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DEVELOPEMENT OF MATHEMATICAL MODEL FOR THE MILLING OF GFRP

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ABSTRACT

Glass Fibre Reinforced Plastics (GFRP) is now finding applications in different engineering markets. Its use has increased manifold over last few years. This has necessitated the need for accurate machining of composite. Milling is the most practical machining operation available for producing a accurate shape and high quality surface. But, milling composite materials posses a number of problems, such as delamination, surface roughness associated with cutting parameters and material characteristics. The aim of this paper is to study the influence of cutting parameters such as feed, speed and depth of cut on surface roughness of GFRP. And develop the mathematical model for milling of GFRP using Response surface method

Key word: Milling, GFRP, Response surface method.

1.INTRODUCTION

Traditionally, Fibre-reinforced plastics were and still are used for decorative and lightly loaded structures. A typical general application might be a metal space frame clad with Fibre-reinforced panels. Here the major loads are carried by the metal frame; the panels fill the interstices and provide a functional surface. Fibre-reinforced plastics are now regularly used in stress critical applications, as more and more designers are realizing the high specific strength and stiffness properties available from these materials. Unfortunately, this material substitution is not without drawbacks. In general the raw material costs are higher than for metals, but the processing costs are generally lower. Therefore the material processing package has to be taken into consideration when choosing these materials. Complex parts in metals often necessitate the use of multiple parts and processes including joining. Using Fibre-reinforced plastics, the shape potential is virtually limitless and part consolidation reduces assembly time and costs. The most pronounced advantage of Fibre-reinforced plastics over metals is the ability to be able to tailor the material to a given application leading to efficient material utilization. However, the material is simultaneously processed at the component manufacturing stage. It is therefore important that the component is designed for the process. This is a major source, of difficulty for designers new to these materials. A good working knowledge of the materials and processes is therefore essential to be an effective designer. In addition to the considerations normally made when designing with conventional engineering materials the designer using Fibre-reinforced plastics has to also consider the selection of constituents, i.e. proportions, types, distribution and orientation, depending on the properties required and the selection of processes.

2. REINFORCEMENT MATERIALS

There are a variety of reinforcing agents for Fibre-reinforced plastics; Such as Fibres, particles, flakes and whispers. Fibres, especially long and continuous forms, provide the stiffest and strongest materials and it is for this reason that they are also the most common method of reinforcing FRPs. The other reinforcement agents mentioned above are normally classified as 'fillers'. The introduction of Fibres into the matrix induces directionality or anisotropy in the material. The properties of the FRP are therefore highly dependent on the alignment of the Fibres.

The variables that have a major influence on the properties of FRPs are:

1. Alignment of the Fibre;
2. Distribution of the Fibre;
3. Fibre-matrix interface;
4. Size and shape of the Fibre; and
5. Loading direction.

