ISLAMIC UNIVERSITY OF TECHNOLOGY
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EFFECTS OF MAGNETISM ON THE ROUGHNESS OF DRILLED HOLES OF A GLASS FIBER REINFORCED POLYMER COMPOSITE MATERIAL

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ABSTRACT

Have superior properties of the glass fiber reinforced polymer (GFRP) composite materials, the use of it is being accelerated recently. That is why the machining of these GFRP materials is a great concern for engineers. It became relevant for the researchers to analyze and introduce to improved machining. One of the most conventional way of machining is drilling process. Drilling is the mostly used in hole creating method in conventional machining. Hole creation in these composite materials is also mostly done by the drilling process. But the laminated structure of the composite material caused several types of damages and other surface irregularities during drilling process. About 60 percent of the rejections in the assembly plant are caused by the defects in the holes. The main contributor for defects in holes in the machining of the composite materials is surface roughness. These defects would create reduction in structural stiffness, which may lead to variation of dynamic performance of the whole structure. Hence, achieving the desired hole quality is of great importance for the functional behavior of the mechanical parts. In this present work, an observation is made on the effect of the permanent magnets of different magnitudes. Experiments are performed under different magnetic drilling conditions of spindle speed, feed rate and drill diameter on CNC drilling machine using three levels of factors with three different magnets of different magnitudes. A procedure has been adopted to assess and optimize the chosen factors by the use of Box-Behnken design to analyze the effects of different parameters. From the experimental results, it has been observed that the technique used is convenient to predict the main effects and their interaction effects of different influential combinations of machining parameters on surface roughness. It has been found that effect of permanent magnets on the guiding mechanism of the drill bit which lead to get improved surface roughness with better circularity

compared to normal drilling processes and with the increase of the magnitude of the magnets, the results became better. A mathematical model has been developed for the prediction of surface roughness using permanent magnets and normal drilling processes.

ACKNOWLEDGEMENT

First of all, we would like to thank our senior sub supervisor Md. Sulaiman from last year who was studying in the M. Sc. In Mechanical and Chemical Engineering in IUT who guided firstly us and introduced us with the project.

Next, we would like to thank Mr. Shakhawat Hossain sir to help us in CNC drilling operation. His relentless help was essential for us to get our work done by time. His expertise in CNC drilling was the mole which helped us our research go smoothly.

We would also like to thank Mr. Rajaul Karim sir who helped us measuring the roughness factor of the drilled surface by the roughness measuring tool.

Lastly and most importantly, we would like to thank our thesis supervisor Professor Dr. Anayet Ullah Patwari, who provided us with ample of literature for the study with his invaluable guidance and help without which this work might not be possible.

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CHAPTER 1 : INTRODUCTION

1.1. IMPORTANCE OF THE STUDY

Composite materials are increasingly used in various fields of science and engineering due to their unique properties such as durability, low maintenance, high stiffness, lightweight, good corrosive resistance, low thermal expansion etc. Although these composite materials like glass fiber reinforced polymer (GFRP) material parts are processed to a nearly net shape for using, for most of the cases machining is essential, like trimming, grinding, drilling, turning etc. For this reasons, conventional machining on GFRP composite has gained importance to meet the required dimensional accuracy and good surface quality.

Among these machining processes, drilling is frequently used in industries owing to the need for component assembly in mechanical structures. [1].

Taking into account the wide variety of work material, cutting tool material, cutting conditions and their combinations, it becomes very convenient that for different parameters and factors, the resultant surface quality varies significantly, for a complicated process like drilling.

Much of the literature reported on drilling if FRP material by conventional tools has shown that the quality of the cut surface is strongly dependent on the cutting parameters, tool geometry, tool material, work piece material, machining process etc. An improper selection of these parameters can lead to unacceptable material degradation, such as fiber pullout, matrix cratering, thermal damage and widespread delamination. [2]

In this paper, we wanted to know how we can optimize the surface roughness by changing various parameters and factors that has effect on the surface directly. And further we used magnets i.e. permanent magnets to achieve better results. This experimentation will help us to find some optimized values and parameters which will lead us to get an optimized value for drilling on GFRP composite materials.

GFRP materials has a very wide area of application, so that this experimentation can be used and taken into consideration before doing any machining i.e. drilling for getting a better surface quality.

