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Research Article

Experimental Investigation for finding optimum Surface roughness, VMRR and Interface Temperature during turning of AISI 8620 Alloy Steel using CNMG Insert

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Abstract

This paper envisages an experimental investigation on turning of AISI 8620 alloy steel using PVD coated cemented carbide CNMG inset. Nine experimental runs based on Taguchi factorial design were performed to find out optimal factio level condition. The main focus of present experimentation is to optimize the process parameters namely spindle speed, feed and depth of cut for desired response characteristics i.e. surface roughness, VMRR and interface temperature. To study the performance characteristics in this work orthogonal array(OA), analysis of means(ANOM) and analysis of variance(ANOVA) were employed.The experimental results showed that the spindle speed affects more on surface roughness, feed affects more on VMRR and feed affects more on interface temperature.Confirmation tests also been performed to predict and verifythe adequacy of models for determining optimal values of response characteristics.

Keywords*: AISI 8620 alloy steel, PVD tool, CNMG insert, turning, surface roughness, VMRR, interface temperature, OA, ANOM, ANOVA*

1. Introduction

Surface finish is a important parameter which ascertains the quality of production during machining operation. It gives an aesthetic appeal to the product which gives maximum satisfaction to the customer. In an manufacturing industry surface finish will not suffice the completeness and if productivity adds to it, will give the total completeness. For this purpose quality of a product as well as productivity should be high. To ensure high productivity the material removal rate need to be considerably high and hence material removal rate need to be considered in metal machining operation. The interface temperature between tool and work while turning is an important factor which affects cutting tool wear, work piece surface integrity and surface quality of the work. The amount of heat generated depends on type of material being machined and to large extent cutting speed and to some extent feed and depth of cot. The interface temperature need to kept at low level by which work piece surface integrity will not be affected as also tool life will be improved which reduces tooling costs. Hence an attempt is made to evaluate optimum cutting parameters for minimum surface roughness, minimum interface temperature and maximum material removal rate. In the present work, AISI 8620 alloy steel was selected as work material which finds applications in the manufacture of gears. pinions, lay shaft, cam shafts, mining haulage, cage suspensions, lifting gears, fasteners, chains and many more.For the purpose of experimentation, factorial design experiments are considered as per Taguchi DOE. By advocating Taguchi design, a clear understanding of the nature of variation and economical consequences of quality engineering in the world of manufacturing can be clearly got through.

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2. Literature Survey

W.H.Yang& Y.S Tang envisages that the Taguchi method is a powerful tool to design optimization for quality and is used to find the optimal cutting parameters for turning operations. An orthogonal array , the signal to noise ratios and ANOVA are employed to investigate the cutting characteristics of S45C steel bars using Tungsten carbide cutting tools. Through this study, not only optimal cutting parameters for turning operations obtained, but also the main cutting parameters that affect the cutting performance in turning operations are found.

S.Thamighamani *et al* studied the tool wear and surface roughness of AISI 8620 using coated ceramic tool during turning process. Ceramic tool with Al203 +TiC(golden) coating was used to investigate the surface roughness and tool wear on AISI8620 material without coolant. The tests were carried under various combinations of cutting speed, feed rate and depth of cut and fixed time period. It is seen that cutting speed was increased and tool

Table1: Chemical composition of work material

Element	C	Si	Mn	NI	Cr	Mo	S	P
% of Composition	0.18 to 0.23	0.30 to 0.60	0.60 to 0.100	0.40 to 0.70	0.40 to 0.60	0.15 to 0.25	0.04	0.035

Table 2: process parameters

Cutting Parameters	Level 1	Level 2	Level 3
Spindle speed (S) (rpm)	450	580	740
Feed(F) (mm/rev)	0.05	0.07	0.09
Depth of cut(D) (mm)	0.10	0.20	0.25

wear was not noticeable for few tests. It increase rapidly at higher cutting speed, feed rate, higher depth of cut and increase in time

Adeel H Suhail *et al* focused the optimization of cutting parameters using two performance measures work piece surface temperature and surface roughness. The work material used is medium carbon steel AISI 1020. Optimal cutting parameters for each performance measure were obtained by employing Taguchi technique. The orthogonal array, signal to noise ratio and analysis of variance were employed to study the performance characteristics in turning operation

