International Journal of Advanced Mechanical Engineering.
ISSN 2250-3234 Volume 4, Number 2 (2014), pp. 151-160

http://www.ripublication.com/ijame.htm

Study of Cutting Forces and Surface Roughness in Turning of Bronze Filled Polytetrafluoroethylene

Mohd. Suhail Ansari[1] Deepak Sharma[2] and Sagar Nikam[3]

[1]*Student at Dept of Material Science and Nano Technology, University of Petroleum and Energy Studies, Dehradun, Uttrakhand,*
[2]*Dept of Material Science and Nano Technology, University of Petroleum and Energy Studies, Dehradun, Uttrakhand*
[3]*Post Graduate Schlor at NIT, Trichy.*

Abstract

There are many applications in world today that require materials with different combination of properties that cannot be met by the conventional metal alloys. It is important to study the effect of the cutting parameters and insert radius on the cutting force and surface roughness to improve machinability of polymer matrix composites. Taguchi is used for design of experiments. The material used for study is bronze plus MoS_2 filled polytetrafluoroethylene (PTFE). PTFE composites are used in many industrial applications, especially, Piston Seals, andfor Hydraulic Piston Rings industries. Two performances characteristic are considered cutting force and surface roughness, the various process parameters are selected and varied in three different levels. Cutting tool used for turning operation is cemented carbide tips. Analysis of variance (ANOVA) technique is used to find out the significant parameters influencing the performance measure. ANOVA result shows that feed (f), nose radius(r), and depth of cut are most significant process parameters to influence surface roughness; change in these parameters can increase surface roughness. A new class of material called polymer matrix composites has answered to this question in great extent. Also metal alloy reinforcements in polymer based composites leads to increase in cutting force, when cutting force is increased machining temperature is increased and it leads to soften base polymer material, hence the behavior machined polymer based matrix differ from metal alloys due to temperature dependence polymer. Cutting forces and surface roughness are two important different problems in the machining of polymer-based composites.

Cutting forces has a direct influence on specific cutting pressure and specific power consumption, tool wear and internal heat generation. On the other hand, surface roughness is an important output characteristic that describes the quality of the machined surface. In order to obtain good machinability and to improve the product quality, it is necessary to obtain minimum values of cutting force and surface roughness(primary and waviness). The optimization of cutting force and surface roughness consumes lot of time and is expensive, if it is to be done for all the possible experimental combinations. Hence the data during machining are analyzed using different statistical methods such as Taguchi's design of experiments, analysis of variance (ANOVA), Taguchi methods and grey relational analysis.. However machining consists of more number of process parameters hence the requirement of optimum combination of cutting parameters is different for each of these characteristics and depends on the type of material being machine.

Keywords: ANOVA, Taguchi Method, Cutting Forces, Nose Radius, surface Roughness.

1. Introduction

A new class of material called polymer matrix composites are the game changer. The commercial and technological interest in polymer matrix composites materials derives from the fact that their properties are not only different from their components but rather superior to other alloys. There are various manufacturing process like molding ,machining, extrusion or sintering by which polymer based composites can be processed. But machining of polymer-based composites exhibits problem like fiber pullout it leads to surface finish damage. Surface finish damage mechanisms are fiber pull out, fiber fragmentation, delaminating, matrix burning or cracking. Also metal alloy reinforcements in polymer based composites leads to increase in cutting force, when cutting force is increased machining temperature is increased and it leads to soften base polymer material, hence the behavior of machined polymer based matrix differ from metal alloys due to temperature dependence polymer. surface roughness Cutting forces are two important different problems in the machining of polymer-based composites. Cutting forces has a direct influence on specific cutting pressure and power consumption, tool wear and heat generation. On the other hand, surface roughness is an important output characteristic that describes the quality of the machined surface. In order to obtain good machinability and to improve the product quality, it is necessary to obtain minimum values of cutting force and surface roughness. Cutting forces have a direct effect on specifictool wear heat generation. Cutting energy, and. and surface roughness are two important issues in the machining of polymer-based composites material like BRONZE filled polytetrafluoroethylene (PTFE).Surface roughness affects different characteristics of machined parts likeheat transmission friction, wear. So for good machinabilitysurface roughness cutting for value should be minimum. As machining involves a great number of process variables, the optimization of cutting force and surface roughness is time consuming and expensive.