1.2. OBJECTIVE

- To optimize surface generation mechanism on GFRP/
- To know how different factors influences surface quality on GFRP
- To find out the effect(s) of magnetic fields on drilling tool and the work piece(GFRP)
- To demonstrate a mathematical model for the prediction of surface roughness in GFRP

1.3. SCOPE AND LIMITATION

- This work can be applied for only drilling purposes.
- The result of the experiment is going to be an empirical evaluation of the factors and parameter we are considering.
- The data points are going to be limited as we are using Box-Behnken method.
- Variety of experimental data can be collected if electromagnets are used.

1.4. METHODOLOGY

- Identifying the important factors, which influence the surface quality on machining of GFRP composites
- The upper and lower limits of the factors identified
- Developing the experimental design matrix using design using design of experiments; Box-Behnken design
- Conducting the experiment as per design matrix
- Assessing the factors and its effects using response table and graph.

1.5. APPLICATION OF THE STUDY

- In structural design and engineering, it is observed that the use of GFRP is increasing day by day. So, improvement in machining will definitely boost up the production and use of this type of composite materials.
- This empirical implication can be further used for other composite materials too.

CHAPTER 2 : LITERATURE REVIEW

2.1. INTRODUCTION

In this paper, we tried to cover up every aspect of the research. Starting from the specifications of the components we used to the result and discussions, everything throughout the process was mentioned. To get a very good idea about our project, just going through this paper is enough.

2.2. GLASS FIBER REINFORCED POLYMAR

First developed in the mid 1930's, Glass Fiber Reinforced Plastic (GFRP) has become a staple in the building industry. Originally used merely for the construction of parts, in 1967, the architectural advantages were discovered with the attempted destruction of Disneyland's "House of the Future." Built in 1956-7, the futuristic house was built entirely of fiberglass, and when the attraction was no longer deemed necessary, it was scheduled to be destroyed in 1967. Amazingly, the wrecking ball merely bounced off the structure, and the possibilities for GFRP were recognized and began to grow. By 1994, nearly 600 million pounds of composite materials were used in the building industry. [3]

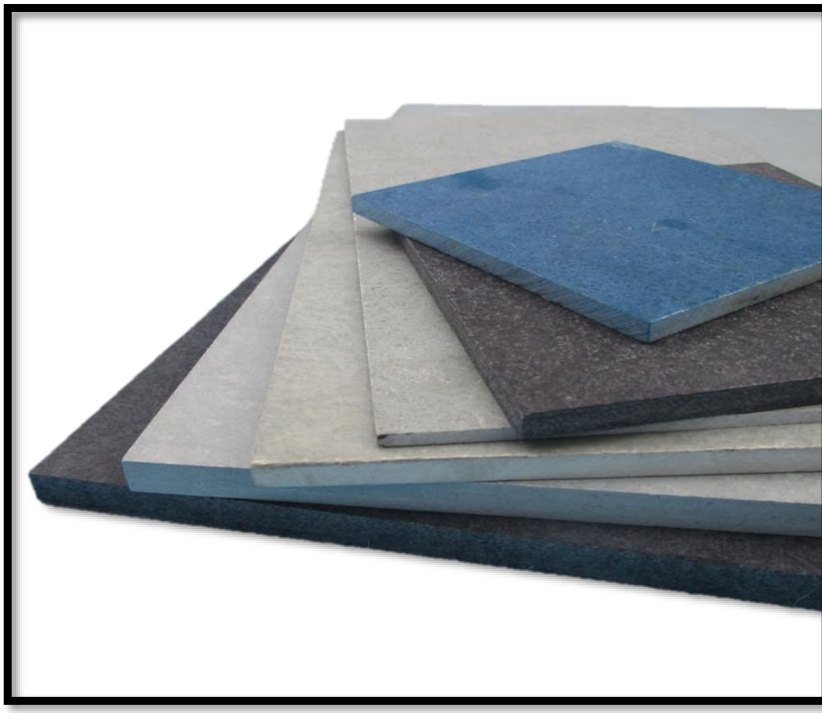


Fig 2-1: GFRP sheets

The GFRP we used has the following percentage of components:

Resin: 19%

MEKPO: 3.8%

Glass fibre: 77.2%

2.3. SIGNIFICANCE OF GFRP

Superior mechanical properties of GFRP:

