ISSN: 0974-5823 Vol. 7 No. 2 February, 2022

International Journal of Mechanical Engineering

# Optimization of Material Removal Rate In Drill Bit, Cutting Speed And Feed Rate of Carbon Nanotube Epoxy Composite Specimen by Taguchi Method

[1]V.Gopinath, [2]Srinivasareddy Vempati, [3]Sk.Kareem Basha, [4]Y.Sesha Rao

[1,2,3,4]Department of Mechanical Engineering, QIS College of Engineering & Technology, Ongole, Andhra Pradesh, India

*Abstract* - The aim of this work is utilize Taguchi optimization methodology in optimizing the drilling parameters such as cutting speed, diameter of drill bit and feed rate for machining pristine and functionalized multi walled carbon nanotube epoxy composite material to obtain maximum material removal rate.While, the response factor to be measured is the material removal rate of the composite material. An orthogonal array was set up and signal-to-noise (S/N) ratio was employed to find the optimal levels of drilling parameters for achieving maximum material removal rate. Minitab 18 software was used to find out signal-to-noise (S/N) ratio and mean.ANOVA is used to determine the most significant control factors affecting the material removal rate. Analysis of variance (ANOVA) revealed that speed is the dominant parameter followed by feed and diameter of drill bit for pristine multi walled carbon nanotube epoxy composite while feed is the dominant factor followed by diameter of drill bit and speed for functionalized multi walled carbon nanotube epoxy composite.

*Index Terms* - About four, alphabetical order, key words or phrases, separated by commas (e.g., Camera-ready, FIE format, Preparation of papers, Two-column format).

## INTRODUCTION

Davim et. al. [1] established an empirical relation between feed rate and cutting velocity with reference

to thrust force, cutting pressure, a factor of damage and surface roughness in machining of GFRP composites by using cemented carbide tool. ANOVA has been also performed to investigate the effects of process parameters. El-SonbatyI. et. al. [2] examined the effects of process parameters on the thrust force, torque and surface roughness in drilling of fiber-reinforced composite materials. It has been demonstrated from the result that epoxy resin, cutting speed has insignificant effect on thrust force whereas cutting speed and feed has significant influence on surface roughness. Singh et. al. [3] approached a fuzzy inference system to predict torque and thrust in drilling of GFRP composites using solid carbide drill bit with eight facet. Experiments conducted by L27 Orthogonal array and ANOVA has been done to investigate the influence of process parameters. Kilickap et. al. [4] investigated the effect of cutting parameter that was feed rate, chisel angle of drill tool and cutting speed indrilling of glass fiber reinforced polymer. The primary aim was in this paper minimized the delamination that was produced after drill on GFRP and Taguchi method had used in this research. Latha et. al. [5] assessed the effects of drill parameters on thrust in machining of GFRP composites. Kumar et al. studied the influence of factors such as feed rate, cutting velocity, environment condition of the experiment, rake angle of tool and depth of cut in turning of GFRP composites. The optimal machining condition is obtained by Distance Based Pareto Genetic Algorithm. Rahaman et. al [6] studied on machinability aspects of carbon fiber reinforced composite. Three types of cutting tool inserts: uncoated tungsten carbide, ceramic and cubic boron nitride (CBN) were used to machine short (discontinuous) and long (continuous) fiber carbon epoxy composites. Ferreira et. al [7] studied the performance of different tool materials such as ceramics, cemented carbide, cubic boron nitride (CBN), and diamond (PCD). The results showed that only diamond tools were suitable for use in finish turning. An optimization methodology was used in rough machining to determine the best cutting conditions. It was concluded that the optimization of the cutting conditions is extremely important in the selection of the tools and cutting conditions to be used in the CFRP manufacturing process. Enemuoh et. al [8] presented a new comprehensive approach to select cutting parameters for damage-free drilling in

carbon fiber reinforced epoxy composite. The approach was based on a combination of Taguchi's experimental analysis technique and a multi-objective optimization criterion. The optimization objective included the contributing effects of the drilling performance measures: delamination, damage width, surface roughness, and drilling thrust force. Palanikumar et. al. [9] has utilized grey relation analysis with Taguchi Technique to obtain the optimal machining condition. Experiments were carried out throughL16 4-level orthogonal array in order to investigate the effects of spindle speed, feed on thrust force, delamination factor at an inlet and outlet on composite and surface roughness.Verma et. al. [10] proposed fuzzy inference system integrated with Taguchi to assess the favorable machining condition in turning of GFRP composites using HSS tool. The machining evaluation characteristics are taken as Material removal rate and surface roughness.

From the literature review done above, it reveals the following gap Because of the fact that Nano composites are a relatively newly established material, few studies have been produced on the machining of polymer Nano composites.Till now, from the literature available, only three studies have investigated drilling on Nano composites. The development and assessment of polymer Nano composite properties is also considerably scarce within literature. So the purpose of present research work is: (1)

To confirm the grafting of carboxylic group on to the walls of MWCNT's by FTIR spectrometer. (2)To investigate whether the functionalization condition were smooth enough so as not to disturb the conjugated structure of MWCNT by XRD. (3) To find the optimum parameters of drilling operation by Taguchi design. (4) To study the effect of cutting speed, diameter of drill bit and feed rate on material removal rate on pristine and functionalized multi walled carbon nanotube epoxy composite.

## PREPARATION OF COMPOSITE MATERIALS

In this study polymer matrix is chosen as they are readily available, can be easily fabricated , and its properties can be altered according to the need of applications very effectively when compared with the ceramic and metal matrix .For the present study thermosetting polymer matrix is chosen. Epoxy has been used widely for many advanced composites. Besides this, epoxy resin with a reinforcement of carbon nanotubes shows excellent mechanical and thermal properties even at high temperature and wide range of viscosity is available with the epoxy. While for carbon nanotube a low viscosity matrix material is needed in order to obtain good dispersion. Due to these advantages with the Multi walled carbon-nanotube epoxy material Lapox L12 is selected. Lapox L12 is unmodified epoxy resin of medium viscosity that can be used with different kinds of hardeners. The decision of selecting a hardener depends not only upon the processing methods to be used but also on the properties required of the cured composite. So, hardener K6 is chosen as it has a low viscosity as it is of prime importance with carbon nanotubes. Due to the fact that it is reactive by nature, it gives a short pot life and rapid cure at ambient temperatures.

