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Mechanical Strength Analysis of Composite made by Epoxy Resin as Matrix Material and Marble Dust as Filler material: Taguchi based Study

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A B S T R A C T

This research paper describes a study in which researchers attempted to create composite materials by combining marble dust with polymers like epoxy resin, and reinforcing it with glass fiber. The researchers used the Taguchi technique to conduct 16 different trials, and selected strength parameters (Tensile Strength and hardness) as the two response parameters to evaluate. They used a signal-to-noise ratio test and an ANOVA technique to analyze the results, and also performed single and multi response optimization. The results of the signal-to-noise ratio test showed that glass fiber had the most significant effect on achieving maximum strength parameters, followed by marble dust. For the tensile strength, epoxy and marble dust were found to play significant roles in the drilling operation of these types of composite materials.

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

1. Introduction

Composite materials are materials made up of two or more distinct materials that are combined to form a new material with improved properties. Epoxy resins are a type of polymer that can be used to make composite materials.Epoxy resins are known for their excellent adhesion, durability, and chemical resistance, making them well-suited for use in a variety of applications. They are often used as adhesives, coatings, and matrix materials in composite materials.When used in composite materials, epoxy resins are combined with reinforcement materials such as fibers, particles, or flakes to improve the strength and stiffness of the material. The most common reinforcement materials used with epoxy resins include glass fibers, carbon fibers, and Kevlar fibers.

The properties of epoxy resin composites depend on the type and amount of reinforcement material used, as well as the processing conditions and the cure temperature. Epoxy resin composites can be fabricated using a variety of techniques, including hand layup, filament winding, pultrusion, and injection molding.

Epoxy resin composites have a number of advantages over traditional materials. They are lightweight, strong, and have good fatigue and impact resistance. They also have good dimensional stability and low shrinkage, making them well-suited for use in applications where precise tolerances are required.In addition to their mechanical properties, epoxy resin composites also have good corrosion resistance and good electrical and thermal insulation properties. They are also resistant to UV light and can be made fire resistant through the use of additives.Despite their many advantages, epoxy resin composites also have some limitations. They can be brittle and have low tensile strength, making them less suitable for certain applications. They are also more expensive than some other materials, such as metals, and can be challenging to work with due to their sensitivity to moisture and temperature.Overall, epoxy resin composites are a versatile and useful material with many potential applications in a variety of industries. They can be tailored to meet specific requirements by adjusting the type and amount of reinforcement material used, and the processing conditions.

The aim of present research paper is to develop a composite material using epoxy resin and marble dust with nano particle TiO_2 and reinforcement with glass-fiber material. DOE method taguchi method was selected for conducting the study.

2. Literature Review

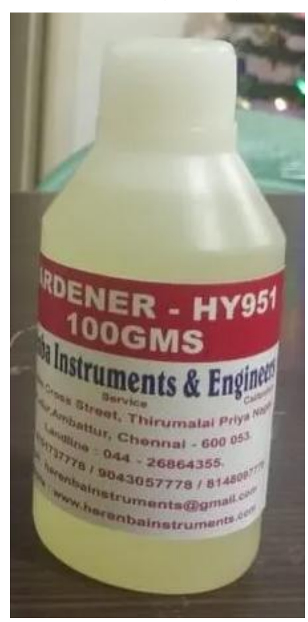
Several studies have been conducted on the use of different fibers and fillers as reinforcement in polymer composites. In one study (Ravitej et al, 2021), banana and e-glass fibers were used as reinforcement in a hand lay-up process to create composite materials with different volume fractions of fibers. The materials were tested for their tensile, bending, and hardness properties using a 100 kilonewton universal testing machine (UTM). Another study (Abdel et al, 2005) looked at the properties of an E-glass/epoxy composite before and after being subjected to mechanical stress and moisture conditioning. The results showed that both 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. In a more recent study (Rajawat et al, 2022), the use of basalt fiber and waste marble powder as reinforcement in epoxy resin was examined. The composite was found to have 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 led to an increase in specific wear rate. Another study (Aditya et al, 2022) explored the use of marble dust and wheat straw fibers as reinforcement in epoxy composites. The composite materials were found to have improved tensile and flexural properties, as well as increased hardness, when reinforced with up to 4% weight of wheat straw fibers. Finally, in a study by (Kumar et al, 2020), the use of recycled plastic bottles as reinforcement in concrete was investigated. The results 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.