A.Youssef presents a comparison of three different experimental designs aimed at studying the effects of cutting parameters variations on surface finish. The results revealed that the effects obtained by analyzing both fractional and Taguchi design were comparable to the main effects and low-level interaction obtained by full factorial design

Arsecularatine J.A describes an experimental investigation on machining of a difficult-to-cut material AISI D2 steel with PCBN tools. It was found that the most feasible feeds and speeds fall in the ranges of 0.08-0.20 mm/rev and 70-120 m/min respectively and most of tested PCBN tools reached the end of life mainly due to flank wear.

MeenuSahu and KomeshSahu presents an optimization method ofcutting parameters (cutting speed, depth of cut and feed) in dry turning of AISID2 steel to achieve minimum tool wear, low work piece surface temperature and maximum material removal rate. The experimental layout was designed based on Taguchi OA technique and ANOVA was performed to identify the effect of cutting parameters on the response variables. The results showed that depth of cut and cutting speed are the most important parameters influencing wear. Similarly low work piece surfacetemperature was influenced by cutting speed followed by depth of cut. The depth of cut and feed significantly influences high MRR. The optimal range of tool wear, work piece surface temperature and MRR were predicted. Finally the relationship between factors and performance measures were developed using multiple regression Analysis.

HardeepSingh *et al* depicts experimental study to investigate the effect of cutting parameters like spindle speed, feed and depth of cut on surface roughness and material removal rate on En 8. Taguchi methodology has been employed applied to optimize cutting parameters. The results showed that spindle speed affects most followed by depth of cut and feed rate.

R.K Suresh &G.Krishnaiah investigated an optimal setting of process parameters in turning for maximizing material removal rate. In this work En 41B alloy steel has been taken as work material and cermet as tool. A number of experiments have been conducted as Taguchi DOE. By Taguchi analysis process parameters such as spindle spped, feed and depth of cut has been optimized for maximum MRR and by ANOVA the percentage contribution by each process parameters on response characteristic has been depicted.

N.Tosum&l.Ozler presented an investigation in optimization and effect of cutting parameters on multiple performance characteristics (the tool life and work piece surface roughness) obtained by hot turning operation. A plan of experiments based on Taguchi method was designed M20 sintered carbide as tool and high manganese steel as work material were used in the experiments. The results showed that the cutting speed, feed rate were dominant variables on multi cutting performance characteristics. An optimal parameter combination was obtained by using statistical Analysis. From the literature survey, it is evident that no work has been reported on AISI 8620 alloy steel work with combination of PVD coated tool with designation CNMG 120408EN-M30 CTPM125. Hence the experimentation is done on above said combination of work piece and tool

3. Materials and Methods

3.1 Specification of work material

The work material used for the present study is AISI 8620 alloy steel.The chemical composition of the work material is shown in Table 1.

3.2 Taguchi Method

The objective of the robust design is to find the controllable process parameters setting for which Noise or variation as a minimal effect on the product or process functional characteristics. It is to be noted that the aim is not to find the parameter setting for the uncontrollable noise variables but the controllable design variables. To attain this objective, the control parameter also known as inner array variables, are systematically varied as stipulated by the inner orthogonal array. For the each experiment of inner array, a series of new experiments is conducted by varying the level settings of the uncontrollable noise variables. The level combinations of noise variables are done using the outer orthogonal array.

Table 3: Experimental data and results for 3 parameters, corresponding Surface roughness, VMRR and Interface temp for PVD tool.

