ENGINEERING RESEARCH JOURNAL (ERJ)
Vol. 1, No. 45 July. 2020, pp. 54-61
Journal Homepage: http://erj.bu.edu.eg

Experimental Analysis of surface Roughness and Material Removal Rate in Turning Operation using Response Surface Methodology

M. I. MANSOUR, E. H. MANSOUR[1] AND S. S. HABIB[2]

[1]. Assistant professor, [2]. Professor,Mechanical engineering department, Faculty of engineering at shoubra,Benha University

Abstract. : In this study three cutting conditions namely cutting speed, cutting feed rate,and depth of cut as well as multi-wall carbon nano tubes ($MWCNT_S$) volume fractions were studied at three levels. Work piece of aluminum –siliconalloy was reinforced with different nanovolume fractions (0%, 0.5% and 1%) of multi-wall carbon nano tubes($MWCNT_S$). Samples were fabricated using stirring casting technique. Machining processes were done on center lathe machine. Response surface methodology (RSM) and ANOVA analysis were applied to design and analyze experimental results. Results indicated that feed rate is the most significant factor on surface roughness, increasing in feed rate leads to increasing surface roughness value.

Keywords: Aluminum, Surface roughness, Metal matrix composites, RSM, $MWCNT_{S.}$

1. INTRODUCTION

Today's many engineering applications are based on metal matrix composites (MMC_S) due to their improved (chemical, physical and mechanical) properties since composite materials contain two or more different constituents[1, 2].Alloys reinforced with ceramic particles or fibers are harder than and superior with respect to unreinforced alloys because of excellent characteristics. Structural industries, aerospace, automobile industrials, and etc are some of the applications of metal - matrix composites [3].

In recent years many researchers used metal matrix composite materials in machining processes U.A.Dabadea et al [4].adopted experimental study of surface roughness integrity of AL-SiC particles metal- matrix composites in hot machining for turning process. They used three cutting conditions feed rate, depth of cut, and the Preheating temperature. Depending on taguchi method and ANOVA model the surface roughness and micro hardness were predicted. It is seen that feed rate, the preheating temperature, and depth of cut have great significant effect on surface roughness.samyaDahbiet al [5]. selected AISI 1042 steel standard carbide tool insertsCNMG120402,CNMG120404,and CNMG120408using taguchi design. Their study aimed to optimize

of surface roughness. Input cutting factors like cutting speed, feed rate, depth of cut, and tool nose radius were used. The results showed that the interaction between nose radius and feed rate had significant effect on surface roughness.

Ranaganath M Singari et al [6]. developed prediction of surface roughness in CNC turning of aluminum 6061 based on taguchi and ANOVA methods. Rake angle, nose radius, cutting speed, feed rate, and depth of cut were applied as cutting variables. The results indicated that the most major factor affects influentially on surface roughness was feed rate and surface roughness increased by increasing feed rate.Devendra singh et al [7]. derived effect of nose radius on surface roughness during CNC turning of AISI 6061 in dry conditions using response surface method and ANOVA. Cutting variables such as speed, feed rate, and depth of cut were used for turning operation. The results illustrated that the nose radius is the influential factor for minimizing surface roughness, in addition to increasing of nose radius leads to reducing in surface roughness

Vishal Sardana et al [8]. investigated the effect of three cutting variables cutting speed, feed rate, and depth of cut on surface roughness for CNC turning. They selected aluminum material for predicting surface roughness. Their experimental results showed that feed rate is the most significant parameter for minimizing surface roughness, and the best method for optimization of surface roughness was response surface. Mahesh Kumar et al [9].improved optimization of cutting parameters for turning en-31 for alloy steel material using RSM model and coated carbide tool. Predicted machined surface roughness was done by three factors like cutting speed, depth of cut, and feed rate. The results attempt that major factor effects on surface roughness is cutting speed followed by feed rate.