3.LITRATURE SURVEY

Drilling is one of the major machining operations which are currently carried out on Fibre-reinforced composite materials. There are typical problems encountered when drilling Fibre-reinforced composites. These problems include the delamination of the composites, rapid tool wear, Fibre pullout, presence of powdery chip, and the delamination of the composites is generally the main concern. This is so because the occurrence of delamination wil1 reduces the strength against fatigue, result in a poor assembly tolerance, and affect the composite's structure integrity. Surface roughness is a parameter that has a greater influence on dimensional precision, performance of mechanical pieces and on production costs. For these reasons, research developments have been carried out with the purpose of optimizing the cutting conditions to reach a specific surface roughness for achieving the desired quality of the machined surface, it is necessary to understand the mechanisms of material removal, the kinetics of machining processes affecting the performance of the cutting tools. The works of a number of authors, when reporting on milling of FRP, have shown that the type and orientation of the Fibre, cutting parameters and tool geometry have an essential paper on the machinability.Today fibre-reinforced plastics (FRP) occupy an important place as high performance engineering materials. Although in most of the fabrication processes used for glass-fibre-reinforced plastics (GFRP) machining is avoided, sometimes the machining of an FRP product to achieve the required shape and dimensional tolerance cannot be avoided.Machining of FRP parts includes turning, drilling, milling, grinding and the like. Machining may also be desirable for making high precision components from standard shapes, prototype development and when the production volume is not large enough to justify the investment for moulds and molding equipment. Hence there has been an increased demand for machining of FRP in recent years.Surface roughness and specific cutting pressure are two important criteria used for evaluate the machinability of a composite material. Surface roughness is a widely used index of product quality and in most cases a technical requirement for mechanical products. Specific cutting pressure is a parameter giving an indication of the efficiency of the process. GFRP's contain two phases of materials that possess very different mechanical properties and the mechanism of material removal is different from that of machining single-phased materials, such as metals. GFRP's are extremely abrasive when machined. Thus the selection of the cutting tool and the cutting parameters is very important in the machining process. The use of composite materials has increased in various areas of science and technology due to their high specific strength, high specific stiffness, light weight, good corrosive resistance and directional properties. Glass fibre reinforced plastics (GFRP's) have been widely used in a variety of structures, such as aircraft, robots and machines. The applications require high quality machined surfaces, including dimensional accuracy and surface integrity, using appropriate tools and cutting parameters.Machining composite materials is a rather complex task owing to its heterogeneity, heat sensitivity, and to the fact that reinforcements are extremely abrasive. Conventional machining methods should be adapted in such a way that they diminish thermal and mechanical damage. Many authors, when reporting about the drilling of laminated composite materials by conventional tools, have shown that the quality of the cut surfaces is strongly dependent on the drilling parameters, tool geometry and tool material. An inappropriate choice of these parameters can lead to unacceptable material degradation, such as Fibre pull-out, matrix cratering, thermal damage and delamination. In the present work, a mathematical model has been developed to predict the surface roughness of machined GFRP work piece using response surface method. This model can be effectively used to predict the surface roughness of the machined GFRP components.

4. STAGES OF FABRICATION

1.First the plate is coated with silicon gel for the smooth surface .

2.After getting the polished surface the first layer is kept over the plate and the resin mixture is applied equally all over the layer till the layer is wetted fully.

3.firs apply the resin for first layer and then keep the glass fibre and then apply the final layer of resin

4.Then after completion the weight press plate is placed over it and the entire experimental setup is kept for curing time at room temperature.

5. After curing time the weight press plate is removed and the required laminate is obtained.

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5. STEPS INVOLVED IN FABRICATION:

Fig.No : 1. Glass Fiber Woven Roving (after cutting

Fig.No:2. Preparation of Mould surface with grease into specified dimensions) and PVC sheets

Fig.No:3. Fabrication – Applying resin for first layer

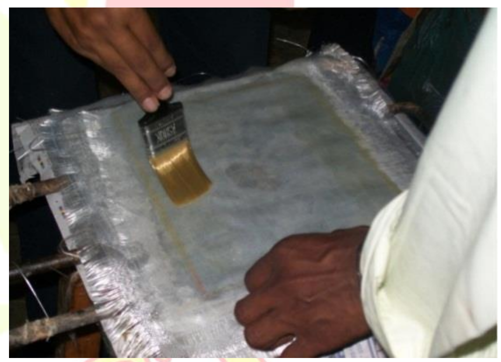

Fig.No:4. Fabrication – applying resin for final layer

Fig.No:5.Setting the composite after fabrication

Fig.No:6.GFRP composite Fabricated Specimen of Epoxy GFRP composite

6.RESPONSE SURFACE METHOD

A set of advanced Design Of Experiments (DOE) techniques that help you better understand and optimize your response. Response surface design methodology is often used to refine models after important factors have been determined using factorial designs.The difference between a response surface equation and the equation for a factorial design is the addition of the squared (or quadratic) terms that allow

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you to model curvature in the response, making them useful for:

- Understanding or mapping a region of a response surface. Response surface equations model how changes in input variables influence a response of interest.
- Finding the levels of input variables that optimize a response.
- Selecting the operating conditions to meet specifications.

For example, you would like to determine the best conditions for injection-molding a plastic part. You first used a factorial experiment to determine the significant factors (temperature, pressure, cooling rate). You can use a response surface designed experiment to find the optimal settings for each factor.