- **High Strength to Weight ratio:** GFRP has a very high strength to weight ratio.
- **Lightweight:** Low weights of 2 to 4 1/2 lbs. per square foot mean faster installation, less structural framing, and lower shipping costs.
- **Resistant to Salt water, Chemicals and the Environment:** GFRP is unaffected by acid rain, salts, and most chemicals.
- **Seamless Construction:** Dome and cupola sections can be resined together to form a single watertight structure.
- **Can be molded into complex shapes:** Virtually any shape or texture can be produced.
- **Low maintenance:** Research shows no loss of laminate properties in GFRP after 30 years.
- **Durability:** Stromberg's GFRP elements stood up to hurricane Floyd, a category five storm, without sustaining any damage. Nearby structures were completely destroyed. [3]

2.4. APPLICATION OF GFRP

Wide range of application:

GFRP is used for both interior and exterior fixtures in a variety of shapes, styles, and textures; in new buildings or restorative projects.

- Domes
- Fountains
- Columns
- Balustrade
- Planters
- Panels
- Sculpture
- Entryways
- Moldings
- Facades
- Cornice
- Porticos
- Cupolas
- Signs
- Roofs

2.5. MACHINING PROCESSES

Machining is the broad term used to describe removal of material from a workpiece, it covers several processes, which we usually divide into the following categories:

- Cutting, generally involving single-point or multipoint cutting tools, each with a clearly defined geometry.
- Abrasive processes, such as grinding.
- Nontraditional machining processes, utilizing electrical, chemical, and optimal sources of energy.

It is important to view machining, as well as all manufacturing operations, as a system consisting of the workpiece, the tool and the machine. The introduction topic in this section covers primers on topics like mechanics & shear bending in machining, and heat in machining. The traditional machining includes primers on turning, milling, drilling, and grinding. It also includes computer applications which are being supported by the primers. The non-traditional machining includes primers on the topics like ECM, EDM, AFM, USM.

Table 2-1: Machining

Introduction to Machining • Mechanics of Machining • Heat in Machining	Micro-Machining • Micro Machining
Traditional Machining • Turning • Milling • Drilling • Grinding	Non-Traditional Machining • Water Jet Cutting • ECM • EDM • AFM • USM

[4]

2.6. DRILLING

Drilling is a cutting process that uses a drill bit to cut a hole of circular cross-section in solid materials. The drill bit is usually a rotary cutting tool, often multipoint. The bit is pressed against the workpiece and rotated at rates from hundreds to thousands of revolutions per minute.

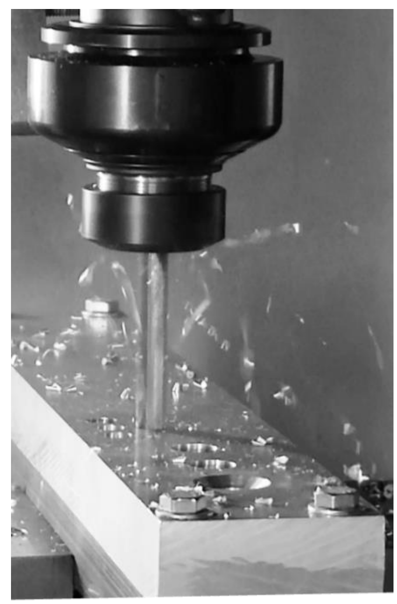


Fig 2-2: Drill operation

2.7. CNC DRILLING

Computer Numeric Control (CNC) is the automation of machine tools that are operated by precisely programmed commands encoded on a storage medium (computer command module, usually located on the device) as opposed to controlled manually by hand wheels or levers, or mechanically automated by cams alone. Most NC today is computer (or computerized) numerical control (CNC), in which computers play an integral part of the control.

CNC drilling machine is also one kind of CNC machine which is used for automated precise computer programs in order to get precise result. The model of the CNC machine we used in our experiment was WDM ZK2515. It can work on 380V voltage difference, drill speed is 1.5 m/min. It has a position accuracy of 0.035 mm and the speed of the spindle could be 0~940,0~1440,0~2880 rpm.

Fig 2-3: CNC

Specification of the CNC drill machine: (Table 2-2)

Name	**WDM ZK2515**
Voltage	**380V**
Drill speed	**1.5 m/min**
Speed of Spindle(r/min):	**0~940,0~1440,0~2880**
Positioning accuracy(mm):	**0.035**

2.8. MAGNET AND MAGNETISM

A magnet is a material or object that produces a magnetic field. This magnetic field is invisible but is responsible for the most notable property of a magnet: a force that pulls on other ferromagnetic materials, such as iron, and attracts or repels other magnets.

