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Optimization of Turning Process Parameter for GFRP through CNC Turning Process

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Abstract **- Nowadays, glass fiber reinforced plastics (GFRP) composites play a vital role new line in many engineering applications as an alternative to various heavy exotic materials. Newline in GFRP polymeric composites, the matrix of polymer (resin) is reinforced with glass line fibers. Glass fiber reinforced plastics are increasingly used for variety of engineering new line applications from automobile to air craft components because of their superior new line advantages when compared to the other engineering materials. Turning of GFRP composite materials is a rather complex task owing to its heterogeneity and the number of problems. The Problems are surface delimitation, which appear during the machining process that is associated with the characteristics of the material and the cutting parameters. Optimization of machining parameters is an important process in machining. Experiments were conducted based on the established Taguchi's technique L9 orthogonal array on a lathe machine. The cutting parameters are speed, feed rate, and depth of cut on the surface roughness, machining timing and material removal rate produced. The performances of the various parameters are evaluated by measuring surface roughness and material removal rate. The results indicate that the developed model is suitable for prediction of surface roughness and material removal rate in machining of glass fiber reinforced plastics composites. The percentage of contribution was analyzed speed parameter 80% for surface roughness feed parameter 66%for machining timing s and feed parameter 64% for MRR.**
Key words: **GFRP, glass fiber, optimization, surface roughness and Taguchi's technique.**

I.INTRODUCTION

FRP OVER VIEW In recent years, fiber reinforced plastics (FRPs) are continuously replacing traditional engineering materials because of their superior advantage over other engineering materials. The advantages include high strength to weight ratio, high fracture toughness, and excellent corrosion and thermal resistance. The glass fiber reinforced plastic (GFRP) composites are being extensively used in various fields like Aerospace, Automobile, Chemical industries, Off shore power plants, Refinery, Oil and Gas, Pulp and paper, Waste and waste water etc,. The application filed of FRP composites, expands the opportunity of machining such as cutting off, drilling, milling, turning etc, and has increased for its fabrication. However, the users of FRP have faced difficulties to machine it, because knowledge and experience acquired for conventional materials cannot be applied to such new materials, of which machinability is completely different from that of conventional materials. Generally, composite materials are engineered materials and are made from two or more constituent materials with significantly different physical and chemical properties. The two types of constituent phases are matrix and reinforcement. Generally, most materials, especially brittle ones, exhibit an important characteristic that a small-diameter shape is much stronger than the bulk material. This feature has been taken as an advantage in FRPs. The fiber therefore can provide the key structural properties such as high specific strength and stiffness for FRPs, while the polymer matrix provide support to the fiber and also transmit the load to the fibers and protect them from harsh environment. These materials could meet the requirements of modern technology, not met by the conventional materials.

A.Classification of composites

A simple scheme for the classification of composite materials is shown in Figure 1.

1. Particle Reinforced Composites

The various types of particle reinforced composites are discussed below.

a. Large particle Reinforced composites

Large particle and dispersion-strengthened composites are the two sub classifications of particle-reinforced composites. The distinction between these is based upon reinforcement or strengthening mechanism.

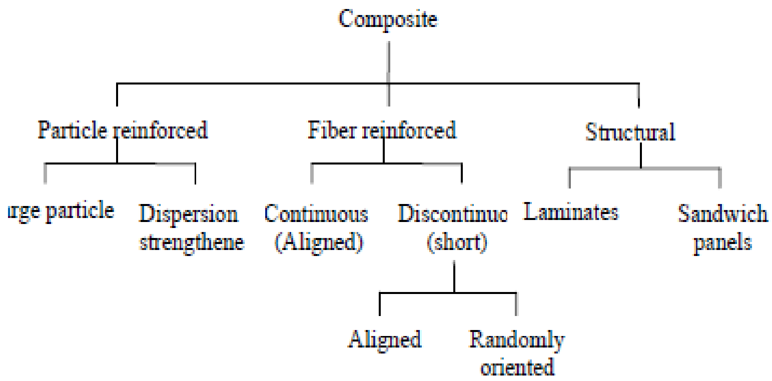

Fig. 1 Classification of composite materials

The term "large" is used to indicate that particle-matrix interactions cannot be treated on the atomic or molecular level. For most of these composites, the particle phase is harder and stiffer than the matrix. These reinforcing particles tend to retain the movement of the matrix phase in the vicinity of each particle. In essence, the matrix transfers some of the applied stress to the particle, which bears a fraction of the load. The degree of reinforcement or improvement of mechanical behavior depends on strong bonding the matrix– particle interface.