2. Litreture Review

Felicia Stan Catalin Fetecau, Investigate the turning of PTFE composites using a polycrystalline diamond tool in order to analyze the effect of the cutting parameters and insert radius on the surface roughness cutting force. A strain gauge based dynamometer for the main cutting force measurement in turning was constructed. The force signals were captured and processed using a strain data acquisition system based on the Sider8 and CATMAN software.surface roughness Cutting force were measured through longitudinal turning. Francisco Mata, V.N. Gaitonde, S.R. Karnik and J. Paulo Davim Establishes the relationships between the cutting conditions (cutting speed and feedrate) on two aspects of machinability, specific cutting pressure namely, power. The study carried by Rama Rao. S, Padmanabhan. The process parameters were determined by using Taguchi's experimental design method.

Mustafa Suleyman Yaldız, Faruk Unsacar Designed and developed a turning dynamometer that measure static and dynamic cutting forces by using strain gauge and piezo-electric accelerometer. The orientation of octagonal rings and strain gauge locations has been determined to maximize sensitivity and to minimize cross-sensitivity. The developed dynamometer is connected to a data acquisition system. Cutting force signals were captured and transformed into numerical form and processed using a data acquisition system consisting of necessary hardware and software running on MS-Windows based personal computer. The obtained results of machining tests performed at different cutting parameters showed that the dynamometer could be used reliably to measure cutting forces. Although the dynamometer was developed primarily for turning operations, it can be used to measure cutting forces during nearly all machining operations. (drilling ,milling,etc.).

3. Material and Experimental Procedure

3.1. Material Used

Investigation is done on Bronze plus MoS_2 filled the polytetrafluoroethylene (PTFE). PTFE is widely used in many industrial applications, especially for energy transmitting andself-lubricating bearings devices such as clutch plates, because of its high strength, thermal stability andchemical resistance. In many applications, bronze particles are added to improve the thermal conductivity of PTFE, while the addition of molybdenum disulphide and bronze fillers improves the wear resistance of PTFE. By the manufacturing point of view, the main drawback is that material is its high melt viscosity which prevents the injection molding and blow molding from being possible. Thus, for parts production, one can consider the sintering, extrusion or machining manufacturing processes, Chemical compositions of bronze filled, 5% molybdenum disulphidePTFE are 55% bronze and 45% polytetrafluoroethylene.

3.2 Machine Tool

The experiments were carried out on a CNC Turning center of Leadwell CNC turning center installed at National Institute of Technology, Production Engineering Department, Trichy, Tamilnadu, India. The CNC turning machine tool.

3.3 Experimental setup

The machining tests were performed on cylindrical molded bars with 56 mm diameter by using a cemented carbide insert tool. The following cutting geometry was employed for the insertclearance angle α = 7, rake angle γ = 5 and cutting edge angle χ= 45 degree. The cutting parameters selected for turning are: depth of cut (d), feed rate (f), and cutting speed (Vc). Three insert radii (r) were considered in order to evaluate the effect of the insert radius on the surface roughness and cutting force.

The main cutting force and the surface roughness parameter were measured for longitudinal turning. The cutting tests were conducted on a universal lathe model SN400 without coolant and the cutting speed values were restricted bythe workpiece diameterand the speed of the lathe.

3.4. Experimental design:

Taguchi methodis used for design of experiment The L_{27} orthogonal array is chosen which has 27 rows corresponding to the number of parameter combinations with three levels.

Table 3.4: Process Parameters.

Process parameters	Depth of cut (mm)	Feed rate (mm/rev)	Nose radius (mm)	Cutting speed (m/min)
Level 1	0.5	0.05	0.4	50
Level 2	1	0.15	0.8	100
Level 3	2	0.25	1.2	150

3.5. Analysis of variance (ANOVA)

ITIS a mathematical technique which based on the least square approach. This method is used fortheir interactions on turning of all the process parameters andfind the percentage of influence of various factors. The experimental resultsis based on the analysis of average and analysis of variance.

3.6. Grey relational analysis

The optimization of process parameters are carried out using Taguchi method with grey relational analysis. The grey relational theory provides an efficient management upon the uncertainty, multi-input and discrete data. Grey relational analysis is actually a measurement of the absolute value of the data difference between sequences, and it could be used to measure the approximate correlation between sequences.