Magnetism is a class of physical phenomena that are mediated by magnetic fields. Electric currents and the magnetic moments of elementary particles give rise to a magnetic field, which acts on other currents and magnetic moments. The most familiar effects occur in ferromagnetic materials, which are strongly attracted by magnetic fields and can be magnetized to become permanent magnets, producing magnetic fields themselves. Only a few substances are ferromagnetic; the most common ones are iron, nickel and cobalt and their alloys. The prefix ferrorefers to iron, because permanent magnetism was first observed in lodestone, a form of natural iron ore called magnetite, Fe_3O_4.

Fig 2-4: Permanent magnets

A permanent magnet is an object made from a material that is magnetized and creates its own persistent magnetic field. An everyday example is a refrigerator magnet used to hold notes on a refrigerator door. Materials that can be magnetized, which are also the ones that are strongly attracted to a magnet, are called ferromagnetic (or ferrimagnetic). These include iron, nickel, cobalt, some alloys of rare earth metals, and some naturally occurring minerals such as lodestone. Although ferromagnetic (and ferrimagnetic) materials are the only ones attracted to a magnet strongly enough to be commonly considered magnetic, all other substances respond weakly to a magnetic field, by one of several other types of magnetism.

2.9. EFFECT OF MAGNETISM

Now as we know how magnet can affect ferromagnetic metals, we will try to use this property that is magnetism on the drill bit material while the drilling process is ongoing. The magnetic field will have an effect on the vibration of the drill bit.

The magnets we used had the following specifications: (Table 2-3)

Magnet size	Magnetic Field
No Magnet	**200 µT**
Small Magnet	**1700 µT**
Big Magnet	**2600 µT**

2.10. BOX-BEHNKEN DESIGN

A Box-Behnken design is a type of response surface design that does not contain an embedded factorial or fractional factorial design.

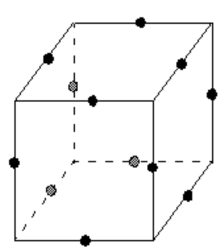
For example, you would like to determine the best conditions for injection-molding a plastic part. The factors you can set are:

- Temperature: 190° and 210°
- Pressure: 50Mpa and 100Mpa
- Injection speed: 10 mm/s and 50 mm/s

For a Box-Behnken design, the design points fall at combinations of the high and low factor levels and their midpoints:

- Temperature: 190°, 200°, and 210°
- Pressure: 50Mpa, 75Mpa, and 100Mpa
- Injection speed: 10 mm/s, 30 mm/s, and 50 mm/s

Box-Behnken designs have treatment combinations that are at the midpoints of the edges of the experimental space and require at least three continuous factors. The following figure shows a three-factor Box-Behnken design. Points on the diagram represent the experimental runs that are done:



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 do 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 conduct 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 not set at their high levels at the same time.

2.11. ANOVA

Analysis of variance (ANOVA) is a collection of statistical models used to analyze the differences among group means and their associated procedures (such as "variation" among and between groups), developed by statistician and evolutionary biologist Ronald Fisher. In the ANOVA setting, the observed variance in a particular variable is partitioned into components attributable to different sources of variation. In its simplest form, ANOVA provides a statistical test of whether or not the means of several groups are equal, and therefore generalizes the t-test to more than two groups. ANOVAs are useful for comparing (testing) three or more means (groups or variables) for statistical significance. It is conceptually similar to multiple two-sample t-tests, but is more conservative (results in less type I error) and is therefore suited to a wide range of practical problems.

CHAPTER 3 : PROJECT DESIGN AND MACHINING

3.1. INTRODUCTION

This experimentation needs a CNC drilling machine set up which was provided by the university laboratory facility. Magnets were bought to have it checked if the magnetic field actually works.

