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Enhancing Mechanical and Thermal Properties of Polyester Composites with Nano Clay Reinforcement

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This study investigates the fabrication and mechanical properties of polyester composites reinforced with nano clay. Composites were produced using a hand lay-up technique with varying nano clay concentrations (50g, 100g, and 200g), while pure polyester resin served as a control. The mechanical properties, including tensile strength, hardness, and impact resistance, were evaluated, along with the thermal resistance determined through a muffle furnace test. Results demonstrate that increasing the nano clay content significantly improves the thermal and mechanical properties of the composites, surpassing the performance of pure polyester resin. These findings highlight the potential of nano clay as a promising reinforcement for enhancing the properties of polymer composites in various applications.

Keywords: polyester, nano clay, and reinforcement.

1. Introduction

Composite materials are engineered by combining two or more distinct materials to achieve properties superior to the individual components. Over centuries, advancements in composite technology have revolutionized various industries, including aerospace, automotive, and construction. Nano clay, particularly montmorillonite (MMT), has emerged as a significant component due to its unique structural properties and high aspect ratio. This study investigates the incorporation of nano clay into polyester resin to improve its mechanical and thermal characteristics, focusing on applications requiring enhanced strength, durability, and thermal resistance.

Nano clays are layered silicates with tetrahedrally bound Si atoms to an octahedrally shared edge of Al $(OH)_3$ or Mg $(OH)_2$. Layered nano silicates possess very high aspect ratios with about 1 nm thick layers. These layers are stacked by weaker physical forces like van der Waals interactions to form a gallery (Paul and Robeson, 2008). Some widely used nano clay include nacrite, antigorite, MMT, bentonite, beidellite, kolinite, hectorite, illite, taenolite, sapiolite, talc, lizardite, halloysite, octosilicate, kenyaite, magadite, brucite, berlinite, etc.

The essential nano clay raw material is montmorillonite a 2-to-1 layered smectite clay mineral with a platy structure. Individual platelet thicknesses are just one nanometer (one-billionth of a meter), but surface dimensions are generally 300 to more than 600 nanometers, resulting in an unusually high aspect ratio. Naturally occurring montmorillonite is hydrophilic. Since polymers are generally organophilic, unmodified nano clay disperses in polymers with great difficulty. Through clay surface modification, montmorillonite can be made organophilic and, therefore, compatible with conventional organic polymers. Surface compatibilization is also known as intercalation. Compatibilized nano clays disperse readily in polymers.

The nano clay used in this experiment was Metakaolin. High-purity kaolinitic clays can be calcined at relatively low temperature 600-700^{0}C to keep silica and alumina in amorphous state, then pulverized to particles smaller than 2 microns. The product is a highly reactive pozzolan of white color that is especially suitable for use in architectural concrete.

2. Materials and Methods

The materials used are:

- Nano clay
- Epoxy
- Hardener
- Cobalt
- PVA

2.1 POLYSTER RESIN:

Polyester resins are unsaturated synthetic resins formed by the reaction of dibasic organic acids and polyhydric alcohols. Maleic Anhydride is a commonly used raw material with diacid functionality. Polyester resins are used in sheet molding compound, bulk molding compound and the toner of laser printers. Wall panels fabricated from polyester resins reinforced with fiberglass—so-called fiberglass reinforced plastic (FRP)—are typically used in restaurants, kitchens, restrooms and other areas that require washable low-maintenance walls. They are also used extensively in cured-in-place pipe applications. Departments of

Transportation in the USA also specify them for use as overlays on roads and bridges. In this application they are known as PCO Polyester Concrete Overlays. These are usually based on isophthalic acid and cut with styrene at high levels—usually up to 50%. Polyesters are also used in anchor bolt adhesives though epoxy-based materials are also used. Many companies have and continue to introduce styrene free systems mainly due to odor issues. Most polyester resins are viscous, pale colored liquids consisting of a solution of polyester in a monomer which is usually styrene.

2.2 METHYL ETHYL KETONE PEROXIDE

The MEKP Liquid Hardener is an industry standard hardener consisting of Methyl Ethyl Ketone Peroxide. It is required in jobs that use polyester resins, gel coats, and vinyl ester resin. It is required in various concentrations as needed for each resin product. The MEKP acts as a catalyst when mixed with the resin.

Methyl Ethyl Ketone Peroxide (MEKP) is an organic peroxide, a high explosive similar to acetone peroxide. MEKP is a colorless, oily liquid whereas acetone peroxide is a white powder at STP; MEKP is slightly less sensitive to shock and temperature, and more stable in storage. Depending on the experimental conditions, several different adducts of methyl ethyl ketone and hydrogen peroxide are known. The first to be reported was a cyclic dimer, $C_8H_{16}O_4$, in 1906. Later studies found that a linear dimmer is the most prevalent in the mixture of products typically obtained, and this is the form that is typically quoted in the commercially available material from chemical supply companies.