Specification of resins and hardener

**Hardener K-6**

Visual appearance pale yellow liquid

Water content 1% max

Refractive index at 25 ºC 1.4940-1.5000

**Lapox L-12**

Epoxide equivalent gm/eq. 182-192

V) Viscosity at 25ºC 9000-12000 mPa.S

Epoxy value eq. / kg 5.25-5.5

**Processing parameters**

Lapox L-12 100 parts by weight

Hardener K-6 10-12 parts by weight

Viscosity at 20ºC 5000-8000 mPa.S

Pot life at 20 ºC 0.5-1 hrs.

Lapox L-12 and hardener K-6 can be easily mixed at room temperature. Both the epoxy resin and corresponding hardener are available from polymer processing lab at Applied chemistry deptt. At DTU.

### I. *Filler Material*

Multi walled carbon nanotubes have been chosen as a filler material, the reason being it's very high aspect ratio,Young's Modulas (over 1TPa), estimated tensile strength (around 200 GPa) .It is as stiff as Diamond. Because of the reason that carbon nanotubes have a low density for a solid of 1.3-1.4 g/cm³, its specific strength is the best of known materials. Therefore, these properties are best suited for fabricating reinforced composites. Multi walled carbon nanotubes have been procured from Appied Physics deptt. At DTU. Its specifications as mentioned by supplier are given below:-

Outer Diameter – 11-20 nm

Purity > 97%

Length – 10-30 microns

### II. *Chemical Functionalization of Multi-walled Carbon nanotubes*

Inorder to chemically functionalize multi walled carbon nanotubes by carboxyl group, mixture of acid is used which is a combination of nitric acid and sulphuric acid. Sulphuric acid with 98 wt. % concentrations and nitric acid with 69-72 weight percent concentration are taken. 100 ml of mixture acid is taken where Sulphuric acid and nitric acid (Mixture acid) are taken in a 3:1 ratio, 3 parts of sulphuric acid is mixed with 1 part of nitric acid in a beaker and then multi walled carbon nanotube is added to it. After this, the mixture is sonicated in an ultrasonicator for 15 minutes for proper mixing of CNT with the mixture acid. Now the sonicated mixture is poured in a double neck round bottom flask whose one neck has been equipped with thermometer for measuring temperature accurately and other neck is occupied by the condenser arrangement so as to heat the solution under reflux, thus not allowing CNT to escape. We have to heat the solution in a mantle under reflux for 30 minutes while maintaining temperature of 120º C. After heating the mixture it is allowed to cool to a room temperature. Then washing and filtering of MWCNT by The PTFE membrane filter is done. Pore size and material of the filter is chosen carefully as mixture acid may dissolve the material of the filter. Thus, Poly Tetra Flouro Ethylene (PTFE) is selected as the filter material as it will sustain the acid, pore size is selected at 0.22 micron for the CNT to be filtered from the solution and the size of the filter is selected as 25mm diameter according to our set up for filter. Filter is kept in a filter assembly which is connected to a vacuum pump so as to create vacuum for easily facilitating the filtering of CNT. Filtered CNT is then washed several times by the deionized water (5 washing cycles are enough for neutralising the pH level of MWCNT and pH is measured by litmus paper, it must be neutral for further processing. After this, the filtrate obtained is kept in a pettry dish and put in an oven at 60º C for 24 hours for the CNT to dry.

Fig 1: Refluxing set up

### III. *Composite Fabrication*

Composite is fabricated by both pristine MWCNT and functionalized MWCNT. By keeping in view the concentration of MWCNT in matrix, MWCNT is taken and mixed with acetone which act as a solvent. MWCNT's were taken in a small beaker, sonicated for 15 minutes, followed by addition of epoxy into the mixture. It is mechanically stirred for 2 minutes followed by sonication for 4 hours, the dispersed mixture thus obtained is then magnetically stirred for 1 hour at 70ºC so as to completely dispersed the MWCNT into the epoxy matrix, this will completely vaporize the acetone present in the mixture which is added so as to obtain better dispersion by decreasing the viscosity of the mixture. After this, the hardener is added into this mixture followed by mechanical stirring for 2 minutes after which it is poured into the mould. Then, samples are allowed to cure at room temperature for 1 day as shown in Fig. 2

Fig 2: Samples of MWCNT composite and neat epoxy

## PHYSICAL TESTS

### I. *Tensile Test*

Fig 3: UTM testing apparatus

**Test process:** During the tensile testing process, the test specimen is placed in the testing machine and tensile force is applied to it until it fractures. During the application of tensile force, the elongation of the gauge section is noted against the applied force. The data is manipulated so that it is not specific to the geometry of the test sample.The machine does the calculations of engineering strain and engineering stress, as the force increases, so that the data points can be graphed into a stress-strain curve.

### II. *Flexural Test*

The three-point bending flexural test gives us the values for the flexural stress , modulus of elasticity in bending , flexural strain , and the flexural stress-strain relationship of the material. Advantage of a three point flexural test is the easy way of the specimen preparation and testing. However, the results being sensitive to specimen strain rate and loading geometry is one of its disadvantage.

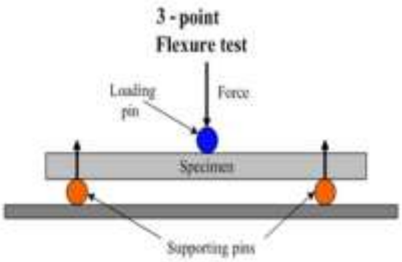



Fig 4: Flexure Test

### III. *Scanning Electron Microscope (SEM)*

In this microscope electron beam is scanned in a raster scan mode. For this research work SEM-JEL-JSM-648 equipment has been used as shown in the Fig 5. Inorder to prepare sample for SEM examination the surface of the specimen was coated with platinum for 5 minutes prior to the observation at 50 kV after that the surface topography of the multi walled carbon nanotubes was studied

Fig 5: SEM set up

### IV. *Fourier Transform Infrared Spectroscopy (FTIR)*

Generally average modern infrared instrument records spectra from around 4000 cm-1 down to 400 cm-1 as defined by the optics of the instrument. That is why, when a spectral region is quoted, the higher value will be quoted first, consistent with the normal left-to-right (high to low cm-1) representation of spectra.

Fig. 6: FTIR instrument (Perkin Elmer, USA)

FTIR instrument used here is Perkin Elmer, USA (as shown in Fig. 6) which is installed in the Uflex chemical laboratory, pallets of CNT were made with the help of a palletizer.

