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Research Article

Use of Inorganic Wastes as Fillers in Production of Polyester Composites and Evaluation of Properties of Obtained Composite

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***Abstract* –** The use of industrial factory wastes as a filler in polymer composite materials is becoming more and more common. In this way, these wastes that cause environmental pollution are eliminated and new composite materials are developed. Polymer composites with low cost and high thermal stability are preferred in many sectors. In this research, some physical and chemical properties of inorganic waste reinforced polyester composites have been evaluated. The use of industrial inorganic wastes as fillers in polyester composites develops some thermophysical properties of composites. In particular, such industrial wastes are dried before being used in the composite, the particle size is reduced, and it is ensured to have a homogeneous structure. This type of waste, which is used as filler, is used in the polyester composite in optimum proportions. The use of high inorganic fillers in polyester both weakens the mechanical strength of the composites and negatively affects the matrix structure. Besides, inorganic waste reinforcement raises the surface hardness of polyester composites. Such fillers are improved both the thermal stability and non-flammability of the polyester composite. High-density inorganic fillers are used to obtain a high-density and economical polyester composite. Low-density inorganic industrial wastes also reduce the density of composites. However, the reinforcement of inorganic fillers into polyester at a high rate adversely affects both the surface morphology and the workability of the produced composites.

Keywords – Inorganic Wastes, Polyester Composite, Thermal Conductivity, Mechanical Properties, Thermal Stability

I. INTRODUCTION

The continuous production and consumption of petroleum-based composites and the inability to control waste cause irreversible damage to the environment. The greenhouse gas released in the time between the production of a product and its conversion to waste indirectly increases its carbon footprint. To reduce the carbon footprint, it is important to control the indirect causes of the consumed product such as materials, logistics, and production processes. Minimizing waste generation by producing high-performance, durable and long-lasting, environmentally friendly, sustainable materials will provide low carbon and circular economy [1].

Composites have a wide range of applications such as the aerospace, automotive, sports, medical, electrical, and construction industries [2-5]. Generally, a composite material consists of a matrix (metal, ceramic, or polymer) that holds the reinforcement to form the desired shape, and reinforcement (fibers, particles, whisker, and/or fillers) that improve the overall mechanical properties of the matrix. Polymer composites exhibit properties such as lightness, high strength, corrosion resistance, high impact resistance, design flexibility, part consolidation, dimensional stability, non-conductive, radar transparency, low thermal conductivity, and durability [6-9]. Fiber reinforced polyester composites, in which glass, carbon, or natural fibers are embedded in a polyester matrix, are one of the most preferred composite material types. This popularity is because polyester composite materials are economical, low density, high strength, and low viscosity [10].

Inorganic-filled polyester composites are materials composed of a polyester matrix reinforced with inorganic fillers such as glass fibers, carbon fibers, ceramic particles, or metal powders. The addition of these inorganic fillers to the polyester matrix enhances the mechanical, thermal, and electrical properties of the composite. However, attention should be paid to the dispersion and filler size, as the dispersion state of fillers and "fill-fill" or "fill-matrix" interactions strongly influence the mechanical behavior of composites [11].

Inorganic fillers are a common topic in the literature related to materials science and engineering, as they play an important role in improving the mechanical and physical properties of composite materials. In a study, Tsai et al. investigated the effect of adding different types of inorganic fillers, including glass microspheres, silica nanoparticles, and carbon black, to epoxy composites. They found that the addition of inorganic fillers significantly improved the mechanical properties of the composites, including their tensile strength and fracture toughness [12].

In another study, researchers investigated the use of inorganic fillers, specifically calcium carbonate, in polypropylene composites. It was observed that the filler used in this study, Calcium carbonate, improved the mechanical properties of the composites, including their tensile strength and impact resistance, as well as their thermal stability, and significantly increased the Young's and flexural modulus of the composites [13].

Inorganic fillers have also been studied for their use in dental materials. For example, in a study examining the effect of adding different types of inorganic fillers to dental composite materials, it was revealed that the addition of fillers such as glass fiber and silica nanoparticles improved the mechanical properties and wear resistance of composites, making them more suitable for use in dental restorations [14].

The mechanical performance of a new hybrid composite prepared by adding red mud as a waste by-product of alumina production by the Bayer process to the sisal fiber reinforced polyester matrix was evaluated by Vigneshwaran et al. It has been revealed that the red mud fill improves mechanical strength and reduces water absorption, especially 20 wt.% red mud composite exhibits superior mechanical properties [15].