Dilute solutions of 30 to 40% MEKP are used in industry and by hobbyists as the catalyst which initiates the cross linking of unsaturated polyester resins used in fiberglass, and casting. For this application, MEKP is dissolved in dimethyl phthalate, cyclohexane peroxide, or diallyl phthalate to reduce sensitivity to shock. Benzoyl peroxide can be used for the same purpose. MEKP is a severe skin irritant and can cause progressive corrosive damage or blindness.

Fig: MEKP Structure, catalyst, cobalt and resin

Chemical formula	$C_8H_{18}O_6$
Molar mass	210.226 g·mol^{-1}
Appearance	Colorless liquid

Density	1.170 g cm^{-3}
Boiling point	Decomposition beyond 80 °C (176 °F)
Solubility in water	Soluble

2.3 COBALT:

Cobalt composite materials reinforced with continuous silicon carbide fibers, which have a high tensile strength, a low elongation, a high Young modulus and a high tensile strength at a high temperature, are produced by filling spaces in piles of the continuous silicon carbide fibers containing 0.01%-30% by weight of free carbon with melted or powdery metallic cobalt or cobalt alloy and integrating the said fibers with the said metal.

2,4 MECHANICAL PROPERTIES:

The mechanical properties of cobalt are tabulated below.

Properties	Metric	Imperial
	225 MPa	32600 psi
Poisson’s ratio	0.32	0.32
Modulus of elasticity	211 GPa	30600 ksi
Shear modulus	82.6 GPa	12000 ksi
Hardness, Brinell	125	125
Hardness, Vickers	253	253

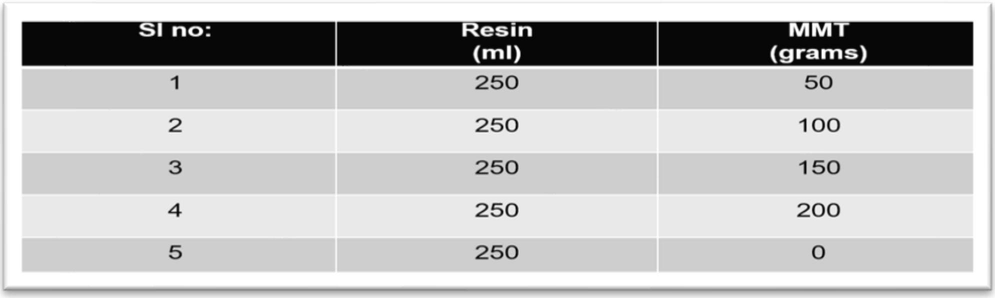
2.5 PREPARATION OF SPECIMEN:

2.5.1 Mould: Molding or moulding is the process of manufacturing by shaping pliable raw material using a rigid frame called a mold or matrix. This it may have been made using a pattern or model of the final object. A mold or mould is a hollowed-out block that is filled with a liquid or pliable material such as plastic, glass, metal, or ceramic raw material. The liquid hardens or sets inside the mold, adopting its shape. A mold is the counterpart to a cast. The very common bi-valve molding process uses two molds, one for each half of the object.

Fig: Mould

2.5.2 Mixing Of Materials for The Process of Moulding:

Here we are going to add the available materials process by adding epoxy resin and hardner and cobalt to the mixture in this manner we are preparing the five different specimens for the finding of the mechanical properties how varies in it.



Sl no:	Resin (ml)	MMT (grams)
1	250	50
2	250	100
3	250	150
4	250	200
5	250	0

Fig :materials used for the lamination of the specimen with nanoclay

Fig: Mixing of materials

2.5.3 Moulding of Laminate:

The mold surface is treated by release anti adhesive agent that is PVA to avoid the sticking of polymer to the surface. Then, a thin plastic sheet is applied at the top and bottom of the mold plate to get a smooth surface of the product. The resin mixed with the nano clay and other ingredients and infused onto the surface of reinforcement already positioned in the mold using a help brush to uniformly spread it. After curing at room temperature, the mold is opened and the nano clay composite is removed from the mold surface.

Fig : moulding of laminate

Soil:

- Appearance: Typically, soil appears darker in color, ranging from brown to black. It has a granular texture and may contain visible particles of various sizes.
- Composition: Soil is a complex mixture of mineral particles, organic matter, water, and air. It supports plant growth and provides habitat for various organisms.

Nanoclay:

- Appearance: Nanoclay is often lighter in color, appearing white or light gray. It has a fine, powdery texture with a smooth surface.
- Composition: Nanoclay is a type of clay mineral with a layered structure. Each layer is only a few nanometers thick, making it a highly effective adsorbent and catalyst.

3. Experimentation:

3.1 Mechanical Testing

- Tensile Test: Conducted using a universal testing machine to measure ultimate tensile strength and modulus.
- Impact Test: Charpy impact test to evaluate energy absorption and toughness.