b. Dispersion strengthened composites

For dispersion-strengthened composites, particles are normally much smaller, having diameter between 0.01 and 0.1 µm. Particle-matrix interactions that lead to strengthening occurs at the atomic or molecular level. Matrix bears the major portion of an applied load, and the small dispersed particles hinder the motion of dislocations. Thus plastic deformation is restricted so that yield and tensile strengths, as well as hardness are improved.

2. Fiber reinforced composites

Figure 1.2 shows the some kinds of fiber and matrix phases.

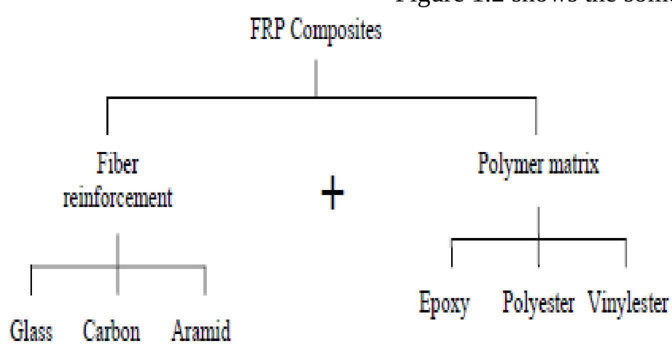

Fig. 2 Fiber reinforced composites

A composite is a structural material which consists of combining two or more constituents. The constituents are combined at a macroscopic level and are not soluble in each other. One constituent phase is called the reinforcing phase and the one in which it is embedded is called the matrix. The reinforcing phase may be in the form of fibers, particles or flakes. The matrix phase materials are generally continuous. The design goals of fiber reinforced composites often include high strength and or stiffness on a weight basis. These characteristics are expressed in terms of specific strength and specific modulus parameters, which correspond respectively, to the ratio of tensile strength to specific gravity and modulus of elasticity to the specific gravity.

The performance of a fiber reinforced composite is judged by its length, shape, orientation, composition of the fibers and the mechanical properties of the matrix.

a. Glass fibers

Over 95% of the fibers used in reinforced plastics are glass fibers, as they are inexpensive, easy to manufacture and possess high strength and stiffness with respect to the plastics, with which they are reinforced. Their low densities, resistance to chemicals, insulation capacity are the other bonus characteristics of the glass fiber. Glass fibers are available in the form of mats, tapes, cloths, continuous and chopped filaments, roving and yarns. Addition of chemicals to silica sand while making glass yields different types of glasses. The main types are E-glass (also called "fiberglass") and S-glass. The E in E-glass stands for electrical as it was designed for electrical applications as an insulator. However, it is used for many other purposes now such as decorations and structural applications. The S in S-glass stands for higher content of silica. It retains its strength at high temperature as compared to E-glass and has higher fatigue strength. It is used mainly for aerospace applications. Other type of fibers available are C-glass (C stands for corrosion) used in chemical environments such as storage tanks, R-glass used in structural application such as constructions. Dglass (D stands for dielectric) used for applications requiring low dielectric constants such as radomes, and A-glass (A stands for appearance) used to improve surface appearance.

b. Carbon fibers

Carbon fibers are very common in high modulus and high strength applications such as aircraft components etc. The advantages of carbon fibers include high specific strength and modulus, low coefficient of thermal expansion, high fatigue strength. The drawbacks include high cost, low impact resistance, high electrical conductivity.