4. Result and Discussion

Table 1: S/N ratio of each experiment for cutting force and surface roughness.

Experiment no	Depth of cut	Feed rate	Nose radius	Cutting speed	Cutting force(N)	S/N Ratio	Surface roughness(μm)	S/N ratio
1	0.5	0.05	0.4	50	10.94	-20.796671	2.62	-8.3660258
2	0.5	0.05	0.8	100	10.56	-20.4565	2.23	-6.9660973
3	0.5	0.05	1.2	150	9.14	-19.26671	2.47	-7.8539391
4	0.5	0.15	0.4	100	12.98	-22.265464	3.15	-9.9662111
5	0.5	0.15	0.8	150	12.6	-22.007471	2.68	-8.5626959
6	1.5	0.05	0.4	50	12.66	-22.048684	2.92	-9.3076579
7	1.5	0.05	0.8	100	12.11	-21.662853	2.63	-8.399615
8	1.5	0.05	1.2	150	11.06	-20.875133	2.89	-9.2179369
9	1.5	0.15	0.4	100	15.7	-23.916953	3.05	-9.6856768
10	1.5	0.15	0.8	150	15.63	-23.85928	2.74	-8.7557813
11	2	0.05	0.4	50	13.62	-22.633572	3.47	-10.806879
12	2	0.05	0.8	100	13.28	-22.464992	3.26	-10.2643982
13	2	0.05	1.2	150	12.67	-22.054502	2.89	-9.2179909
14	2	0.15	0.4	100	15.87	-24.015599	3.17	-10.021195
15	2	0.15	0.8	150	15.53	-23.829449	3.04	-9.6574717

4.1. S/N ratios for cutting force

Table.1. shows the calculated cutting force and surface roughness values for14 experiments conducted on different set of parameters with signal to noise ratio (S/N).The average S/N ratio for cutting forceis -22.883781 dBSurface roughness is as important characteristic for quality and reliability point of view. Surface roughness should be as low as possible of a machined component. The average S/N ratios for each level of the cutting parameters are -9.350850 dB the analysis was made using the popular software specifically used for design of experiment applications known as MINITAB 16.0. Irrespective of the characteristic; a smaller S/N ratio value always represents the better performance.

4.2. Optimization of Cutting force

To obtain the best combination of cutting parameters including the minimization of cutting force, the Taguchi method signal to-noise (S/N) ratio is used i.e. the ratio of the mean (the signal or the desirable value for the output characteristic) to the standard deviation (the noise or the undesirable value for the output characteristic).The highest S/N ratio for each factor shows the most significant level which has an effect on the cutting force.

In ANOVA analysis physical significance of feed rate (f) ,depth of cut (d) and nose radius(r) on the main cutting force is analyzed, since P- value for these is less than 0.05 and the F-value of feed rate, depth of cut and nose radius are greater than

1.The feed rate, depth of cut and nose radius contributes 57.81%, 35.02% and4.29%, in total variability of the result while cutting speed do not significantly influence the main cutting force as contribution is less than 1%

Table 2: ANOVA for cutting force.

Source	DOF	Seq SS	Adj SS	Adj MS	F	P	Contribution %
d	2	53.262	53.222	26.641	127.36	0	35.01
f	2	87.939	87.949	43.999	210.48	0	57.88
r	2	6.447	6.478	3.210	15.45	0	4.20
Vc	2	0.071	0.028	0.01	0.06	0.652	0.094
d x f	4	2.271	2.234	0.5553	1.74	0.391	1.42
d x r	4	0.056	0.093	0.256	0.00	1.00	0.08
d x Vc	4	0.696	0.656	0.1553	0.03	0.978	0.30
Error	18	3.708	3.779	0.299			
Total	26	152.167					

4.3 Optimization of Surface roughness

To obtain the optimal combination of the process variables that gives the optimum surface roughness for each level of the factors, the S/N ratio for smaller-is-better is calculated. Table 5.2presents the S/N ratio for the surface roughness at each level of the factors.

From table 5.1 the controlled variables combination for minimum surface roughness are depth of cut 1.5 mm (level 2), feed rate 0.25mm/rev (level 2), nose radius 1.2 mm(level 3), cutting speed 100m/min(level 2).