Anthony Xavoir et al [10].examined surface roughness using technique of ANOVA analysis with five machining factors cutting speed, feed rate, depth of cut, tool geometry, and tool material. Machinability of hybrid metal-matrix composite based on aluminum alloy reinforced with single- wall, multi - wall carbon nano tubes, and ceramic particles was investigated. They found that feed rate had great influence on surface roughness followed by cutting speed.PoojaA.Sutar [11].checked effect of cutting parameters on surface roughnessin CNCend milling of AISI316L.Taguchi and ANOVAmethods were applied.Input cutting parameters cutting speed, feed rate, depth of cut, and type of coolant were used. The results said that type of coolant is the most factor amongst parameters had best effect on surface roughness.

MeltemAltinKaratas [12]. Reviewed the machinability of carbon fiber reinforced polymer (CFRP) and glass fiber reinforced polymer (GFRP) composite materials for turning .Cutting speed and feed rate were two cutting parameters used to obtain surface roughness. Methods of ANOVA, artificial neural network (ANN), fuzzy inferences systems (FIF), and taguchi method are applied. It is observed that increasing feed rate enhancing mean surface roughness.Alokesh P Ramarrik [13]. investigated face milling of nano particles reinforced Al-based metal matrix composites using single milling tool. They used DOE model to predict surface roughness. Spindle speed, feed rate, and

depth of cut were three parameters applied for milling process. The results confirmed that feed rate has most influence on surface roughness.

2. EXPERIMENTAL WORK

2.1 Workpeice Material

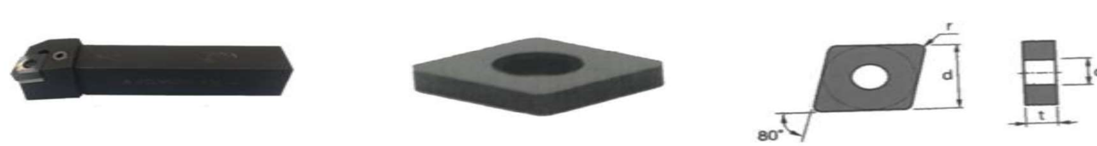
A stir casting process for aluminum alloy A 356 was done in a cylindrical steel mould with length 200 mm and diameter 40 mm. The chemical composition of A 356 is shown below in Table 1.This alloy was reinforced with different volume fraction (0 %, 0.5%, and 1%) of multi-wall carbon nano tubes ($MWCNT_S$).

TABLE 1. Chemical composition of aluminum silicon alloy A 356

Constitute	Weight %	Constitute	Weight %	Constitute	Weight %	Constitute	Weight %
Al	92.3000	Cr	0.0001	Cu	0.0002	Ti	0.1550
Si	6.9400	Pb	0.0010	Mn	0.0010	V	0.0160
Fe	0.0840	Sn	0.0004	Mg	0.3750	Zn	0.0050

2.2 Machine and Tool

The conventional center lathe machine Germaine 86 is used for cutting runs. The holder MCLNR 2525 M12 is chosen and according to the manufacturing catalogofkorloy uncoated carbide tip insert of ISO designation of CNMG 120408 – HA is selected as indicated on Fig1. The insert dimensions are shown in Table 2



(A) Holder (B) Carbide inserts (C) Dimensions of carbide insert

Fig .1. Cutting tool

TABLE 2. Dimensions of carbide insert

d (mm)	r (mm)	dl(mm)	t (mm)
12.70	0.8	5.16	4.76

2.3 Measurement Device

Talysurf Mitutoyo SJ-310 device for measuring the mean arithmetic surface roughness (Ra) of machined surfaceis shown in Fig .2

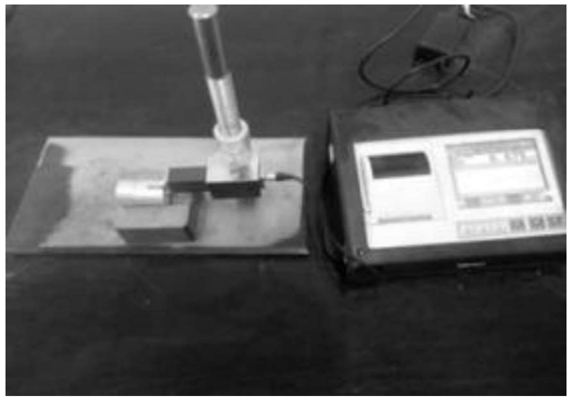


Fig.2. Talysurf Mitutoyo SJ - 310 device

2.4 Material Removal Rate Calculations

Material removal rate is used to determine the amount of material removed per second. It is calculated by the formula in equation (1) as mentioned[14].

$$MRR = V_C * f * d \qquad mm^3/sec \qquad (1)$$

Where: V_C is cutting speed (mm / sec), f is cutting feed rate (mm / rev), and d is depth of cut (mm).

