

## *Retraction*

# **Retracted: Study of Mechanical Properties on Ferric Oxide Microparticles Reinforced with Polyethylene**

### **Advances in Materials Science and Engineering**

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This article has been retracted by Hindawi, as publisher, following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of systematic manipulation of the publication and peer-review process. We cannot, therefore, vouch for the reliability or integrity of this article.

Please note that this notice is intended solely to alert readers that the peer-review process of this article has been compromised.

Wiley and Hindawi regret that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

### **References**

- [1] U. Tamilarasan, S. Dhanasekar, K. Raja Karthikeyan et al., "Study of Mechanical Properties on Ferric Oxide Microparticles Reinforced with Polyethylene," *Advances in Materials Science and Engineering*, vol. 2022, Article ID 3077301, 7 pages, 2022.

## Research Article

# Study of Mechanical Properties on Ferric Oxide Microparticles Reinforced with Polyethylene

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Polyethylene and ferric oxide microparticles were mixed in this work to generate a new polymer composite. Weight fraction and microparticle size were studied experimentally to discover how they influenced the tensile strength and Young's modulus. A response surface methodology was employed in the design of the research. The increased weight fraction of reinforcement results in the increase in Young's modulus and lowers the elongation percentage. As the microparticles expanded in size, so did their effect on the composite's mechanical characteristics. The tensile strength of specimens containing 20% ferric oxide and particle size of more than 91  $\mu\text{m}$  was dropped by 18 percent due to the agglomeration of microparticles. The addition of 24%  $\text{Fe}_2\text{O}_3$  microparticles smaller than 33  $\mu\text{m}$  raised Young's modulus and tensile strength by 340 percent and 65 percent, respectively.

## 1. Introduction

A large amount of applications have taken advantage of the inherent properties of polyethylene (PE), including its high melting point, outstanding mechanical capabilities, less in density, corrosive resistance, and chemical resistance [1, 2]. With a wide range of applications, this thermoplastic material can be used to make pipes and fibres, make automotive parts, and produce aviation parts. Mechanical features such as Young's modulus and tensile strength keep material from being widely used in its current form [3]. Polymers can be

made to perform better by combining them with other polymers or by adding the appropriate reinforcements [4, 5]. The mechanical characteristics of polymers can be adjusted and enhanced by including diverse organic, inorganic, and mineral particles. Small amounts of fillers and the production of polymeric composites at the nano/microscale can considerably increase mechanical characteristics such as Young's modulus and tensile strength [6, 7]. However, filler collection and consequent inappropriate scattering in the polymer matrix are to blame for the composite material's poor mechanical characteristics [8]. Many researchers have

therefore been interested in improving polymer mechanical properties with numerous nano/microfillers such as carbon nanotubes,  $\text{CaCO}_3$ , and  $\text{ZnO}$ .

The impact strength and Young's modulus were both raised to 68% after  $\text{SiO}_2$  particles were incorporated into the PE polymer matrix [9, 10]. Young's modulus and tensile strength of polystyrene are significantly improved by mixing in titanium dioxide ( $\text{TiO}_2$ ) particles. Young's modulus, tensile strength, and impact strength were all improved when clay nanoparticles were introduced to polyethylene (PE) at a weight concentration of roughly 1%. A more elastic and tensile polyethylene and PE mould with a  $\text{TiO}_2$  stiff structure was shown to be more effective. Reinforced polymer composites' mechanical properties are influenced by a variety of parameters, including the size, shape, features, and distribution of the fillers inside the matrix. The authors in [11, 12] investigated the mechanical characteristics of a glass fibre reinforced polyethylene composite. The authors in [13] introduced polyethylene composites containing fine particles. According to their findings, the impact resistance of these composite materials is greatly improved by using these amplifiers.

