should be as low as possible. Hence the objective of the present work is to optimize spindle speed, feed and depth of cut so as to minimize surface roughness, and maximize MRR and minimize power consumption.

AISI 1042 is a medium carbon low alloy steel and finds its typical applications in the manufacture of automobile and machine tool parts, low specific heat, tendency to strain harden, and diffuse between tool and work material AISI 1042 alloy steel gives rise to problems like large cutting forces. High cutting tool temperatures, poor surface finish and built up edge formation. In today's manufacturing industry, special attention is given to surface finish and power consumption. Traditionally the desired cutting parameters are determined based on hands on experience. Of the many goals focused in manufacturing industry, power consumption plays vital and dual role. One its cuts down the cost per product and secondly the environmental impact by reducing the amount of carbon emissions that are created in using by electrical energy.

Literature Review

S. M. Ali, and N. R. Dhar, Tool wear and surface roughness prediction plays a significant role in machining industry for proper planning and control of machining parameters and optimization of cutting conditions. He deals with developing an artificial neural network (ANN) model as a function of cutting parameters in turning steel under minimum quantity lubrication (MQL). A feed-forward back propagation network with twenty five hidden neurons has been selected as the optimum network.

Benardos and Vosniakos discussed the surface quality is a central parameter to evaluate the productivity of machine tools as well as machined components. Hence, achieving the desired surface quality is of great importance for the functional behavior of the mechanical parts.

Black [14] defined metal cutting as the removal of metal chips from a work piece in order to obtain a finished product with desired characteristics of size, shape, and surface roughness. The challenge that the engineers face is to find out the optimal parameters for the preferred output and to maximize the output by using the available resources.

Davim[11] has presented a study of the influence of cutting parameters on the surface roughness obtained in turning of free machining steel using Taguchi design and shown that the cutting velocity has a greater influence on the roughness followed by the feed rate.

H.Ganesan, G.Mohankumar, K.Ganesan, K.Ramesh kumar. Optimization of machining parameters in turning process using genetic algorithm and particle swarm optimization with experimental verification. In this paper the optimal machining parameters for continuous profile machining are determined with respect to the minimum production time, subject to a set of practical constraints, cutting force, power and dimensional accuracy and surface finish. 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.

F.Jafarian[9] developed a new intelligent method for presenting a predictive and optimizing model of the turning process. Application of ANN and evolutionary algorithms to determine suitable input parameters for optimizing outputs of the process.

Farhad Kolahan1, A. Hamid Khajavi, A Statistical Approach for Predicting and Optimizing Depth of Cut in AWJ Machining for 6063-T6 Al Alloy, Taguchi method and regression modeling are used in order to establish the relationships between input and output parameters. The adequacy of the model is evaluated using analysis of variance (ANOVA) technique

C. Natarajan, S. Muthu and P. Karuppuswamy [2010], find a suitable optimization method which can find optimum values of cutting parameters for minimizing surface roughness. The turning process parameter optimization is highly constrained and nonlinear. To predict the surface roughness, an artificial neural network (ANN) model was designed through back propagation network using MATLAB 7 software for the data obtained.

Material and Methods

A. Specifications of Work material

The work material used for the present work is AISI No. 1042 alloy steel of 30mm diameter and 500mm length. Common application of this material in casting dies, Gears, Abrasive wheels, Spindles etc., the chemical composition of the material is C 0.4, Si 0.25, Mo 0.35, Al 1.2, Cr 1.6, S 0.05 m, P0.05 m, Mn 0,5, Ni 0.04

B. Taguchi Method

Taguchi method is an effective tool in designing of high quality system. It provides simple efficient and systematic qualitative optimal design to aid high performance, quality at a relatively low cost. Conventional methods for experimental design are of complex in nature and difficult to use. In addition to that these methods require a large number of experiments when the process parameters increase. In order to minimize number of experiments, a powerful tool has been designed for high quality system by Taguchi. For determination of the best design it requires the use of statistically designed experiment. Taguchi approach in design of experiments is easy to adapt and apply for uses with limited knowledge of statistics and hence gained wide popularity in the engineering and scientific community. The cutting parameters ranges were selected based on machining guidelines provided by manufacturer of cutting tool manufacturers Kayocera. The control factors and levels are shown in Table 1

Table 1: Process Parameters with Different Levels

Process Parameters	Levels		
	1	2	3
Cutting speed, S (rpm)	360	450	580
Feed, F (mm/rev)	0.05	0.07	0.09
Depth of cut, Doc (mm)	0.05	0.1	0.15

C. Analysis of variance (ANOVA)

ANOVA is used to determine the influence of any given process parameters from a series of experimental results by design of experiments and it can be used to interpret experimental data. Since there will be large number of process variables which control the process, some mathematical model are require to represent the process. However these models are to be develop using only the significant parameters which influences the process, rather than including all the parameters. In order to achieves this, statistical analysis the experimental results will be processed using analysis of variance (ANOVA).