2.5Design Of Experiments

The response surface methodology and design expert version7software are used for experimental design and the modeling and analysis of the influence of process variables on the results. Three independent cutting parameters namely rotational speed, feed rate, and depth of cut as well as volume fraction of MWCNTs with three levels for each factor are indicated in Table3

TABLE 3. Investigated parameters and levels

Symbol	Variables	Levels		
		1	2	3
A	Rotational speed N (r.p.m)	142	427	712
B	Feed rate f (mm / rev)	0.09	0.13	0.16
C	Depth of cut d (mm)	0.25	0.50	0.75

3. RESULTS AND DISCUSSION

Results showed measured mean surface roughness (Ra) and calculated material removal rate (MRR) in a Table 4 below

TABLE 4. Experimental runs and results

Run	Cutting Speed (mm/sec) (A)	Feed rate (mm/rev) (B)	Depth of cut (mm) (C)	MWCNTs (%) (D)	Mean Ra (µm)	MRR (mm^3/sec)
1	1305	0.09	0.75	0.00	4.572	88.087
2	1305	0.16	0.25	0.00	7.409	52.200
3	260	0.16	0.25	0.00	6.675	10.400
4	782	0.13	0.50	0.50	5.235	50.830
5	260	0.13	0.50	0.50	6.383	16.900
6	1305	0.13	0.50	0.50	6.104	84.825
7	782	0.13	0.50	0.50	5.352	50.830
8	260	0.09	0.25	0.00	4.472	5.850
9	260	0.16	0.75	0.00	7.696	31.200
10	782	0.13	0.50	0.50	5.442	50.830
11	260	0.09	0.75	1.00	4.654	17.550
12	782	0.13	0.75	0.50	6.583	76.245
13	782	0.13	0.50	1.00	5.555	50.830
14	782	0.13	0.25	0.50	5.041	25.415
15	1305	0.09	0.75	1.00	4.603	88.087
16	782	0.13	0.50	0.50	5.94	50.830
17	1305	0.16	0.75	1.00	7.792	156.600
18	782	0.13	0.50	0.50	5.452	50.830
19	782	0.09	0.50	0.50	3.442	35.190
20	782	0.13	0.50	0.00	5.361	50.830
21	782	0.16	0.75	0.50	7.435	62.560
22	260	0.09	0.75	0.00	4.723	17.550
23	1305	0.16	0.75	0.00	7.739	156.600
24	260	0.16	0.7 5	1.00	7.445	31.200
25	260	0.16	0.25	1.00	6.625	10.400
26	1305	0.16	0.25	1.00	6.874	52.200
27	782	0.13	0.50	0.50	4.781	50.830
28	260	0.09	0.25	1.00	4.416	5.850
29	1305	0.09	0.25	1.00	3.084	29.352
30	1305	0.09	0.25	0.00	3.127	29.352

The response surface 3D plot of mean surface roughness is shown in Fig 3. It describes the values of mean surface roughness at the input factors (cutting speed, feed rate, and depth of cut).

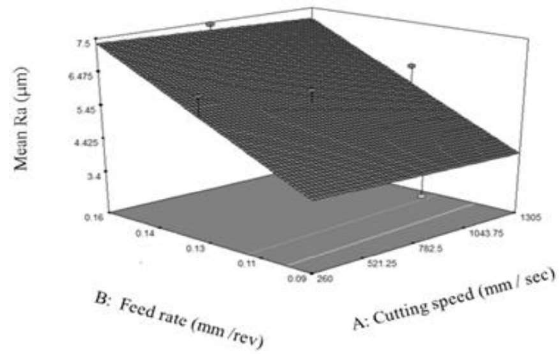


Fig. 3. Response surface 3D plot of mean surface roughness Ra

3.1 Effect of process parameters on surface roughness (Ra)

Table 5 listed ANOVA for mean surface roughness results. According to P-values less than 0.0500 indicate that the model terms are significant. Values greater than 0.0500 indicate that the model terms are not significant.So feed rate is the most significant parameter effects on surface roughness. Cutting speed and volume fraction of MWCNTs have no significant effects.

