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Drilling Time Optimization of Composite made by matrix material Epoxy Resin and Filler material Marble Dust and Nano particle TiO_2

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A B S T R A C T

In this research study, the aim was to explore the possibility of creating composite materials by combining marble dust with polymers such as epoxy resin, and reinforcing it with glass fiber. The researchers employed the Taguchi technique to conduct 16 experiments, and selected cutting time (drilling parameter) as the two response parameters to evaluate. They utilized a signal-to-noise ratio test and an ANOVA technique to analyze the results, and also carried out single and multi response optimization. The findings of the signal-to-noise ratio test indicated that glass fiber had the most significant impact on maximizing strength parameters, followed by marble dust. For drilling, epoxy and marble dust were found to play significant roles in the drilling operation of these composite materials. Overall, the researchers' goal was to investigate the potential of using these materials to create composite materials that are strong and capable of withstanding various types of stress.

Keywords: Composite materials, Epoxy Resin, nano particle, Marble Dust particle

1. Main text

1.Introduction

The creation of composite materials involves the combination of two or more materials with distinct physical and chemical properties in order to achieve a material with improved characteristics. One way to make a composite material is by using epoxy resin and marble dust. Epoxy resin is a type of polymer that is known for its excellent adhesion, chemical resistance, and durability. It is often used in the manufacturing of composite materials because it is able to bond well with other materials and provide strength and stiffness to the final product.

Marble dust, on the other hand, is a fine powder made from grinding down marble stones. It is rich in calcium carbonate and has a very high surface area, making it an effective filler material. When combined with epoxy resin, marble dust can improve the strength and toughness of the composite material.

To make a composite using epoxy resin and marble dust, the two materials are first mixed together in a specific ratio depending on the desired properties of the final product. The mixture is then placed into a mold and left to cure, usually at a high temperature. The curing process involves the epoxy resin undergoing a chemical reaction that results in it hardening and bonding with the marble dust.

Once the composite has fully cured, it can be removed from the mold and shaped or machined as needed. The resulting material will have improved strength and durability compared to the individual components, making it suitable for a wide range of applications.

Epoxy resin composites offer numerous benefits compared to traditional materials. These benefits include low weight, high strength, and good resistance to fatigue and impact. Additionally, epoxy resin composites have good dimensional stability and low shrinkage, making them suitable for use in applications that require precise tolerances. They also have good corrosion resistance and good electrical and thermal insulation properties. Moreover, epoxy resin composites can be made resistant to UV light and can be made fire resistant through the use of additives. However, there are also some limitations to consider. Epoxy resin composites may be brittle and have low tensile strength, making them less suitable for certain applications. They are also generally more expensive than other materials, such as metals, and can be challenging to work with due to their sensitivity to moisture and temperature.

The goal of the current research paper is to develop a composite material using epoxy resin and marble dust with the inclusion of nano-particle TiO2 and reinforcement with glass fiber material. The Taguchi method was chosen for conducting the study via the DOE (Design of Experiments) method.

2. Literature Review

Numerous research studies have been conducted on the use of various fibers and fillers as reinforcement in polymer composites. In one such study (Ravitej et al, 2021), banana and e-glass fibers were used as reinforcement in a hand lay-up process to create composite materials with various volume fractions of fibers. The materials were then tested for their tensile, bending, and hardness properties using a 100 kilonewton universal testing machine (UTM). The results of this study showed that the inclusion of fiber reinforcement improved the mechanical properties of the composite materials, with the highest improvements observed in the materials with the highest volume fractions of fibers.

Another study (Abdel et al, 2005) looked at the properties of an E-glass/epoxy composite before and after subjecting it to mechanical stress and moisture conditioning. The results of this study showed that both of these variables had an influence on the modulus, strength, and strain of the material, with longer durations of conditioning leading to a decrease in strength and strain-to-failure. This highlights the importance of controlling the exposure of composite materials to mechanical stress and moisture in order to maintain their optimal performance.

A more recent study (Rajawat et al, 2022) examined the use of basalt fiber and waste marble powder as reinforcement in epoxy resin. The results of this study showed that the composite material had improved tensile, flexural, and impact energy properties, as well as increased Vickers hardness, when reinforced with up to 7.5% weight of waste marble powder. However, the inclusion of waste marble powder also resulted in an increase in specific wear rate. This suggests that there may be a trade-off between the improved mechanical properties and increased wear resistance of the composite material when using waste marble powder as reinforcement.