### V. *X-Ray Diffraction (XRD)*

The condition for maximum intensity contained in Bragg's law as written below allow us to calculate details about the crystal structure. However, if the crystal structure is known, it can also be used to determine the wavelength of the x-rays incident upon the crystal. It is explained by Bragg's law as: - $n\lambda=2d\sin\Theta$

Where, $\lambda$ is wavelength of x ray. $\Theta$ is the angle between the incident rays and surface of the crystal. d is spacing between layers of atoms. Constructive interference occurs when n is an integer. When n is an integer 1, 2, 3 etc.

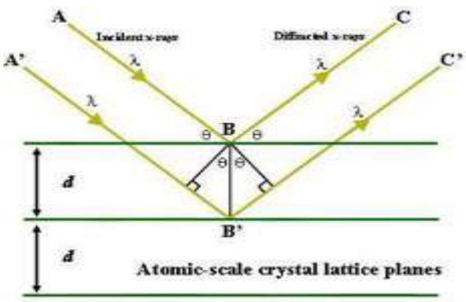



Fig. 7: Incident & reflected rays in XRD


Fig. 8: XRD instrument a) Setup of XRD b) Place for holding the slide during the XRD.

X-Ray Diffraction (XRD) is carried out using Rigaku Japan/Ultima-IV equipment as shown above. Both functionalized and pristine MWCNT were taken in a slide and the following parameters were chosen

Source of wavelength - Cu Kα X ray

10º per step per minute Wavelength - 1.5418Å Range - 5º -90º (2Ɵ) Step size of 0.02º

### *VI. Thermo Gravimetric Analysis (TGA)*

This technique observes mass of sample with reference to the temperature as it is heated or cooled. It employs a simple pan which is attached with a precision balance, this pan is kept inside a furnace and weight loss is observed as a function of time. Environment of the sample is filled by sample purge gas which may be inert or reactive, it flows over the sample and exits as exhaust. In this work, sample is heated from the room temperature to the 700ºC in a nitrogen atmosphere with a gas flow rate of 20ml/minute with a heating rate of 10ºC/minute.

### *VII. Differential Scanning Calorimetry (DSC)*

In the glass transition temperature region there is steep increase in the heat capacity . But where glass transition temperature is absent heat capacity increases linearly with temperature. The heating process was scanned from 30-150 C .Besides this heating rate of 10ºC/min under nitrogen atmosphere was employed. DSC is performed on neat epoxy, pristine MWCNT’s composite, and functionalized MWCNT’s composite, latter two are prepared at different composition. The prepreg were kept in an Al pan & weight of the samples were taken in between 10 to 30 milligram.

Fig. 9: DSC setup and computer attached to it for monitoring the data

## TESTS RESULTS

### *I. Tensile Test*

The tensile strength of the CNT reinforced epoxy composite sample was found good and was found increased. Test results were obtained in the form of graph between tensile load and extension, which shows that most of the response is linear, followed by brief nonlinearity before fracture. Tensile strength value as functions of loading direction was derived respectively from the gradient of the linear portion and the maximum stress before failure. The relationship between tensile load and extension for the reinforced epoxy composite is as shown and is compared with the un-reinforced normal epoxy sample. As observed, the tensile strength of Functionalized MWCNT reinforced epoxy composite was greater than pristine MWCNT reinforced epoxy composite at all composition. Although tensile strength of pristine MWCNT reinforced epoxy composite was greater than neat epoxy composite sample. These results are compared through bar chart as shown below.

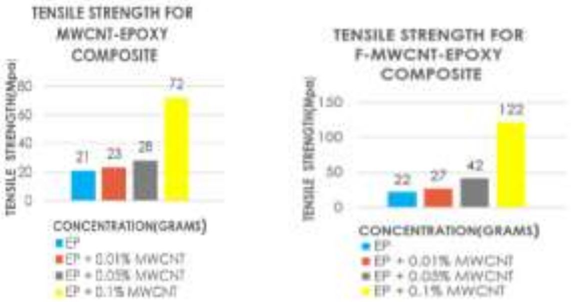



Fig. 10: Tensile test results for pristine and functionalized MWCNT epoxy composite

## II. *4.2 Flexural Test Analysis*

As observed, the flexural strength of Functionalized MWCNT reinforced epoxy composite was greater than pristine MWCNT reinforced epoxy composite at all composition. Although flexural strength of pristine MWCNT reinforced epoxy composite was greater than neat epoxy composite sample. These results are compared through bar chart as shown below

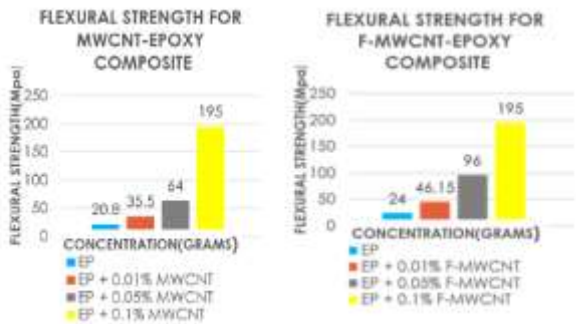



Fig. 11: Flexural test for pristine and functionalized MWCNT-EP composite

## VIII. *Characterization of Surface Morphology using SEM*

It is evident from the Fig.12 that in the case of pristine MWCNT epoxy composite, relatively larger sized undispersed CNT bundles can be observed whereas in Fig.13 uniform dispersion of individual CNTs were seen in case of functionalized MWCNT epoxy composite .Grafting of carboxyl group onto the walls of MWCNT is responsible not only for prevention of formation of agglomerates form but it is also responsible for improving the dispersion of MWCNTs in the nanocomposite which provides improved wetting between CNTs and epoxy. Because of the Improve wetting of CNTs by epoxy, there is better extent of adhesion which results in better interfacial interaction. Although all three materials failed in brittle manner at room temperature but the CNT presence as reinforcement in epoxy matrix modifies the fracture morphology. While for neat epoxy a relatively smooth surface containing few river lines were observed as shown in Fig.14, whereas for both Functionalized MWCNT epoxy and pristine MWCNT epoxy, the fracture surfaces were found to be relatively rough with more number of river lines which is an indication of relatively large deformation of polymer matrix as shown in Fig.15,16. The possible reason for higher deformation of polymer matrix must have been combined effect of various toughening and strengthening micro mechanisms and induced by the presence of CNT in epoxy. SEM micrographs shown below support the improvement in mechanical property caused by CNT addition in epoxy.