TABLE 5.ANOVA for mean surface roughness Ra

ANOVA for response surface linear model						
Source	Sum of squares	Df	Mean square	F-Value	P-Value	Notes
Model	49.27	4	12.32	62.00	<0.0001	Significa nt
A-Cutting speed	0.18	1	0.18	0.89	0.3543	
B-Feed rate	45	1	45.43	228.68	<0.0001	
C-Depth of cut	43	1	3.63	18.27	0.0002	
D-MWCNTs%	3.63	1	0.029	0.15	0.7043	
Residual	4.97	25	0.20			

Normal probablity plots of residuals for mean surface roughness shown in Fig 4-a examines distribution of residuals in straight line. This means that the errors are distributed normally. the points not falls on a line shows non-mormality in errors. While

Fig 4-billustrates the residuals plot versus predicted surface roughness which rondomly distribution without megaphone shape.

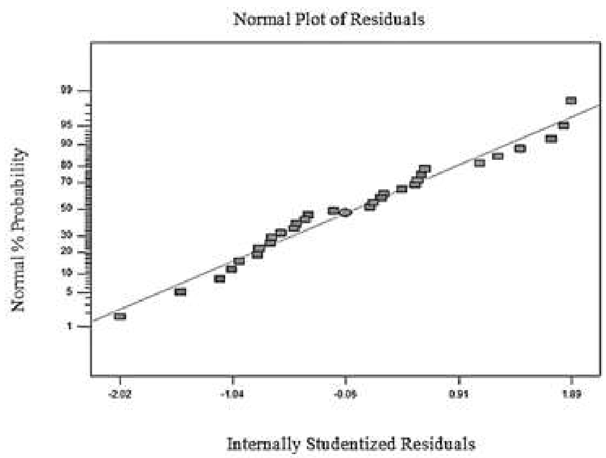


Fig .4-a. Normal probability plot of residuals for mean surface roughness Ra

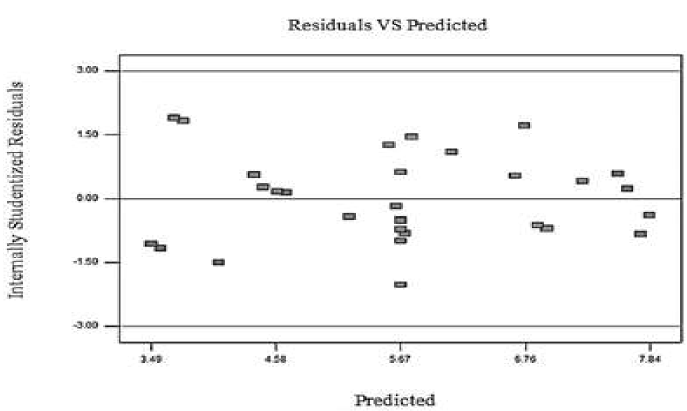


Fig . 4-b. Residuals plot versus predicted surface roughness Ra

The response surface 3D plot of material removal rate is shown in Fig 5. It describes the values of material removal rate at the input factors (cutting speed, feed rate, and depth of cut).

