PARAMETRIC ANALYSIS OF OPTIMUM CUTTING PARAMETERS FOR AISI1042 USING PVD TOOL IN TURNING OPERATION USING GREY RELATION ANALYSIS

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Abstract: *The paper study is carried out on orthogonal cutting of AISI 1042(EN 41B) carbon steel under dry turning conditions with PVD coated cemented carbide inserts. This paper presents the cutting parameters which influences the Surface roughness (Ra) and Material Removal Rate (MRR) on AISI 1042. Experiments are carried out by conducting experiments based on Taguchi technique considering L27 orthogonal array on a lathe (PSG A141). The process parameters considered for the study are cutting speed, feed rate, and depth of cut and the output parameters are MRR and Ra. 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. For predicting the surface roughness, an Artificial Neural Network (ANN) model was designed through back propagation network using MATLAB software for the data obtained. Comparison of the experimental data and ANN results shows that there is no significant difference and ANN was used confidently. Optimal machining parameters were determined by the grey relation grade obtained from the grey relation analysis for multi-performance characteristics (the surface roughness and Material removal rate). The results of confirmation experiments reveal that grey relation analysis coupled with factorial design can effectively be used to obtain the optimal combination of turning parameters. Experimental results have shown that the surface roughness and material removal rate in the turning process can be improved effectively through the new approach.*

Keywords: *AISI No1042 Alloy Steel, PVD Coated Tool, Taguchi Technique, ANN and Grey Relational Analysis.*

1. INTRODUCTION

The manufacturers are facing problems and challenges on quality, cost and lead time in order to sustain in the global market. The quality of the machined product is evaluated in respect of how closely they are manufactured with close tolerance limits. Increased in Productivity and machined part quality characteristics are the main hinderers 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. The aim of this study was to set up a multiple objective function which minimizes surface roughness and maximizes MRR for the given cutting parameters.

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. In today’s manufacturing industry, special attention is given to surface finish and MRR. Traditionally the desired cutting parameters are determined based on hands on experience.

2. 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 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 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.

F.Jafarian 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 Kolahan, 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.

Nihat Tousun [2006], Optimal machining parameters were determined by the grey relation grade obtained from the grey relation analysis for multi-performance characteristics. Conducted experiments on surface roughness and the burr height in drilling process.

L.B. Abhang, M. Hameedullah [2011], Optimization of multi-performance characteristics is more complex compared to single-performance characteristics. The theory of grey system is a new technique for performing prediction, relational analysis and decision making in many areas.

Tzeng and Chen (2007) described the application of the fuzzy logic analysis coupled with Taguchi method to optimise the precision and accuracy of the high-speed electrical discharge machining (EDM) process.

Rajyalakshmi et al. (2012) used fuzzy logic integrated with Taguchi method for optimization of process parameters of wire electrical discharging machine.

Sarfaraz Khabbaz et al. (2009) applied a simplified fuzzy logic approach for material selection in mechanical engineering design.

Vimal Sam Singh, et al. (2009) worked on modelling and analysis of thrust force and torque in drilling GFRP composites by multi-facet drill using fuzzy logic

3. MATERIAL AND METHODS

3.1 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

3.2 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 control factors and levels are shown in Table 1

3.3 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).

4. EXPERIMENTATION AND MATHEMATICAL MODELLING

The experiment is conducted for Dry turning operation of using AISI 1042 Alloy steel as work material and PVD as tool material on a conventional lathe PSG A141. The tests were carried for a 500 mm length work material. The process parameters used are spindle speed (rpm), feed (mm/rev), and depth of cut (mm). The response variables are Surface roughness and material removal rate. Experimental setup and surface roughness of machined surface has been measured by using Talysurf instrument shown in Fig 1 & Fig 2.