In another study (Aditya et al, 2022), the use of marble dust and wheat straw fibers as reinforcement in epoxy composites was explored. The results of this study showed that the composite materials had improved tensile and flexural properties, as well as increased hardness, when reinforced with up to 4% weight of wheat straw fibers. This demonstrates the potential of using natural fibers as reinforcement in composite materials, which may have advantages over traditional synthetic fibers in terms of cost and environmental impact.

Finally, in a study by Kumar et al (2020), the use of recycled plastic bottles as reinforcement in concrete was investigated. The results of this study showed that the use of recycled plastic bottles as reinforcement improved the flexural and compressive strength of the concrete, as well as its toughness and impact resistance. This highlights the potential for using recycled materials as reinforcement in construction materials, which could have benefits in terms of cost and sustainability.

Overall, these studies demonstrate the potential for using different fibers and fillers as reinforcement in composite materials to improve their mechanical properties and other characteristics. However, it is important to consider the trade-offs and limitations of different reinforcement materials, as well as their potential impact on the processing and performance of the composite materials.

3. 3.Material and Methods

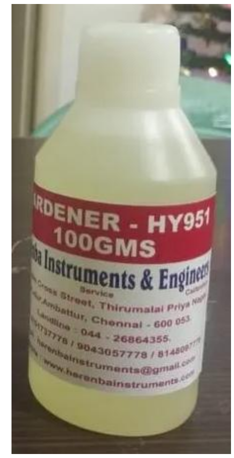
In recent years, there has been a growing interest in the use of waste resources, such as plastic, wood, metals, sand, and marble dust, to create a variety of composite materials with a range of industrial applications. These applications include the use of composite materials as base sheets, in general household products, in agricultural applications, and in the manufacturing of secondary goods.

This research paper focuses on the process of fabricating composite materials using micro particles made from marble dust, with the aim of developing an industrial application for marble slurry. This research has the potential to bring significant innovation to the field of composite materials, as there is limited literature available on this new type of material. The research work also explores various testing options for composite materials, including the use of epoxy resin purchased from India-mart online. All of the materials required to make the composite are shown in Figure 1.

The use of waste resources in the creation of composite materials not only has the potential to reduce the amount of waste generated, but it can also lead to cost savings and improved sustainability in the manufacturing process. The development of new applications for these materials has the potential to drive innovation and create new opportunities in a variety of industries.

Epoxy Resin (LY-556)

Hardener (HY-951)



E-Glass Fiber Sheet

Marble Dust/Nano Particle

Fig.1. In-gradients of Composite made for present investigation

4. 4.Fabrication Steps

The process of fabricating a composite material using marble dust, epoxy resin, and E-glass fiber as the primary components involves the following steps:

- Preparing the mold: The first step in the manufacturing process is to prepare the mold by maintaining a clean and dry environment. This helps ensure that the composite material will have a smooth, even surface when it is removed from the mold.
- Applying a releasing agent: To prevent the composite material from sticking to the mold, a releasing agent is applied to the surface of the mold and left to dry for 30 minutes.
- Pouring the initial layer of resin: The initial layer of epoxy resin is poured into the mold and spread evenly using a brush. This helps to create a uniform base for the composite material.
- Dispensing the fiber and filler: The E-glass fiber and marble dust are then dispersed evenly over the mold. This helps to reinforce the composite material and improve its mechanical properties.
- Applying a final layer of resin: A fresh layer of epoxy resin is applied using a roller to create a uniform layer and remove any excess resin. This helps to ensure that the composite material is fully saturated with resin and that the final product has a smooth surface.
- Curing the composite material: Once the mold is sealed, the composite material is compacted uniformly for 24 hours to allow it to cure. The curing process involves the epoxy resin undergoing a chemical reaction that results in it hardening and bonding with the fiber and filler.
- Removing the composite material from the mold: Once the curing process is complete, the composite material is removed from the mold. It can

then be shaped or machined as needed for its intended application.

Fig.2. Sample of the Composite fabricate with Epoxy Resin

The final sample Products made by epoxy resin and filler materials with fibre materials are shown in figure 2.