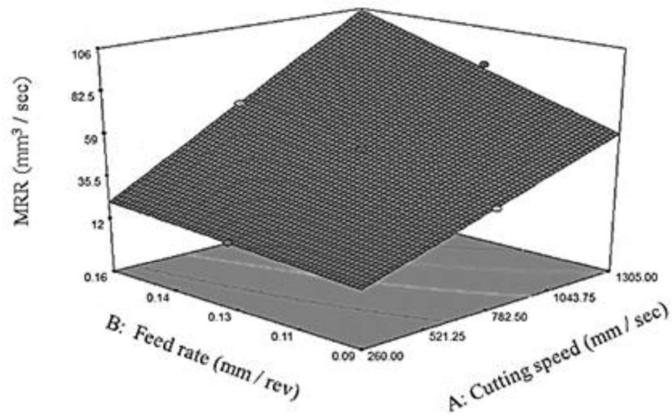


Fig.5. Response surface 3D plot of material removal rate MRR

3.2 Effect of process parameters on material removal rate (MRR)

Table 6 listed ANOVA for material removal rate results. According to P-values less than 0.0500 indicate that the model terms are significant. Values greater than 0.0500 indicate that the model terms are not significant. Socutting speed, feed rate, and depth of cut have the same significant effect on material removal rate and volume fraction of MWCNTs has no significant. Interactions between cutting speed and feed rate (AB), cutting speed and depth of cut (AC), and feed rate and depth of cut (BC) have the same significant effect on material removal rate.

Table 6. ANOVA formterial removal rate MRR

ANOVA for response surfaceLinear Model						
Source	Sum of squares	df	Mean square	F-Value	P-Value	Notes
Model	39953.56	10	3995.36	207.49	<0.0001	Significant
A-Cutting speed	19365.32	1	19365.32	1005.69	<0.0001	
B-Feed rate	3375.46	1	3375.46	175.30	<0.0001	
C-Depth of cut	10858.47	1	10858.47	563.91	<0.0001	
D-Nano ratio	0.000	1	0.000	0.000	1.0000	
AB	1338.13	1	1338.13	69.49	<0.0001	
AC	4266.38	1	4266.38	221.56	<0.0001	
BC	749.80	1	749.80	38.94	<0.0001	
Residual	365.86	19	19.26			

Normal probablity plots of residuals for material removal rate shown in Fig 6-a examines distribution of residuals in straight line this means that the errors are distributed normally. the points not falls on a line shows non-mormality in errors. While Fig 6-b illustrates the residuals plot versus predicted material removal rate which rondomly distribution without megaphone shape.

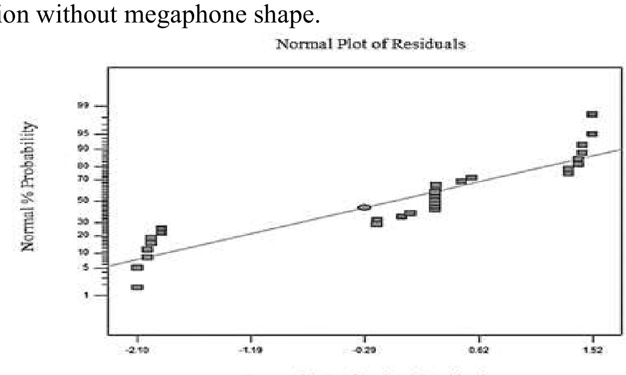


Fig . 6-a . Normal probability plot of residuals for material removal rate MRR

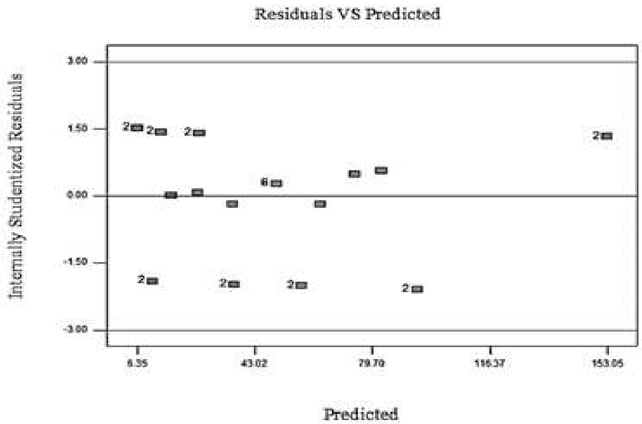


Fig . 6-b. Residuals plot versus predicted material removal rate MRR

4. CONCLUSIONS

1. Feed rate is the most significant effect on a surface roughness Ra.
2. cutting speed and volume fraction of MWCNTS have no significant on surface roughness.
3. cutting speed, feed rate, and depth of cut have the same degree of significanc on a material removal rate,while the nano ratio is not significant.
4. Interactions between cutting speed and feed rate, cutting speed and depth of cut, and feed rate and depth of cut have the same effect on a material removal rate, in addition to the interactions between cutting sped and volume fraction of $MWCNT_S$, between feed rate and volume fraction of $MWCNT_S$, and between depth of cut and volume fraction of $MWCNT_S$ have no significant.
5. Increasing the value of cutting speed and decreasing the values of feed ratea depth of cut leads to negative effect on a surface roughness.

