JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

DEVELOPMENT AND CHARACTERIZATION OF POLYMER COMPOSITES REINFORCED WITH MICRO-FILLERS

[1]Satish J,[2]Madhu K C,[3]Viswanatha D,[4]Nagaraja B
[1&2]Associate Professor, [3&4]Assistant Professor
[1, 2, 3 & 4]Department of Mechanical Engineering,
[1, 2, 3 & 4]SJM Institute of Technology, Chitradurga, Karnataka, India

Abstract: This study focuses on the development and characterization of polyvinyl alcohol (PVOH)-based polymer composites reinforced with micro-sized aluminum oxide (Al_2O_3) fillers. A systematic fabrication approach was adopted to achieve uniform dispersion of the micro-fillers within the PVOH polymer matrix and to promote effective interfacial bonding between the matrix and reinforcement. The composites were prepared using the solution combustion method, which offers a cost-effective and efficient route for incorporating micro-sized aluminum oxide into the polymer matrix. The fabricated composite specimens were subjected to density measurements to evaluate the influence of micro-Al_2O_3 reinforcement on the physical properties of the PVOH matrix. The results indicate that the density of the PVOH composites increased progressively with the addition of micro-aluminum oxide. This increase can be attributed to the higher density of Al_2O_3 compared with the PVOH matrix.

IndexTerms **- Polymer matrix composites, Polyvinyl alcohol polymer matrix composites with micro aluminum oxide, Density.**

I. INTRODUCTION

Over the past three decades, composite materials, plastics, and ceramics have emerged as some of the most important advanced engineering materials. The use of composites has grown steadily, with their applications expanding into a wide range of industries and continuously entering new markets. Today, modern composite materials represent a significant part of the engineered materials sector, finding applications in everything from common everyday products to advanced and specialized engineering systems. Although composites have already demonstrated their excellent potential for reducing weight and improving performance, one of the major challenges today is to develop them in a more cost-effective manner.

A composite material is formed by combining two or more distinct materials to achieve improved overall properties. Typically, one material acts as the reinforcing phase and may be present in the form of fibers, sheets, or particles, while the other serves as the matrix phase, which surrounds and supports the reinforcement. Both the reinforcement and matrix can be made from metals, ceramics, or polymers [1].

In polymer composites, solid fillers such as minerals and glass are commonly incorporated into the polymer matrix to enhance its properties. The addition of these fillers can improve processability, reduce material cost, and provide better control over density. They can also contribute to improved optical and thermal properties, control thermal expansion, provide flame-retardant characteristics, and modify the electrical and magnetic behavior of the composite. In addition, fillers can significantly enhance mechanical properties, including fatigue resistance, wear resistance, and hardness [1].

Polymer matrix composites (PMCs) are among the most widely used and versatile classes of composite materials due to their ability to combine low density with desirable mechanical, thermal, and functional properties. In these materials, a polymer acts as the continuous matrix phase, while one or more reinforcing materials or fillers are incorporated to modify and improve the properties of the resulting composite. The type, size, shape, surface characteristics, and concentration of the reinforcement play an important role in determining the final performance of the composite. By carefully selecting the matrix and reinforcement and controlling their proportions, composite materials can be designed to achieve specific combinations of properties that are difficult to obtain from conventional materials alone. Polymer matrix composites have evolved from specialized engineering materials into widely accessible materials capable of meeting diverse performance and economic requirements [2].

Micro-particles are widely incorporated into polymer matrices to overcome the limitations of neat polymers and to tailor the properties of the resulting composite materials. The addition of inorganic microparticles such as aluminium oxide (Al_2O_3), silica

(SiO_2), calcium carbonate ($CaCO_3$), glass, and silicon carbide (SiC) can significantly alter the mechanical, thermal, tribological, and dimensional characteristics of polymer composites. The final properties depend not only on the type and amount of filler but also on particle size, particle morphology, dispersion, particle–matrix interfacial bonding, and filler loading [3].