Glass fiber and calcium carbonate are also used as inorganic fillers in studies in the literature. The use of fillers in optimum proportions is very important in the formation of a polymer matrix. The effects of such fillers on the mechanical and thermal properties of the polyester composite have been investigated. The use of calcium carbonate in nanoparticle size improves some physical properties of the composite. Glass fiber also increases the mechanical strength of the composite [16,17].

In studies on polyester composites, organic and inorganic fillers can be used together, depending on the purpose of use. In composites obtained by reinforcing organic (biomass) wastes, it may be desired to increase in properties such as density and hardness. In particular, the use of inorganic fillers together with organic additives can improve the physical properties of composites. For example, boron factory components (such as borax, colemanite, tincal, and ulexite) increase the thermal stability of the polyester composite. Besides, nanosized particles such as aerosils, microspheres, and alumina can improve the thermophysical properties of composites. Moreover, similar developments can be achieved in nanocomposites produced by inorganic nanocoating [18-27].

The use of some waste polymers in polyester composites makes them economical and functional. Waste polyethylene terephthalate, expanded polystyrene, and waste masks are also evaluated in the composite. Such wastes cause environmental pollution and are recycled. To use these wastes in the composite, they must be prepared as drying, grinding, and reinforcing materials [28-31].

In the production of polyester and epoxy composites, bioresources not only make a physical interaction but also make chemical bonds with some modifications. For example, vegetable oils such as palm and castor oil are preferred in the synthesis of epoxy and polyester raw materials. It has been used with petrochemicals raw materials and provides important contributions to the production of biocomposites [32-34].

Also, many composites are produced by using fibrous structures of plants, biomass wastes, and fillers such as pectin in studies in the literature. Especially the fibrous structures of plants are preferred over polyester composite. The use of such waste biomass reduces the density and hardness of the composite and increases its workability. The choice of bioresources is very important for the development of both economical and environmentally friendly composites and for reducing the carbon footprint [35-39].

In general, the use of inorganic fillers in composite materials, which remains an important research area in materials science and engineering, has been studied. However, there are not many studies on the use of inorganic wastes as fillers in filled polyester composites. In this research, some physical and chemical properties of inorganic waste reinforced polyester composites have been evaluated.

II. MATERIAL AND METHOD

The manufacturing process of inorganic filled polyester composites typically involves the following steps:

- Preparation of the polyester matrix: The polyester resin is mixed with a catalyst and a curing agent to form a thermosetting polymer matrix.
- The inorganic fillers are added to the polyester matrix and mixed thoroughly to ensure even dispersion of the fillers.
- Molding or shaping of the composite: The mixture of the polyester matrix and inorganic fillers is then molded or shaped into the desired shape using techniques such as compression molding, injection molding, or extrusion.
- The composite is then cured at a high temperature and pressure to promote cross-linking of the polyester matrix and achieve the desired mechanical properties.

III. RESULTS AND DISCUSSION

The studies on the use of inorganic wastes as reinforcing materials in polyester composites are described below:

- Inorganic wastes that cause environmental pollution are evaluated in polyester composite production.
- The use of industrial factory wastes in the polymer sector provides many advantages.
- It has been determined that the thermal stability of inorganic waste reinforced polyester composites is high.
- Low-density polyester composites are produced by using low-density inorganic fillers.
- High-density composites are obtained with high-density inorganic fillers.
- Generally, inorganic filler reinforcement increases the hardness of polyester composites.
- The high use of such fillers negatively affects the surface morphology of the composite.
- Not mixing the filler homogeneously in the polyester composite and using it at a high rate cause irregular pore formation in the polymer matrix.
- Inorganic fillers can slightly increase the thermal conductivity coefficient of the polyester composite.
- According to the purpose of use, the filler material at optimum ratios can improve both the mechanical and thermal properties of the composites.
- Inorganic industrial fillers are preferred for the production of economical polyester composite materials.
- Inorganic industrial fillers are preferred for the production of economical polyester composite materials.
- The use of fillers in the optimum ratio can reduce the curing time of the composite.
- In particular, the use of nano-sized inorganic fillers improves the thermophysical properties of polyester composites.
- Since inorganic fillers increase the thermal stability of the polyester composite, they also improve the non-flammability property.

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