The mathematical model is developed on the basis of dry machining experimental results and are given in Table 2. Experimental results are used to develop mathematical model and linearized by performing Logarithmic transformations converting into a linear modeling using computational software, from the observed data

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, d (mm)	0.05	0.1	0.15

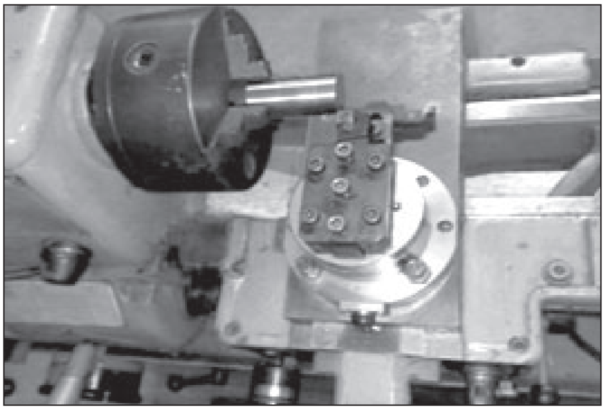

Fig 1. Experimental Setup

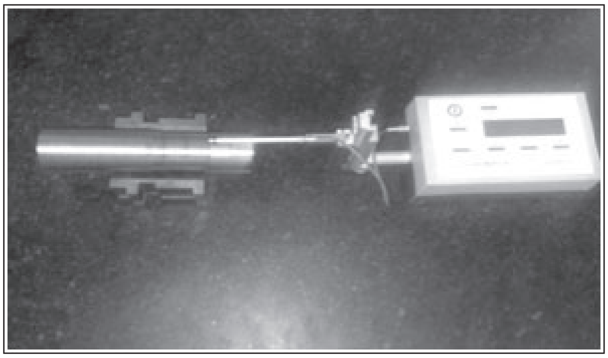

Fig 2. Surface Roughness Measuring Instrument

for surface roughness and material removal rater, the response function has been determined using regression is,

The regression equation for surface roughness is
ln(Ra) = - 0.04 + 0.259 ln(s) + 0.242 ln(f) - 0.261 ln(doc)

The regression equation for MRR is
ln(mrr) = - 5.01 + 0.340 ln(s) - 0.018 ln(f) - 0.604 ln(doc)

Surface roughness need to the minimum for good quality product (Lower is the better) The surface roughness, Ra

Minimizing ln(Ra) = - 0.04 + 0.259 ln(s) + 0.242 ln(f) - 0.261 ln(doc)

Table 2: Experimental Data and Results for 3 Parameters, Corresponding Ra and MRR for PVD Coated Tool

S.No	Speed, s (rpm)	Feed, f (mm/rev)	D of cut, (mm)	Ra Roughness Ra (µm)	MRR(mm^3/min)	S/N Ratio for Ra	S/N Ratio for MRR
1	360	0.05	0.05	3.79	0.26	-11.5728	-11.7005
2	360	0.05	0.1	3.46	0.28	-10.7815	-11.0568
3	360	0.05	0.15	3.16	0.18	-9.9937	-14.8945
4	360	0.07	0.05	4.82	0.31	-13.6609	-10.1728
5	360	0.07	0.1	4.1	0.32	-12.2557	-9.8970
6	360	0.07	0.15	3.67	0.11	-11.2933	-19.1721
7	360	0.09	0.05	6.17	0.33	-15.8057	-9.6297
8	360	0.09	0.1	5.25	0.31	-14.4032	-10.1728
9	360	0.09	0.15	4.91	0.17	-13.8216	-15.3910
10	450	0.05	0.05	5.96	0.31	-15.5049	-10.1728
11	450	0.05	0.1	5.46	0.28	-14.7439	-11.0568
12	450	0.05	0.15	4.22	0.07	-12.5062	-23.0980
13	450	0.07	0.05	4.72	0.26	-13.4788	-11.7005
14	450	0.07	0.1	4.9	0.18	-13.8039	-14.8945
15	450	0.07	0.15	3.63	0.17	-11.1981	-15.3910
16	450	0.09	0.05	4.41	0.33	-12.8888	-9.6297
17	450	0.09	0.1	4.14	0.24	-12.3400	-12.3958
18	450	0.09	0.15	4.09	0.17	-12.2345	-15.3910
19	580	0.05	0.05	5.58	0.54	-14.9327	-5.3521
20	580	0.05	0.1	3.68	0.25	-11.3170	-12.0412
21	580	0.05	0.15	3.22	0.25	-10.1571	-12.0412
22	580	0.07	0.05	6.36	0.34	-16.0691	-9.3704
23	580	0.07	0.1	5.71	0.34	-15.1327	-9.3704
24	580	0.07	0.15	5.58	0.24	-14.9327	-12.3958
25	580	0.09	0.05	6.45	0.28	-16.1912	-11.0568
26	580	0.09	0.1	4.7	0.25	-13.4420	-12.0412
27	580	0.09	0.15	3.58	0.15	-11.0777	-16.4782