3.2. MACHINE SET UP

The following picture shows the actual Machine setup:

Fig 3-1: Machine setup

3.3. DRILLING WITHOUT MAGNET

The very first experiment was done without using any magnet. The experiment was done and 15 data points were collected. The drilled holes were looked like the following picture after drilling:

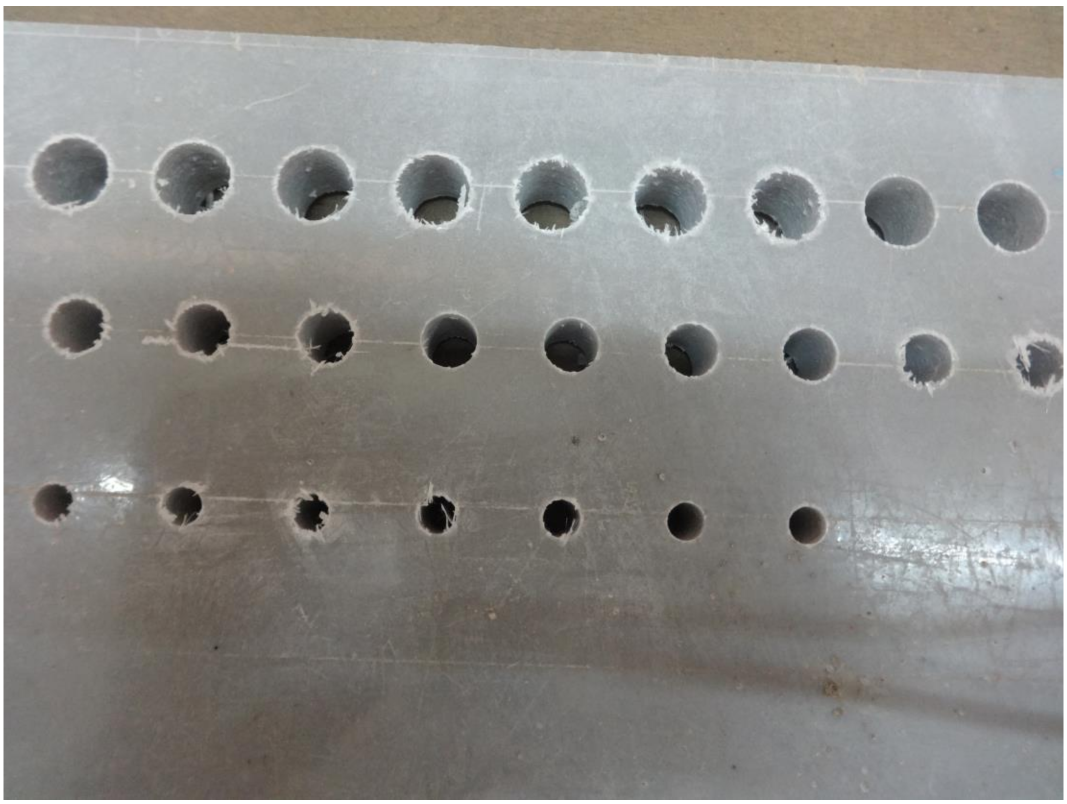


Fig 3-2: Drilled holes without using magnet

3.4. DRILLING WITH SMALL MAGNET

In this experiment, 15 drills were done and it didn't look very different from the drilled surface without using the magnet. The drilling experimental set up is shown in the below picture:

Fig 3-3: Drill using small magnet

3.5. DRILLING WITH LARGE MAGNET

The large magnet has a larger magnetic field and it really made difference in drilled surfaces. The experimental set up is shown below:

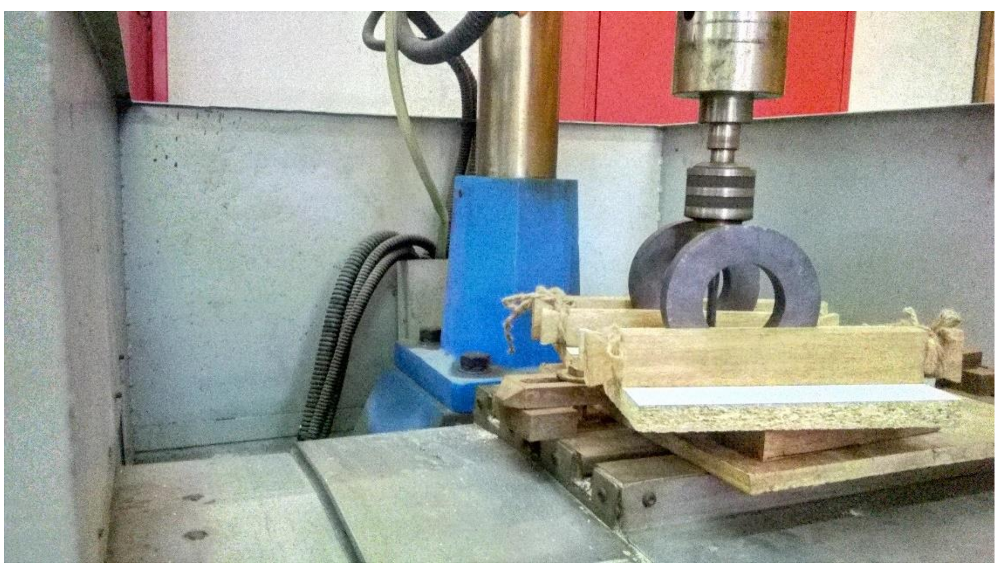


Fig 3-4: Drill using large magnet

CHAPTER 4 : DATA COLLECTION & ANALYSIS

4.1. INTRODUCTION

The values of roughness were calculated by the roughness measuring tool and for each data, two times the measuring tool were run. And finally, the average value was taken.

4.2. DATA TABLES

Box-Behnken design consisting of experiments for the study of three experimental factors (without magnets): (Table 4-1)

Run	Block	Factor 1: Drill Diameter, mm	Factor 2: Feed, mm/min	Factor 3: Speed, rpm	Responses for Surface roughness, micro-m (Without magnet)
1	Block 1	6.00	100	500	8.189
2	Block 1	6.00	300	500	8.728
3	Block 1	6.00	300	750	9.544
4	Block 1	6.00	500	750	11.622
5	Block 1	6.00	500	1000	10.724
6	Block 1	9.00	100	500	7.202
7	Block 1	9.00	300	500	6.31
8	Block 1	9.00	300	750	6.4
9	Block 1	9.00	500	750	7.902
10	Block 1	9.00	500	1000	7.43
11	Block 1	12.00	100	500	6.45
12	Block 1	12.00	300	500	6.976
13	Block 1	12.00	300	750	7.956
14	Block 1	12.00	500	750	5.982
15	Block 1	12.00	500	1000	7.746

Box-Behnken design consisting of experiments for the study of three experimental factors (with small magnets): (Table 4-2)

Run	Block	Factor 1: Drill Diameter, mm	Factor 2: Feed, mm/min	Factor 3: Speed, rpm	Responses for Surface roughness, micro-m (1 Pair magnet, Small)		
					Response 1	Response 2	Avg
1	Block1	6.00	100	500	4.777	5.291	5.034
2	Block1	6.00	300	500	5.741	5.438	5.6895
3	Block1	6.00	300	750	6.592	6.285	6.4385
4	Block1	6.00	500	750	6.874	6.649	6.7615
5	Block1	6.00	500	1000	5.444	5.755	5.5995
6	Block1	9.00	100	500	4.448	4.703	4.5755
7	Block1	9.00	300	500	5.902	4.721	5.3115
8	Block1	9.00	300	750	5.911	5.565	5.738
9	Block1	9.00	500	750	6.463	6.709	4.586
10	Block1	9.00	500	1000	5.625	6.403	6.014
11	Block1	12.00	100	500	5.560	5.743	5.6515
12	Block1	12.00	300	500	5.428	5.541	5.4845
13	Block1	12.00	300	750	7.418	8.159	7.7885
14	Block1	12.00	500	750	6.101	5.849	5.975
15	Block1	12.00	500	1000	8.045	8.299	8.172

Box-Behnken design consisting of experiments for the study of three experimental factors (with large magnet): (Table 4-3)

Run	Block	Factor 1: Drill Diameter, mm	Factor 2: Feed, mm/min	Factor 3: Speed, rpm	Responses for Surface roughness, micro-m (1 Pair magnet, Big)		
					Response 1	Response 2	Avg
1	Block1	6.00	100	500	2.864	2.993	2.9285
2	Block1	6.00	300	500	5.522	5.519	5.5205
3	Block1	6.00	300	750	5.025	5.240	5.1325
4	Block1	6.00	500	750	6.025	6.280	6.1525
5	Block1	6.00	500	1000	5.467	5.324	5.4455
6	Block1	9.00	100	500	4.418	4.245	4.3315
7	Block1	9.00	300	500	2.896	3.014	2.955
8	Block1	9.00	300	750	1.880	1.874	1.877
9	Block1	9.00	500	750	6.085	6.053	6.069
10	Block1	9.00	500	1000	4.033	4.771	4.402
11	Block1	12.00	100	500	4.060	4.422	4.241
12	Block1	12.00	300	500	4.183	4.212	4.1975
13	Block1	12.00	300	750	5.141	5.162	5.1515
14	Block1	12.00	500	750	7.088	7.389	7.2385
15	Block1	12.00	500	1000	6.871	6.303	6.587

