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Analysis and Optimisation of Process Parameters for Obtaining Optimal Surface Finish Using Cvd and Pvd Coated Cemented Carbide Tools in Turning Operation

A. Muni Tanuja, Anoop Kumar
Assistant Professor, St.Martin's Engineering College, Hyderabad, Telengana, India
Professor, St.Martin's Engineering College, Hyderabad, Telengana, India

Abstract: *The product's accuracy and surface finish depends upon the process parameters governing the process conditions. The main objective of this study is to analyse and optimise the metal cutting parameters in turning of AISI-1016 steel. The optimisation of process parameters is done for minimising the surface roughness using Taguchi's technique and Analysis of variance(ANOVA). The different cutting tools coated with different methods, Chemical Vapor Deposition (CVD) and Physical Vapor Deposition (PVD) are used to obtain better surface finish. Taguchi's design of Experiments (L9 array) is used and accordingly experiments conducted at different cutting conditions. The four process parameters selected are Cutting Speed (V), Feed (f), Depth of cut (d) and Hardness Ratio between tool and material (h) and optimal value of these process parameters is evaluated and identified the level of importance of these parameters by using ANOVA.*
Keywords: *ANOVA, CVD, Design of Experiments, PVD, Taguchi's technique.*

I. Introduction:

Turning operation is the most fundamental metal removal operation in the manufacturing industry. Surface finish, is used to determine and evaluate the quality of a product, is one of the major attributes of a product obtained from turning operation[1]. Achieving the desired surface quality is of great importance for the functional behaviour of a part and greatly influences the manufacturing cost[2].

The surface finish in turning is found to be influenced in varying amounts by a number of factors such as cutting speed, feed rate, Depth of cut, machining characteristics, tool geometry, Work Piece deflection, cutting tool, built up edge, cutting fluid etc[3].

Physical vapor deposition (PVD) can be done in Vacuum at low temperatures (400 - 600^0 C) and involves bombardment of the substrate to be coated with energetic positively charged ions during the process to promote high density. PVD coatings add wear resistance to a grade due to their hardness. Their compressive stress also adds edge toughness and crack resistance.

Chemical vapor deposition (CVD) is an atmosphere control process conducted at elevated temperatures (700 – 1050^0 C) in a CVD reactor[4] Thin film coatings are deposited, as a result of reactions between various gases and heated surface of substrates with in the CVD reactor. CVD coatings have high wear resistance and excellent adhesion to cemented carbide. Tool life is nearly increased by 10 times and MRR nearly doubled.

Surface roughness is significantly influenced by feed and cutting speed. In fact, increase in cutting results in better surface finish. From this study, the effectiveness and potential of multilayer TiN/TiCN/Al_2 O_3 coated cemented carbide tool for turning possesses high yielding and cost effective benefit and forms good option to costlier CBN and ceramic tools [5].

The experimentation for this wok was based on Taguchi's design of experiments (DOE) and orthogonal array.

Taguchi method focuses on Robust Design and uses three quality control for optimization of Static Problems.They are i) Smaller-The-Better, ii) Larger-The-Better and iii) Nominal-The-Best[6].

Taguchi's method uses special design of orthogonal arrays to study entire parameter space with small number of experiments only [7]. For three factors at three levels and one factor at two levels, Taguchi specified L_9 orthogonal array has been used in this work and optimal value of the process parameters were determined and their level of importance is identified by using analysis of variance (ANOVA).

II. Literature Review:

Adeel H. Suhail, N. Ismail, S.V. Wong and N.A. Abdul Jali [1], The focus of present experimental study is to optimize the cutting parameters using two performance measures, workpiece surface temperature and surface roughness. Optimal cutting parameters for each performance measure were obtained employing Taguchi techniques. The orthogonal array, signal to noise ratio and analysis of variance were employed to study the performance characteristics in turning operation. V.N.

Gaitondea, S.R. Karnikb, J. Paulo Davi[2],Selection of optimal MQL and cutting conditions for enhancing machinability in turning of brass, The present work aims at determining the optimum amount of MQL and the most appropriate cutting speed and feed rate during turning of brass using K10 carbide tool. Taguchi technique with the utility concept, a multi-response optimization method, has been proposed for simultaneous minimization of surface roughness and specific cutting force.