MRR need to be maximum for increasing the production rate (Higher is the better) The material removal rate, MRR

Maximizing $\ln(MRR) = -5.01 + 0.340 \ln(s) - 0.018 \ln(f) - 0.604 \ln(doc)$

Tables 3, 4, 5 & 6 shows the Responses for Signal to Noise ration and Means for Surface Roughness and MRR their plots are shown in Fig 3, 4, 5 & 6 and testing and performance of the data for ANN using MATLAB is shown in Fig 7, 8, 9, & 10).

Table 3: Response Table for Signal to Noise Ratios Smaller is Better for Ra for PVD

Level	Speed	Feed	D of cut
1	-12.62	-12.39	-14.46
2	-13.19	-13.54	-13.14
3	-13.69	-13.58	-11.91
Delta	1.07	1.19	2.54
Rank	3	2	1

Table 4: Response Table for Means for Ra for PVD

Level	Speed	Feed	D of Cut
1	4.37	4.281	5.362
2	4.614	4.832	4.6
3	4.984	4.856	4.007
Delta	0.614	0.574	1.356
Rank	2	3	1

Table 5: Response Table for Signal to Noise Ratios larger is better for MRR for PVD

Level	Speed	Feed	DoC
1	-12.454	-12.379	-9.865
2	-13.748	-12.485	-11.436
3	-11.127	-12.465	-16.028
Delta	2.62	0.106	6.163
Rank	2	3	1

Table 6: Response table for Means for MRR for PVD

Level	Speed	Feed	DoC
1	0.2522	0.2689	0.3289
2	0.2233	0.2522	0.2722
3	0.2933	0.2478	0.1678
Delta	0.07	0.0211	0.1611
Rank	2	3	1