Steel scrap with the best reinforcing characteristics is widely available, and this is one of the most common of those commodities [14–17]. In addition to environmental advantages such as low cost and great corrosive resistance, this material also has a high load capacity, making it a perfect reinforcement. Ferric oxide particles can improve the mechanical behavior of polymers because of their large surface area and energy and surface-to-volume ratio [18, 19]. This has resulted in the rise of  $\text{Fe}_2\text{O}_3$ -reinforced polymer composites. The authors in [20] examined the mechanical behavior of epoxy reinforced with ferric oxide particles. An increase in tensile strength of 50% and fracture toughness of 106% was seen in their study. Researchers evaluated the epoxy matrix's mechanical properties in relation to ferric oxide-coated particles [21]. According to their observations in [22, 23], Young's modulus and toughness of epoxy resin increased from 300 MPa to 500 MPa when 3 wt. percent of ferric oxide is added.

Large-scale studies have found that ferric oxide particles have no effect on the mechanical behavior of polyethylene, one of the most broadly utilized polymers around the globe [24]. It was shown that incorporating ferric oxide particles into polyethylene can improve the material's mechanical qualities by conducting experimental tests. When analyzing the experimental data with response surface methods, tensile strength and Young's modulus are taken into account for the response [25–27]. Thus, our aim is to reinforce ferric oxide microparticles with polyethylene polymer tensile specimens made by melting and injecting the material in weight fractions of 6, 12, 18, and 24. The response surface methodology utilized to analyze the experiment's data made use of tensile strength and Young's modulus as variables.

## 2. Experimental Studies

**2.1. Materials.** It was found that polyethylene polymer with a melt flow and density of  $906 \text{ kg/m}^3$  was used in the composite sector in this investigation. It was found that

ferric oxide particles can be found in five different sizes, ranging from  $33 \mu\text{m}$  in diameter (grade A) to  $125 \mu\text{m}$  in diameter (grade E), where  $\mu\text{m}$  is the average grain size. Using a twin-screw extruder by specifications of length = 580 mm, screw diameter = 18 mm, and  $L/D = 45$ , by melt blending process, the composites were made. The six heat zones of the extruder's temperature distribution were modified in accordance with the polyethylene material's melting temperature at 60, 90, 120, 150, 180, and 210 C inputs. According to Table 1, plastic injection equipment is used to generate various test samples with various weight % and sizes of ferric oxide particles after extrusion. With an inlet pressure of 90 bar and a cooling time of 65 seconds during molding, the device maintains a temperature range of 180–210 C. Standard injection molding was used to create samples for five various volume fractions of  $\text{Fe}_2\text{O}_3$  particles (0, 6, 12, 18, and 24 percent wt.) and five distinct sizes.

The speed of the test was adjusted to 5 mm/min using the universal testing machine as shown in Figure 1. Until the sample failed, 1 ms of force-displacement data was recorded. Additionally, three trials were performed on each sample as shown in Figure 2 to ensure that there were no mistakes during the testing process. The response surface approach will be utilized to examine the data in this study, and Table 1 demonstrates the elements selected for this work and their range of differences in relation to research objectives.

## 3. Results

These are the outcomes of the experiments that were carried out for this investigation. Tests on different PE samples with different sizes and weight fractions of ferric oxide microparticles yield the results through direct tensile tests. The linear component of a stress-strain curve can be used to calculate a material's tensile strength by putting a lot of stress to it and then computing the elastic modulus. When doing ASTM tensile testing, pure PE20A and PE20E samples all fail. Using ferric oxide microparticles enhances strain variation and decreases the fracture strains of the specimens in general, as demonstrated by comparing the deformation of the specimens following the tensile test [28]. Polymer matrix microparticles embedded with ferric oxide microparticles boost the material's tensile strength under stress. Because of this, cracking can develop and spread more easily in a matrix that is under more tensile stress than it is under less stress. The polymer composite is tearing in a few places. These values increased to 2612 MPa and 38 MPa, respectively, when 24 weight percent of ferric oxide microparticles of grade A particle size was added to pure polyethylene, according to the data. Polyethylene terephthalate (PET) microparticles were employed to boost the modulus of the PE polymer by 300 percent and the material's strength by 60%. Ferric oxide particles can easily increase Young's modulus and tensile strength, according to these findings [29]. There was also an increase in tensile strength of 21.8 MPa when 20% grade E particles were added to the polyethylene. When compared to pure polyethylene, grade E microparticles raise Young's modulus by around 280 percent while decreasing tensile strength by about 18 percent and it

TABLE 1: Specimen specifications.

