

Analysis of Aluminium Nano Composites using Anova in CNC Machining Process

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Abstract – The Objective of this work is to reinforce the Aluminum alloy with CNT by Stir Casting Method in different weight percentage of CNT was added to Aluminium separately to make composites and its physical and thermal properties have been investigated using test like tensile, hardness, Micro Structure and XRD. The improvement of mechanical, Physical and thermal properties for both the cases has been compared with pure aluminum. The TAGUCHI – ORTHOGONAL ARRAY experimental technique is used to optimize the machining parameters. The predicted surface roughness was estimated using S/N ratio and compared with actual values. ANOVA analysis is used to find the significant factors affecting the machining process in order to improve the surface characteristics of Al Material.

Keywords – [I] Proposed methodology, [II] Results and discussions, [III] Conclusion & References

I. PROPOSED METHODOLOGY

1.1 Selection of Material

We selected an aluminum alloy as our test material and added to it multi walled carbon Nano tube at varied percentage by weight. Alloys of this and similar compositions are rather difficult to machine. This is due firstly to their tendency to drag and secondly to the rapid tool wear caused by the high silicon content. The property is reduced by the addition of carbon Nano tube to the metal matrix.

1.2 Preparation

Composites are prepared according to the following specifications and casting is done for two different combinations.

Table I : Specimen Specifications

Specimen	LM24 (gm)	CNT (%by wt.)	Length (mm)	Dia (mm)
Cast 1	1000	0	100	20
Cast 2	1000	0.5	100	20

Table II- Coded level of three machining parameters and their range

	Parameters	Units	Coded Value		
			-1 (Low)	0 (Medium)	+1 (High)
A	Cutting Speed (X1)	rpm	100	200	300
B	Depth of Cut (X2)	mm/rev	.01	.05	.1
C	Feed (X3)	mm	.1	.15	.20

1.3 Selection of Parameters for Machining

The Aluminum alloy and the Aluminum Nano composite specimens are divided into 15 specimens each. Each surface is machined using different machining parameters.

1.4 Roughness Measurement

Once, the machining is over, the next step is finding out the roughness of different surfaces. The surface roughness tester we used is SRG-4000 portable surface roughness tester. The surface roughness of the aluminum alloy and the aluminum Nano composite is found out using the tester.

1.5 Finding the Mechanical Properties

In this paper we will be finding out the mechanical properties like tensile strength, yield strength and the elongation percentage of aluminum alloy and aluminum Nano composite. The purpose of this test is to find out the difference in these properties taking place on addition of MWCNT.

II. RESULTS AND DISCUSSIONS

2.1 Aluminium alloy material properties

It has highest percentage of Aluminum and having Properties of Good cast ability, improved corrosion resistant, low coefficient of thermal resistant and low density. Table.1 lists the chemical composition (wt. %) of the material of the aluminum alloy were tested in Material Lab, Brakes India Ltd India according to OES-CML/WP/35 & IS 1586- 2000.

Table III : Composition of AL alloy

Al %	Si%	Fe%	Mn%	Cu%	Mg%	Ti%
89.129	7-8	0.07	0.03	3.2	0.166	0.009

2.2 CNT Material properties

The sources of carbon Nano tubes are received from Cheap tubes Inc., USA [www.cheaptubes.com]. The specifications of multiwall carbon Nano tubes are given in table 2. The Nano tubes had an average diameter of 10 - 20 nm and a length of 10 - 30 micrometers, and were produced catalytically from hydrocarbon materials on Nano catalysts under high pressure. Multiwall carbon Nano tubes were mixed with fluids using ultrasonic processor. Fig.1 shows a Transmission Electron Microscopy (TEM) image of the multiwall carbon Nano tubes.

Table IV: Specification of MWCNTs

OD	10 nm to 20 nm
Length	10 μ m to 30 μ m
Purity	> 95 wt%
Ash	< 1.5 wt%
Specific Surface Area	> 233 m ² g ⁻¹
Electrical Conductivity	> 10-2 S cm ⁻¹

