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Study of the Machinability of Aluminum Silicon Metal Matrix Nano Composites Using Taguchi Approach

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Abstract

Recently, metal matrix Nano composites are considered a leading material. The attention of Nano particles reinforced aluminum is increased due to excellent properties. The machinability of these materials is difficult due to high hardness and abrasive nature of reinforcement elements like aluminum oxide (Alumina) particles. In this investigation, aluminum silicon alloy reinforced with homogeneous 0.5% and 1% by volume of aluminum oxide Nano particulates were used as workpiece material. The stir casting route was used to fabricated the workpiece material . The concentration of Nano reinforced particles, cutting speed, feed rate and depth of cut are selected as process parameters in dry turning. While surface roughness, roundness error and metal removal rate are considered as evaluating parameters for machinability of metal matrix nano composites. Taguchi method was used to design these experiments. The experimental results have been analyzed using both signal to noise ratios and ANOVA.The results obtained showed that feed rate was the most significant parameter on surface roughness followed by aluminum oxide Nano particulates% while, aluminum oxide Nano particulates% was the most significant parameter on roundness error followed by feed rate and the most significant parameter on MRR was depth of cut followed by cutting speed.

Key Words: Nano composites, Turning, Surface roughness, MRR, Taguchi method.

1. Introduction

Aluminum and silicon carbide, have different mechanical properties. By carefully controlling the relative amount and distribution of the ingredients of a composite as well as the processing conditions, these properties can be further improved. Therefore, this work is aimed to fabricate and study the machinability of AL-Sic alloy reinforced with various weight percentages of Alumina Nano particles. T.Sasimurugan and K.Palanikumar [1] studied the effect of machining characteristics on surface roughness of a hybrid aluminum metal matrix composite (Al6061-SiC-Al2O3), they recommended polycrystalline diamond (PCD) tools in turning process, the conditions were feed rate, depth of cut and cutting speed, surface roughness as a response. the experiment showed that the surface roughness is increasesed with the increase of feed rate and is improved with the increase of cutting speed. Madicet et. al. [2] 0ptimized the surface roughness when turning polyamide using artificial neural network (ANN) approach and Taguchi method with L9 orthogonal array, they found that spindle speed was the most significant parameter on surface roughness, followed by depth of cut. Sahoo[3] investigated the parametric analysis and optimization of turning operation by using Taguchi approach of L9 orthogonal array, he found that spindle speed is the most influence parameter on surface roughness, followed by feed rate. A similar results obtained by [4,5,6,7].M. Kaladhar, K. et.al [8] studied the parametric optimization during machining of (AISI 304) austenitic stainless steel using Taguchi method and ANOVA, they found that the nose radius was most significant parameter on surface roughness . C. X. Feng, et.al [9] studied the development of empirical models for surface roughness prediction in finish turning operation using Taguchi method, they found that tool point angle was most influence on surface roughness, followed by cutting speed. P. R. Patel, et.al [10] studied the effect of machining parameters on surface roughness for 6063 Al-Tic (5 & 10 %) metal matrix composite using response surface methodology, by using the PCD tool in turning process. They found that Feed rate was the most significant effect on surface roughness. The increase of feed rate increases the surface roughness Tatjana V. et al [11] applied Taguchi L 9 orthogonal array method and (GRA) in their experiments, they found that Taguchi's SN ratio and quality loss, relative significance of responses are adequately represented and the response mean and variation are assessed simultaneously.

The aim of this research is to deduce the machining parameters which produce better workpiece surface for metal matrix Nano composites.

2. Exprimental Work :

Work piece material in this work is aluminum silicon alloy reinforced with nano aluminum oxide particulates (40nm). The chemical composition of aluminum silicon alloy is indicated in table 1.

Table.1 The chemical composition of the work piece material

Al	Si	Mn	Ni	Fe	Ti
93.2	5.50	0.014	0.62	0.221	0.14

2.1. Steps of Material Preparation:

Stir casting route was used to fabricate the Al-Si/Al_2O_3 nano composites as follows: About, 1 Kg of the Al-Si alloy was charged into the crucible made from graphite and heated up to 750ºC for melting. After complete melting of the Al alloy, a steel mixer fixed on the mandrel of the drilling machine was inserted into the crucible and started to stir the molten alloy at stirring speed ranges from 750 to 1000 rpm. The, aluminum oxide (Alumina) particles (40 nm) was heated to 400 ºC for 10 minutes, were dispersed into the vortex developed during stirring. After complete mixing, the mixer was turned off and the molten mixture was poured into preheated permanent steel mould. The steel mould has a cylindrical shape cavity with 40 mm diameter and 220 mm height.