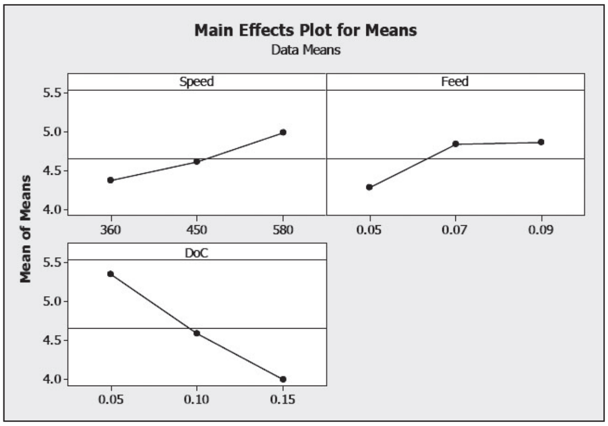

Fig 3. Main Effects Plot for Means for Ra

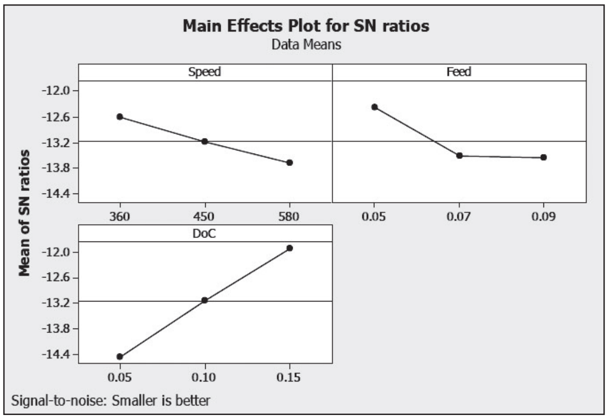

Fig 4. Main Effect Plot for S/N Ratios for Ra

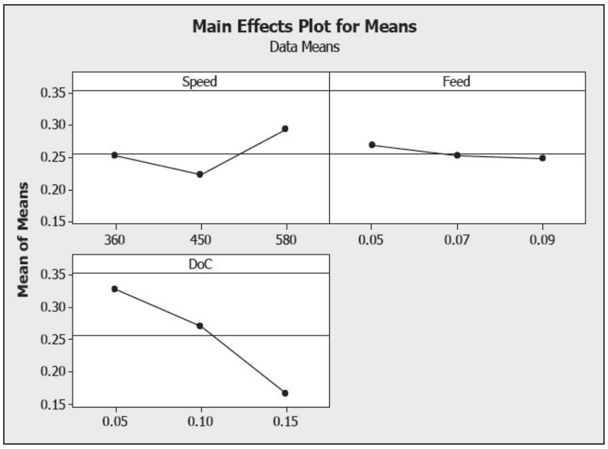

Fig 5. Main Effects Plot for Means for MRR

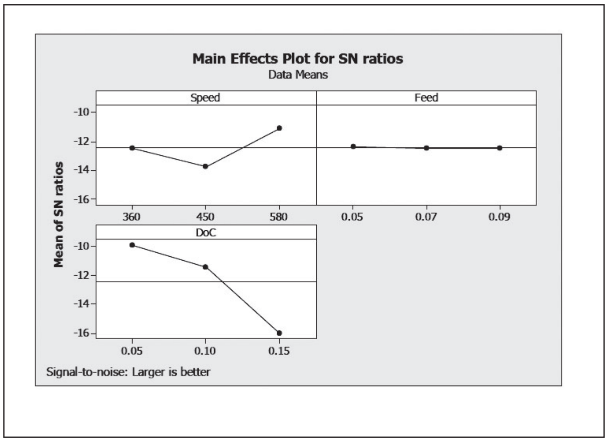

Fig 6. Main Effects Plot for S/N Ratios for MRR