S. no.	Fe <sub>2</sub> O <sub>3</sub> wt.%	Grain size ( $\mu\text{m}$ )				
		33 $\mu\text{m}$ (grade A)	33 to 61 $\mu\text{m}$ (grade B)	62 to 68 $\mu\text{m}$ (grade C)	68 to 92 $\mu\text{m}$ (grade D)	92 to 125 $\mu\text{m}$ (grade E)
1	6	PE6A	PE6B	PE6C	PE6D	PE6E
2	12	PE12A	PE12B	PE12C	PE12D	PE12E
3	18	PE18A	PE18B	PE18C	PE18D	PE18E
4	24	PE24A	PE24B	PE24C	PE24D	PE24E

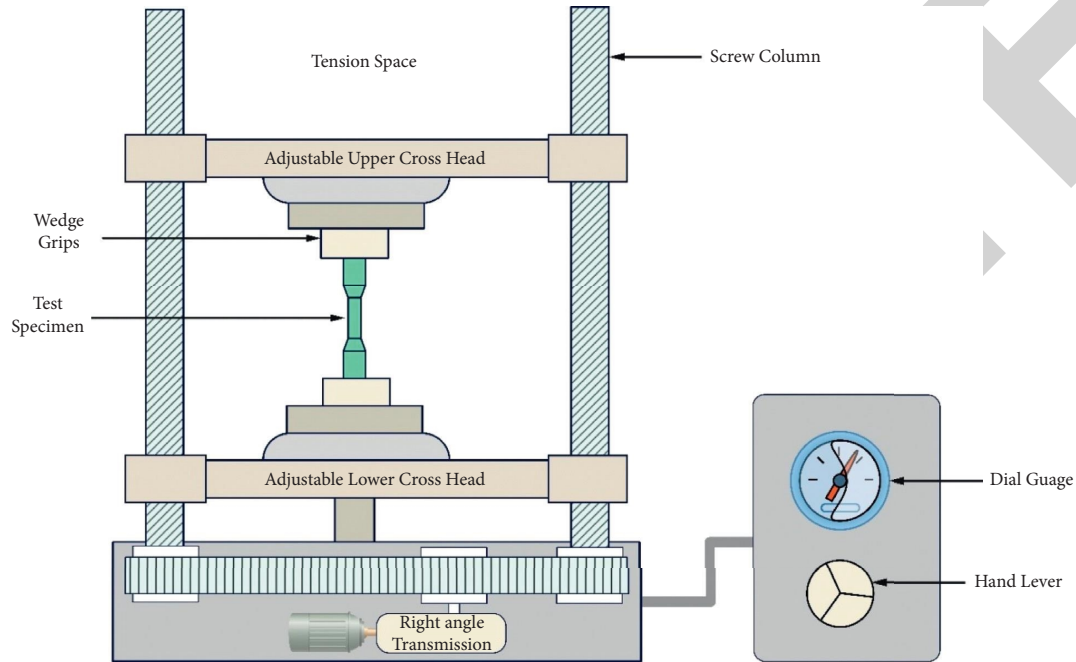


FIGURE 1: Universal testing machine.

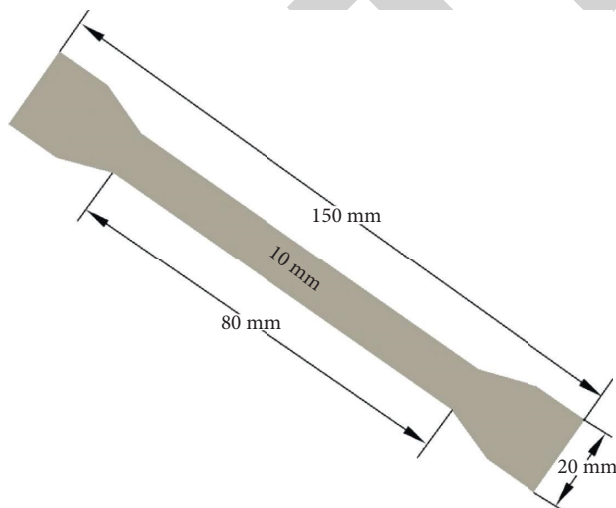


FIGURE 2: Specimen for tensile test.

matrix. According to the results of this study, using smaller microparticles improved polyethylene mechanical properties by increasing cohesiveness and decreasing particle aggregation.