2.2. Machine and Cutting Tool Specifications:

Cutting experiments were carried out on a conventional center lathe machine (Length between chuck Center to Dead Center 750 mm- Power 5 HP- Speed from 28 to 1250 rpm - Feed motion Range (From 0.03: 1.30 mm) using Uncoated cemented carbide tip insert of ISO designation of CNMG 120408-HA as shown in Fig.1 and Table.2 shows the properties of the insert. The insert is mounted on a tool holder of MCLNR2525M12 giving approach angle of 95^0, The selection of the insert uncoated cemented carbide tip was chosen according to the manufacturing catalog of KORLOY considering workpiece material and the recommended other cutting parameter.[range of Speed (290 – 2133 mm/sec), range of feed (0.10 - 0.40 mm/rev), range of depth of cut (0.50 - 3.50 mm).]

Table.2 the specification of cutting tool

ISO catalog number	Tip	Grade	dimension			
			d	t	Re	d1
CNMG 120408-HA	Uncoated carbide	H01	12.70	4.76	0.8	5.16

Fig.1

2.3. Measurement devices

The surface roughness parameter (R_a) of the workpiec after machining was measured with Surftest SJ-310 instrument shown in figure.2, while the roundness tester Talyrond 73- taylor hobson, S/no. 112/2802-0123, L.R = 0.01 µm shown in figure.3.

- **Uncertainty (U):**

The uncertainty evaluation is carried out in accordance with the JCGM 100:2008.U is the expanded uncertainty using a coverage factor K = 2, providing a level of confidence of approximately 95 %.(U = $\pm$ 2.0 µm)

Traceability: All equipment used for measurement are traceable to gauge blocks which were calibrated by optical interferometer at KRISS traceable to SI units .

Figure.2

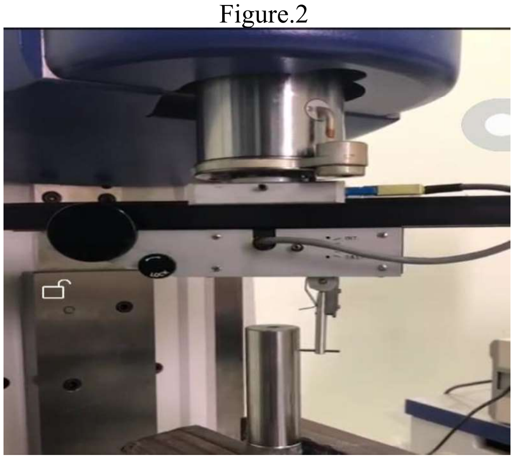

Figure.3

2.4. Design of experiment using Taguchi method

Tte experiments have been conducting according to Taguchi L27 orthogonal array. The process parameters chosen are volume % of alumina, cutting speed, feed rate and depth of cut , the values and their levels are indicated in Table 3 . The process parameters and thier levels, each experiment was repeated three times to avoid the effect of noise factors.

Table.3 The process parameters and thier levels

Parameter	Unit	Level 1	Level 2	Level 3
Nano % (A)	-	0 %	0.5 %	1 %
Cutting speed (B)	(mm/sec)	895	1253	1790
Feed rate (C)	(mm /rev.)	0.09	0.12	0.16
Depth of cut (D)	(mm)	0.25	0.50	0.75

3. Results and discussion

3.1 .Taguchi method:

Taguchi mehod is used to minimize the qquality loss function by using one of three options in design analysis . The nominal is the best , the larger is the better and the smaller is the better**.** Table 4 showed the layout of the experiments and results.

Table.4 The layot of Taguchi model Alumina Nano

	Nano A %	Cutting speed	Feed rate	D-of cut	MRR(mm 3/sec)	Mean Ra um	Mean Ro um
1	0%A	895	0.09	0.25	20.137	3.341	18
2	0%A	895	0.09	0.25	20.137	3.432	20
3	0%A	895	0.09	0.25	20.137	3.432	20
4	0%A	1253	0.12	0.50	75.180	3.568	20
5	0%A	1253	0.12	0.50	75.180	3.945	23
6	0%A	1253	0.12	0.50	75.180	3.849	23
7	0%A	1790	0.16	0.75	214.800	4.030	23
8	0%A	1790	0.16	0.75	214.800	4.329	24
9	0%A	1790	0.16	0.75	214.800	4.230	3
10	0%A	895	0.12	0.75	80.550	4.639	27
11	5%A	895	0.12	0.75	80.550	4.720	29
12	5%A	895	0.12	0.75	80.550	4.835	26
13	5%A	1253	0.16	0.16	50.120	5.976	30
14	5%A	1253	0.16	0.16	50.120	5.779	33
15	5%A	1253	0.16	0.16	50.120	6.357	34