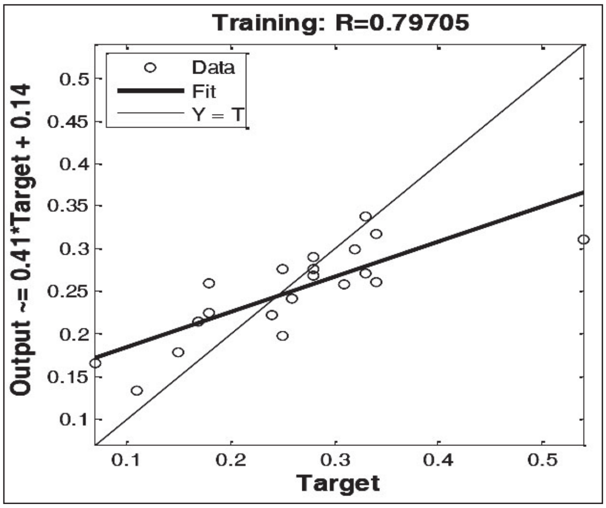

Fig 7. Regression Line for MRR using PVD Tool

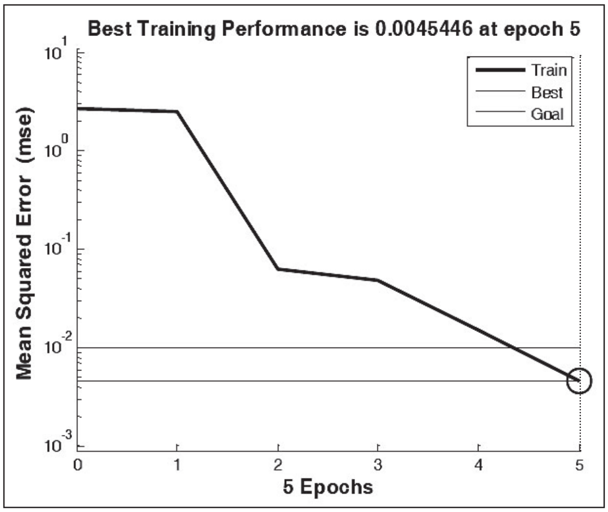

Fig 8. Performance Curve for MRR using PVD Tool

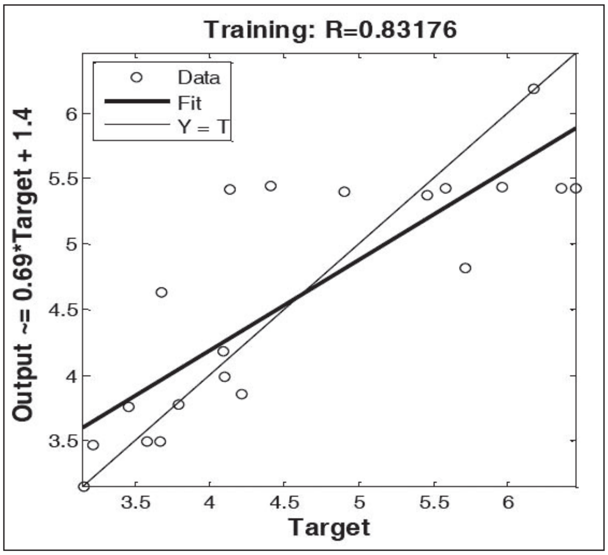

Fig 9. Regression Line for Ra Using PVD Tool

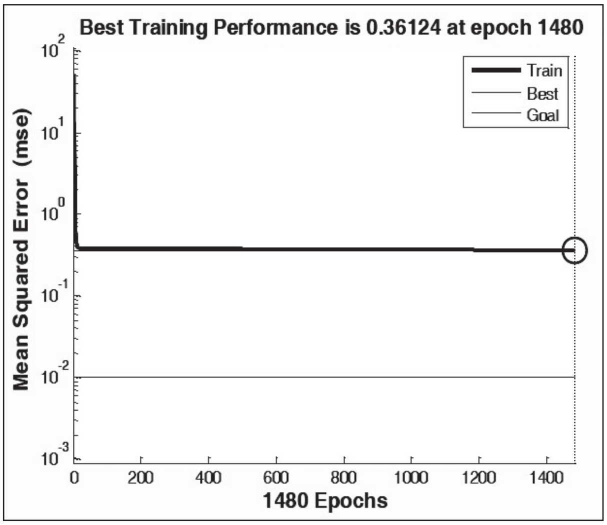

Fig 10. Performance Curve for Ra Using PVD Tool

For Surface Roughness(Ra)