5. 5.Taguchi Method

The Taguchi method is a statistical methodology that is used to optimize the performance of a product or process by identifying the most important factors that affect its quality or efficiency. It was developed by Genichi Taguchi, a Japanese engineer, in the 1950s and has since been widely used in various fields, including engineering, manufacturing, and research.

The Taguchi method involves conducting experiments using a designed array of combinations of different factors or variables, called "factor levels." These factor levels are chosen based on the characteristics of the product or process being studied, and may include things such as material properties, temperature, humidity, and other variables. The results of the experiments are then analyzed using statistical techniques, such as analysis of variance (ANOVA), to identify which factor levels had the greatest impact on the performance of the product or process.

One key advantage of the Taguchi method is that it allows researchers to identify the optimal factor levels for a given product or process using a relatively small number of experiments, which can save time and resources compared to traditional experimentation methods. It is also useful for identifying the relationships between different factors and their impact on the performance of a product or process, which can help researchers identify the most important factors to focus on in order to improve the performance of the product or process.

The Factor and Levels selected for the present study was present in table 1 and the orthogonal array developed for the present study was present in table 2.

TABLE 1

FACTOR AND LEVEL SELECTION

	Factor	**1**	**2**	**3**	**4**
A	**E-Glass Fiber (% by Weight)**	5	10	15	20
B	**Marble Dust (% by Weight)**	7	14	21	28
C	**Nano Particle (TiO^2) (% by Weight)**	1	2	3	4

TABLE 2

WEIGHT PERCENTAGE OF EPOXY COMPOSITE COMPONENTS

RunOrder	A	B	C	Epoxy Weight (%)
1	5	7	1	87
2	5	14	2	79
3	5	21	3	71
4	5	28	4	63
5	10	7	2	81
6	10	14	1	75
7	10	21	4	65
8	10	28	3	59
9	15	7	3	75
10	15	14	4	67
11	15	21	1	63
12	15	28	2	55
13	20	7	4	69
14	20	14	3	63
15	20	21	2	57
16	20	28	1	51

6. 6.Result and Discussion

The Taguchi Orthogonal Array developed for the present study for the response parameter of drilling time is presented in Table 3, along with all of the experiments. The drilling time was measured using a digital stopwatch machine, which provided precise and accurate measurements of the time required for each experiment. The Taguchi Orthogonal Array is a statistical methodology that is used to optimize the performance of a product or process by identifying the most important factors that affect its quality or efficiency. By conducting experiments using a designed array of combinations of different factors or variables, called "factor levels," researchers can identify the optimal factor levels for a given product or process using a relatively small number of experiments. In this study, the researchers used the Taguchi Orthogonal Array to identify the optimal combination of factor levels for the drilling time response parameter, which is an important factor in the performance of the composite materials being studied. The results of the experiments are analyzed using statistical techniques, such as analysis of variance (ANOVA), to identify the factor levels that had the greatest impact on the drilling time of the composite materials.

TABLE 3

RESPONSE DATA FROM DOE EXPERIMENTS (L16)

A (%)	B (%)	C (%)	Epoxy Weight (%)	Drilling Time
5	7	1	87	33.9
5	14	2	79	37.5
5	21	3	71	40.1
5	28	4	63	42.9
10	7	2	81	37.8

A (%)	B (%)	C (%)	Epoxy Weight (%)	Drilling Time
10	14	1	75	41.1
10	21	4	65	36.1
10	28	3	59	37.4
15	7	3	75	38.6
15	14	4	67	35.9
15	21	1	63	37.7
15	28	2	55	33.1
20	7	4	69	36.7
20	14	3	63	32.5
20	21	2	57	35.3
20	28	1	51	34.6

The formula required for the signal to noise ratio analysis was present in table 4.

TABLE 4

SIGNAL TO NOISE RATIO FORMULATION FOR RESPONSES

Response Parameter	S/N ratio Option	Formula
Tensile Strength	Larger is better	$S/N = -10\log\frac{1}{n}\left(\sum y^2\right)$
Drilling Time	Smaller is better	$S/N = -10\log\frac{1}{n}\left(\sum \frac{1}{y^2}\right)$

7. 7.S/N Ratio-Tensile Strength (TS)

In the production of composite materials, epoxy resin, marble dust (micro particles), and TiO2 (nano particles) are combined with glass fiber material for reinforcement. The composite materials are then subjected to drilling operations in preparation for further testing of their machinability. In the current investigation, the parameters of the drilling process are kept constant for each test piece in order to accurately compare the results.