Experimentation and Mathematical modeling

The experiment is conducted for Dry turning operation of using AISI 1042 Alloy steel as work material and CVD as tool material on a conventional lathe PSG A141. The tests were carried for a 500 mm length work material. The process parameters used as spindle speed (rpm), feed (mm/rev), depth of cut (mm). The response variables are Surface roughness, material removal rate and power consumption. Surface roughness of machined surface has been measured by a Talysurf instrument.

Surface roughness need to the minimum for good quality product (Lower is the better)

The surface roughness, Ra

Min Ra (s, f, d)

Minimizing Ra = 0.905 + 0.00324

speed + 51.6 feed-10.7 depth of c (1)

MRR need to be maximum for increasing the production rate (Higher is the better)

The material removal rate, MRR

Max MRR (s, f, d)

Maximizing MRR =-0.286 + 0.000322

speed + 7.42 feed-0.50 depth of c (2)

Table 2: Experimental data and results for 3 parameters, corresponding Ra, MRR for CVD tool

S. No	Speed, s (rpm)	Feed, f (mm/rev)	Depth of cut, (mm)	Surface Roughness Ra (µm)	Material removal rate (mm^3/min)	S/N Ratio for Ra	S//N Ratio for MRR
1	360	0.05	0.05	3.83	0.18	-11.66	-14.89
2	360	0.05	0.1	3.67	0.09	-11.29	-20.92
3	360	0.05	0.15	3	0.09	-9.54	-20.92
4	360	0.07	0.05	6.28	0.23	-15.96	-12.77
5	360	0.07	0.1	4.34	0.22	-12.75	-13.15
6	360	0.07	0.15	3.3	0.12	-10.37	-18.42
7	360	0.09	0.05	6.33	0.33	-16.03	-9.63

8	360	0.09	0.1	5.66	0.17	-15.06	-15.39
9	360	0.09	0.15	5.54	1.41	-14.87	2.98
10	450	0.05	0.05	4.18	0.22	-12.42	-13.15
11	450	0.05	0.1	3.26	0.22	-10.26	-13.15
12	450	0.05	0.15	3.12	0.22	-9.88	-13.15
13	450	0.07	0.05	5.79	0.42	-15.25	-7.54
14	450	0.07	0.1	5.88	0.32	-15.39	-9.90
15	450	0.07	0.15	4.01	0.3	-12.06	-10.46
16	450	0.09	0.05	6.38	0.58	-16.10	-4.73
17	450	0.09	0.1	5.65	0.2	-15.04	-13.98
18	450	0.09	0.15	5.18	0.21	-14.29	-13.56
19	580	0.05	0.05	4.64	0.29	-13.33	-10.75
20	580	0.05	0.1	4.3	0.29	-12.67	-10.75
21	580	0.05	0.15	3.87	0.14	-11.75	-17.08
22	580	0.07	0.05	6.06	0.54	-15.65	-5.35
23	580	0.07	0.1	5.97	0.34	-15.52	-9.37
24	580	0.07	0.15	5.71	0.32	-15.13	-9.90
25	580	0.09	0.05	5.78	0.74	-15.24	-2.62
26	580	0.09	0.1	5.97	0.5	-15.52	-6.02
27	580	0.09	0.15	5.94	0.27	-15.48	-11.37

Table3: Response Table for Signal to Noise Ratios Smaller is better for Ra for CVD

Level	Speed	Feed	Depth of cut
1	-13.6	-11.42	-14.63
2	-13.4	-14.23	-13.72
3	-14.48	-15.29	-12.60
Delta	1.42	3.87	2.03
Rank	3	1	2

Table4: Response table for Means for Ra for CVD

Level	Speed	Feed	Depth of cut
1	4.661	3.763	5.474
2	4.828	5.260	4.967
3	5.360	5.826	4.408
Delta	0.699	2.062	1.067
Rank	3	1	2