NexhatQehaja, KaltrineJakupiAvdylBunjaku, MirlindBruçi, Hysni Osmani[3], Effect of Machining Parameters and Machining Time on Surface Roughness in Dry Turning Process. This paper a model of surface roughness was developed based on the response surface method to investigates the machining parameters such as feed rate, tool geometry, nose radius, and machining time, affecting the roughness of surface produced in dry turning process.

HaruyoFukui[4], Evolutional History of Coating Technologies for Cemented Carbide Inserts — Chemical Vapor Deposition and Physical Vapor Deposition, This paper looks back at 50 years of history of coated materials development and introduces new materials. The chipping resistance and wear resistance of coated cemented carbide inserts are compared with uncoated inserts made of other materials.

Sudhansu Ranjan Das, Asutosh Panda and DebabrataDhupal[5], Experimental investigation of surface roughness, flank wear, chip morphology and cost estimation during machining of hardened AISI 4340 steel with coated carbide insert. The present study addresses surface roughness, flank wear and chip morphology during dry hard turning of AISI 4340 steel (49 HRC) using CVD (TiN/TiCN/Al2O3/TiN) multilayer coated carbide tool. To justify the economical feasibility of coated carbide tool in hard turning application, a cost analysis was performed based on Gilbert’s approach by evaluating the tool life under optimized cutting condition.

FarhadKolahan, A. Hamid Khajavi[6], 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 objective is to determine a suitable set of process parameters that can produce a desired depth of cut, considering the ranges of the process parameters. Computational results prove the effectiveness of the proposed model and optimization procedure.

Palanikumar, k. And karthikeyan[7], optimal machining conditions for turning of particulate metal matrix composites using taguchi and response surface methodologies, In this work, the effect of machining parameters on the surface roughness is evaluated and optimum machining conditions for maximizing the metal removal rate and minimizing the surface roughness are determined using response surface methodology.

ShuhoKoseki, Kenich Inoue, ShigekazuMorito, Takuya Ohba, Hiroshi Usuki[8], Comparison of TiN-coated tools using CVD and PVD processes during continuous cutting of Ni-based superalloys. In this work, PVD- and CVD-deposited TiN coatings are tested in continuous cutting of Ni-based superalloy.

Aman aggarwal and harisingh[9],Optimization of machining techniques – A retrospective and literature review. In this paper an attempt is made to review the literature on optimizing machining parameters in turning processes. Various conventional techniques employed for machining optimization include geometric programming, geometric plus linear programming, goal programming, sequential unconstrained minimization technique, dynamic programming etc. The latest techniques for optimization include fuzzy logic, scatter search.

AdestaErryYulian T., Riza Muhammad, HazzaMuataz, AgusmanDelvis, Rosehan[10], Tool Wear and Surface Finish Investigation in High Speed Turning Using Cermet Insert by Applying Negative Rake Angles, Tool wear and surface roughness under different rake angles and different cutting speed were investigated and Experiments were carried out by using cermet (CT5015).

Aslan E, Camuşcu N, BingörenB[11], Design optimization of cutting parameters when turning hardened AISI 1016 (63 HRC) with Al2O3+TiCN mixed ceramic tool, In this work, two kinds of Al2O3-TiC-TiN ceramic cutting tools (AC2U and AC2UN2) were developed by hot-pressing sintering techniques. The mechanical properties were measured and the cutting performance was investigated.

Chavoshi SZ, TajdariM[12], Surface roughness modelling in hard turning operation of AISI 1016 using CBN cutting tool. Int. J. Mater. Forming. 3(4): 233-239, the influence of hardness (H) and spindle speed (N) on surface roughness (Ra) in hard turning operation of AISI 4140 using CBN cutting tool has been studied. A multiple regression analysis using analysis of variance is conducted to determine the performance of experimental values.

Indrajit Mukherjee, Pradip Kumar Ray[13], a review of optimization techniques in metal cutting processes, In this paper, the application potential of several modelling and optimization techniques in metal cutting processes, classified under several criteria, has been critically appraised, and a generic framework for parameter optimization in metal cutting processes is suggested for the benefits of selection of an appropriate approach.