3. Material and Methods

In the modern era, a variety of composite materials are made using waste resources such as plastic, wood, metals, sand, and marble dust. These composite materials can have various industrial uses, including base sheets, general household applications, agricultural applications, and the manufacture of secondary goods. This research paper discusses the process of fabricating composite materials using micro particles made from marble dust, with the aim of creating an industrial application for marble slurry. The research has the potential to bring significant innovation to the manufacturing of composite materials, as there is limited literature available on this new material. The research work also covers the various testing options for composite materials, including the use of epoxy resin purchased from India-mart online. All materials required to make the composite was shown in figure 1.

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. Fabrication Steps

The production process for creating a composite material involves using marble dust as a filler, epoxy resin as the matrix, and E-glass fiber as the reinforcing material. These components are mixed together at an appropriate concentration. The steps of the manufacturing process are as follows:

The mold is prepared by maintaining a clean and dry environment.
A releasing agent is applied to the mold and left to dry for 30 minutes.
The initial layer of polyester resin is poured into the mold and spread evenly using a brush.
The fiber and filler are dispersed evenly over the mold.
A fresh layer of polyester resin is applied using a roller to create a uniform layer and remove any excess resin.
The mold is sealed and the composite material is compacted uniformly for 24 hours to allow it to cure.
Once the curing process is complete, the composite laminate is removed from the mold.

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. Taguchi Method

The Taguchi method, also known as the Taguchi design of experiments, is a statistical method for designing and optimizing manufacturing processes and product design. It was developed by Dr. Genichi Taguchi, a Japanese engineer and statistician, in the 1950s. The main goal of the Taguchi method is to improve the quality and reliability of products and processes by reducing variability and minimizing the negative impact of noise factors (external factors that affect the process but are not controlled by the process itself). This is achieved through the use of statistical design of experiments and analysis of variance (ANOVA) to identify the optimal levels of process and design parameters that result in the desired product characteristics and performance.

The Taguchi method follows a systematic and structured approach to experiment design and data analysis, which includes the following steps:

Define the product or process characteristics that need to be improved (quality characteristics or "performance characteristics").

Identify the critical factors (process and design parameters) that have the greatest impact on the quality characteristics.

Determine the levels of each factor that will be tested in the experiment.

Select the experimental design (e.g., full factorial design, fractional factorial design, or custom design) based on the number of factors and levels.

Conduct the experiment and collect data on the quality characteristics and factors at different levels. Use ANOVA to analyze the data and identify the optimal levels of the factors that result in the desired product characteristics. Validate the results through confirmation experiments or by implementing the optimal levels in the production process. The Taguchi method has been widely used in various industries, including automotive, electronics, and aerospace, to improve product quality, reduce defects, and lower costs. It is known for its simplicity, efficiency, and robustness in the face of noise factors. However, it has some limitations, such as the assumption of normality of the data and the lack of flexibility in the experimental design. Despite these limitations, the Taguchi method remains a popular and effective tool for quality improvement and optimization in manufacturing and product design.

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

RunOrder	A	B	C	Epoxy Weight (%)
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. Result and Discussion

The Taguchi Orthogonal Array developed for present study for response parameter Tensile Strength and hardness was present in table 3 with all experiments. The tensile strength was measured using UTM machine and hardness was measured by suing hardness testing machine.

TABLE 3

RESPONSE DATA FROM DOE EXPERIMENTS (L16)

A (%)	B (%)	C (%)	Epoxy Weight (%)	Tensile Strength	Hardness
5	7	1	87	35.7	28.7
5	14	2	79	36.5	29.8
5	21	3	71	39.6	32.3
5	28	4	63	44.2	37.7
10	7	2	81	40.1	33.0
10	14	1	75	36.1	29.0
10	21	4	65	45.1	38.3
10	28	3	59	42.2	35.2
15	7	3	75	41.6	34.3
15	14	4	67	43.5	36.1
15	21	1	63	40.8	33.7
15	28	2	55	42.1	35.4

A (%)	B (%)	C (%)	Epoxy Weight (%)	Tensile Strength	Hardness
20	7	4	69	46.7	39.4
20	14	3	63	45.3	38.7
20	21	2	57	43.8	37.3
20	28	1	51	42.1	35.5

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. S/N Ratio-Tensile Strength (TS)

The signal-to-noise ratio can be used to determine where each element falls in the hierarchy of the selective response's difficulty. Each and every necessary formula was covered in the present section that came before. In this section, Tensile Strength (TS) has been chosen as one of the output characteristics, and the "Larger is Better" option for the S/N ratio has been selected. S/N ratio help to find the rank among the factors for the selective response parameter. In table 5 the rank was calculated using Delta formulation as discussed in previous sections.