Table5: Response Table for Signal to Noise Ratios larger is better for MRR for CVD

Level	Speed	Feed	Depth of cut
1	-13.67	-14.973	-9.05
2	-11.07	-10.76	-12.52
3	-9.25	-8.26	-12.43
Delta	4.432	6.717	3.47
Rank	2	1	3

Table6: Response table for Means for MRR for CVD

Level	Speed	Feed	Depth of cut
1	0.316	0.193	0.392
2	0.299	0.312	0.261
3	0.381	0.490	0.342
Delta	0.0822	0.297	0.131
Rank	3	1	2

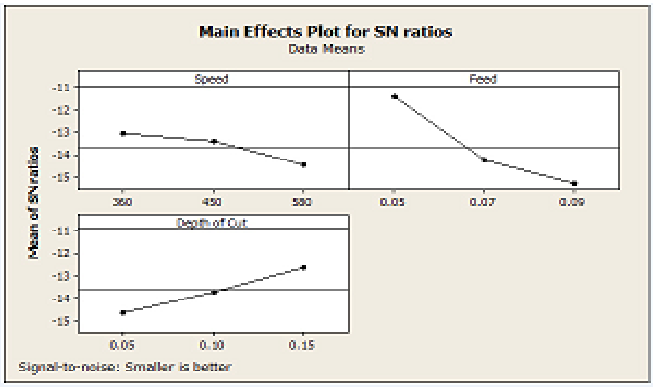

Fig:1 Main effects plot for S/N Ratios for Ra

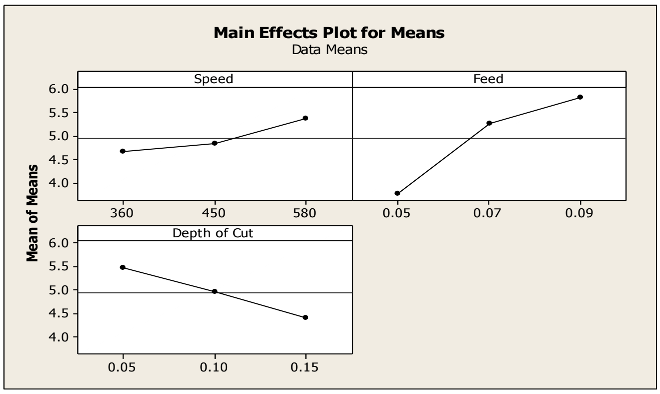

Fig:2 Main effects plot for Means for Ra

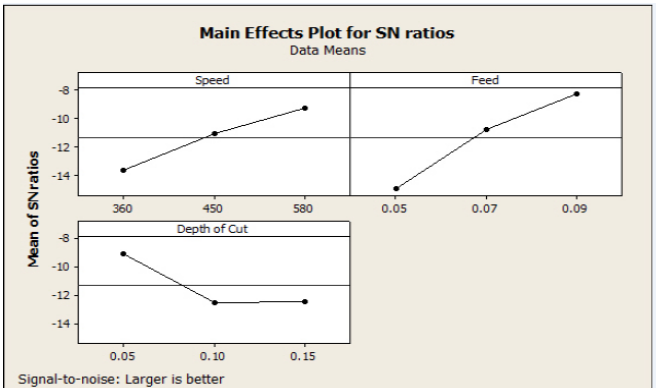

Fig:3 Main effects plot for S/N Ratios for MRR

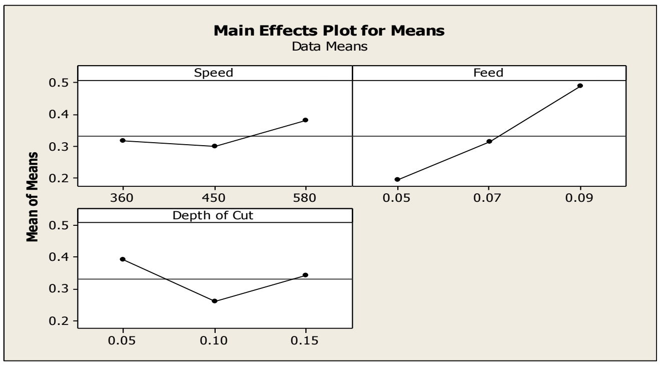