These 20 polyethylene samples were reinforced with iron oxide microparticles of changing weight fraction and particle size [30]. There was a correlation between the amount and the size of reinforcement particles in the polymer matrix and an increase in Young's modulus as shown in the results of this research. Adding ferric oxide microparticles enhanced Young's modulus from 110 to 275 percent in comparison with pure polyethylene, based on weight fraction and microparticle size. The ratio of reinforcement to matrix modulus determines the composite material's elastic modulus. In order to enhance the modulus of a polyethylene/ferric oxide composite, the weight percentage of ferric oxide microparticles must be increased [31]. For specimens with a ferric oxide weight percentage of less than 12 percent, Young's modulus increases with increase in microparticle size in the experimental studies. Large microparticles have less impact on the composite material's Young's modulus if the polyethylene is reinforced with weight fraction larger than 12 weight percent. Particle agglomeration and a reduced bonding level between microparticles and matrix result in a lower modulus for greater percentages of ferric

is shown in Figure 3. There was also evidence of significant microparticle agglomerations, which resulted in stress concentration and crack initiation, leading to brittle material. In addition, the tensile strength decreases as a result of the weak connection between large microparticles and the

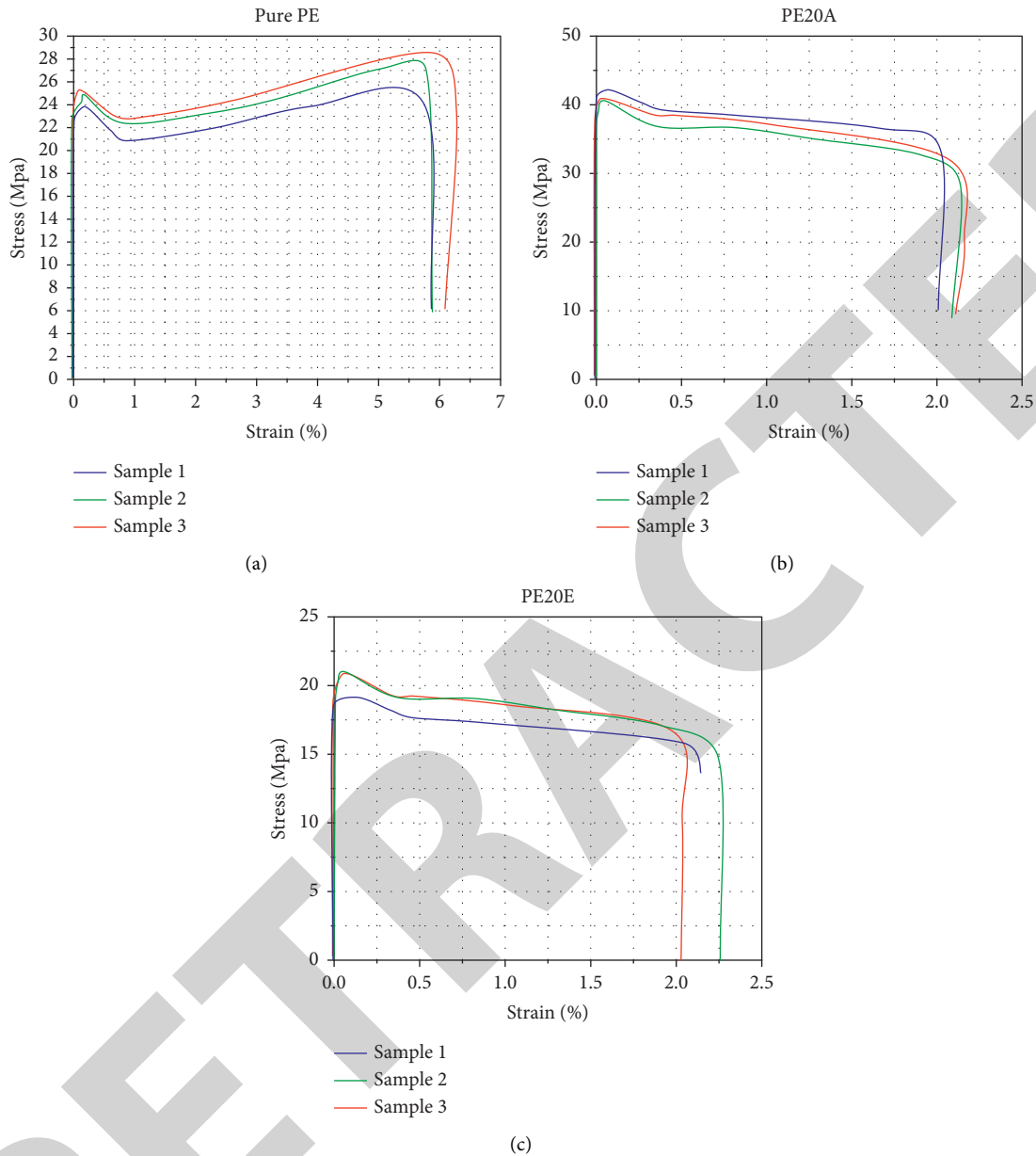


FIGURE 3: Stress-strain curve samples for (a) pure polyethylene, (b) polyethylene containing 20 wt percent of iron oxide with grade A particle size, and (c) polyethylene having 20 wt percent of iron oxide with grade E particle size.

oxide microparticles with big diameters (C and D grades) and it is seen in Figure 4.

PE enhanced with ferric oxide microparticles demonstrates increased tensile strength in Figure 5. The tensile strength of the polyethylene/ferric oxide composite is greatly affected by weight fraction and the microparticles used, and this behavior varies with particle size. The higher interfacial bonding between the polyethylene polymer and ferric oxide microparticles is also thought to lead to an increase in the sample's tensile strength and Young's modulus compared to the specimen. The polymer matrix/reinforcement particle interface is a key factor in determining the mechanical properties of polyethylene/ferric oxide composites at 24 wt percent [32]. For microparticle grade A, tensile strength is 60

percent more than that of polyethylene, making the composite more resistant to stress cracking than pure polyethylene. For microparticle grades B, C, and D, the tensile strength increased at first but later dropped when ferric oxide was added to polyethylene. The greater effective surface contact area between microparticles and matrix improves the tensile strength, which is highly dependent on stress transfer.

A method for increasing microparticle tensile strength involves transferring stress from the matrix to the microparticles. According to these findings, the polyethylene/ferric oxide composite with a tensile strength of 37.5 MPa, which contains 18 weight percent of grade B microparticles, has a tensile strength that is 70% higher than that of pure