TABLE 5

RANK IDENTIFICATION FOR RESPONSE TS (TENSILE STRENGTH)

Level	A	B	C
1	31.8	32.22	31.73
2	32.2	32.07	32.16
3	32.47	32.53	32.49
4	32.95	32.6	33.04
Delta	1.16	0.52	1.31
Rank	2	3	1

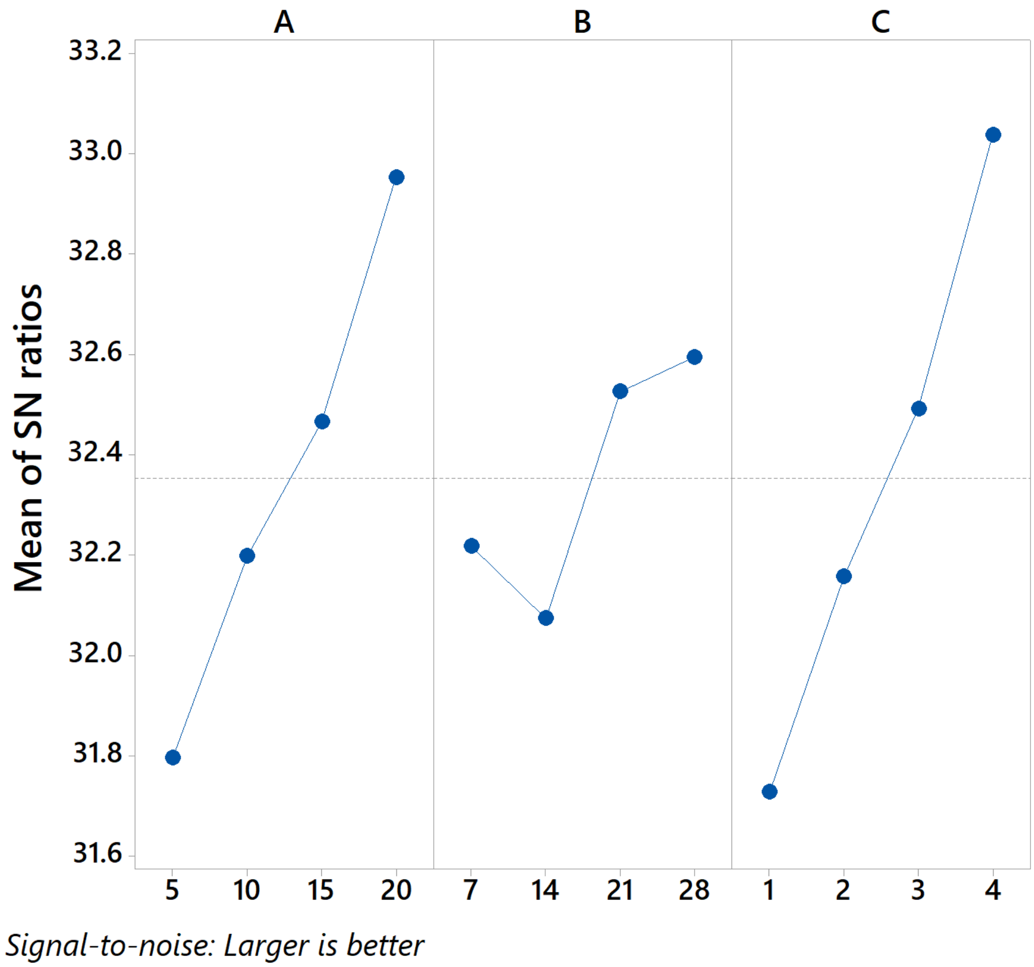


Fig.3. S/N Ratio (Larger is Better) calculations for TS Response

As can be seen in table 5, the component with the highest rank is "Nano Particle (TiO2)," the factor with the second highest rank is "E-Glass Fiber," and the factor with the lowest rank is "Marble Dust." It was 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; however, 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. The least important factor does not contribute significantly to the overall success of the effort to increase the tensile strength of the composite material.

8.Conclusion

In polymer nanocomposites, a large interfacial area can be produced as a result of the homogeneous dispersion of nanoparticles at the molecular level. As a result, the substantial interfacial interaction that exists between the organic and inorganic phases results in a significant influence being exerted on the properties of the polymer nanocomposites. Polymer nanocomposites have been developed using a wide range of nanoparticles, which has led to the creation of materials with enhanced electrical, rheological, mechanical, and tribological properties

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