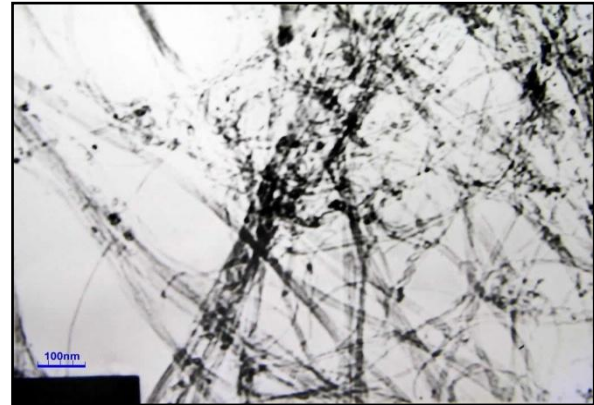


Fig.1 : TEM image of our MWCNTs 95wt% <8nm OD

Table V : Chemical Composition of Multi wall carbon Nano tubes

Elements	C	Al	Cl	Co	S
Wt%	96.3	0.08	0.41	2.91	0.29

X ray diffraction techniques are used to find the The mechanical properties like young's modulus and density of carbon Nano tubes are superior than steel. CNT is having 100 times stronger than steel and 1/6th weight of aluminum. Higher thermal conductivity of CNT is 6000 w/mk when compare to copper is 3300 w/mk. The Grinding System is mainly composed of a grinding wheel, electrode, and power supply. The water-soluble alkaline grinding fluid is used The Hommel surface roughness tester T500 is used to evaluate the component surface quality, size, shape and internal stress of small crystalline regions and determine the orientation of single grains, measure average spacing between layers of atoms. The atomic planes of a crystal cause the incident beam of x rays interface with Nano composites are measured the highest peak profile of the Nano composites with CNT.

2.3. Al / CNT Nano composite properties

Hardness of different aluminium Nano composite and composition has been tested at Material Lab at Brakes India according to OES-CML/WP/35 & IS 1586- 2000. The results shows that the carbon Nano tube is added to Al nanocomposite the hardness is decreased, which means that high strength of alloy with high flexibility to absorb forces which is used in aerospace industry. Carbon Nano tube is having 1 to 10 nm diameter is easily mixed with micro particles of Al and this Nano tube having low density of 2.6 gram/cm³ which is lighter than aluminium.

Table VI: Hardness test of different wt % of CNT Composition

Composition	RHB-1	RHB-2	RHB-3	Avg (RHB)
0 wt% CNT with Al alloy	34	35	36	33
0.5wt% CNT with Al alloy	28	29	30	29

Table VII : Nano composites composition with different wt % of CNTs

Element (wt%)	0wt% CNTs	0.5 wt% CNTs
Al	89.129	89.129
Fe	0.007	0.005
Si	7.37	6.7
Mn	0.033	0.029
Cu	3.22	3.21
Ni	0.002	0.002
Ti	0.010	0.009
Zn	0.055	0.009
Pb	0.005	0.005
Mg	0.033	0.166

From the composition analysis the carbon content is increased when mixing CNT and Al content also increased which is used to increase the strength

2.4 Material Test Report

Table VIII : Mechanical properties and chemical composition of Aluminium alloy (without CNT).

Mechanical Properties :			
S.no	Parameter	Specification	Observation
1	Tensile Strength	180 N/mm ² min	249.01 N/mm ²
2	Yield Strength	100 to 120 N/mm ²	115.2 N/mm ²
3	Elongation	1.5% min	8.75%
4	Hardness	85 HRB max	34 to 36 HRB
Chemical Composition:			
S.no	Parameter	Specification	Observation
1	Silicon	7 ~ 9.5%	7.370%
2	Copper	3 ~ 4%	3.220%
3	Magnesium	0.30% max	0.210%
4	Manganese	0.5% max	0.033%
5	Iron	1.3% max	0.007%
6	Titanium	0.2 % max	0.010%
7	Zinc	3.0 % max	<0.009 %
8	Lead	0.30% max	<0.005 %
9	Tin	0.2 % max	<0.005 %
10	Nickel	0.5% max	<0.002%
11	Aluminium	Remainder	Remainder (89.129%)

Microstructure Photographs:



Fig. 2 : Microstructure of Aluminium alloy (without CNT).

Table IX : Mechanical properties and chemical composition of Aluminium alloy (with CNT).