Test data: 3.22, 6.36, 5.71, 5.58, 6.45, 4.7, 3.58

ANN predicted data for Ra

i) 3.5326 6.1148 6.1169 4.6294 4.6228 4.5115 5.7111

ii) 5.7882 4.1133 2.4497 6.1665 4.2506 4.3432 4.6501

iii) 4.6499 3.6936 3.4735 5.4838 4.1879 4.5744 5.7965

For MRR

Test Data: 0.25, 0.34, 0.34, 0.24, 0.28, 0.25, 0.15

ANN predicted data for MRR

i) 0.3224 0.2329 -0.0709 0.3537 0.1469 0.2371 0.2455

ii) 0.3314 0.1491 0.1167 0.3171 0.0862 0.2483 0.3237

iii) 0.3476 0.3754 0.2903 0.2770 0.2434 -0.0189 0.3036

4. GREY RELATION ANALYSIS

In the recent years, Deng proposed application of the principles of grey relational analysis. Grey relational analysis is a method of measuring the degree of approximation among sequences according to the grey relational grade. The theories of grey relational analysis have already attracted the interest of researchers. In the grey relational analysis, the measured values of the experimental results of surface finish and material removal rate were first normalized in the range between

Table 7: The Calculated Grey Relational Coefficient and Grey Relational Grade for L_{27} Comparability Sequences

Speed	Feed	D o cut	G R Coefficient		G Grade	Grey order
			MRR	Ra		
360	0.05	0.05	0.4563	0.7231	**0.5897**	6
360	0.05	0.1	0.4747	0.8458	**0.6603**	4
360	0.05	0.15	0.3950	1.0000	**0.6975**	3
360	0.07	0.05	0.5054	0.4977	**0.5016**	14
360	0.07	0.1	0.5165	0.6364	**0.5764**	9
360	0.07	0.15	0.3534	0.7633	**0.5584**	10
360	0.09	0.05	0.5281	0.3534	**0.4407**	21
360	0.09	0.1	0.5054	0.4404	**0.4729**	17
360	0.09	0.15	0.3884	0.4845	**0.4365**	25
450	0.05	0.05	0.5054	0.3701	**0.4377**	24
450	0.05	0.1	0.4747	0.4170	**0.4459**	20
450	0.05	0.15	0.3333	0.6081	**0.4707**	18
450	0.07	0.05	0.4563	0.5133	**0.4848**	15
450	0.07	0.1	0.3950	0.4860	**0.4405**	22
450	0.07	0.15	0.3884	0.7778	**0.5831**	8
450	0.09	0.05	0.5281	0.5682	**0.5482**	11
450	0.09	0.1	0.4393	0.6267	**0.5330**	12
450	0.09	0.15	0.3884	0.6388	**0.5136**	13
580	0.05	0.05	1.0000	0.4047	0.7023	2
580	0.05	0.1	0.4476	0.7598	**0.6037**	5
580	0.05	0.15	0.4476	0.9648	**0.7062**	1
580	0.07	0.05	0.5402	0.3395	**0.4399**	22
580	0.07	0.1	0.5402	0.3921	**0.4662**	18
580	0.07	0.15	0.4393	0.4047	**0.4220**	26
580	0.09	0.05	0.4747	0.3333	**0.4040**	27
580	0.09	0.1	0.4476	0.5165	**0.4821**	16
580	0.09	0.15	0.3760	0.7966	**0.5863**	7

zero and one, which is also called grey relational generation. Next, the grey relational coefficients were calculated from the normalized experimental results to express the relationship between the desired and actual experimental results. Then, the grey relational grades were computed by averaging the grey relational coefficient corresponding to each performance characteristic. The overall equation of the multiple performance characteristic is based on the grey relational grade. As a result, optimization of the complicated multiple performance characteristics can be converted into optimization of a single grey relational grade. The optimal level of the process parameters is the level with highest grey relational grade. With the grey relational analysis, the optimal combination of the process parameters can be predicted and shown in Table 7.

5. CONCLUSIONS

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 & 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: 580 rpm, Feed: 0.09 mm/rev, and Depth of cut: 0.15 mm
- Using the experimental data, a multi linear regression model is developed for the responses Ra and Material Removal Rate.
- From grey relation analysis the optimum cutting parameters for combined MRR and Ra is Speed 580 rpm, feed 0.05 and depth of cut as 0.15
- The results obtained, conclude that ANN is reliable and accurate for solving the cutting parameter optimization.