c. Aramid fibers

An aramid fiber is an aromatic organic compound made of carbon, hydrogen, oxygen and nitrogen. Its advantages are low density, high tensile strength, low cost, and high impact resistance. Its drawback includes low compressive strength and degradation in all respects in sunlight. The two main types of aramid fibers are Kevlar 29 and Kevlar 49. Both types of Kevlar fibers have similar specific strength, but Kevlar 49 has higher specific stiffness. Kevlar 29 is mainly used in bullet-proof vests, ropes and cables. High performance applications in the aircraft industry use Kevlar 49.

d. Polymer Matrix

In matrix based composites, the matrix serves two paramount purposes viz., binding the reinforcement phases in place and to distribute the stresses among the constituent reinforcement materials under an applied force. Polymers are the ideal materials as they processed easily, possess lightweight, and desirable mechanical properties. The two main kinds of polymers are thermo sets and thermoplastics. Thermo sets have qualities such as a well-bounded three-dimensional molecular structure after curing. Whereas, thermoplastics have one or two-dimensional molecular structure. Thermoplastics tend to lose their strength at elevated temperatures.

II. LITERATURE SURVEY

Exhaustive literature survey was carried out and the available relevant information was presented under the following headings. It is the conceptual framework of a methodology for quality improvement and process robustness that needs to be emphasized. The entire concept can be described in two basic ideas.

1. Quality should be measured by the deviation from a specified target value, rather than by conformance to preset tolerance limits.
2. Quality cannot be ensured through inspection and rework, but must be built in through the appropriate design of the process and product rather we propose to get the desired quality by presetting the input parameters.

Through the proper design of a system, the process can be made in sensitive to variations, thus avoiding the costly eventualities of rejection and/or rework. In order to determine and subsequently minimize the effect of factors that causes variation. The operational steps as found from the reviews of literatures recommended to State problem and objective first, then to list responses, control parameters, and sources of noise. In the same way thereafter plan the experiment, run experiment and predict improved parameter settings and finally run confirmatory experiment. If the objective is not met, then it's back to step. Otherwise, improved design can be adopted. Traditionally, the selection of cutting conditions for metal cutting is left to the machine operator. In such cases, the experience of the operator plays a major role, but even for a skilled operator it is very difficult to attain the optimum values each time. Machining parameters in metal turning are cutting speed, feed rate and depth of cut. The setting of these parameters determines the quality characteristics of turned parts. Vinothkumar et al (2013)investigated to optimize process parameters namely, cutting speed, feed, point angle and chisel edge width in drilling of glass fiber reinforced polymer (GFRP)composites.

In this work, experiments were carried out as per the Taguchi experimental design and an L9 orthogonal array was used to study the influence of various combinations of process parameters on hole quality. Analysis of variance (ANOVA) test was conducted to determine the significance of each process parameter on drilling. The results indicate that feed rate is the most significant factor influencing the thrust force followed by speed, chisel edge width and point angle; cutting speed is the most significant factor affecting the torque, speed and the circularity of the hole followed by feed, chisel edge width and point angle. This work is useful in selecting optimum values of various process parameters that would not only minimize the thrust force and torque but also reduce the delimitation and improve the quality of the drilled hole. Reddy srinivasulu (2013) is focused on the influence of cutting speed, feed rate and depth of cut on the delamination damage and surface roughness on Glass Fiber Reinforced Polymeric composite material (GFRP) during end milling. Taguchi design method is employed to investigate the machining characteristics of GFRP.

From the results of ANOVA, it is concluded that cutting speed and depth of cut are the most significant factors affecting the responses, their contribution in an order of 26.84% and 40.44% respectively. Confirmatory experiments show that 5.052μm for surface roughness and 1.682 delamination damage to validate the used approach after conducting with optimal setting of process parameters. Finally, artificial neural network has been applied to compare the predicted values with the experimental values, the deviations are found in the range of 3.7%, it shows good agreement between the predictive model results and the experimental measurements. B.V.Kavad et al(2014) is focused Drilling is an important process for making and assembling components made from Glass Fiber Reinforced Plastic (GFRP).