Mechanical Properties :

S.no	Parameter	Specification	Observation
1	Tensile Strength	180 N/mm ² min	282.36 N/mm ²
2	Yield Strength	100 to 120 N/mm ²	116.25 N/mm ²
3	% of Elongation	1.5% min	7.75%
4	Hardness	85 HRB max	28 to 32 HRB

Chemical Composition:

S.no	Parameter	Specification	Observation
1	Silicon	7 ~ 9.5%	6.860%
2	Iron	1.3% max	0.005%
3	Copper	3 ~ 4%	3.210%
4	Manganese	0.5% max	0.029%
5	Magnesium	0.30% max	0.166%
6	Nickel	0.5% max	<0.002%
7	Zinc	3.0 % max	<0.009 %
8	Titanium	0.2 % max	0.009%
9	Lead	0.30% max	<0.005 %
10	Tin	0.2 % max	<0.005 %
11	Aluminium	Remainder	Remainder (89.129)

Microstructure:

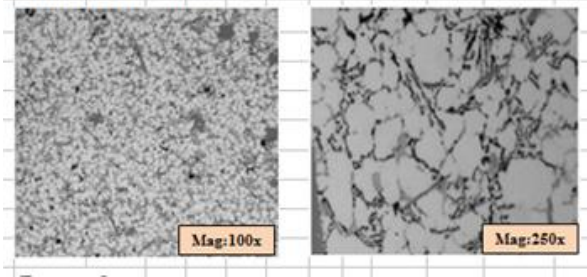


Fig.3 : Microstructure of Aluminium alloy (with CNT).

Table X : Identifying control factors and their levels

Item	Control Factor	Units	Level 1	Level 2	Level 3
A	Cutting Speed	Rpm	2000	2400	2800
B	Feed	m/min	300	600	900
C	Depth of cut	mm	.05	.1	.15

Table XI : L9 orthogonal array

Exp.no	A	B	C
1	1	1	1
2	1	2	2
3	1	3	3
4	2	1	2
5	2	2	3
6	2	3	1
7	3	1	3
8	3	2	1
9	3	3	2

2.5 Surface Roughness And S/N Ratio Value

Table XII(a) : Surface Roughness and S/N Ratio Value

Exp. No	Coded Values			Actual Values		
	A	B	C	A (rpm)	B (mm/min)	C (mm)
1	1	1	1	2000	300	0.05
2	1	2	2	2000	600	0.1
3	1	3	3	2000	900	0.15
4	2	1	2	2400	300	0.1
5	2	2	3	2400	600	0.15
6	2	3	1	2400	900	0.05
7	3	1	3	2800	300	0.15
8	3	2	1	2800	600	0.05
9	3	3	2	2800	900	0.1

Table XII(b) : Surface Roughness and S/N Ratio Value

Exp. No	Without carbon Nano tubes Surface roughness (Ra)(y) μm	With carbon Nano tubes Surface roughness (Ra)(y) μm	S/N ratio Without Nano tubes	S/N ratio With Nano tubes
1	3.297	3.012	-10.3624	-9.5771
2	5.627	4.823	-15.0055	-13.6663
3	8.069	7.873	-18.1364	-17.9228
4	3.638	3.187	-11.2173	-10.0676
5	5.825	4.958	-15.3059	-13.9061
6	8.124	7.823	-18.1954	-17.8675
7	3.136	3.012	-9.92752	-9.5771
8	5.489	5.016	-14.7899	-14.0072
9	8.224	7.986	-18.3017	-18.0466
Mean			-14.5824	-13.8487

To determine the effect of the carbon Nano tubes on the surface roughness of the Aluminium Nano composite, the surface profiles of the CNC lathe machining work piece were measured by Surface roughness tester (Hommel Tester T500).

The Ra value and its graph results for the specimen which was machined without Nano composite. The parameters used are Cutting speed 2000rpm and feed 300mm/min and depth of cut 0.05 mm. The roughness value obtained for the specimen using this parameter is 3.297 μm , and the similar method is done for other readings, and the respective Ra values are in table 2.10(a) and table 2.10(b).

The based on experiments, the optimum level setting of parameters is **A3B1C3**. **Minimum surface roughness value of 3.136(Ra)(y) μm** - good surface finish.

The surface roughness of the Al/CNT was machined by grinding process to improve the surface finish to Nano level. S/N ratio is calculated based on quality characteristics. The objective function is to improve the surface finish of machining process using Nano tubes. The Smaller the best S/N ratio is calculated. The formula used for calculating the S/N ratio is given below:

$$\frac{S}{N} \text{Ratio}(\eta) = -10 \log_{10} \frac{1}{n} \sum_{i=1}^n y^2 \quad (1)$$

n= no of experiments y = no of response value

2.6. Comparison of actual and predicted surface roughness.

The based on experiments, the optimum level setting of parameters is **A3B1C3**. (without CNT).