16	5%A	1790	0.09	0.09	80.550	3.541	25
17	5%A	1790	0.09	0.09	80.550	3.869	24
18	5%A	1790	0.09	0.09	80.550	3.766	25
19	5%A	895	0.16	0.16	71.600	6.772	37
20	1%A	895	0.16	0.16	71.600	6.370	37
21	1%A	895	0.16	0.16	71.600	6.030	32
22	1%A	1253	0.09	0.09	84.578	3.753	27
23	1%A	1253	0.09	0.09	84.578	3.856	27
24	1%A	1253	0.09	0.09	84.578	4.831	34
25	1%A	1790	0.12	0.12	53.700	4.541	30
26	1%A	1790	0.12	0.12	53.700	4.645	33
27	1%A	1790	0.12	0.12	53.700	4.081	29

3.2. Effect of Process Parameters on MRR:

Based on the experimental data S/N ratios are found for each response. For surface roughness and roundness error parameters "Smaller the better "criterion and for material removal rate "Larger the better" criterion has been selected. S/N Ratio of response is given in the figure (4). The figure showed that the most influence factor on metal removal rate (MRR) is depth of cut, followed by cutting speed and then feed rate.

Fig.4 main effects plot for SN ratios of MRR

3.3. Effect of Process Parameters on Surface Roughness:

The main effects plot for SN ratios of surface roughness is given in the figure (5). It is clear that, feed rate is the most significant factor on surface roughness (Ra), followed by aluminum oxide nana particulates % , followed by cutting speed and depth of cut has a smallest effect factor on surface roughness.

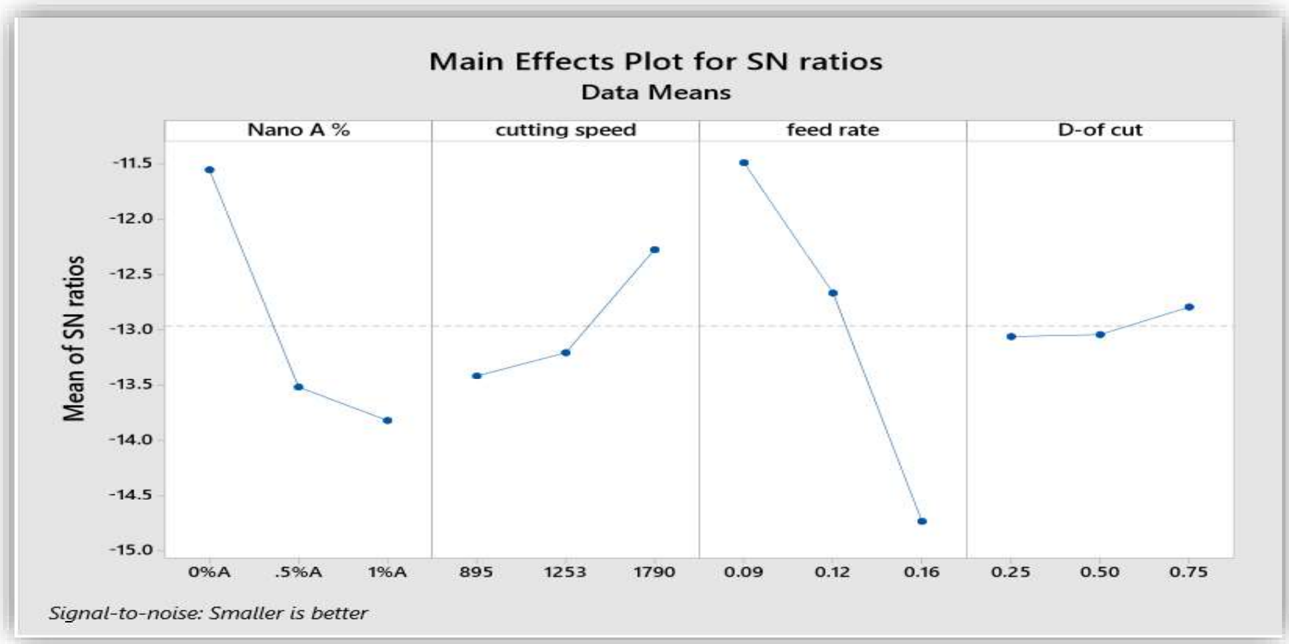

Fig.5 main effects plot for SN ratios of Ra

3.4. Effect of Process Parameters on Roundness Error:
Fig.6 showed the main effects plot for SN ratios of roundness error. It is clear that the most influence factor on roundness error is aluminum oxide nana particulates % followed by feed rate, followed by cutting speed, while the depth of cut has no effect on roundness error.