Various processes like conventional drilling, vibration assisted drilling and ultrasonic assisted drilling have been attempted in order to maintain the integrity of the material and obtain the necessary accuracy in drilling of GFRP. This paper attempts to review the influence of machining parameter on the delamination damage of GFRP during drilling. In conventional machining feed rate, tool material and cutting speed are the most influential factor on the delamination hence machining at higher speed, harder tool material and lower feed rate have lesser delamination of the GFRP. Vibration assisted drilling and Ultrasonic assisted drilling have lesser thrust and hence lesser delamination compared to conventional drilling, which indicates that both vibration assisted drilling and Ultrasonic assisted drilling are more appropriate for drilling of GFRP.

Mr.M.A.Amrn (2013) et al to optimization of surface integrity in drilling process using response surface method (RSM) is presented. This paper investigates the effects of drilling parameter such as spindle speed, feed rate and drill diameter on the surface roughness and surface texture of drilled hole by applying RSM. There are three factors (spindle speed, feed rate and drill diameter) under investigation, therefore, by applying RSM there will be 20 experimental observations. The minimum surface roughness measured for the hole was 1.06m at combination of 2000 rpm spindle speed, 78 mm/min feed rate and 2.5 mm drill diameter. While the maximum surface roughness of 2.59 m was measured at the combination of 250 rpm spindle speed, 153 mm/min feed rate and 3.5 mm drill diameter. One factor plot analysis found that the most significant parameter was spindle speed followed by drill diameter and feed rate. Thus, surface roughness decreased when increasing the spindle speed, feed rate and drill diameter. There were interactions between all the parameter of spindle speed, feed rate and drill diameter in drilling process under investigation. Harsh Y Valera et al(2014) experimental study of power consumption and roughness characteristics of surface generated in turning operation of EN-31 alloy steel with TiN+Al2O3+TiCN coated tungsten carbide tool under different cutting parameters. The study shows the influences of three cutting parameters like spindle speed, depth of cut and feed rate affecting surface roughness as well as power consumption while turning operation of EN-31 alloy steel. The experimental setup includes five different spindle speed keeping feed rate of 0.08 mm/rev and depth of cut of 0.4 mm constant, five different feed rate keeping spindle speed of 710 rpm and depth of cut of 0.4 mm constant and five different depth of cut keeping feed rate of 0.08 mm/rev and spindle speed of 710rpm constant. The experiments were conducted to investigate the effectiveness of surface roughness and power consumption in turning operation of EN 31 alloy steel.

III. CNC TURNING PROCESS

A. CNC

Computer numerical control is a numerical control system that utilizes stored program to perform basic numerical control functions mini or micro computer based microcontroller used. The external appearance of CNC is very similar to that of numerical controller. The part program is entered in similar manner. Punched tape reader is common device for both CNC and NC. In CNC the program is entered once and then stored in computer memory whereas in conventional NC machines for every work piece the punched tape is cycled through the tape reader. When compared to NC, CNC offers more flexibility and computational capability reprogramming is easy. Because of this facility CNC is often termed as soft wired NC. Computer numerical control is defined as a NC system that utilizes a dedicated microcomputer to perform some or all of the basic control functions.

B. CNC turning machine

The CNC turning is a machine tool capable of performing various turning and related operations, on work piece in one set up under CNC system. These are generally provided with two axis control, Z axis parallel to the spindle and X axis perpendicular to the spindle axis. Turning centers are provided with a slant bed to allow for better view of the machining plane as well as for easy placement of various devices involved in the machine zone. It also provided various types. The CNC turning centre is a machine tool capable of performing multiple machining operations on work piece in one setup under CNC system typical machining operation performed on machining centre includes turning, milling, drilling, boring reaming and tapping.

C. CNC program

CNC part program is a detailed list of instructions that need to be executed by the machine control unit to achieve the final component shape. The processing sequence needed to manufacture a given part is broken down into small elements and written in a specific format understood by the machine control unit

D. Properties of metal

The term property may be defined as the quantity which defines the specific characteristics of metal.