REFERENCES

[1] Wang B., Ruan T., Chen Y., Jin F., Peng L., Zhou Y., Wang D., and Dou S. Graphene-based composites for electrochemical energy storage. Energy Storage Mater. 2019 doi: 10.1016/j.ensm.2019.08.004

[2] Wang J., Guo L., Lin W., Chen J., Liu C., Chen S., Zhang S., and Zhen T. Effect of the graphene content on the microstructures and properties of graphene/aluminum composites. New Carbon Mater. 2019;34:275–285. doi: 10.1016/S1872-5805(19)60016-8

[3]Saboori A., Chen X., Badini C., and Fino P., Pavese M. Reactive spontaneous infiltration of Al-activated TiO2 by molten aluminum. Trans. Nonferrous Met. Soc. China. 2019;29:657–666. doi: 10.1016/S1003-6326(19)64976-9.

[4] U. A. Dabadea , and M. R. Jadhav , Experimental study of surface integrity of Al/SiC particulate metal–matrix composites in hot machining. 48th CIRP Conference on MANUFACTURING SYSTEMS - CIRP CMS 2015, Procedia CIRP vl 41 pg 914 – 919. 2016

[5] Samya Dahbi, Haj El Moussami, and LatifaEzzine, Optimization of turning parameters for surface roughness of AISI 1042 Steel standard carbide tool inserts CNMG120402, CNMG120404 and CNMG120408 hal.archives-ouvertes.fr. 2016

[6] Devendra Singh, Vimanyu Chadha and Ranganath M Singar, effect of nose radius on surface roughness during cnc turning of Aluminium (6061) in dry condition using response surface methodology. International Journal of Recent advances in Mechanical Engineering (IJMECH). 2016

[7] VishalSardana, Achintya, and Ranganath M. S. Analysis of surface roughness during CNC Turning using Taguchi and Response Surface Methodology. International organization of Scientific Research ,IOSR Journal of Engineering (IOSRJEN). 2016

[8] Maheshkumarsharma, Sanjay singh, and Rakeshkumar, optimization of cutting parameter for turning en-31 alloy steel material using rsm, Journal of Emerging Technologies and Innovative Research (JETIR). 2016

[9] Ranganath M Singari, Vipin, and Sanchay Gupta, Prediction of Surface Roughness in CNC Turning of Aluminum 6061 Using for the Effect of Tool Geometry. International journal of advanced production and industrial engineering. 2016

[10] Anthony Xavior Ma., and Ajith Kumar J P, Machinability of Hybrid Metal Matrix Composite - A Review. 13th Global Congress on Manufacturing and Management (GCMM-2016), Procedia Engineering vl 174, pg 1110 – 1118. 2017

[11]Pooja A. Sutar , Study the effect of machining parameters on surface roughness in CNC End Milling of AISI 316L. International Journal of Engineering Research and Technology. ISSN 0974-3154 Volume 10, Number 1. 2017

[12] Meltem ALTIN KARATAŞ, A Review on Machinability of Carbon Fiber Reinforced Polymer (CFRP) and Glass Fiber Reinforced Polymer (GFRP) Composite Materials. Defence Technology 2018.

[13] AlokeshPramanik , Face Milling of Nanoparticles Reinforced Al-Based Metal Matrix Composites using a single insert milling tool. J. Compos. Sci. 2018, 2, 13. 2018

[14] Bedamati,Nayak,Multi response optimization in machining exploration of TOPSIS and dengs roukela 769008, India, rollNo.212ME 2296,2014