The study provides a detailed breakdown of the signal-to-noise ratio for the drilling response time, which is an important factor in determining the performance of the composite materials. The "smaller is better" option is used throughout the investigation in regards to drilling time in order to conduct the S/N ratio analysis. In Table 6, the delta is calculated for the response parameter "Drilling Time" and shows the rank among all factors. This information is useful in identifying the factors that have the greatest impact on the drilling time of the composite materials, and in optimizing the production process to improve the performance of the materials.

TABLE 5

RANK IDENTIFICATION FOR RESPONSE DT (DRILLING TIME)

Level	**A**	**B**	**C**
1	-31.7	-31.3	-31.29
2	-31.61	-31.27	-31.1
3	-31.19	-31.43	-31.38
4	-30.82	-31.31	-31.55
Delta	**0.88**	**0.15**	**0.45**
Rank	**1**	**3**	**2**

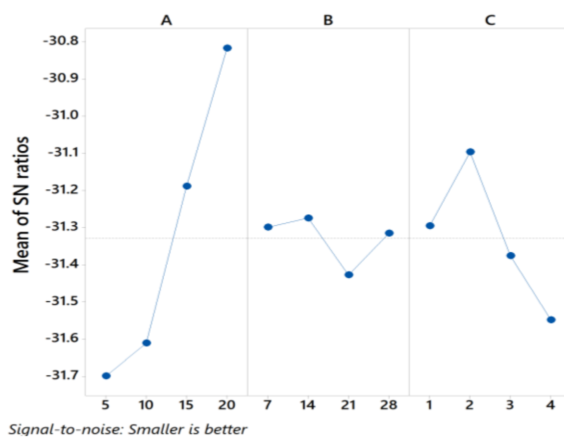


Fig.3. S/N Ratio (Larger is Better) calculations for TS Response

As can be seen in table 6, the component known as "E-Glass Fiber" holds the position with the greatest rank, while "Nano Particle TiO2" is the factor that holds the position with the second highest rank, and "Marble Dust" holds the position with the lowest rank. It has been made abundantly clear that the factor with the highest ranking is the single most important factor in elevating the tensile strength of the composite material. On the other hand, elevating the proportion of the factor with the highest ranking is going to result in an increase in the degree to which the composite material is brittle. This is because elevating the proportion of the factor with the highest ranking is the single most important factor in elevating the tensile strength of the composite material. The aspect that is considered to be of the least importance does not make a major contribution to the accomplishment of the overarching goal, which is to enhance the tensile strength of the composite material.

8. 8.Conclusion

E-Glass Fiber holds the position with the highest rank for the drilling time (DT), "Nano Particle TiO2" holds the position with the second-highest rank, and "Marble Dust" holds the position with the lowest rank. It has been made clearly evident that the highest-ranked element is the single most essential factor in increasing the composite material's tensile strength. In contrast, increasing the proportion of the element with the highest ranking will result in an increase in the brittle nature of the composite material. This is due to the fact that increasing the proportion of the highest-ranked element is the single most critical factor in increasing the strength of the composite material. The least significant factor does not significantly contribute to the achievement of the overarching objective, which is to increase the tensile strength of the composite material.

References

Van der Geer, J., Hanraads, J. A. J., & Lupton, R. A. (2000). The art of writing a scientific article.*Journal of Science Communication, 163*, 51–59.

Strunk, W., Jr., & White, E. B. (1979).*The elements of style* (3rd ed.). New York: MacMillan.

Mettam, G. R., & Adams, L. B. (1999).How to prepare an electronic version of your article. In B. S. Jones & R. Z. Smith (Eds.), *Introduction to the electronic age* (pp. 281–304). New York: E-Publishing Inc.

Fachinger, J., den Exter, M., Grambow, B., Holgerson, S., Landesmann, C., Titov, M., et al. (2004).Behavior of spent HTR fuel elements in aquatic phases of repository host rock formations, 2nd International Topical Meeting on High Temperature Reactor Technology. Beijing, China, paper #B08.

Fachinger, J. (2006). Behavior of HTR fuel elements in aquatic phases of repository host rock formations.*Nuclear Engineering & Design,236*, 54.