Fig:4 Main effects plot for Means for MRR

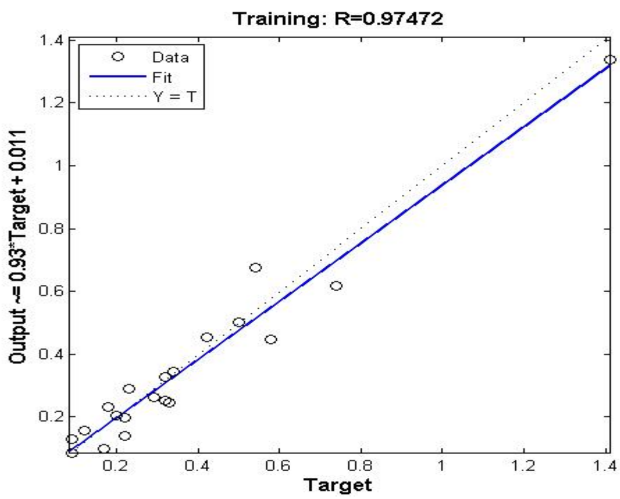

Fig:5 Regression line for MRR using CVD tool

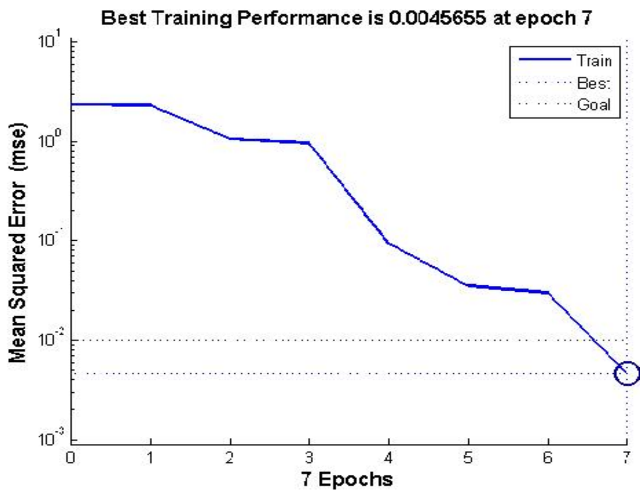

Fig:6 Performance curve for MRR using CVD tool

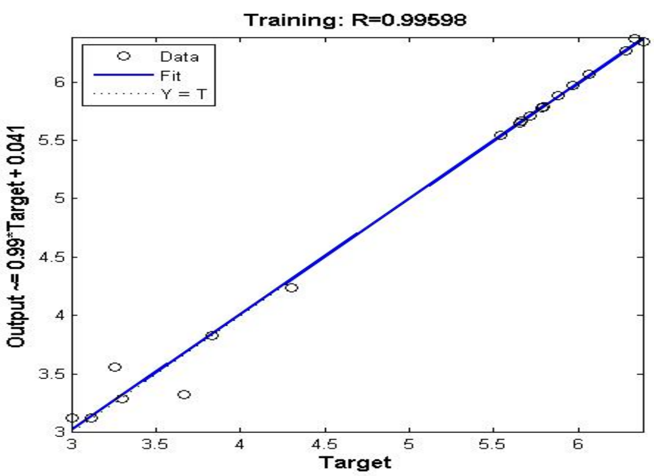

Fig:7 Regression line for Ra using CVD tool

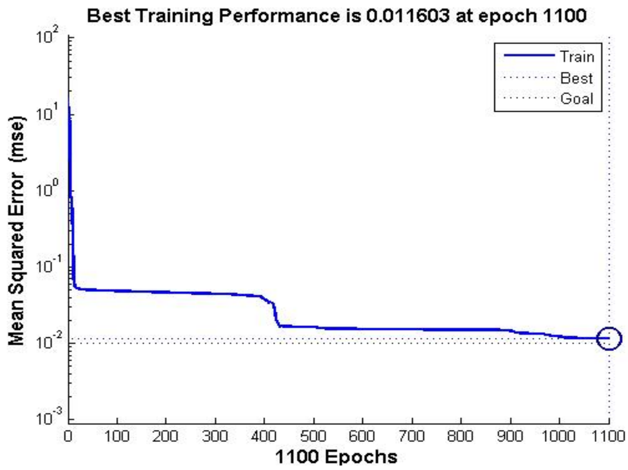

Fig:8 Performance curve for Ra using CVD tool

For Surface Roughness(Ra)
Test data: 4.34 4.18 4.01 5.18 4.64 3.87 5.94

ANN predicted data for Ra
i) 4.8963 3.8292 4.1336 4.1336 3.8292 4.1336 4.1337
ii) 5.0986 4.3555 4.3341 5.8684 5.7747 3.1679 5.8710
iii) 4.3393 4.5426 4.2118 5.1051 4.5284 4.2872 6.3161
iv) 4.7891 4.4411 4.4270 5.7140 5.7176 3.2429 5.9908