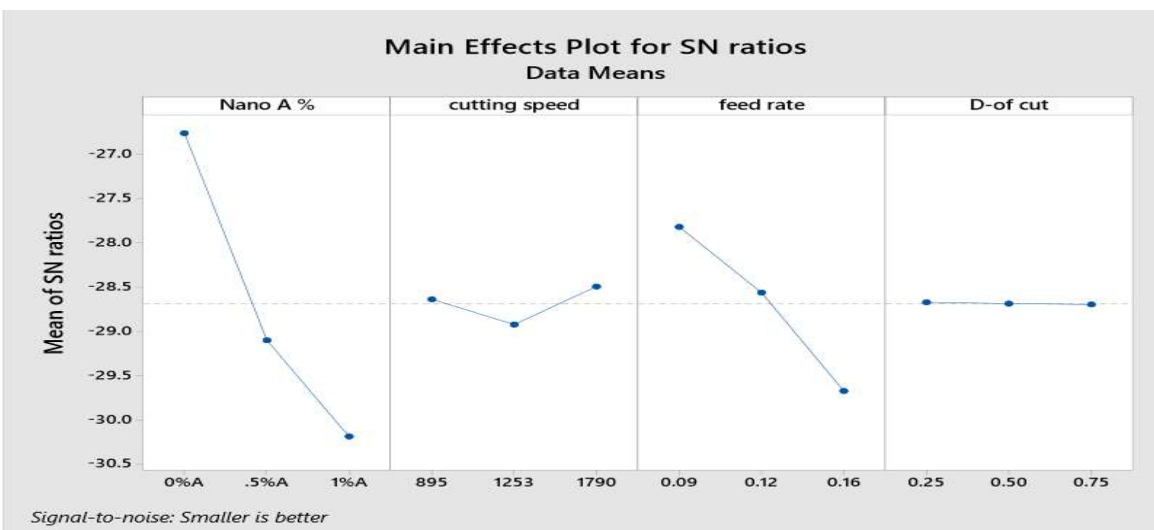

Fig.6 main effects plot for SN ratios of roundness

3.5. Analysis of variance (ANOVA)
ANOVA is a statistical decision making tool, used to analyze the experimental data, for detecting any differences in the response means of the factors being tested, the purpose of analysis of variance is to determine the relative magnitude of the effect of each factor and to identify the factors significantly affecting the response under consideration.In table (5), it is obvious that,the most influence factor on metal removal rate (MRR) is depth of cut, followed by cutting speed.In table (6), showed that feed rate is the most significant factor on surfaceroughness (Ra) is feed rate, followed aluminum oxide nana particulates %finally,in table (7), the most influence factor on roundness error aluminum oxide nana particulates %followed by feed rate.

Table.5 ANOVA for metal removal rate model

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Contribution %
Nano A %	2	6610.2	3305.1	-	-	09.40 %
Cutting speed	2	17342.3	8671.2	-	-	24.66 %
Feed rate	2	13204.6	6602.3	-	-	18.78 %
D-of cut	2	33164.2	16582.1	-	-	47.16 %
Error	18	0	0.0	-	-	0 %
Total	26	70321.3	-	-	-	100 %

Table.6 ANOVA for surface roughness model

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Contribution %
Nano A %	2	7.5650	3.78252	44.21	0.000	27.91 %
Cutting speed	2	2.5620	1.28099	14.97	0.000	09.45 %
Feed rate	2	15.0042	7.50208	87.69	0.000	55.36 %
D-of cut	2	0.4343	0.21717	2.54	0.107	01.60 %
Error	18	1.5400	0.08556	-	-	05.68 %
Total	26	27.1055	-	-	-	100 %

Table.7 ANOVA for roundness error model

Source	DF	Adj SS	Adj MS	F-Value	P-Value	Contribution %
Nano A %	2	509.510	254.755	61.02	0.000	67.02 %
Cutting speed	2	10.671	5.336	1.28	0.303	01.40 %
Feed rate	2	163.277	81.638	19.55	0.000	21.48 %
D-of cut	2	1.547	0.774	0.19	0.832	00.21 %
Error	18	75.150	4.175	-	-	09.89 %
Total	26	760.154	-	-	-	100 %

Conclusions:

In this study the effect of aluminum oxide nana particulates reinforced of aluminum silicon alloy and cutting conditions on the material removal rate, surface roughness and roundness error during dry turning using Taguchi method and ANOVA have been presented. The following results are recommended:

1. The most significant parameter on MRR was depth of cut with a contribution of 47.16 % followed by cutting speed with a contribution of 24.66 %.