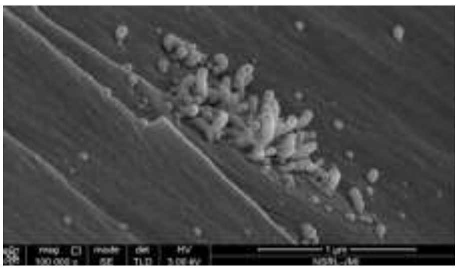


Fig.12 Extent of CNT dispersion in Pristine MWCNT epoxycomposite

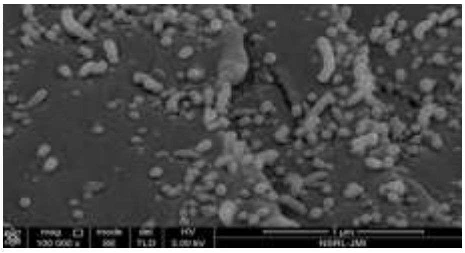


Fig.13 Extent of CNT dispersion in Functionalized MWCNT composite

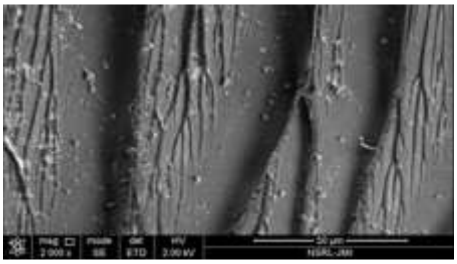


Fig. 14 Fracture morphology in neat epoxy sample

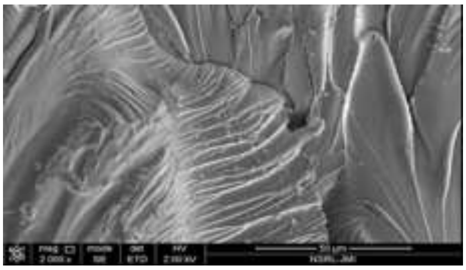


Fig.15 Fracture morphology in Pristine MWCNT epoxy composite

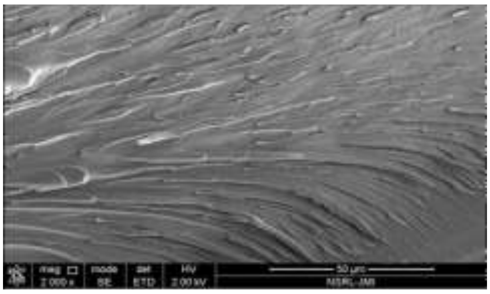


Fig.16. Fracture morphology in functionalized MWCNT epoxy composite

## *III. Tests results for FTIR*

For confirming the grafting of carboxylic group FTIR spectrum is analyzed. For the confirmation of grafting of carboxyl group onto the walls of MWCNT there must be the presence of four bonds and these are C-H bond, C-O bond, C=O bond and O-H Bond, the spectrum for these bonds shows stretching at following wave numbers : O-H stretching varies from 3300-2500 cm-1 and from 1440-1395 cm-1, C=O stretching varies from 1800- 1600 cm-1, C-O stretching varies from 1400-600 cm-1, C-H Stretching varies similar to O-H stretch 3300-2500 cm-1. Carboxylic group is said to be successfully grafted if our spectrum lies in this range

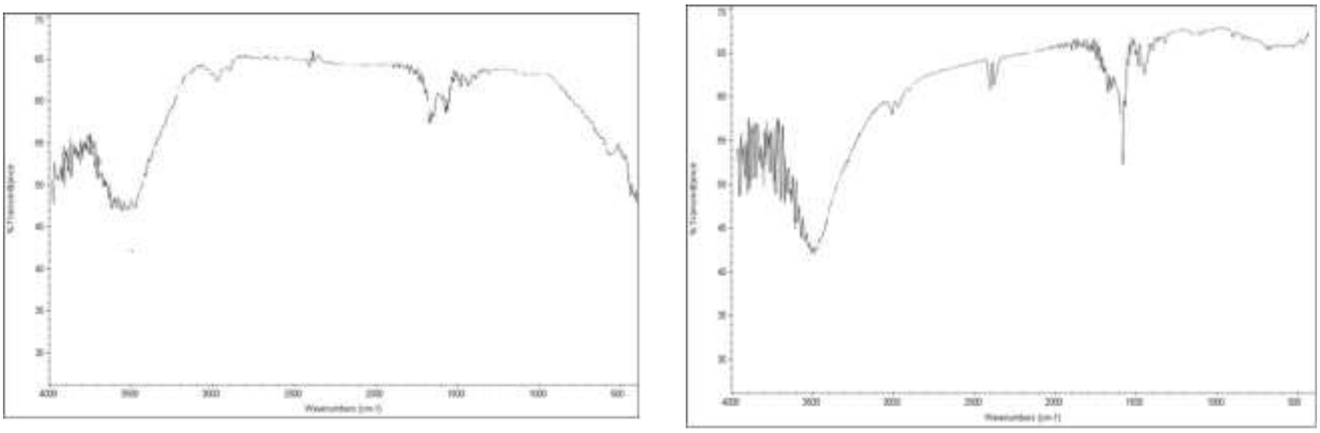


Fig.17 FTIR spectrum for pristine MWCNT and functionalized MWCNT epoxy composite

Above figure shows the FTIR spectrum for pristine MWCNT and the MWCNT sample which is to be declared fictionalized. The graph for the sample shows the C-H peak intensity at 3011.37 cm-1, 2776.28 cm-1, C-O peak intensity at 1230.62 cm-1, C=O peak intensity at 1729.49 cm-1, 1712.31 cm-1, 1694.58 cm-1 and O-H peak intensity at 3011.37 cm-1 and 2776.28 cm-1, 1433.49 cm-1, which lies well within the range for confirming the grafting of carboxyl group. Thus, it is found that the following parameters are needed for functionalization – the mixture acid concentration is kept at 3:1, temperature of the mixture is set at 120ºC, time of heating is 30 minutes and 1g of pristine MWCNT is taken. After this bulk preparation of functionalized MWCNT is done**.**