4.3. GRAPH

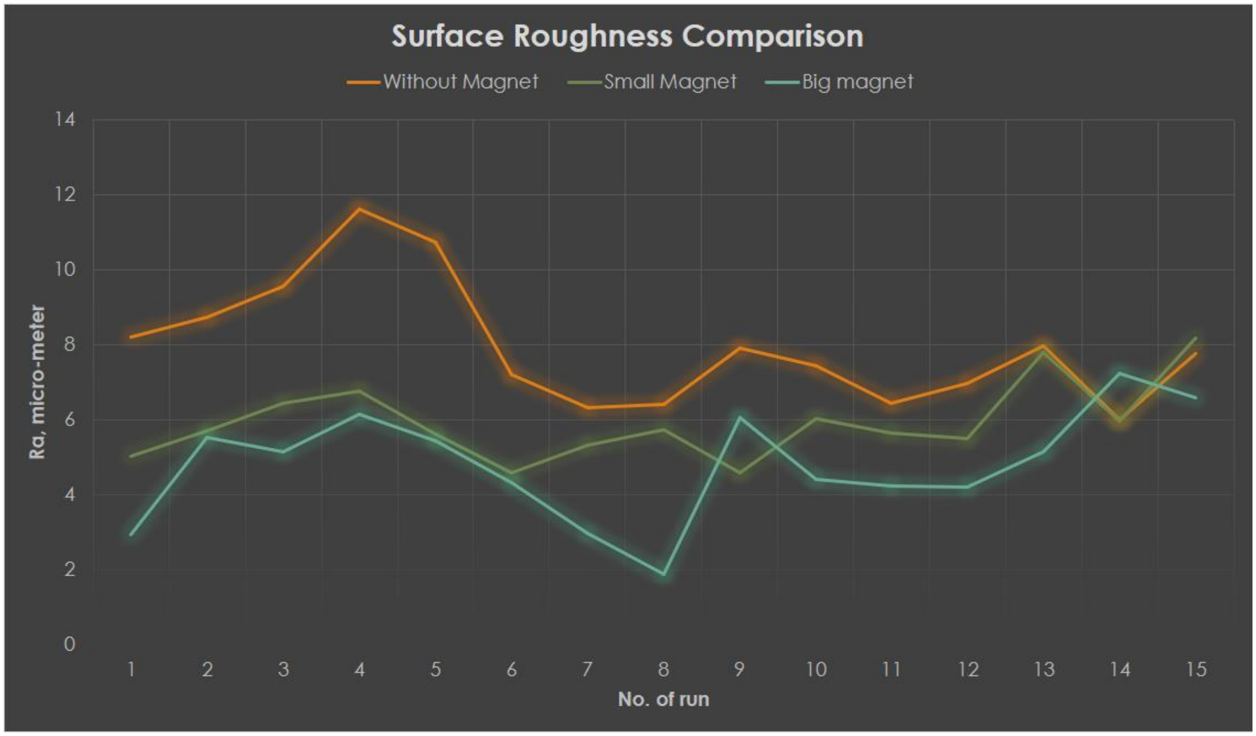


Fig 4-1: Graph

4.4. ANOVA

In analysis of variance, we have the formula:

Total sum of squares= Sum of squares between groups + Sum of squares within groups

By calculation we get the value;