ArsalanQasim, Salman Nisar, Aqueel Shah, Muhammad Saeed Khalid, Mohammed A. Sheikh[14], Optimisation of process parameters for machining of AISI-1045 steel using Taguchi design and ANOVA. In this paper optimization of machining parameters with multiple cutting tools is discussed. This is required to reduce the cutting forces and temperature while machining AISI 1045 steel. In this study, the effects of varying cutting speed, feed rate, depth of cut, and rake angle in orthogonal cutting process have been considered.

CarmitaCamposeco, Negrete[15], Optimisation of cutting parameters for minimizing energy consumption in turning of AISI 6061 T6 using Taguchi methodology and ANOVA,The present paper outlines an experimental study to optimize cutting parameters during turning of AISI 6061 T6 under roughing conditions in order to get the minimum energy consumption. An orthogonal array, signal to noise (*S*/*N*) ratio and analysis of variance (ANOVA) were employed to analyze the effects and contributions of depth of cut, feed rate and cutting speed on the response variable.

Present Work:

In thepresent work, Smaller -The-Better quality control is used and L_9 array is shown in Table 1.

Table1: L_9 orthogonal array

	Column No.			
Trial No	**1**	**2**	**3**	**4**
1	1	1	1	1
2	1	2	2	2
3	1	3	3	1
4	2	1	2	1
5	2	2	3	1
6	2	3	1	2
7	3	1	3	2
8	3	2	1	1
9	3	3	2	1

A Lathe machine was used for conducting the experiments. A combination of AISI 1016 was used as the work material and cemented carbide tipped tools with CVD and PVD coating were used as cutting tools. The average surface roughness on the work piece was measured using Mitutoyo surface finish measuring instrument which is shown in Fig.1. The experimentation for this work was based on Taguchi's design of experiments (DOE) and orthogonal array.

Three parameters (Cutting speed, Depth of cut and Feed rate) each at three levels and a fourth parameter (Hardness Ratio of work piece to tool) at two levels were used as input for the L_9 array. The response obtained from the trials conducted as per L_9 array experimentation was recorded and further analysed. In this study, the minimum surface roughness of cylindrical work piece and cutting forces were investigated. Table 2 shows the parameters and their levels considered for the experimentation.

Table 2: Process parameters and their levels

Parameters	Level1	Level2	Level3
Speed	740	580	450
Feed rate	0.05	0.07	0.09
Depth Of Cut	0.25	0.20	0.10
Hardness Ratio	0.4406	0.634	-

Surface roughness measurement:

Measuring instrument :Mitutoyo SJ-201P
Traverse Speed : 1mm/sec
Measurement : Metric/Inch

Fig 1: Surface finish measuring instrument

The general specification of coated cemented carbide insert is CNMA 120408 KBM10B. The cemented carbides have high hardness over a wide range of temperature; are very stiff (Young's modulus is nearly three times that of steel); exhibit no plastic flow (yield point) even on experiencing stresses of the order of 33300 kg/cm^2, have low thermal expansion compared with steel; relatively high thermal conductivity; and a strong tendency to form pressure welds at low cutting speeds.

AISI 1016 is an unalloyed medium carbon steel with good tensile strength and suitable for manufacturing automobile parts, axles, shafts etc. It is normally supplied in cold drawn or as rolled. Tensile properties can vary but are usually between 500-800 N/mm^2. AISI 1016 is available from stock in bar and can be cut to your requirements. The chemical composition for the chosen work material is given in the Table 3 with diameter Ø50 mm and length 300mm.

Table 3: chemical composition of AISI 1016

Element	Composition
C	0.20(MAX)
Si	0.35(MAX)
Mn	0.50-1.00
S	0.040
P	0.040
Cr	0.75-1.25
Ni	1.00-1.50
Mo	0.08-0.15

III. Results And Discussions:

Taguchi Analysis:

Based on orthogonal array of **L_9,** DOE the experiments were conducted to predict the surface roughness (Ra) and the main objective of this experiment is to predict the better operating conditions and, also the influence of each parameter is evaluated. Therefore the experiments are conducted with cutting tool CVD and PVD on AISI 1016 for mixed level design to predict Ra. From the experimental data, Taguchi analysis is carried out which is explained in the section.

