



PREPARATION OF POLYMER COMPOSITES WITH NANO FILLERS

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Abstract: Polyester resin polymer matrix composites (PMCs) are extensively utilized materials in which polyester resin serves as the matrix, combined with various reinforcements to improve the composite's mechanical, thermal, and chemical characteristics. This study emphasizes the fabrication of polyester resin polymer matrix composites using a systematic approach designed to achieve optimal dispersion and strong interfacial bonding of the reinforcements. In this study, polyester resin polymer matrix composites are developed by reinforcing nano aluminum oxide by method of solution combustion method. This method is cost-effective and highly efficient. Hardness testing was conducted on the specimens produced using the solution combustion technique. The results revealed that the hardness and density of composites was increased with the addition of nano aluminum oxide in polyester resin polymer matrix composites.

IndexTerms - Polymer matrix composites, Polyester resin polymer matrix composites with nano aluminum oxide, Hardness, Density.

I. INTRODUCTION

A composite is combination of two or more materials in which one of the materials, called the reinforcing phase, is in the form of fibers, sheets, or particles, and is embedded in the other materials called the matrix phase. The reinforcing material and the matrix material can be metal, ceramic, or polymer [1]. Polymers are commonly reinforced by incorporating solid fillers such as minerals or glass. These fillers provide numerous advantages, including enhanced processability, reduced cost, and better control over material density. They also improve optical and thermal properties, regulate thermal expansion, offer flame retardancy, and enhance magnetic and electrical behavior. Moreover, they significantly strengthen mechanical performance by increasing fatigue resistance, wear resistance, and hardness [1].

Composites with a polymer-based matrix represent one of the most common and versatile classes of materials. By combining the matrix and filler in various proportions, it is possible to create materials that outperform traditional ones while remaining lighter and easier to reinforce. The advantageous properties of polymer composite materials (PCMs) have made them increasingly accessible, leading to their application not only in advanced aerospace technologies but also in everyday household appliances [2].

Nanotechnology is a vast and rapidly advancing scientific field that has gained significant prominence in recent decades, with nanoparticles serving as its fundamental building blocks. Nanostructures, a class of advanced inorganic materials, have attracted considerable research interest owing to their exceptional properties compared to conventional materials [3]. Nanocomposite particles are made up of two separate materials consolidated into a single hybridized particle, resulting in a multifaceted substance that may be employed in a variety of sectors, such as pharmaceuticals, electronics, and manufacturing, or to improve existing features [4].

Polyester resin is a synthetic polymer widely used as a matrix material in composite manufacturing. It is formed through a chemical reaction between dibasic organic acids and polyhydric alcohols, producing a thermosetting resin that becomes hard and rigid when cured. The main advantages of using Al_2O_3 particles as reinforcement lie in their outstanding mechanical properties and relatively high thermal conductivity, both of which contribute to enhancing the overall performance of composites [5].

Alumina, often known as corundum, is the crystalline form of aluminum oxide. Al_2O_3 is the chemical formula for aluminum oxide. Alumina is commonly utilized in the manufacturing of refractories, ceramics, and aluminum metal. Due to its hardness, it is also utilized as an abrasive [6]. The properties of polyester resin and aluminium oxide are shown in below table 1.1

Table 1.1: Properties of polyester resin and aluminium oxide

Properties	Density (g/cm ³)	Melting point(°C)	Poisson Ratio	Color
Polyester Resin	1.5	246	0.46	White
Aluminum oxide(Al₂O₃) [6]	3.69	2072	0.21	White

II. METHODOLOGY

Polyester resin was chosen as the matrix material due to its superior mechanical properties and strong compatibility with the selected reinforcement. Nano alumina was used as the reinforcing phase, as it exhibits excellent stability with polyester resin. Being an oxide ceramic with low affinity for further oxidation, alumina ensures chemical stability. In its particulate form, the reinforcement disperses uniformly within the matrix, contributing to the composite's isotropic behavior.

Figure 2.1: Polyester Resin Figure 2.2: Aluminum oxide (Al₂O₃)

Nano Aluminium Oxide (Al₂O₃) powder are prepared by Solution Combustion method by using nitrate and urea according to the chemical balanced calculation. The fabrication of polymer composites involves blending and stirring processes. In this study, nano-fillers of aluminum oxide (Al₂O₃) were synthesized and incorporated into the polyester resin using a mechanical stirrer. Initially, a known quantity of polyester resin and a predetermined percentage of Al₂O₃ were mixed and stirred mechanically at 500 rpm for one hour. Subsequently, a measured amount of hardener (Methyl Ethyl Ketone Peroxide) was added to the mixture. The prepared blend was then poured into a mold and left to cure at room temperature for 24 hours. After solidification, the desired composite specimens were obtained. Polyester resin polymer matrix composites were prepared in different compositions, as presented in Table 2.1 below.

Table 2.1: Specimen composition

Specimen Code	Polyester Resin	Nano Aluminium oxide(Al ₂ O ₃)
1	100%	0
2	97%	3%
3	94%	6%
4	91%	9%



Figure 2.3: Mixing of filler with Polyester resin using Mechanical stirrer

III. RESULTS

3.1 Hardness measurement:

The hardness of various composite samples was measured using a Rockwell hardness tester, and the results are presented in Table 3.1. The test was conducted according to Rockwell Hardness Scale B standards, applying a 100 kg load with a 2.5 mm diameter steel ball indenter. The load was applied smoothly for approximately 15 seconds.