### *IV. X-Ray Diffraction (XRD)*

XRD pattern for pristine MWCNT and functionalized MWCNT epoxy composite are shown in Figure 27 and Figure 28 respectively, the diffraction peaks for pristine MWCNT is at 25.728º, 43.26º, 53.70º, 78.15º and for functionalized MWCNT's is at 25.763º, 42.79º, 52.93º, 78.64º. These diffraction patterns can be attributed to hexagonal graphite structure (002), (100), (004), and (110) . This shows that after the chemical functionalization of MWCNT's the structure of MWCNT's is retained even after the grafting by the carboxyl group on the surface of MWCNT**.**

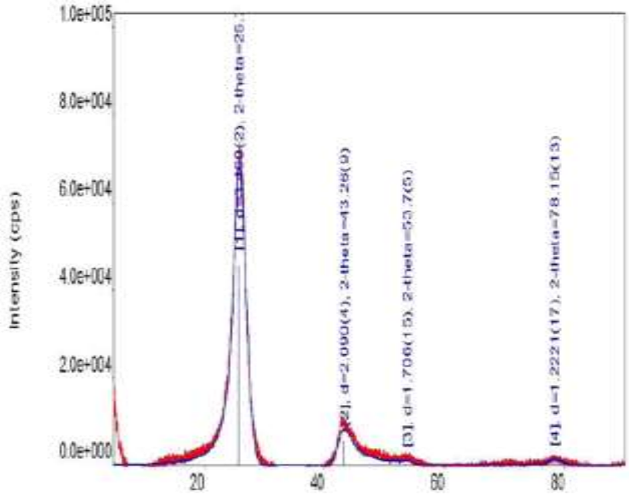



Fig. 18 XRD spectrum of pristine MWCNT epoxy composite.

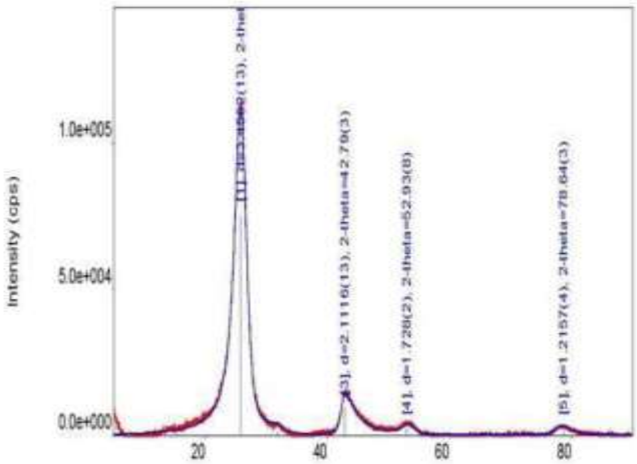



Fig.19 XRD spectrum of functionalized MWCNT epoxy composite.

### *V. Thermo Graviemetric Analysis (TGA)*

Thermo-gravimetric analysis (TGA) studies were carried out for both the composites samples made with pristine and functionalized multi walled carbon nanotubes with 0.1 wt% to know the thermal stability of these composites. It was observed that surface modification of CNTs can alter the thermal stability of the composite materials. Composites made with pristine MWCNTs, which have only slightly affected the thermal decomposing temperature of epoxy resin whereas the acid- functionalized MWCNTs have a great effect on the onset decomposing temperature. Introducing different acidfunctionalized MWCNTs to epoxy resin can increase the initial decomposing temperature of neat epoxy resin. Because of the strong interaction between the epoxy resin and acid functionalized MWCNTs, the diffusion of small molecules can be retarded under high temperature. The surface modified CNTs could significantly enhance interfacial interaction between the CNTs and matrix in the composites. Functionalization would modify the CNT surface characteristics and enable higher polarity so that CNTs can form covalent bonds with the polymer matrix, resulting in enhanced thermal stability.

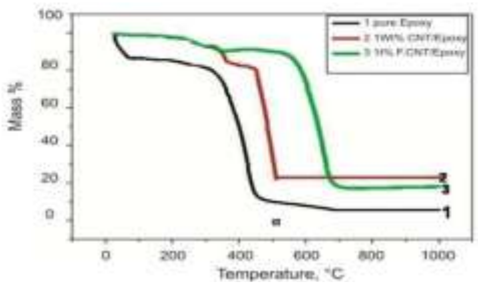



Fig. 20 TGA curve for Neat epoxy , Pristine and functionalized MWCNT epoxy composites

### *VI. Differential Scanning Calorimetry (DSC)*

Tabular data below shows the glass transition onset temperature for pristine MWCNT composite and functionalized MWCNT composite which is observed at different composition.

| | |
|---|---|
| Neap Epoxy | 65.15 ºC |
| Pristine MWCNT Epoxy Composite | 63.18 ºC |
| Functionalised MWCNT Epoxy Composite | 62.41 ºC |

Table 1 Tg of different samples

The Tg of neat epoxy was measured to be about 65.15 ºC. Reduction in Tg to 63.18 ºC was observed due to addition of pristine MWCNT. The reduction in Tg further increased by addition of FMWCNTs and for FMWCNT composite the Tg was about 62.41ºC. The drop in Tg can be explained due to the chemical restructuring of the polymer in the close vicinity of CNT or in the interphase region. This region i.e interphase region can be assumed to be composed of two types of polymeric layers. The first one which is tightly bound to the CNTs due to multi-segment adsorption and this polymer (also called as immobilized polymer) is largely affected by the strong CNTs as they hinder the formation of cross link during curing process. The hindrance in cross link formation reduces the cross link density in the cured polymer net-work and results in decrease in Tg. The second one is loosely bound polymer layer (or polymer of reduced mobility), which is not severely affected but has significant contribution in the interphase region and possess slightly different structure than the polymer in the resin rich zone and has relatively less contribution in the Tg of the nanocomposite. Functionalization further improves the dispersion and in turn the volume of net interphase region in the nanocomposite. Higher interphase volume leads to relatively higher volume of tightly bound polymer layers and which further reduces the Tg of the nanocomposite

**5 Taguchi Method**

In Taguchi's design method the design parameters (factors that can be controlled by designers) and noise factors (factors that cannot be controlled by designers, such as environmental factors) are considered influential on the product quality.The Signal to Noise (S/N) ratio is used in this analysis which takes both the mean and the variability of the experimental result into account. The S/N ratio depends on the quality characteristics of the product/process to be optimized.Usually, there are three categories of the performance characteristics in the analysis of the S/N ratio, i.e. 1. Higher the better

2. Lower the better

3. Nominal the better

The S/N ratio for each response is computed differently based on the category of the performance characteristics and hence regardless of the category the larger S/N ratio corresponds to a better performance characteristic."Larger is better" approach is followed as we have to maximize the material removal rate. Three factors were selected for this experiment. There are spindle speed, feed rate and drill diameter with three levels as shown in Table2. The experiments were conducted with different cutting speeds and feed rates using different diameters of drill bits. The cutting speeds considered are 112rpm, 220rpm, and 440 rpm. Feed rates considered are 0.12 mm/rev, 0.20mm/rev and 0.30mm/rev. and the drill diameters considered are 8mm, 10mm, and12 mm. In all cutting conditions for each hole Material removal rate (MRR) is measured.