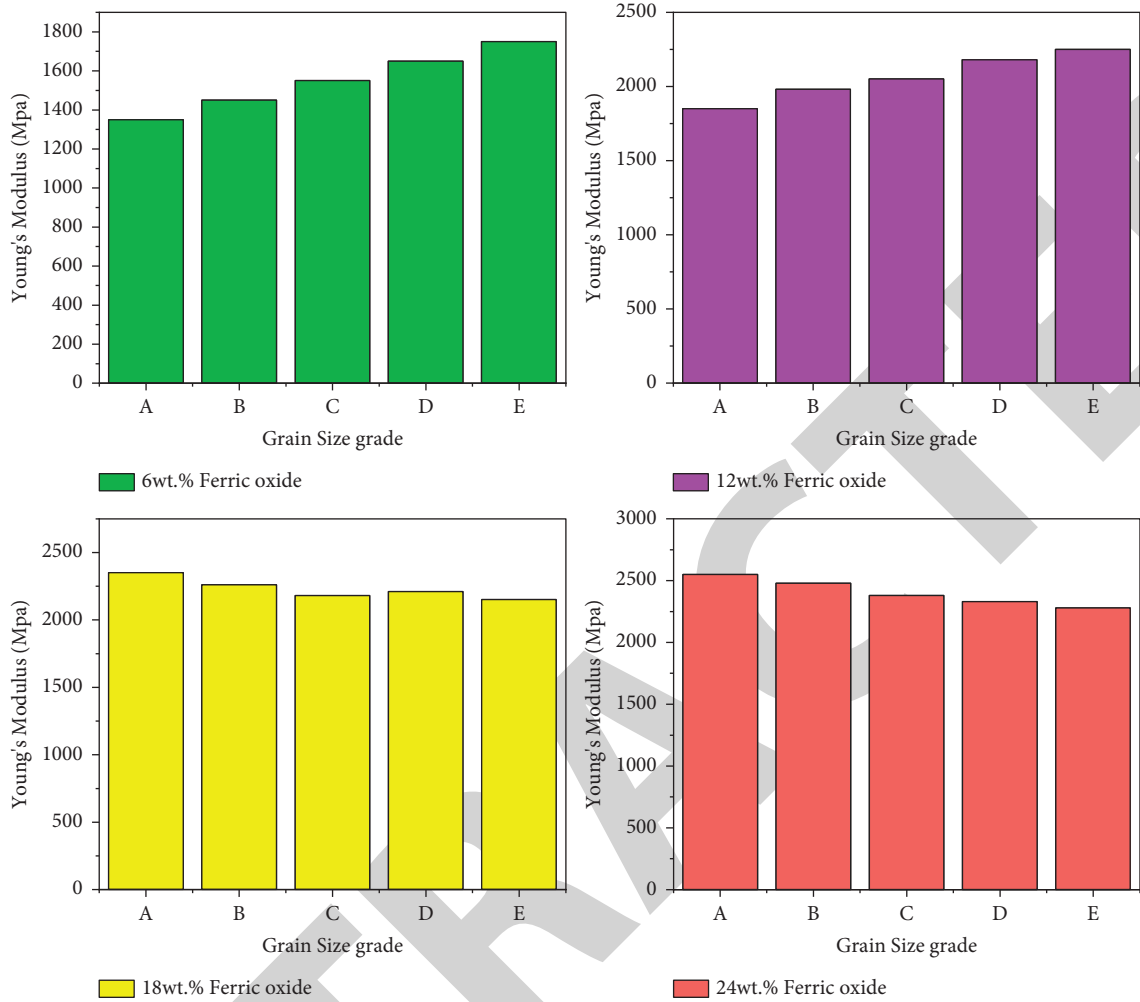


FIGURE 4: Effect of various weight fractions and ferric oxide particle size in Young's modulus of polyethylene/ferric oxide composites.

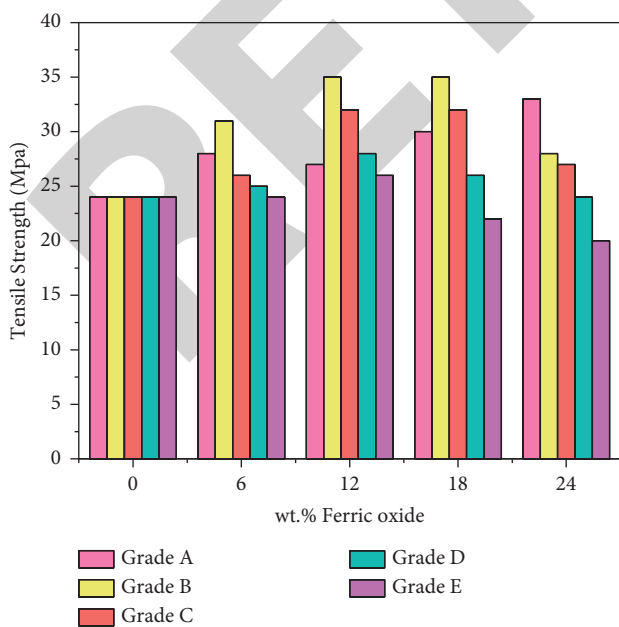


FIGURE 5: Impact of weight fractions and size of iron oxide particles on the tensile strength of polyethylene/ferric oxide composites.