This research highlighted the use of Taguchi design of experiments, Artificial Neural Network and Grey relation analysis. 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.

6. REFERENCES

1. Korat, Mahendra; Agarwal, Neeraj: Optimization of different machining parameters of AISI 1042 Alloy steel in CNC turning by use of Taguchi method, 'International journal of engineering research and application', ISSN: 2248-9622, vol. 2.
2. Singh, Hardeep; Khanna, Rajesh; Gary, MP: Effect of cutting parameters on MRR and surface roughness, in turning En-8, 'International Journal of current Engineering and Technology', vol. 1, Dec 2011.
3. Aslan, E; Camuşcu, N; Birgören, B: Design optimization of cutting parameters when turning hardened AISI 4140 (63 HRC) with Al_2O_3+TiCN mixed ceramic tool, 'Mater. Design', 28, 2007, 1618-1622.
4. Singh, Hari; Kumar, Pradeep; Optimizing cutting forces for turned parts by Taguchi parameters design approach, 'Indian Journal of Engineering and Material Science', vol. 12, April 2005, 97-103.
5. Yang, H; Tang YS: Design of optimization of cutting parameters for turning operation based on Taguchi method, 'Journal of material processing technology', vol. 84, 1988, 122-129.
6. Nalbant, N; Gokkaya, H; Sur, G: Application of Taguchi method in the optimization of cutting parameters for surface roughness in turning, material and design, date received 21.07.2006 and date accepted 06.01.2006.
7. Erasan Alsan, Necip Camscu Burak Bingoren: Design of optimization of cutting parameters When turning hardened AISI 4140 steel (63 HRC) with Al_2O_3+ TiCN mixed ceramic tool, material and design, date received 21.07.2005 and date accepted 06.01.2006.
8. Gaitonde, VN; Karnik, SR; Paulo, Davim J: Modeling and analysis of machinability characteristics in PA6 and PA66 GF30 polyamides through artificial neural network, 'Journal of Thermoplastic Composite Materials', 23(3): 2010, 313-336.
9. Jafarian, F; Taghipour, M; Amirabadi, H: Application of artificial neural network and optimization algorithms for optimizing Surface roughness, tool life and cutting forces in turning operation, 'Journal of Mechanical Science and Technology' 27(5), 2013, 1469-1477.
10. Davim, JP: A note on the determination of optimal cutting conditions for surface finish obtained in turning using design of experiments, 'J Mater Process Technology', 2001, 116:305-308.
11. Doniavi, A; Eskanderzade, M; Tahmsebian, M: Empirical Modeling of Surface Roughness in Turning Process of 1060 steel using Factorial Design Methodology, 'Journal of Applied Sciences', vol. 7, no. 17, 2007, 2509-2513.
12. Davis, Rahul; Madhukar, Jitentdra Singh; Rana, Vikash Singh; Singh, Prince: Optimization of cutting parameters in Dry turning operation of EN24 steel, 'International journal of Emerging technology and Advanced engineering', website: www.ijetae.com, ISSN 2250-2459, October 2012, vol. 2, no. 10.

13. Tosun, Nihat: Determination of optimum parameters for multi - performance characteristics in drilling by using grey relational analysis, 'International Journal of Advanced Manufacturing Technology', 2006.
14. Abhang, LB; Hameedullah, M: Determination of optimum parameters for multi-performance characteristics in turning by using grey relational analysis, 'International Journal of Advanced Manufacturing Technology', 2011 ◘

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He has attended, organized and chaired various Conferences, Seminars of National and International importance. His rich and rewarding experience has been evident in the publications of his analytical articles in various Journals and Conferences of International and National importance. He has successfully handled the sponsored projects of MNES, UGC, and AICTE funded MODROBS, STTPS to the tune of Rs.40 lakhs during his tenure.

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