For MRR
Test Data: 0.22 0.22 0.30 0.21 0.29 0.14 0.27

ANN predicted data for MRR
i) 0.1968 0.4729 0.2693 1.7728 0.6856 0.2046 2.1918
ii) 0.2187 0.2360 0.3754 1.5173 0.4374 0.3140 1.3227
iii) 0.1794 0.2939 0.1837 0.2087 0.2992 0.3494 0.2424
iv) 0.1824 0.1962 0.2659 0.2669 0.2834 0.2666 0.2683

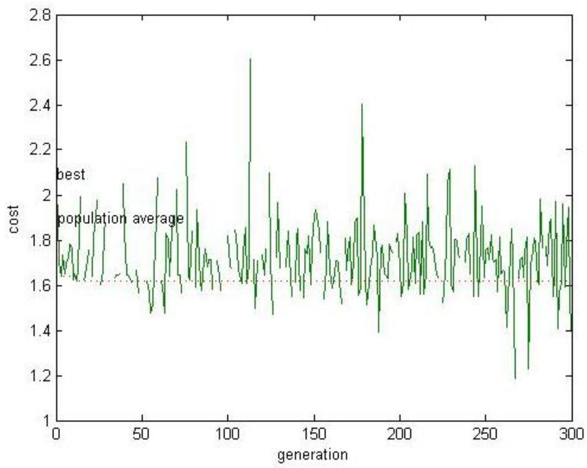

Fig 9: Results for MRR using CVD tool from PSO

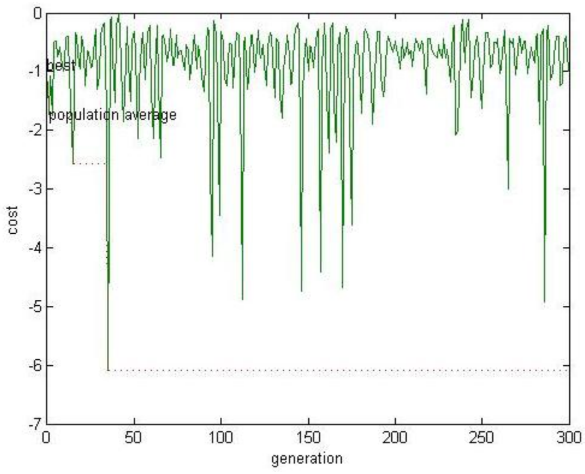

Fig 10: Results for Ra using CVD tool from PSO

Conclusion

The results obtained in this study lead to conclusions for turning of AISI 1042 after conducting the experiments and analyzing the resulting data.

- From the results obtained by experiment, the influence of surface roughness (Ra) and Material Removal Rate (MRR) by the cutting parameters like speed, feed, DOC is

a) The feed rate has the variable effect on surface roughness, cutting speed and depth of cut an approximate decreasing trend.

b) Cutting speed, feed rate and depth of cut for Material Removal Rate have increasing trend.

- For the design of Experiments, Taguchi method is applied for finding optimal cutting parameters of cutting parameters

a). For minimum surface roughness, the optimality conditions are: Speed: 580 rpm, Feed: 0.09 mm/rev, and Depth of cut: 0.05 mm

b). For maximum material removal rate, the optimality conditions are: Speed: 580rpm, Feed: 0.09 mm/rev, and Depth of cut: 0.10 mm

- Using the experimental data, a multi linear regression model is developed for the responses Ra and Material Removal Rate.
- From **PSO** Optimum cutting parameters for MRR is [449, 0.066, 0.086]

Optimum cutting parameters for Rs is [560, 0.068,0.094]

This research highlighted the use of Taguchi design of experiments, Artificial Neural Network and optimization using PSO. In the present study, the process parameters such as spindle speed, feed and depth of cut is considered. Further the study may be extended for more parameters such as nose radius, rake angle, introduction of cutting fluids etc.

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