Polymer matrix composites (PMCs) have become an important class of engineering materials because of their ability to combine low weight, structural flexibility, and tailored functional properties. Among the different polymer matrices available, polyvinyl alcohol (PVA) has attracted significant interest due to its semicrystalline structure, water solubility, and versatility. PVA is a synthetic polymer generally produced through the hydrolysis of polyvinyl acetate [4]. The presence of a large number of hydroxyl (-OH) groups along its polymer backbone contributes to several desirable properties, including excellent film-forming ability, good adhesion, optical transparency, and resistance to oils and many organic solvents [5]. In addition, its relatively low toxicity, biocompatibility, and biodegradability make PVA an attractive and environmentally friendly polymer matrix for the development of sustainable composite materials. Its ease of processing further enhances its suitability as a host matrix for incorporating different reinforcing materials and developing polymer composites with improved mechanical and functional performance [4, 5].

Alumina, often known as corundum, is the crystalline form of aluminum oxide. Al2O3 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 PVA resin and aluminium oxide are shown in below table1.1

Table 1.1: Properties of PVA resin and aluminium oxide

Properties	Density (g/cm^3)	Melting point(^0C)	Poisson Ratio	Color
PVA Resin	1.2	180 - 230	0.45	White
Aluminum oxide (Al_2O_3) [6]	3.69	2072	0.21	White

II. METHODOLOGY

Polyvinyl alcohol (PVA) and starch were selected as the matrix materials because of their favorable mechanical properties, good processability, and strong compatibility with the selected reinforcement. Micro-sized alumina (Al_2O_3) was incorporated as the reinforcing phase due to its excellent chemical stability and compatibility with the PVA–starch matrix. As an oxide ceramic with high resistance to further oxidation and chemical degradation, alumina provides enhanced stability to the composite. Furthermore, the particulate form of micro-alumina facilitates relatively uniform dispersion throughout the polymer matrix, promoting effective stress transfer and contributing to a more homogeneous and approximately isotropic behavior of the resulting composite.



Figure 2.1: Polyvinyl alcohol



Figure 2.2: Aluminum oxide (Al_2O_3)

The fabrication of polymer composites involves blending and stirring processes. In this study, micro-fillers of aluminum oxide (Al_2O_3) were synthesized and incorporated into the PVA resin using a mechanical stirrer. Initially, a known quantity of PVA resin and a predetermined percentage of Al_2O_3 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. PVA resin polymer matrix composites were prepared in different compositions, as presented in Table 2.1 below.

The fabrication of the polymer composites was carried out through a systematic mixing and mechanical stirring process. In the present study, micro-sized aluminum oxide (Al_2O_3) particles were synthesized and subsequently incorporated into the PVA resin as reinforcing fillers. A predetermined quantity of PVA resin was initially mixed with the required proportion of Al_2O_3 particles and mechanically stirred at 500 rpm for 1 hour to promote uniform dispersion of the filler within the polymer matrix. Following this mixing process, a measured quantity of methyl ethyl ketone peroxide (MEKP) was added as a curing agent, and the mixture was thoroughly blended to ensure proper homogenization.

The resulting composite mixture was then carefully poured into a pre-prepared mold and allowed to cure at room temperature for 24 hours. After completion of the curing process, the solidified composite was removed from the mold and subsequently prepared into specimens of the required dimensions for further characterization. A series of PVA-based polymer matrix composites with varying Al_2O_3 filler concentrations were fabricated, and the corresponding compositions are presented in Table 2.1.

Table 2.1: Specimen composition

Specimen Code	PVA Resin	Aluminium oxide (Al_2O_3)
1	98%	2%
2	96%	4%
3	94%	6%
4	92%	8%



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

III. RESULTS

3.1 Successful Formation of PVA–Al_2O_3 Polymer Composites:

The PVA-based polymer composites reinforced with different concentrations of micro-sized aluminum oxide (Al_2O_3) particles were successfully fabricated. The fabricated specimens showed good physical integrity and a reasonably uniform distribution of Al_2O_3 particles throughout the polymer matrix, indicating that the adopted fabrication process was effective. Mechanical stirring helped to disperse the micro-fillers within the matrix, while the subsequent curing process produced well-consolidated and self-supporting composite specimens.