7.BOX-BEHNKEN DESIGN

A type of response surface design that does not contain an embedded factorial or fractional factorial design.Box-Behnken designs have treatment combinations that are at the midpoints of the edges of the experimental space and require at least three factors. The illustration below shows a three-factor Box-BehnkenDesign. Points on the diagram represent the experimental runs that are performed:

Fig.No:7.BOX-BEHNKEN DESIGN

These designs allow efficient estimation of the first- and second-order coefficients. Because Box-Behnken designs often have fewer design points, they can be less expensive to run than central composite designs with the same number of factors. However, because they do not have an embedded factorial design, they are not suited for sequential experiments. Box-Behnken designs can also prove useful if you know the safe operating zone for your process. Central composite designs usually have axial points outside the "cube." These points may not be in the region of interest, or may be impossible to run because they are beyond safe operating limits. Box-Behnken designs do not have axial points, thus, you can be sure that all design points fall within your safe operating zone. Box-Behnken designs also ensure that all factors are never set at their high levels simultaneously.

BOX-BEHNKEN DESIGN
Factors: 4 Replicates: 1 Base blocks: 1 Total blocks: 1
Center points: 3 Base runs: 27 Total runs: 2

MODUS OPERANDI

- The machining was performed as per Box-Behnken Design
- Factors chosen, The four factors are:
  1. Speed
  2. Feed
  3. Depth of cut
  4. Type of tool

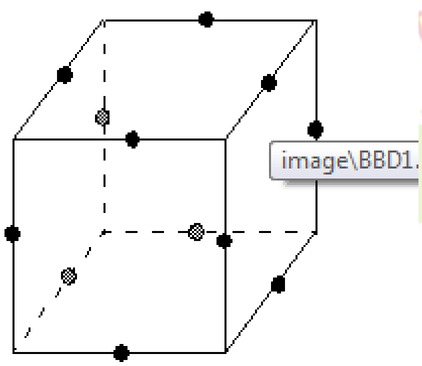

TABLE 1 - INTIAL BOX-BEHNKEN DESIGN

Stdorder	Runorder	Pttype	Blocks	Speed	Feed	Dept Of Cut	Tool
17	1	2	1	-1	0	-1	0
10	2	2	1	1	0	0	-1
27	3	0	1	0	0	0	0

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20	4	2	1	1	0	1	0
25	5	0	1	0	0	0	0
5	6	2	1	0	0	-1	-1
4	7	2	1	1	1	0	0
19	8	2	1	-1	0	1	0
11	9	2	1	-1	0	0	1
15	10	2	1	0	-1	1	0
6	11	2	1	0	0	1	-1
26	12	0	1	0	0	0	0
9	13	2	1	-1	0	0	-1
21	14	2	1	0	-1	0	-1
12	15	2	1	1	0	0	1
13	16	2	1	0	-1	-1	0
7	17	2	1	0	0	-1	1
24	18	2	1	0	1	0	1
14	19	2	1	0	1	-1	0
2	20	2	1	1	-1	0	0
16	21	2	1	0	1	1	0
8	22	2	1	0	0	1	1
1	23	2	1	-1	-1	0	0
3	24	2	1	-1	1	0	0
23	25	2	1	0	-1	0	1
18	26	2	1	1	0	-1	0
22	27	2	1	0	1	0	-1

SLOT SIZE - 40mm in length of diameter 10mm
TOOL USED:
For making slot on the plate the following tools are used

- Too-1: Solid Carbide
- Too-2: Titanium Namite
- Too-3: Titanium Aluminium Nitrate

TABLE 2 -FACTORS AND LEVELS IN BOX-BEHNKEN DESIGN

Levels	Speed(rpm)	Feed(mm/rev)	Depth of cut(mm)
-1	550	0.2	0.4
0	950	0.3	0.6
1	1350	0.4	0.8

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Corresponding values are tabulated in Minitab and according to each row of the Box-BehnkenDesgin, the experiment was conducted.

8.SURFACE ROUGHNESS MEASUREMENTS

Based upon the experiments conducted, the component was tested for its surface roughness using KosacaSurfcoder machine.

Surface Roughness affects several functional attributes of parts such as contact causing surface friction, wearing, light reflection, heat transmission, ability of distributing and holding a lubricant, coating or resisting fatigue. Therefore, the desired finish surface is usually specified and the appropriate processes are selected to reach the required quality. Several factors will influence the final surface roughness in a CNC milling operation.