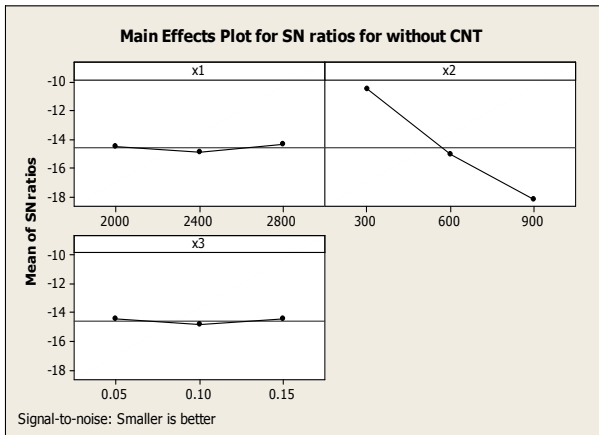


Fig. 4 : Factor effect diagram for S/N Ratio without Nano tubes for surface roughness

From the fig 4 Level 3 of A and Level 1 of B and level 3 of C gives the maximum effect of improving Surface roughness. Naturally A3, B1 and C3 is the best combination i.e. a Cutting speed 2800 rpm and feed 300 mm/min and depth of cut 0.15mm will give the minimum of Surface roughness. From the factor effect graph shows that feed giving more impact to improve the surface finish.

Table XIII . Determining the factor effects of S/N ratio without Nano tubes for surface roughness

Factor	Level 1	Level 2	Level 3	Delta	Rank
A-Cutting speed	-14.50	-14.91	-14.34	0.57	2
B-Feed	-10.50	-15.03	-18.21	7.71	1
C-Depth of cut	-14.45	-14.84	-14.46	0.39	3

The predicted S/N ratio $\hat{\eta}$ using the optimal levels of the machining parameters can be calculated as:

$$\hat{\eta} = \eta_m + \sum_{i=1}^p \eta_i - \eta_m \quad (2)$$

η_m – Total mean of S/N Ratio, η_i - Mean of S/N Ratio at the optimum level and p is the number of main machining parameters that significantly affect the performance.

[1] So predicted Surface roughness without carbon Nano tubes Ra (y) = **3.21 μm** . [2]Actual Surface roughness without carbon Nano tubes Ra (y) = **3.136 μm** .

The based on experiments, the optimum level setting of parameters is **A1B1C1**.. (with CNT).

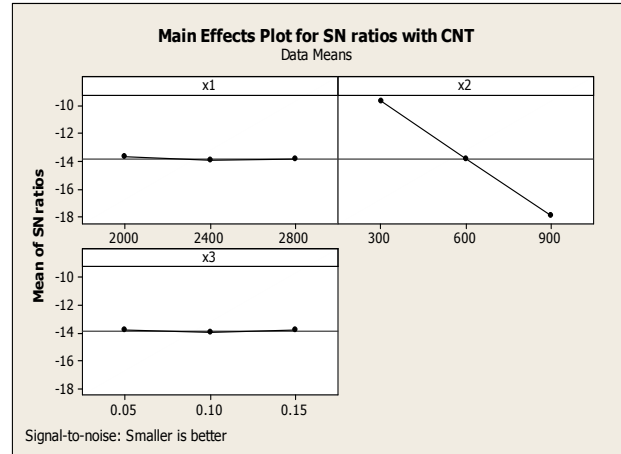


Fig.5 : Factor effect diagram for S/N Ratio with Nano tubes surface roughness

(Refer fig 5) Level 1 of A and Level 1 of B and level 1 of C gives the maximum effect of improving Surface roughness. Naturally A1, B1 and C1 is the best combination i.e. a Cutting speed 2000 rpm and feed 300 mm/min and depth of cut 0.05mm will give the minimum of Surface roughness. From the factor effect graph shows that feed giving more impact to improve the surface finish.

Table XIV : Determining the factor effects of S/N ratio with Nano tubes

Factor	Level 1	Level 2	Level 3	Delta	Rank
A-Cutting speed	-13.722	-13.947	-13.877	0.225	2
B-feed	-9.741	-13.860	-17.946	8.205	1
C-depth of cut	-13.817	-13.927	-13.802	0.125	3

The predicted S/N ratio $\hat{\eta}$ using the optimal levels of the machining parameters can be calculated as:

$$\hat{\eta} = \eta_m + \sum_{i=1}^p \eta_i - \eta_m \quad (3)$$

η_m – Total mean of S/N Ratio, η_i - Mean of S/N Ratio at the optimum level and p is the number of main machining parameters that significantly affect the performance.