2. Feed rate was the most significant parameter on surface roughness with a contribution of 55.36 % followed by aluminum oxide nano particulates with a contribution of 27.91 %. 3. Aluminum oxide nano particulates percent was the most significant parameter on roundness error with 67.02 %, followed by 21, 48% contribution %.

4. The optimal levels of control parameters are determined from main effects plot for SN ratios fordifferent responses, for best MRR the optimal levels are A_1 $B_3C_1D_3$, for best surface roughness $A_2B_3C_1D_3$and roundness error$A_2B_3C_1D_1$.

5. The optimal values corresponding to the optimal levels for best MRR are as follows; Nano %= 0%, cutting speed= 1790 mm/sec, feed rate= 0.09 mm/rev and depth of cut = 0.75 mm.

6. The optimal values corresponding to the optimal values for best surface roughness: Nano %= 0%, cutting speed= 1790 mm/sec, feed rate= 0.09 mm/rev and depth of cut = 0.75 mm.and roundness error are as follows;Nano %= 0%, cutting speed= 1790 mm/sec, feed rate= 0.09 mm/rev and depth of cut = 0.25 mm.

References

[1] T. Sasimurugan and K. Palanikumar, Analysis of the Machining Characteristics on Surface Roughness of a Hybrid Aluminium Metal Matrix Composite (Al6061-SiC-Al2O3) Journal of minerals & Materials characterization & Engineering Vol. 10, No.13, pp.1213-1224, (2011)

[2] Madic et al, Application of surface roughness when turning polyamide using ANN-IHSA approach. International Journal of Engineering and Technology, Vol.1 (4), 432-443.2012

[3] Sahoo, Parametric analysis and optimization of turning operation by using Taguchi approach. International Journal of Modern Engineering Research, Vol. 3(4), 2154-2156. 2013

[4] Chaudhari et al. Optimization of process parameters using Taguchi approach with minimum quantity

lubrication for turning. International Journal of Engineering Research, Vol (4), 1268-1273. 2011

[5] IlhanAsilturk and Harun Akkus, “Determining the Effect of Cutting Parameters on Surface Roughness in Hard Turning using the Taguchi Method”, Measurement, vol. 44, pp. 1697–1704, 2011

[6] Jakhale Prashant P. and Jadhav B. R., “Optimization of Surface Roughness of Alloy Steel by Changing Operational Parameters and Insert Geometry in the Turning Process”, International Journal of Advanced Engineering Research and Studies, II/ IV, pp. 17-21, 2013 M.

[7] Kaladhar, K. V. Subbaiah, Ch. Srinivasa Rao and K. Narayana Rao, “Application of Taguchi Approach and Utility Concept in Solving the Multi-Objective Problem when Turning AISI 202 Austenitic Stainless Steel”, Journal of Engineering and Technology Review, vol. 4, pp. 55-61, 2011

[8] M. Kaladhar, K.VenkataSubbaiah and Ch. Srinivasa Rao, “Parametric Optimization During Machining of AISI 304 Austenitic Stainless Steel using CVD Coated DURATOMICTM Cutting Insert”, International Journal of Industrial Engineering Computations, vol. 3, pp. 577–586, 2012

[9] Feng C. X. and Wang X., “Development of Empirical Models for Surface Roughness Prediction in Finish Turning”, International Journal of Advanced Manufacturing Technology, vol. 20, pp. 348-356, 2002

[10] P. R. Patel et.al, effect of machining parameters on surface roughness for 6063 al-tic (5 & 10 %) metal matrix composite using rsm. International Journal of Research in Engineering and Technology ISSN: 2319-1163 Volume: 02 Issue: 01 pg 65-71. (Jan-2013).

[11] Tatjana V. Šibalija et.al, Novel Approach to Multi-Response optimization for Correlated Responses. FME Transactions vl 38, pg 39-48. (2010)