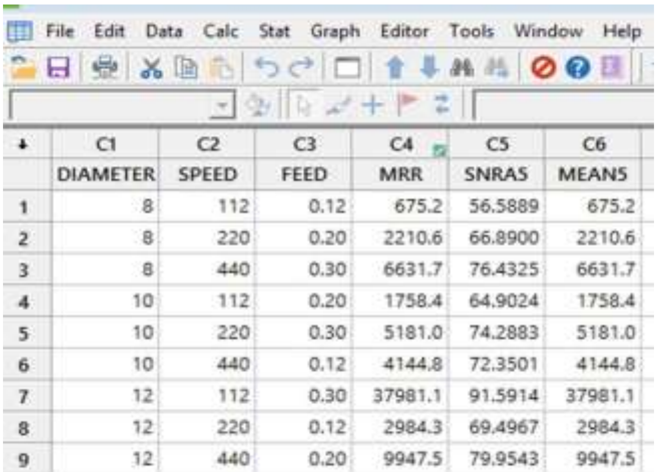
| Level | Drill Diameters (mm) | Cutting speeds (rpm) | Feed Rate (mm/rev) |
|---|---|---|---|
| 1 | 8 | 112 | 0.12 |
| 2 | 10 | 220 | 0.20 |
| 3 | 12 | 440 | 0.30 |

Table 2 Machining parameters and their level

We are conducting experiments on pristine MWCNT epoxy composte and Functionalized MWCNT epoxy composite.

**A)Pristine MWCNT epoxy composite:**

The design of experiment by taguchi L9 orthogonal array is formed using MINITAB and experiments are performed accordingly .The following Fig.21 shows the observations of MRR




| | C1 | C2 | C3 | C4 | C5 | C6 |
|---|---|---|---|---|---|---|
| | DIAMETER | SPEED | FEED | MRR | SNRA5 | MEAN5 |
| 1 | 8 | 112 | 0.12 | 675.2 | 56.5889 | 675.2 |
| 2 | 8 | 220 | 0.20 | 2210.6 | 66.8900 | 2210.6 |
| 3 | 8 | 440 | 0.30 | 6631.7 | 76.4325 | 6631.7 |
| 4 | 10 | 112 | 0.20 | 1758.4 | 64.9024 | 1758.4 |
| 5 | 10 | 220 | 0.30 | 5181.0 | 74.2883 | 5181.0 |
| 6 | 10 | 440 | 0.12 | 4144.8 | 72.3501 | 4144.8 |
| 7 | 12 | 112 | 0.30 | 37981.1 | 91.5914 | 37981.1 |
| 8 | 12 | 220 | 0.12 | 2984.3 | 69.4967 | 2984.3 |
| 9 | 12 | 440 | 0.20 | 9947.5 | 79.9543 | 9947.5 |

Fig. 21: L9 Taguchian array for drilling parameters (Pristine MWCNT Epoxy composite

In this chapter, we are discussing about influence of machining parameters i.e cutting speed, feed rate and drill diameter on material removal rate (MRR) & find out which parameter is most important during an experiment.The graphs shown below are the main effect plot of S/N ratios for process parameters viz. Cutting Speed, Feed rate and Drill Diameter.

**5.1.Taguchi Analysis for MRR**

The S/N ratios for MRR are calculated as given in below Equation. Taguchi method is used to analysis the result of response of machining parameter for "Higher is best" criteria. The Signal-To-Noise ratio for the Higher-the-better is:

S/N = -10*log (mean square of the inverse of the response)

Where: n= number of measurements in trial/row, in

this case

n=1, 2…, 9 and Yi is the ith measured value in

a run/row. I =1, 2…, 27.

$$S/N= -10\log_{10}\left[\frac{1}{n}\Sigma\frac{1}{y_i^2}\right]$$

| Level | Drill Bit Diameter (mm) | Cutting speed (rpm) | Feed Rate (mm/rev) |
|---|---|---|---|
| 1 | 31.72 | 20.77 | 26.01 |
| 2 | 36.95 | 34.59 | 46.39 |
| 3 | 55.77 | 69.08 | 52.04 |
| Delta | 24.04 | 48.31 | 26.02 |
| Rank | 3 | 1 | 2 |

Table 3 Response Table for Means

| Level | Drill Bit Diameter (mm) | Cutting speed (rpm) | Feed Rate (mm/rev) |
|---|---|---|---|
| 1 | 66.64 | 64.36 | 66.15 |
| 2 | 70.51 | 70.23 | 70.58 |
| 3 | 73.68 | 76.25 | 74.10 |
| Delta | 7.04 | 11.88 | 7.96 |
| Rank | 3 | 1 | 2 |

Table 4 Response table for Signal to Noise Ratios:

Higher is Best

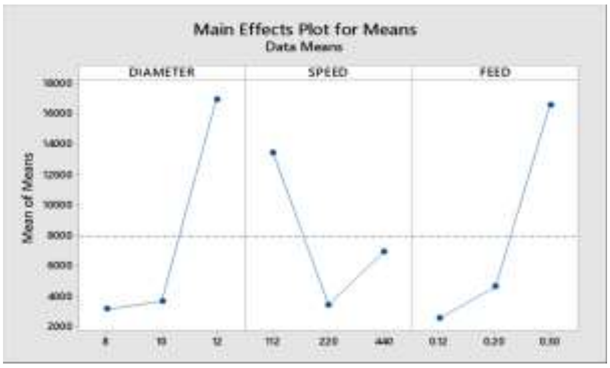



Fig 22. Main Effects Plot for Means

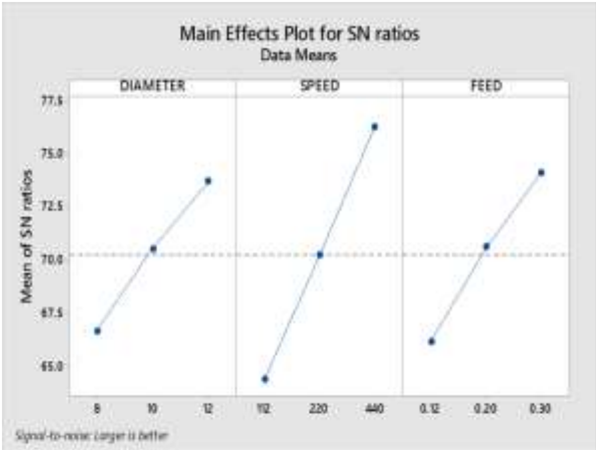



Fig.23: Main Effects Plot of SN Ratios for Material Removal Rate (gm/sec)(Pristine MWCNT epoxy composite)

**Drill Diameter:** From the observation of main effects plot the Maximum MRR is produced when 12 mm drill diameter is used.It shows that increase in drill diameter gives increase in MRR.

**Feed Rate:** Another observation of the present work is that the increase in feed rate improves the MRR. Maximum MRR is produced at 0.30 mm/rev feed rate.

**Cutting Speed:** The Cutting Speed is another factor that increase in speed rate improves the MRR. Maximum MRR is produced at 440 rpm.

**B)Functionalized MWCNT epoxy composite:**

The design of experiment by taguchi L9 orthogonal array is formed using MINITAB and experiments are performed accordingly .The following Fig.24 shows the observations of MRR

| ↓ | C1 | C2 | C3 | C4 | C5 | C6 |
|---|---|---|---|---|---|---|
| | DIAMETER | SPEED | FEED | MRR | SNRA1 | MEAN1 |
| 1 | 8 | 112 | 0.12 | 810.0 | 58.1697 | 810.0 |
| 2 | 8 | 220 | 0.20 | 2652.7 | 68.4738 | 2652.7 |
| 3 | 8 | 440 | 0.30 | 7958.0 | 78.0161 | 7958.0 |
| 4 | 10 | 112 | 0.20 | 2110.1 | 66.4861 | 2110.1 |
| 5 | 10 | 220 | 0.30 | 6217.2 | 75.8719 | 6217.2 |
| 6 | 10 | 440 | 0.12 | 4973.8 | 73.9338 | 4973.8 |
| 7 | 12 | 112 | 0.30 | 41779.2 | 92.4192 | 41779.2 |
| 8 | 12 | 220 | 0.12 | 3282.7 | 70.3246 | 3282.7 |
| 9 | 12 | 440 | 0.20 | 10942.3 | 80.7822 | 10942.3 |

Fig.24: L9 Taguchian array for drilling parameters

(Functionalised MWCNT epoxy composite)

| Level | Drill Bit Diameter (mm) | Cutting speed (rpm) | Feed Rate (mm/rev) |
|---|---|---|---|
| 1 | 3807 | 14900 | 3022 |
| 2 | 4434 | 4051 | 5235 |
| 3 | 18668 | 7958 | 18651 |
| Delta | 14861 | 10849 | 15629 |
| Rank | 2 | 3 | 1 |

Table 5 Response Table for Means

| Level | Drill Bit Diameter (mm) | Cutting speed (rpm) | Feed Rate (mm/rev) |
|---|---|---|---|
| 1 | 66.22 | 72.36 | 67.48 |
| 2 | 72.10 | 71.56 | 71.91 |
| 3 | 81.18 | 77.58 | 82.10 |
| Delta | 12.96 | 6.02 | 14.63 |
| Rank | 2 | 3 | 1 |

Table 6 Response table for Signal to Noise Ratios: Higher is Best

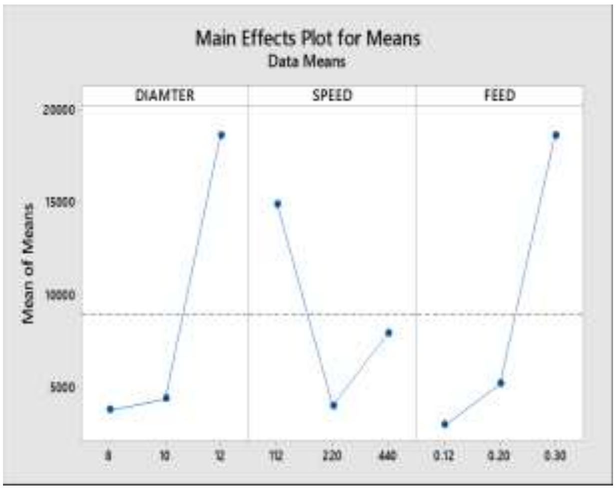



Fig .25: Main Effects Plot for Mean

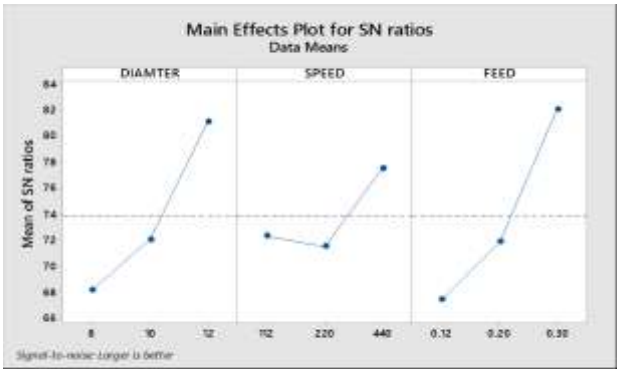



Fig.26: Main Effects Plot of SN Ratios for Material

Removal Rate (gm/sec)(Functionalized MWCNT

epoxy composite)

**Drill Diameter:**

From the observation of main effects plot the Maximum MRR is produced when 12 mm drill diameter is used.It shows that increase in drill diameter gives increase in MRR.

**Feed Rate:**

Another observation of the present work is that the increase in feed rate improves the MRR. Maximum MRR is produced at 0.30 mm/rev feed rate.

**Cutting Speed:**

The Cutting Speed is another factor that shows variation in MRR. Maximum MRR is produced at 440 rpm.