Spindle speed (rpm)	Feed(mm/rev)	Doc(mm)	Surface roughness Ra(μm)	Material removal rate (mm^3/sec)	Temperature Temp(◦c)
450	0.05	0.1	0.9276	3.415	28.88
450	0.07	0.2	0.9728	10.056	33.06
450	0.09	0.25	1.2647	29.156	38.36
580	0.05	0.2	1.7700	11.560	31.21
580	0.07	0.25	1.2390	11.894	36.41
580	0.09	0.1	1.1060	9.722	36.01
740	0.05	0.25	1.5860	15.489	34.83
740	0.07	0.1	1.5819	10.423	34.79
740	0.09	0.2	1.0609	23.536	35.45

Table 4:ANOM for Experimental data (Surface roughness)

Factors	Level 1	Level 2	Level 3	Optimum value (surface roughness)
Spindle speed	1.0550	1.3716	1.4096	1.055 (S1)
Feed	1.4278	1.2645	1.1438	1.1438 (F3)
Depth of cut	1.2052	1,2679	1.3632	1.2052 (D1)

Table 5: ANOM for Experimental data (Material removal rate)

Factors	Level 1	Level 2	Level 3	Optimum value (material removal rate)
Spindle speed	14.2090	11.0586	16.4823	16.4826 (S3)
Feed	10.1546	10.7910	20.8040	20.804 (F3)
Depth of cut	7.8533	15.0510	18.8460	18.846 (D3)

Table 6: ANOM for Experimental data (Interface temperature)

Factors	Level 1	Level 2	Level 3	Optimum value (interface temperature)
Spindle speed	33.433	34.543	35.023	33.433 (S1)
Feed	31.640	34.753	36.606	31.640 (F1)
Depth of cut	33.226	33,240	36.533	33.226 (D1)

Table 7: ANOVA for Surface roughness

Factors	Degrees of freedom	Sum of squares	Mean sum of squares	Percentage contribution
Spindle speed	2	0.1641	0.0820	22.69
Feed	2	0.1220	0.0610	16.87
Depth of cut	2	0.0381	0.0191	5.26
Error	2	0.3989	0.1995	55.16
Total	8	0.7231		100.00

Table 8: ANOVA for Material removal rate

Factors	Degrees of freedom	Sum of squares	Mean sum of squares	Percentage contribution
Spindle speed	2	44.5139	22.2569	9.05
Feed	2	214.100	107.050	43.53
Depth of cut	2	187.053	93.527	38.03
Error	2	46.208	23.104	9.39
Total	8	491.876		100.00

Table 9: ANOVA for Interface temperature

Factors	Degrees of freedom	Sum of squares	Mean sum of squares	Percentage contribution
Spindle speed	2	3.990	1.995	6.03
Feed	2	37.796	18.898	57.13
Depth of cut	2	21.780	10.890	32.924
Error	2	2.587	1.294	3.91
Total	8	66.153		100.00

Table 10: Comparison between optimal and predicted values

Responses	Optimal setting of parameters	Optimal value (confirmation experiment)	Predicted value	Deviation percentage
Surface roughness	S1-F3-D1	0.8858	0.848	4.45
VMRR	S3-F3-D3	30.465	28.299	7.65
Interface temperature	S1-F1-D1	28.90	29.633	-2.40

The interference of noise on the performance characteristics can be found using the ratio where S is the standard derivation of the performance parameters of the each inner array experiment and N is the total number of experiment in the outer orthogonal array. This ratio indicates the functional variation due to noise. Using this result, it is possible to predict which control parameter settings will make the process in sensitive to noise. Taguchi method focus on robust design through use of
1. Signal to noise ratio.
2. Orthogonal array.

3.3 Analysis of Means (ANOM)

ANOM is a process of estimating the effects of various process parameters over response characteristics. The optimum level for a factor is the level that gives requisite value of means in the experimental region viz., for surface roughness and interface temperature, the lowest value of means to be considered and for VMRR, the highest value of means to be considered.

3.4 Analysis of Variance (ANOVA)

Analysis of variance (ANOVA) is a statistical method of determining the existence of several While the aim of ANOVA is to detect the difference among several populations means the technique requires the analysis of different forms of variance associated with random samples under the study hence it is called ANOVA.

The original idea of ANOVA was developed by the English statistician sir Ronald A fisher during the first part of this century. most of the early work in this area deal with the agricultural experiments where crops were given different treatments, such as being grown using different kinds of fertilizes. The researchers wanted to determine whether all treatments under study were equally effective or whether some treatments were better than others. ANOVA is a computational technique that enables the estimation of the relative contributions of each of the process parameters over the response characteristics.