[1] So predicted Surface roughness with carbon Nano tubes Ra (y) = **3.019 μm**. [2]Actual Surface roughness with carbon Nano tubes Ra (y) = **3.012 μm**.

2.7. Confirmation test:

The confirmation experiment is the final step in the first iteration of the design of experiment process. The purpose of the confirmation experiment is to validate the conclusions drawn during the analysis phase. The confirmation experiments were conducted by setting the process parameters at optimum level. i.e. Cutting speed 2800 rpm and feed 300 mm/min and depth of cut 0.15mm as optimum parameters and the actual surface roughness was obtained without carbon Nano tubes is 3.136 μm compared to predicted surface roughness 3.21 μm. Similar way the with carbon Nano tubes based machining of a Cutting speed 2000 rpm and feed 300 mm/min and depth of cut 0.05mm as optimum parameters and the actual surface roughness was obtained with carbon Nano tubes 3.012 μm compared to predicted surface roughness 3.019 μm.

2.8 ANOVA Analysis

The purpose of analysis of variance is to find the significant factors affecting the machining process to improve the surface characteristics of Al Nano composite in CNC machining process. ANOVA gives clearly how the process parameters affect the response and the level of significance of the factor considered. The ANOVA table for surface roughness of with and without carbon Nano tubes is calculated.

Table XV (a): Shows the results of ANOVA for the surface roughness without carbon Nano tubes

Machining parameters	Degree of Freedom (f)	Sum of Squares(SSA)	Variance (VA)
A	2	0.1020	0.0510
B	2	34.3217	17.1608
C	2	0.0623	0.0311
Error	2	0.0365	0.0183
Total	8	34.5225	

Table XV (b) : Shows the results of ANOVA for the surface roughness without carbon Nano tubes

Machining parameters	FAo	P	Contribution (%)
A	2.79	0.264	0.295
B	939.86	0.001*	99.41
C	1.70	0.370	0.18

Error			0.105
Total			100

*Significant

S = 0.135126 R-Sq = 99.89% R-Sq (adj) = 99.58%

Table XVI (a) : Shows the results of ANOVA for the surface roughness with carbon Nano tubes

Machining parameters	Degree of Freedom	Sum of Squares(SSA)	Variance (VA)
A	2	0.0182	0.0091
B	2	35.5063	17.7531
C	2	0.0049	0.0025
Error	2	0.0309	0.0154
Total	8	35.5602	

Table XVI (b) : Shows the results of ANOVA for the surface roughness with carbon Nano tubes

Machining parameters	FAo	P	Contribution (%)
A	0.59	0.630	0.511
B	1149.78	0.001*	99.84
C	0.16	0.862	0.13
Error			0.86
Total			100

*Significant

S = 0.124260 R-Sq = 99.91% R-Sq (adj) = 99.65%

The R2 value of developed empirical model for surface roughness with Nano tubes is 99.91 %. The high R2 value indicates that better the model fits the data. Here 0.001 p value of feed factor is significant. The main output from an analysis of variance study ANOVA is arranged (see Table XV & Table XVI). List the sources of variation, their degrees of freedom, the total sum of squares, and the mean squares. The analysis of variance table also includes the F-statistics and p-values. Use these to determine whether the predictors or factors are significantly related to the response. Larger FAo (1149.78) value indicates that the variation of the process parameter makes a big change on the surface roughness.

III. CONCLUSION

The addition of carbon Nano tube increases the tensile strength, yield strength and elongation of the Aluminum Alloy. It was further noted that the surface hardness of the material reduced on the addition of carbon Nano tube. The confirmation experiments were conducted by setting the process parameters at optimum level. i.e. Cutting speed 2800 rpm and feed 300 mm/min and depth of cut 0.15mm as optimum parameters and the actual surface roughness was obtained without carbon Nano tubes is 3.136 μm compared to predicted surface roughness 3.21 μm . Similar way the with carbon Nano tubes based machining of a Cutting speed 2000 rpm and feed 300 mm/min and depth of cut 0.05mm as optimum parameters and the actual surface roughness was obtained with carbon Nano tubes 3.012 μm compared to predicted surface roughness 3.019 μm . ANOVA Analysis indicates that the variation of the process parameter makes a big change on the surface roughness.

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