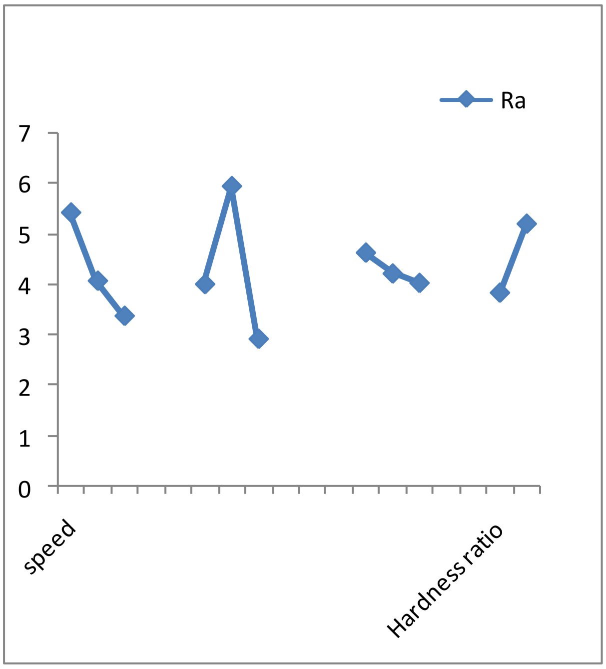

Figure 2: Plots of main effects for means of Surface roughness (Ra)

Analysis of Variance (ANOVA):

The experimental results were analyzed with the analysis of variance (ANOVA), which is used to investigate which design parameters significantly affect the quality characteristic.

Table 4: ANOVA for the response surface roughness (Ra)

S.No	Factor	DOF (f)	Sum of Sqrs (S)	Variance (v)	F-Ratio (F)	Pure Sum (S)	Percentage (p)
1	Speed	2	6.387	3.193	31935.78	6.386	26.107
2	Feed Rate	2	13.855	6.927	69276.28	13.855	56.634
3	Depth of Cut	2	0.557	0.278	2787.694	0.557	2.278
4	Hardness Ratio	1	3.663	3.663	36639.22	3.663	14.976
5	Error	1	0.001	0.001			0.005

It is observed that the feed rate and speed have great influence on Surface roughness.

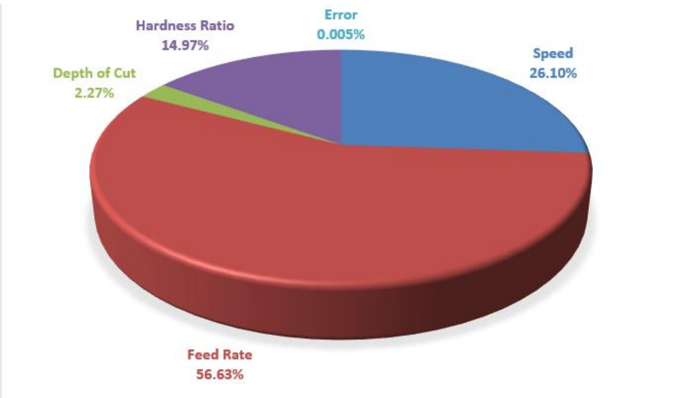

Figure 3: Percentage contribution of each factor

From Fig.3it is clear that, Feed rate has maximum influence on Surface Roughness followed by speed and Hardness ratio.The Optimized parameters for controlling of Ra are shown in the Table 5.

Table 5: Optimized table obtained

Factors	Speed (v)	Feed Rate (f)	Depth of Cut (d)	Hardness Ratio (h)
Surface Roughness	450	0.09	0.10	0.4406

IV. Conclusions:

The results obtained in this study lead to conclusions for turning of AISI 1016 after conducting the experiments and analyzing the resulting data:

The design of experiments (DOE), Taguchi method is applied for optimization of cutting parameters and Analysis of Variance (ANOVA) is done and found that, The optimal combination of process parameters for minimum surface roughness is obtained at 450 rpm cutting speed, 0.09 mm/rev feed, 0.10 mm of depth of cut and when CVD coated cemented carbide tool is used.