- Hardness Test: Rockwell hardness test to determine surface hardness.
- Thermal Testing: Conducted using a muffle furnace to assess thermal stability and resistance at varying temperatures.

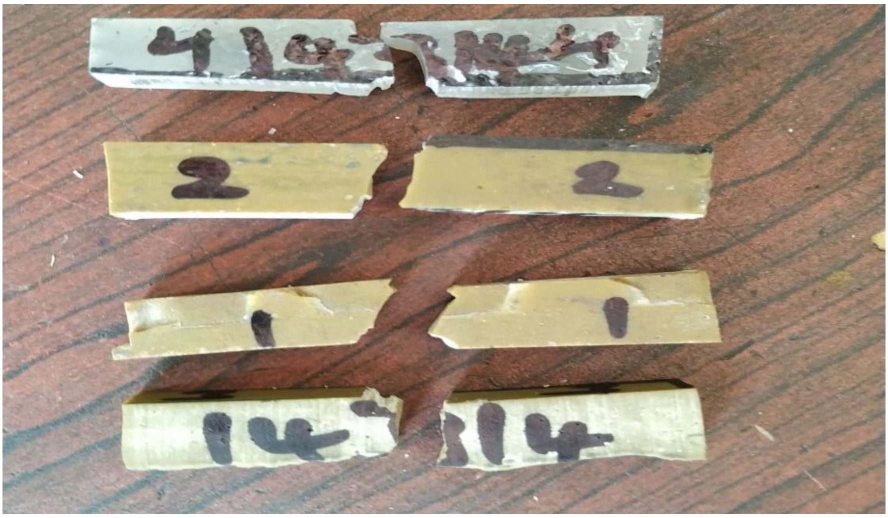



Fig: Tested nano clay composed samples

4. Results and Discussion

Tensile Strength

The tensile strength of the composites improved with increasing nano clay content. The composite with 200g nano clay exhibited the highest tensile strength, demonstrating the superior reinforcing effect of nano clay. Compared to pure polyester resin, composites with 50g and 100g of nano clay showed moderate improvements, indicating a progressive enhancement in load-bearing capacity. This increase can be attributed to the strong interfacial bonding between the nano clay particles and the polyester matrix, which effectively transferred the applied stress.

Hardness

Hardness tests revealed a significant improvement in the hardness values of the composites as the nano clay content increased. The composite with 200g nano clay exhibited the highest hardness value, confirming the ability of nano clay to enhance the surface resistance of the material. This is likely due to the uniform dispersion of nano clay particles, which restricts the mobility of the polyester matrix, thereby increasing its resistance to deformation.

Impact Resistance

The impact resistance of the composites also increased with the addition of nano clay. The composite with 200g nano clay showed the highest impact resistance, reflecting enhanced energy absorption capabilities. The improved impact properties are attributed to the nano clay's ability to dissipate energy effectively, providing additional resistance to crack propagation under impact loading conditions.

Thermal Resistance

Thermal resistance, as evaluated through the muffle furnace test, demonstrated substantial improvements with increasing nano clay content. The composite with 200g nano clay exhibited the highest thermal stability, outperforming pure polyester resin. This enhancement can be linked to the high thermal stability of nano clay and its effective barrier properties, which slow down the degradation of the polyester matrix under elevated temperatures.

Comparison with Pure Polyester Resin

Pure polyester resin served as the baseline for evaluating the enhancements achieved through nano clay reinforcement. The results consistently showed that even the lowest concentration of nano clay (50g) led to noticeable improvements in mechanical and thermal properties. This emphasizes the significant role of nano clay in reinforcing polymer matrices.

The study confirms that nano clay acts as an effective reinforcement material for polyester composites. The progressive improvements in tensile strength, hardness, impact resistance, and thermal stability with increasing nano clay content highlight the synergistic interaction between the polyester matrix and nano clay particles. The uniform dispersion of nano clay and its intrinsic properties contribute to the observed enhancements.

These findings demonstrate the potential of nano clay-reinforced polyester composites in applications requiring enhanced mechanical and thermal performance, such as automotive components, construction materials, and electronic housings. Future studies could explore optimizing the dispersion process and evaluating the long-term performance of these composites under various environmental conditions.

- Specimen Type: Flat
- Diameter (mm): 10
- Gauge Length (mm): 25
- Cross-Sectional Area (mm^2): 78.54

Test Results:

- Ultimate Load (N): 2000
- Ultimate Tensile Strength (MPa): 25.45
- Yield Load (N): 1000
- Yield Stress (MPa): 12.72
- Elongation (%): 10
- Fracture Type: Ductile

5. Conclusion

The incorporation of nanoclay into polyester resin significantly enhances mechanical and thermal properties, making it a promising material for advanced applications. Higher nanoclay content results in improved tensile strength, impact resistance, and thermal stability. These findings establish nanoclay composites as a viable alternative to conventional materials in industries requiring lightweight, durable, and thermally stable solutions.

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