E. Mechanical properties

The mechanical properties of metals are those properties which completely defines its behavior under the external loads or forces. Or in other words mechanical properties are those properties which are associated with its ability to resist failure as well as behavior under the action of the external force. These properties include hardness, elasticity, plasticity, ductility, brittleness toughness stiffness, creep etc.

F. Hardness

The term hardness may be defined as he property of a metal by virtue of which it is able to resist abrasion, indentation(or penetration) and scratching by harder bodies. It is measured by the resistance of the metal which it offers to scratch.

G. Cutting tool

Cutting tool is one which removes metal from work piece in the form of chips during machining operation to achieve required dimensions of the work piece. Cutting tool must be harder than the material which is to be cut. The selection of cutting tool material will depend upon the following factor such as volume of production, tool design, and types of machining process, physical and chemical properties of work material and rigidity and condition of the work piece

H. Machining parameters

1. Cutting speed

The cutting speed of a cutting tool may be defined as the speed at which the cutting edge passes over the material. Cutting speed ordinarily expressed as meter per minute.

2.Feed

The feed of a cutting tool is the distance the tool advances into or along the work piece each time the tool point passes a certain position in its travel over the surface.

3.Depth of cut

The depth of cut is the perpendicular distance measured from the machined surface to the uncut surface of the work piece. In a lathe the depth of cut expressed as follows

$$Doc = \frac{d_1 - d_2}{2}$$

Where d1=diameter of the work surface before machining d2=diameter of the work surface after machining

I.Surface roughness

Whatever may be the manufacturing process, an absolutely smooth and flat surface cannot be obtained. The machine elements or parts retain the surface irregularities left after manufacturing The surface of a part is exterior or boundary and the surface irregularities consists of numerous small wedges and valleys that deviate from a hypothetical nominal surface. These irregularities are responsible to a greater extent for the appearance of a surface and its suitability for an intended application of the component. These irregularities are usually understood in terms of surface roughness. Surface roughness plays a major role in many areas and is a factor of greater importance in the evaluation of machining.

J. Metal removal rate and machining time

In any machining operation in the view of production the machining time must be reduced in order to improve productivity. The metal removal rate majorly influences the machining time. In order to improve productivity the MRR must be maximized simultaneously satisfying other objective functions without any considerable effect on them.

IV.PROPOSED SYSTEM

A mathematical model is to generated for the above proposed responses. In this a linear multi variant regression model is generated for metal removal rate/machining time/surface roughness. The relation between cutting speed, feed and depth of cut was obtained for surface roughness as equations. The equation given the expected value of the surface roughness/metal removal rate /machining time for the above combinations factor level within the given in table 3 The correlation between the factors cutting speed, feed and depth of cut and measured surface roughness/metal removal rate/ machining time were obtained by multiple linear regression analysis. The mathematical model suggested was in the following form Y = nβ0+β1x1 + β2x2 +β3x3+ . . . . .+βnxn+€ Here y is the performance output terms and β are model constant. The constants were calculated using linear regression analysis with the help of design expert software and the following relations were obtained. The calculated co efficient from design expert software was substituted in equation. The correlation among the factors (i.e.) cutting speed, feed and depth of cut and performance measure are obtained by the multiple linear regression analysis.

TABLE I INPUT PARAMETER

Sl.No.	SPEED	FEED RATE	DOC
1	1000	0.03	0.5
2	1000	0.05	0.7
3	1000	0.07	1.0
4	1500	0.03	0.7
5	1500	0.05	1.0
6	1500	0.07	0.5
7	2000	0.03	1.0
8	2000	0.05	0.5
9	2000	0.07	0.7

V.RESULTS AND DISCUSSION

The project mainly concerned in developing a parameter optimization model for CNC turning machining using modified Taguchi's parameter design, the following are the major steps involved in this project Selection of important control factors of CNC machine to investigate their effect on performance measures like Material Removal Rate, surface Roughness. Selection of levels for control factors within the available range. Selection of tool work piece material and working conditions like experimental duration etc. Analysis of performance measures to plot the main effects of control factors. Determining the optimum parameter combination in order to satisfy the given criteria or to maximize or minimize the respective output parameter in response to the given input parameter. Predicting the values of performance measures using modified Taguchi method.