TSS= 157.93

SSB= 75.52

SSW= 82.431

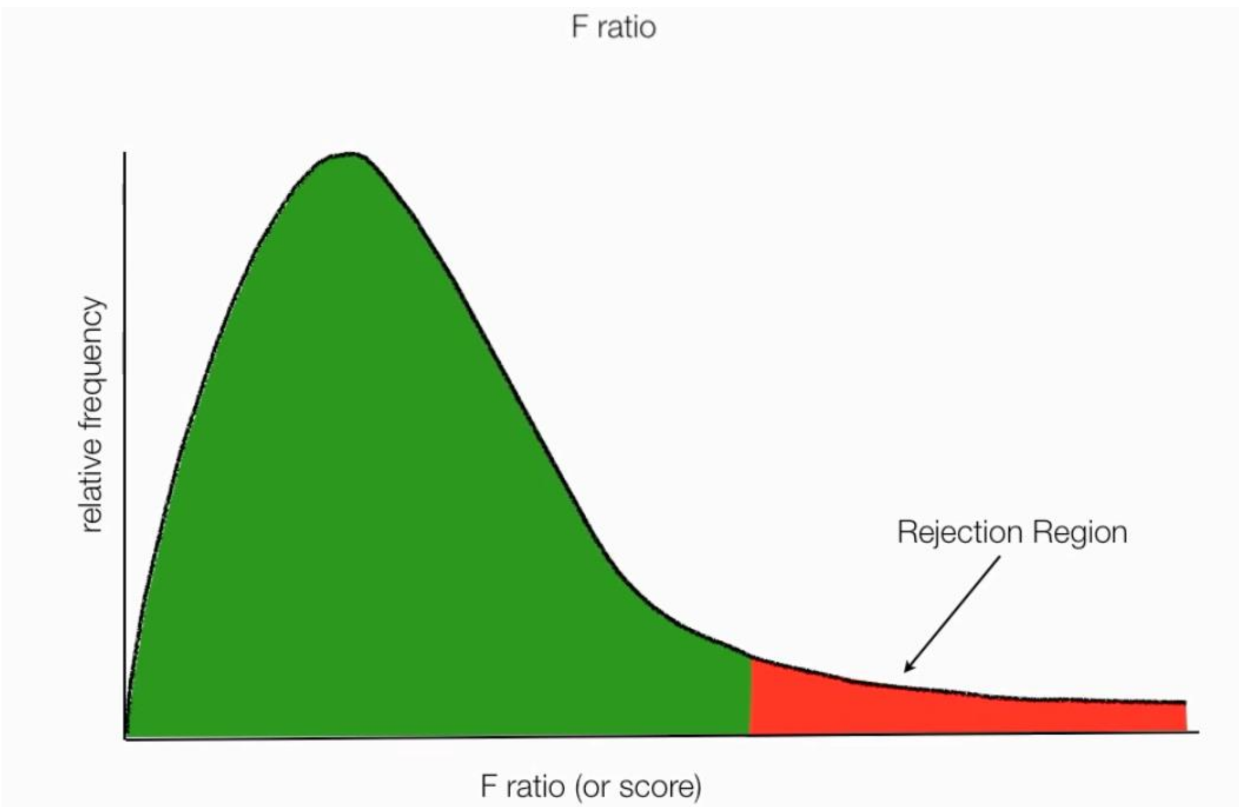
So, we find that the analysis of variance gives us the value of '**F**' for **F-test**:

F (2,42) = 19.243

The formula for 'F' value is,

$$F= \frac{\frac{SSB}{Degree\ of\ freedom\ between\ groups}}{\frac{SSW}{Degree\ of\ freedom\ within\ groups}} = \frac{\frac{75.52}{2}}{\frac{82.431}{42}} = 19.243$$

The critical value for F (2,42) = 4.1185



4.1185 19.243

Fig 4-2: F-test

CHAPTER 5 : DISCUSSION, RECOMMENDATION & CONCLUSION

5.1. INTRODUCTION

From the graph, tables and analysis of variance analysis showed us that using magnets definitely increases the quality of surface roughness of the glass fiber reinforced polymer.

5.2. RESULT AND DISCUSSION

- 15 experiments were performed based on BBD
- Roughness Factor (Ra) was measured using SJ 210
- Using magnets definitely increases the quality of the surface of the GFRP for lower diameter drill bits and lower feed and speed values. For higher values, it does not affect so much.
- The confidence level of the model was obtained using ANOVA.

5.3. APPLICATION OF THE RESEARCH

- In structural design and engineering.
- Production of GFRP based materials.
- Less machining for improving surface roughness.

5.4. RECOMMENDATION FOR FURTHER RESEARCH

- Experiments with Different Drill Bit Material
- Keeping Some Parameters Constant
- Use of Electromagnet with varying current and voltage
- Use of New Machining Technique in Drilling GFRP

5.5. CONCLUSION

This experiment showed us how the magnetic field created from the permanent magnet made the surface roughness of the drilled holes of the glass fiber reinforced polymer reduced and improved the quality of the surface.

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