ANOVA shows that the Feed rate has great influence for the response surface roughness (Ra).

References:

[1]. Adeel H. Suhail, N. Ismail, S.V. Wong and N.A. Abdul Jalil [2010], Optimization of Cutting Parameters Based on Surface Roughness and Assistance of Workpiece Surface Temperature in Turning Process, American J. of Engineering and Applied Sciences 3 (1): 102-108, 2010

[2]. V.N. Gaitondea, S.R. Karnikb, J. Paulo Davim [2008], Selection of optimal MQL and cutting conditions for enhancing machinability in turning of brass, journal of materials processing technology 2 0 4 (2 0 0 8) 459–464

[3]. NexhatQehaja, KaltrineJakupi, AvdylBunjaku, MirlindBruçi, HysniOsmani , Effect of Machining Parameters and Machining Time on Surface Roughness in Dry Turning Process, 25th DAAAM International Symposium on Intelligent Manufacturing and Automation, DAAAM 2014.

[4]. Haruyo Fukui, Evolutional History of Coating Technologies for Cemented Carbide Inserts — Chemical Vapor Deposition and Physical Vapor Deposition, SEI Technical Review, April 2016.

[5]. Sudhansu Ranjan Das, Asutosh Panda and DebabrataDhupal, Experimental investigation of surface roughness, flank wear, chip morphology and cost estimation during machining of hardened AISI 4340 steel with coated carbide insert, Das et al. Mechanics of Advanced Materials and Modern Processes (2017).

[6]. FarhadKolahan, A. Hamid Khajavi [2010], A Statistical Approach for Predicting and optimizing Depth of Cut in AWJ Machining for 6063-T6 Al Alloy, International Journal of Mechanical Systems Science and Engineering 2:2 2010

[7]. Palanikumar, k. And karthikeyan, r.(2006) optimal machining conditions for turning of particulate metal matrix composites using taguchi and response surface Methodologies, machining science and technology, 10: 4, 417 — 433

[8]. ShuhoKoseki, Kenich Inoue, ShigekazuMorito, Takuya Ohba, Hiroshi Usuki [8], Comparison of TiN-coated tools using CVD and PVD processes during continuous cutting of Ni-based superalloys, Surface and Coatings Technology, Volume 283, 15 December 2015.

[9]. Aman aggarwal and harisingh [2005], Optimization of machining techniques – A retrospective And literature review, SadhanaVol. 30, Part 6, December 2005, pp. 699–711

[10]. AdestaErryYulian T., Riza Muhammad, HazzaMuataz, AgusmanDelvis, Rosehan, Tool Wear and Surface Finish Investigation in High Speed Turning Using Cermet Insert by Applying Negative Rake Angles, European Journal of Scientific Research Vol.38 No.2 (2009): pp.188.

[11]. Aslan E, Camuşcu N, Bingören B (2007), Design optimization of cutting parameters when turning hardened AISI 1016 (63 HRC) with Al_2O_3+TiCN mixed ceramic tool, Mater. Design, 28: 1618-1622.

[12]. Chavoshi SZ, Tajdari M (2010). Surface roughness modelling in hard turning operation of AISI 1016 using CBN cutting tool. Int. J. Mater. Forming. 3(4): 233-239.

[13]. Indrajit Mukherjee, Pradip Kumar Ray [2006], a review of optimization techniques in metal cutting processes, Computers & Industrial Engineering 50 (2006) 15–34.

[14]. ArsalanQasim, Salman Nisar, Aqueel Shah, Muhammad Saeed Khalid, Mohammed A. Sheikh[2015], Optimisation of process parameters for machining of AISI-1045 steel using Taguchi design and ANOVA, Simulation Modelling Practice and Theory, vol 59, December 2015: 36-51.

[15]. CarmitaCamposeco, Negrete[2013], Optimisation of cutting parameters for minimizing energy consumption in turning of AISI 6061 T6 using Taguchi methodology and ANOVA, Journal of Cleaner Production, vol. 53, 15 August 2013, 195-203.