In ANOVA analysis for surface roughness, out of the four parameters analyzed, the feed rate (f), nose radius(r) and interaction of depth of cut and nose radius have physical significance on the surface roughness, and it’s contributes are 14.49%, 14.05%, and 20.88%, in total variability of the result while cutting speed do not significantly influence the surface roughness. Since P- value for these is less than 0.05 and the F-value of feed rate, depth of cut and nose radius are greater than 1.

Table 3: ANOVA for surface roughness.

Source	DOF	Seq SS	Adj SS	Adj MS	F	P	Contribution %
D	2	0.0900	0.9082	0.4536	3.11	0.045	1.11
F	2	1.168	1.144	0.588	4.03	0.036	14.69
R	2	1.1318	1.1411	0.5749	3.93	0.033	14.02
Vc	2	0.0121	0.0231	0.0111	0.07	0.956	0.277
d x f	4	1.687	1.691	0.456	3.64	0.027	20.83
d x r	4	0.335	0.343	0.0806	0.46	0.776	4.20

d x Vc	4	0.253	0.214	0.0561	0.21	0.935	2.68
Error	18	2.6124	2.6229	0.1447			
Total	26	8.1966					

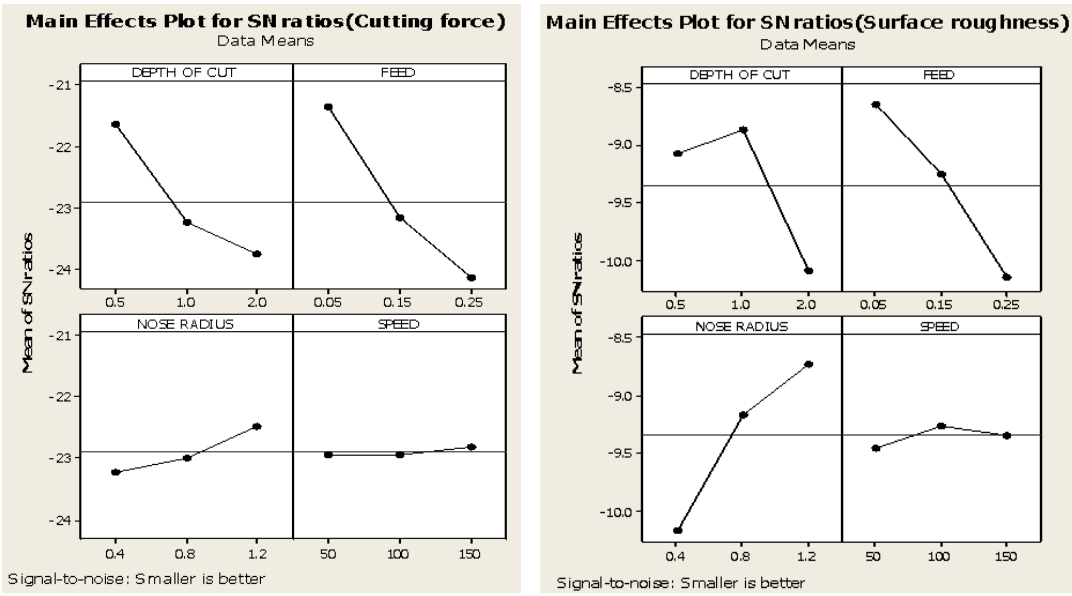

Fig. 4: ANOVA result showing influence of controlled parameter at three different levels.

4.4 Grey Relational Analysis

It is observed that optimal parametric combination for minimum cutting force and minimum surface roughness is not same but it is different for each responset if we want to obtain minimum cutting force we have to compromise with surface finish and for minimum surface roughness we have compromise with cutting force. Hence, to obtain a best combination for both minimum cutting force and minimum surface roughness correlation is obtained between cutting force and surface roughness and grey-Taguchi optimization is used. Normalizing of calculated S/N ratio has been done ranging from 0 to 1 and grey coefficients are calculated and grey grades are calculated by taking mean of grey coefficients.

Table 4: ANOVA for cutting force and surface roughness.