Figure 3.1 illustrates the variation of hardness values with different reinforcement percentages. It is observed that the hardness of polyester resin polymer matrix composites increases with the addition of nano alumina particles, reaching a maximum at 9 wt% reinforcement compared to the base matrix. The improvement in hardness at 3 wt%, 6 wt% and 9 wt% Al_2O_3 can be attributed to the presence of hard alumina particles, which enhance the composite's resistance to plastic deformation, thereby increasing its overall hardness.

Table 3.1: Hardness of polymer matrix composites

Specimen Code	Hardness
1	44
2	73
3	74.4
4	74.7

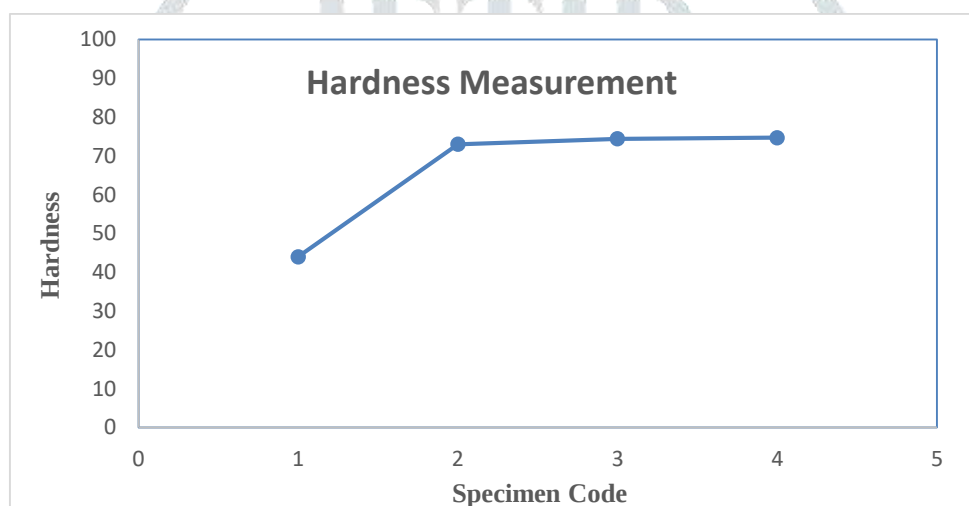


Figure: 3.1 Variation of Hardness of specimens

3.2 Density measurement:

The graph below illustrates the density of the prepared specimens with varying compositions of polyester resin polymer matrix composites. It can be observed that as the nano reinforcement percentage increases, the density of the composites also rises. This is attributed to the higher density of alumina compared to the polyester resin matrix, as shown in Graph 3.2.

Table 3.2 : Density of polymer matrix composites

Specimen Code	Density (kg/m^3)
1	1.4
2	7.10
3	7.27
4	7.49

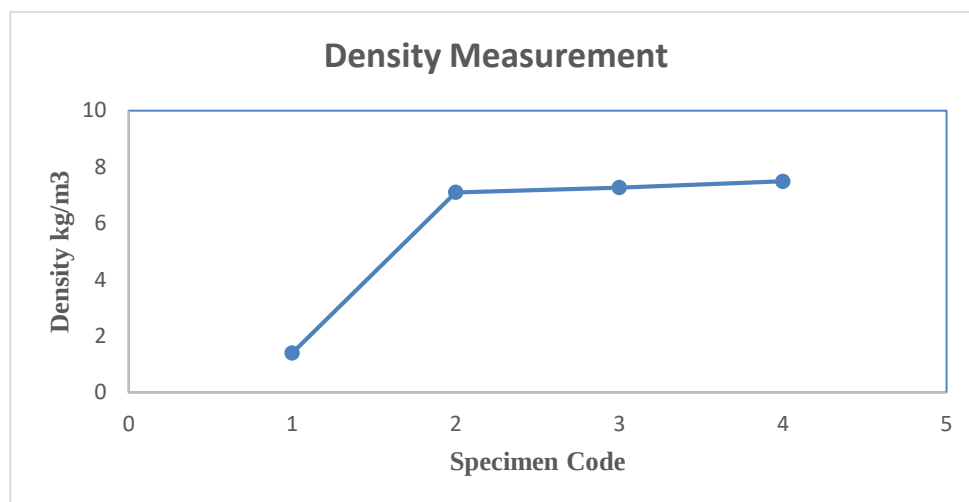


Figure: 3.2 Variation of Density of specimens

IV. CONCLUSION

Polyester resin polymer matrix composites reinforced with 3 wt%, 6 wt%, and 9 wt% nano alumina (Al_2O_3) particles were successfully fabricated using the blending and stirring method. The experiments were conducted on test-ready specimens. Owing to the higher density of nano alumina, the composite density increased with the rise in reinforcement percentage. It was also concluded that, compared to pure polyester resin, the hardness values of the composites reinforced with 3 wt%, 6 wt% and 9 wt% Al_2O_3 particulates showed significant improvement.

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