TABLE II KEY SPECIFICATIONS

Trial No.	Designation	Speed	Feed	DOC
1	$A_1B_1C_1$	1200	0.03	0.2
2	$A_1B_2C_2$	1200	0.05	0.4
3	$A_1B_3C_3$	1200	0.07	0.6
4	$A_2B_1C_2$	1700	0.03	0.4
5	$A_2B_2C_3$	1700	0.05	0.6
6	$A_2B_3C_1$	1700	0.07	0.2
7	$A_3B_1C_3$	2200	0.03	0.6
8	$A_3B_2C_1$	2200	0.05	0.2
9	$A_3B_3C_2$	2200	0.07	0.4

TABLE III AN ORTHOGONAL ARRAY L_9 FORMATION

Levels	Process parameters		
	speed	feed	DOC
1	1200	0.03	0.2
2	1700	0.05	0.4
3	2200	0.07	0.6

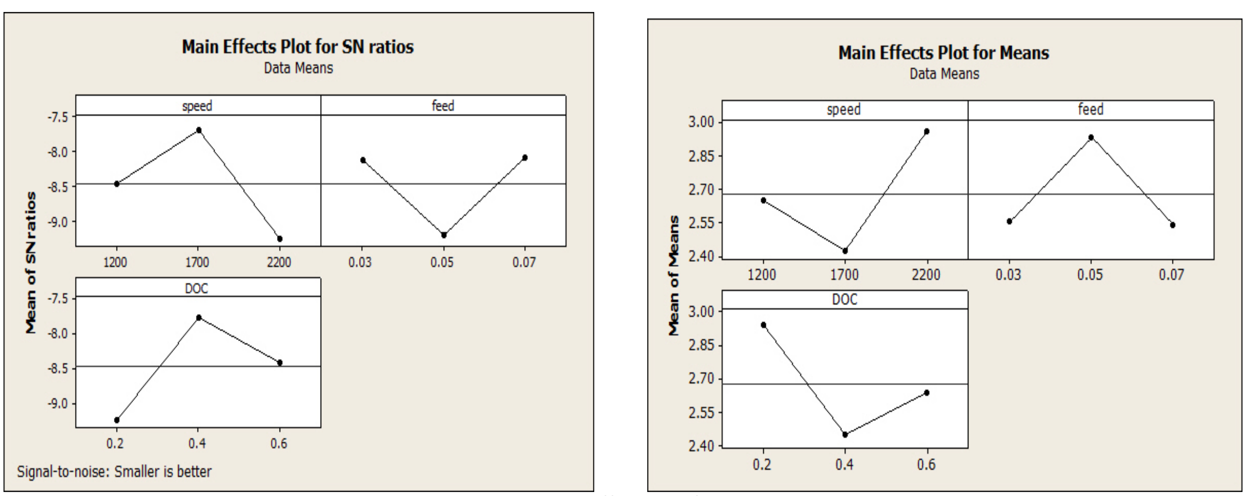

Fig.3 Main effects plot for means

VI.CONCLUSION AND RESULT

In this study, the Taugchi technique and ANOVA were used to obtain optimal Turning parameters in the Turning of GFRP under dry conditions. The experimental results were evaluated using ANOVA. The following conclusion can be drawn.

A. Optimal control factor

1. Surface Roughness-A1 (Speed -1200) B3 (Feed -0.07) C2 (DOC-0.4).

2. Machining Timing-A2 (Speed-1700) B1 (Feed 0.03) C3 (DOC0.6).
3. Material Removal Rate- A2 (Speed-1700) B1 (Feed 0.03) C3 (DOC0.6).

B. Percentage of contribution of Process parameter

1. Surface Roughness- speed 80%.
2. Machining Timing- Feed 66%.
3. Material Removal Rate- Feed64%.

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