polyethylene. Ferric oxide microparticles, which strengthen the matrix and deflect fracture propagation, are to blame for this increase in strength. The polyethylene/ferric oxide composite with increasing percentages of ferric oxide has weak regions that contribute to a decrease in the composite's strength. Ferric oxide agglomerations with enormous diameters are also observed at high levels of ferric oxide, weakening the matrix-particle connection even further. Due to the large stress concentrations, cracks may form in the vicinity of the agglomeration areas. The microcomposite's strength may decrease as the weight percentage and the size of the ferric oxide microparticles rise. The smallest rise in tensile strength is seen for microparticles of grade E. Although ferric oxide was used at a high percentage of 24 weight percent, the tensile strength of the microcomposite was 18 percent lower than that of pure polyethylene owing to agglomeration and reduced surface contact area [33]. Furthermore, the tensile strength and modulus of the polyethylene composites made in this study are comparable to those of specimens made in references with clay and aluminum hydroxide particles as reinforcement. RSM was utilized to decrease the number of tests and establish a measurable relationship between the mechanical parameters

TABLE 2: Statistical investigation and experimental information.

Model	SD	$R^2$
Linear	2.16	0.85
2F1	1.75	0.86
Quadratic	1.21	0.91
Cubic	0.62	0.95

of the composite as well as input factors (temperature and humidity) in this research. Some of the more accurate mathematical models for predicating mechanical qualities are provided in Table 2, which shows how well they perform.

According to statistical analysis, each parameter's relative relevance was estimated using a cubic model that had the lowest error. The response surface approach was used to construct surface curves for the PE/Fe<sub>2</sub>O<sub>3</sub> composite with a standard deviation of 0.57. As a result, matrix and micro-particle bonding is highly stable in samples with more weight % of ferric oxide particles. The mechanical behavior of the composites has been greatly enhanced by the microparticles' ability to withstand the majority of the applied forces, and the results are shown in equations (1) and (2). The specimens containing microparticles with a diameter of 20 to 35 and a weight fraction of 15% to 20% had the highest tensile strength based on the results.

$S$  and  $W$  denote microparticle size and weight fraction of ferric oxide microparticles. In the tensile strength equation, the microparticle size has the highest negative coefficient  $S$ .  $SW$  coefficient shows that increasing particle size and weight have a detrimental effect on tensile strength. This shows a negative contact among the size and weight fraction of particles. Agglomeration of microparticles occurs when the size and weight proportion of microparticles are simultaneously raised.

$$\begin{aligned} \text{Tensile Strength (MPa)} = & 27.62 - 9.30S + 3.91W - 5.01SW \\ & - 2.56S^2 - 3.54W^2 + 3.65S^3 \\ & - 0.77W^3 - 0.67SW^2. \end{aligned} \quad (1)$$

$$\begin{aligned} \text{Young's Modulus (MPa)} = & 1896.7 + 169.6S + 701.3W \\ & - 111SW - 5.6S^2 - 488.4W^2 \\ & - 32.7S^3 + 190.8W^3 \\ & - 216.8SW^2 + 1.8S^2W. \end{aligned} \quad (2)$$

#### 4. Conclusion

This research was to examine the impact of microparticle size and volume % on polyethylene reinforcement.

- (i) When particles are dispersed, the strength and Young's modulus of the material increase dramatically by 100–260 percent depending on microparticle weight percentage and dimension.
- (ii) This process can manufacture PE/ferric oxide composites with more weight percent of microparticles

smaller than 62  $\mu\text{m}$  to obtain composites with adequate mechanical characteristics for different technical applications.

- (iii) Using ferric oxide microparticles, polyethylene's force is efficiently transferred to their matrix. As well as bolstering the matrix and preventing cracks, the strong surface effect and the bond between ferric oxide microparticles and the matrix also play a role in this increased strength.
- (iv) For the PE/ferric oxide composite having 18 wt.% of microparticles of the size of  $20 = a \leq 36 \mu\text{m}$  diameter, a 35 MPa value was achieved, which was approximately 75% greater than that of the pure PE material.

#### Data Availability

The data used to support the findings of this study are included within the article. Further data or information is available from the corresponding author upon request.

#### Conflicts of Interest

The authors declare that they have no conflicts of interest regarding the publication of this paper.

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