Source	DOF	Seq SS	Adj SS	Adj MS	F	P	Contribution %
D	2	0.097395	0.097395	0.04869	13.66	0	20.86
F	2	0.20192	0.20192	0.10096	28.31	0	43.23
R	2	0.052958	0.052958	0.02647	7.43	0.004	11.34
Vc	2	0.004231	0.004231	0.002116	0.59	0.563	0.91

d x f	4	0.0194	0.0194	0.048	0.86	0.509	4.15
d x r	4	0.0166	0.0166	0.004	0.29	0.878	3.55
d x Vc	4	0.0103	0.0103	0.0026	0.15	0.961	2.21
Error	18	0.064182	0.064182	0.00356			
Total	26	0.466987					

According to ANOVA study showed in table 5.11 the most significant parameter to obtain minimum cutting force and minimum surface roughness aredepth of cut and feed rate, and with contribution of 42.63%, 21.56% and 11.34%. Fig 5.3 shows the optimal parameter combination and effect of each control parameter on both responses.

Optimum controlled variables are obtained by maximum value of S/N ratios for grey grades. From the table 5.9 the optimum controlled variable for minimum cutting force and minimum surface roughness are depth of cut is 0.5 mm (level 1), feed rate is 0.05(level 1), nose radius 1.2 mm (level 3), cutting speed 100 m/min (level 2).

Taguchi's optimization method used for optimization of controlled variables for these responses but Taguchi is single objective optimization tool so; to achieve simultaneous optimization with Taguchi method grey relational analysis is done. The input values for Taguchi method are taken as obtained grades from table 5.9. This optimization can be called as grey-Taguchi based optimization.

Table 5.9: Grey relational grades.

Expriment No.	γi(K) CF	γi(K)SR	gi(Grade)	S/N ratios
1	0.397225	0.465946	`0.4319245	7.2519239
2	0.3823394	0.3934488	0.3280491	8.2122666
3	0.3333333	0.3333333	0.3333333	9.5224251
4	0.488871	0.5933673	0.5395442	5.3194601
5	0.4697571	0.478428	0.4741425	6.4218217
6	0.4424603	0.5844616	0.5161169	5.7451388
7	0.5379677	0.7975926	0.6729772	3.4504707
8	0.5552049	0.5955832	0.5668331	4.937279
9	0.5274812	0.7573968	0.620229	4.13890212
10	0.4749747	0.5318647	0.5023647	5.97235312
11	0.4461227	0.4673841	0.4574584	6.7929679
12	0.4019291	0.5244922	0.463307	6.6418044
13	0.6579435	0.5639193	0.6109364	4.2203643
14	0.6526311	0.4965892	0.57144501	4.843556

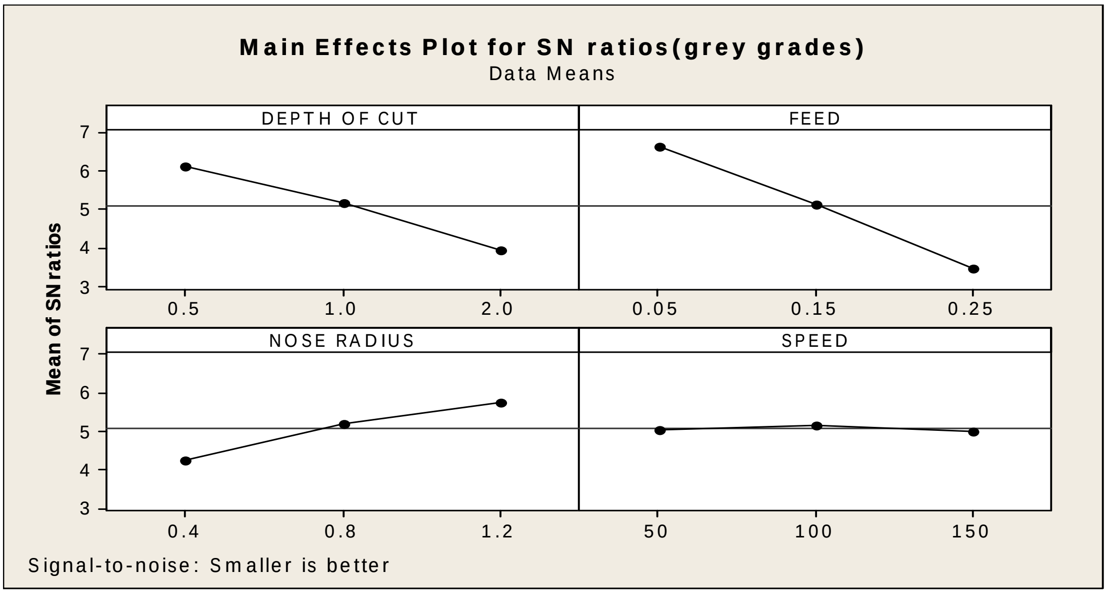

Fig. 5: ANOVA result showing influence of controlled parameter at three different levels.