## *VII. ANOVA and the Effects of Factors*

Analysis of variance for MRR is given in below table. These values are obtained from MINITAB software. The last column of the table indicates percentage contribution of the control factors and their interactions on the performance output i.e. material removal rate. Analysis is done for a level of confidence of significance of 5%.

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| Diameter (mm) | 1 | 8669906 | 8669906 | 5.13 | 0.073 |
| Speed (rpm) | 1 | 37058274 | 37058274 | 21.94 | 0.005 |
| Feed (mm/rev) | 1 | 9695817 | 9695817 | 5.74 | 0.062 |
| Residual Error | 5 | 8446980 | 1689396 | | |
| Total | 8 | 63870977 | | | |

Table 7 ANOVA table for MRR(For Pristine

MWCNT reinforced epoxy composite)

| Source | DF | Seq SS | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|---|

| | | | | | | |
|---|---|---|---|---|---|---|
| Diameter(mm) | 2 | 423864078 | 423864078 | 211932039 | 1.65 | 0.377 |
| Speed (rpm) | 2 | 181151735 | 181151735 | 90575867 | 0.71 | 0.586 |
| Feed (mm/rev) | 2 | 429173941 | 429173941 | 214586971 | 1.67 | 0.374 |
| Residual Error | 2 | 256613349 | 256613349 | 128306674 | | |
| Total | 8 | 1290803103 | | | | |

Table 8 ANOVA table for MRR (For Functionalized

MWCNT reinforced epoxy composite)

REGRESSION EQUATION USING ANOVA:

MRR=-8601+ 601 DIAMETER + 14.87 SPEED+14096 FEED

In above table DF:degree of freedom, Seq SS: sequential sum of squares, Adj. SS: extra sum of squares,Seq MS: sequential mean squares, F: F-test, P: percent contribution. From Table 7 it can be observed for pristine MWCNT composite speed(p=0.005) have major influence on material removal rate. The interaction of Diameter of drill bit (p= 0.073) and feed rate(p=0.062)have relatively less significant contribution.From Table8 it can be observed that COOH functionalized MWCNT composite feed (p=0.374) have major influence on material removal rate. The interaction diameter (p = 0.377) and speed (p = 0.586) have relatively less significant contribution.

## CONCLUSIONS

In design of an application based product its lifecycle is foremost criterion and information about machining properties provides essential evidence towards selection of a product. To this end, MWCNT's were first functionalised by the carboxyl group by the help of chemical functionalization and then are characterized by FTIR, XRD, TGA and SEM. Nano composites is fabricated by sonication and stirring and drilling operation is conducted at various parameters for functionalised Nano composites. The following conclusions are derived from this study:-

1. Parameters for functionalization of MWCNT were found to be at an acid ratio of 3:1 in a 100 ml mixture acid, temperature at 120oC, time during which solution is heated is 30 minute, and 1g of MWCNT is used for the functionalization.

2. FTIR confirmed the grafting of carboxylic group on to the walls of multi walled carbon nanotubes.

3. Condition of chemical functionalization was not harsh as the structure of graphite is retained as confirmed by XRD.

4. For both the samples, that is pristine and functionalized MWCNT epoxy composite, optimum parameters for maximizing material removal rate were obtained at speed 440 rpm, feed 0.30 mm/rev and drill bit diameter of 12 mm. For pristine MWCNT composite, speed (p=0.005) have major influence on material removal rate. The interaction of Diameter of drill bit (p= 0.073) and feed rate (p=0.062) have relatively less significant contribution. While for COOH functionalized MWCNT composite, feed (p=0.374) has major influence on material removal rate. The interaction diameter (p = 0.377) and speed (p=0.586) have relatively less significant contribution.

5. Material removal rate at any parameter has been found to be higher for functionalized MWCNT epoxy composite than of pristine MWCNT epoxy composite. Secondly, tensile and flexural strength for functionalized MWCNT composite is higher than that of pristine MWCNT composite thus functionalized MWCNT composite has higher load resistance. This variation is attributed to the better dispersion of MWCNT in epoxy matrix medium in case of functionalized MWCNT epoxy composite which makes it stiff and harder to exhibit better mechanical and thermal properties

## REFERENCES


[1] J.P. Davim, P. Reis, C.C. António, "Experimental study of drilling glass fiber reinforced plastics (GFRP) manufactured by hand lay-up," *Composites Science and Technology*, Volume 64, Issue 2, February 2004

[2] I. El-Sonbaty, U.A. Khashaba, T. Machaly, "Factors affecting the machinability of GFR/epoxy composites," *Journal of Composite Structure*, vol.63, pp. 313-327, 2004.

[3] I. Singh, N. Bhatnagar, "Drilling induced damage in uni-directional glass fiber reinforced plastic (UD-GFRP) composite laminates.," *International Journal of Advanced Manufacturing Technology*, pp. 877-882, 2006

[4] E. Kilickap, "Optimization of cutting parameters on delamination based on Taguchi method during drilling of GFRP composite," *E.S.A. 37*, 2010.

[5] B. Latha, V.S. Senthilkumar, K. Palanikumar, "Influence of Drill Geometry on Thrust Force in Drilling GFRP Composites," *Journal of Reinforced Plastics and Composites*, pp. 463-472, March 2007.

[6] M.Rahman,S.Ramakrishna,J.R.SPrakash,"Machinability study of carbon fiber reinforced composite," *Journal of Materials Processing Technology*, vol. 89–90, pp. 292- 297, 1999.

[7] R.Ferrriera,D.Carou, "Surface Roughness Investigation in the Hard Turning of Steel Using Ceramic Tool," *Journal of Materials Processing Technology*, vol.31, pp. 290- 291, February1999

[8] E.U. Enemuoh, A.S. El-Gizawy, A.C. Okafor, " An approach for development of damage-free drilling of carbon fiber reinforced thermosets,," *International journal of machine tools manufacturing*, vol. 41, pp. 1795-17814, 2001.

[9] Palanikumar K., "Experimental investigation and optimisation in drilling of GFRP composites". *Measurement*, vol.44, pp.2138-2148, 2011

[10] Verma R. K., Abhishek K., Datta S. and Mahapatra S. S., "Fuzzy rule based optimization in machining of FRP composites", *Turkish Journal of Fuzzy System*, vol.2: pp.99-121, 2011.