4. Experimentation

Turning plays a significant role in metal cutting operation where in lathe is used to perform metal machining. It is a machining process in which a cutting tool insert removes unwanted material from the surface of a rotating cylindrical work piece. The cutting insert is fed linearly in a direction parallel to the axis of rotation. In the present work , three levels, three factors and nine experiments are identified. By using Taguchi design, L_9 orthogonal array has been selected. Metal cutting operation are performed on PSG A141 lathe under dry cutting condition. The surface roughness of machined surface has been measured by a stylus (Surf test SJ 210-P instrument) the dependent variable is surface roughness. The volumetric material removal rate (VMRR) is calculated using

$[\pi/4(D_1^2 - D_2^2)*L]/t$ where D_1,D_2 are diameter of work before and after each run
L is length of machined surface
t is machining time

The interface temperature is measured by using non-contact infrared thermometer.

5. Results

5.1 Analysis of Experimental data

5.2Prediction of optimal design and confirmation experiments

From mean response graphs for surface roughness, the optimal setting is found at: spindle speed at level 1, feed at level 3 and depth of cot at level 1. The predicted optimum value for surface roughness can be computed as

$\mu_{SR} = S_1+F_3 +D_3-2*T_{SR}$

where T_{SR} is overall mean experimental surface roughness values
Hence the predicted value of experimental data for surface roughness is 0.848 µm.

Confidenceinterval for predicted optimum experimental data on a confirmation run can be calculated using

$C.I = \sqrt{(F\alpha()1, fe)Ve[\frac{1}{neff}+\frac{1}{R}]}$

Where Fα is F-ratio, fe is the degrees of freedom, Ve is error variance, n_{eff} is the effective number of replications,

$n_{eff} = \frac{N}{1+total\ DOF}$, R is the number of repetitions and N is total number of experiments

Using the values of experimental data, Ve = 0.1995, fe = 2
From F-table at 95% confidence intervel, $F_{0.05(1,2)} = 18.51$
Hence C.I for experimental data = +or- 2.562

Confidence intervel of predicted mean = 0.848 +or- 2.562 = - 1.714 to 3.41

The confirmation experiment is carried out by setting as spindle speed = 450 rpm, feed = 0.09 mm/rev and depth of cut = 0.1 mm

Based on above setting, the corresponding surface roughness is 0.8858 µm which is within the limits -1.714 to 3.41. The difference between predictive surface roughness and the surface roughness from confirmation experiment is well within limits of 5% and hence accepted. Likewise for VMRR and interface temperature, the above calculations is made and tabulated as depicted in the table 10.

Conclusions

1. The Results depicted that Taguchi design is an effective way in finding optimal process parameters for achieving low surface roughness, high VMRR and low interface temperature.
2. The spindle speed significantly affects the surface roughness (22.69%) followed by feed (16.87%) and depth of cou (5.26%). Also since error component is significantly high the interactions need to be considered.
3. As far as VMRR is concerned, the contributions by feed is maximum (43.52%) followed by depth of cut (38.02%). The spindle speed has less significant on VMRR.
4. The significant contributing factor for interface temperature is feed with 57.13% followed by depth of cut with 32.92%.
5. The predicted optimal range of surface roughness is -1.714 to 3.41. VMRR is 0.7276 to 55.871 and interface temperature is 23.1092 to 36.1568.
6. From the confirmation experiment the optimal values obtained for surface roughness, VMRR and interface temperature are 0.8858 µm, 30.465 mm^3/sec and 28.90^0C respectively.
7. Finally the deviation percentage between the optimal value and experimental value (from confirmation experiment) for various responses are significantly low and hence acceptable.

Future Scope of Work

In the present paper, only three process parameters has been studied in accordance with their effects. Further study can be possible by considering other input factors like tool nose radius, style of tool insert, tool material, cutting environment etc. and by which other response characteristics such as power consumption, forces, tool wear, tool life, tool vibration chatter etc. can be evaluated. Also future research opportunities in the field of machining of metal matrix composite can be thought of.

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