4.5 Conformation Test

For conformation test combining cutting force and surface roughness grey relational analysis is used which is called as grey Taguchi optimization. Considering the obtained values for cutting force and surface roughness from table 5.12 the grey Taguchi optimization gave us cutting force of 9.44 N and surface roughness of 2.03µm.

5. Summary and Conclusion

An investigation into the turning of polytetrafluoroethylene (PTFE) composites has been performed in order to analyze the effect of the cutting parameters an insert radius on the machinability, defined in terms of cutting force and surface roughness. The main cutting force was also measured using a Kistler piezoelectric dynamometer. The main cutting force and surface roughness measured through longitudinal turning were analyzed using the S/N ratio and analysis of variance (ANOVA), and with grey relational analysis.

The following conclusion can be drawn for the parameters depth of cut, feed rate, nose radius and cutting speed effects on cutting force and surface roughness.

1. The surface roughness is significantly influenced by the feed rate, the insert radius, and depth of cut. The surface roughness increases with the increase of the feed rate, decreases with the increase of insert radius and increases with increase in depth of cut. The effect of cutting speed is less significant, the surface roughness slightly decreases with the increase cutting speed, respectively..

2. The cutting force is significantly influenced (at a 95% confidence level) by feed rate, depth of cut, while cutting speed and insert radius have a small influence. The cutting force increases with the increase of feed rate and depth of cut, respectively
3. Based on the analysis of the S/N ratio, and grey relational analysis the optimal cutting force and surface roughness is obtained when depth of cut and feed rate is set to their low level (level 1), cutting speed at medium level (level 2) and nose radius at high level(level 3).
4. The PTFE composites exhibit different behavior with respect to the machinability aspects. The machinability of PTFE composites is better when PTFE is reinforcedwith bronze. These results will be helpful for industries andpeople working in PTFE.
5. Composites Grey relational analysis with Taguchi method is feasible option to find out optimal parametric combination for simultaneous minimization of CF and minimization of SR.

References

[1] **CatalinFetecau, Felicia Stan** (2012) Study of cutting force and surface roughness in the turning ofpolytetrafluoroethylene composites with a polycrystalline diamond tool, *Measurement*, 1367–1379.

[2] **Francisco Mata, V.N. Gaitonde, S.R. Karnik and J. Paulo Davim** (2009) Influence of cutting conditions on machinability aspectsof PEEK, PEEK CF 30 and PEEK GF 30 composites using PCD tools, *Journal of materials processing technology*, 1980–1982, 1984–1987.

[3] **Rama Rao. S, Padmanabhan** (2012) Application of Taguchi methods and ANOVA in optimization of process parameters for metal removal rate in electrochemical machining of Al/5%SiC composites, *International Journal of Engineering Research and Applications (IJERA),*192-197.

[4] **G. Petropoulos, F. Mata, J. Paulo Davim** (2008) Statistical study of surface roughness in turning of peek composites, *Materials and Design*, 218–223.

[5] **Palanikumar, J. Paulo Davim**(2007) Mathematical model to predict tool wear on the machining of glassfibre reinforced plastic composites, *Materials and Design*, 2008–2014.

[6] **FarhadKolahan, Reza Golmezerji, MasoudAzadiMoghaddam** (2012) Multi Objective Optimization of Turning Process using Grey RelationalAnalysis and Simulated Annealing Algorithm, *Applied Mechanics and Materials*, 2926-2932.

[7] **FarukUnsacar** (2006) SuleymanYaldız Design, development and testing of a turningdynamometer for cutting force measurement, *Materials and Design*, 839–846.

[8] **Mustafa Gunay, IhsanKorkut, ErsanAslan, UlviSeker**(2005) Experimental investigation of the effect of cutting tool rake angleon main cutting force, *Journal of Materials Processing Technology*, 44–49