The final surface roughness might be considered as the sum of two independent effects:

Fig. No :8. Surf coder machine

1. The ideal surface roughness is a result of the geometry of tool and feed rate and
2. The natural surface roughness is a result of the irregularities in the cutting operation.

factors such as spindle speed, feed rate and depth of cut that control the cutting tools operation can be setup in advance. However, factors such as too geometry, tool wear, chip loads and chip formations or the material properties of both tool and work piece are uncontrolled. Even in the occurrence of chatter or vibrations of the machine tool, defects in the structure of the work material, wear of tool or irregularities of chip formation contribute to the surface damage in practice during machining.

Based upon the measurements made in Surfcoder for measuring the surface roughness, the results are being tabulated.

950	0.4	0.4	4.46
1350	0.2	0.8	3.80
1350	0.3	0.4	3.15
1350	0.4	0.6	5.85

TABLE 3 - suface roughness value for plate

SPEED	FEED	DOC	Surface Roughness Value(µm)		
			Tool 1	Tool 2	Tool 3
550	0.2	0.4	3.88	2.71	2.54
550	0.3	0.6	4.90	3.17	2.36
550	0.4	0.8	5.79	4.09	1.68
950	0.2	0.6	5.46	3.72	3.11
950	0.3	0.8	4.17	4.10	2.21

9.RESULTS AND DISCUSSIONS

RESULTING EQUATIONS

RA=4.54462 - 3.89227*10^{-4} S - 0.758865 F + 1.64963 DOC - .731637 TOOL

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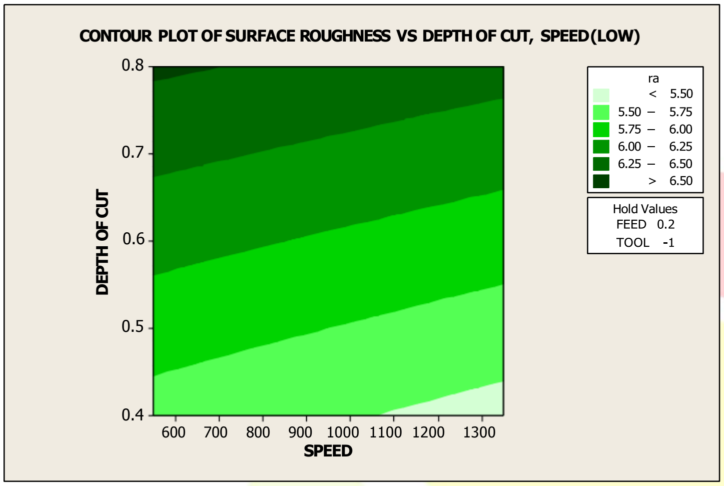

Fig.No:9. Contour plot of surface roughness vs depth of cut at various speed

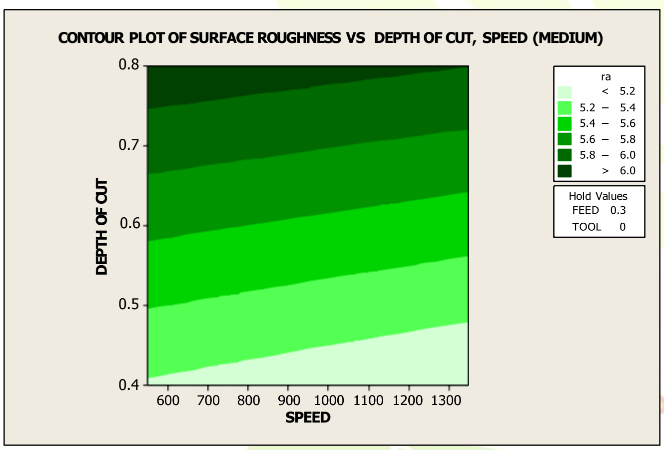

Fig.No.10. Contour plot of surface roughness vs depth of cut at various feed

9. Conclusion:

From the entire project it was revealed that the surface roughness value for the entire project may change depending upon the three parameters of speed, feed and depth of cut. From the response surface method, the mathematical formulae for surface roughness has been created and found by applying the value of speed, feed and depth of cut. At the value of speed 550 rpm, 0.4 mm/rev feed and the depth of cut as 0.8 mm lead to decrease the surface roughness.