On visual inspection, the fabricated samples did not show any noticeable cracks, large voids, or major surface defects, suggesting good compatibility between the polymer matrix and the Al_2O_3 reinforcement. A gradual change in the appearance and surface texture of the specimens was observed as the Al_2O_3 content increased. This change can be associated with the increasing presence of ceramic particles within the polymer matrix. Overall, the successful fabrication of specimens with different Al_2O_3 concentrations demonstrates that the selected processing conditions were suitable for producing the PVA–Al_2O_3 composites. The compositions of the fabricated composites are shown in Figure 2.4.



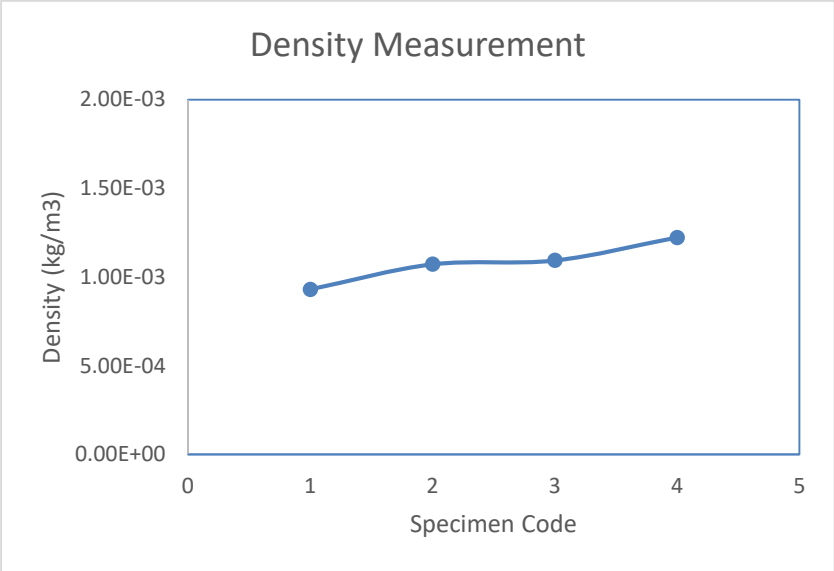
Figure 2.4: Photographs of fabricated PVA–Al_2O_3 polymer composites

3.2 Density measurement:

The graph below illustrates the density of the prepared specimens with varying compositions of PVA resin polymer matrix composites. It can be observed that as the micro reinforcement percentage increases, the density of the composites also rises. This is attributed to the higher density of alumina compared to the PVA resin matrix, as shown in Graph 3.1.

Table 3.1: Density of polymer matrix composites

Specimen Code	Density (kg/m^3)
1	9.3025e-4
2	1.07125e-3
3	1.0129e-3
4	8.0625e-4



Graph 3.1: Variation of Density of specimens

IV. CONCLUSION

PVA resin-based polymer matrix composites reinforced with different amounts of micro-sized aluminum oxide (Al_2O_3) particles (2%, 4%, 6%, and 8%) were successfully fabricated using a blending and mechanical stirring technique. The adopted method provided a simple and effective approach for incorporating the micro-Al_2O_3 particles into the PVA matrix.

The experimental results showed that the addition of micro-Al_2O_3 had a noticeable effect on the physical properties of the PVA composites. In particular, the density of the composites increased gradually as the Al_2O_3 content was increased. This behavior can mainly be attributed to the higher density of aluminum oxide compared with the PVA matrix. Therefore, increasing the amount of Al_2O_3 in the composite resulted in a greater contribution from the denser ceramic particles, leading to an overall increase in the density of the fabricated composites.

The gradual increase in density also indicates the successful incorporation of Al_2O_3 particles into the PVA matrix. The observed change confirms that the amount of ceramic reinforcement has a significant influence on the physical characteristics of the developed PVA/Al_2O_3 composites.

V. ACKNOWLEDGMENT

The authors would like to obliged to R&D Centre, Department of Mechanical Engineering, SJM Institute of Technology, Chitradurga for providing experimental facilities to carry out the research work.

REFERENCES

[1] Mahmoud Yousry Mahmoud Zaghloul, Moustafa Mahmoud YousryZaghloul, Mai Mahmoud YousryZaghloul "Developments in polyester composite materials – An in-depth review on natural fibres and nano fillers", Elsevier, Composite structures, volume 278, 15 December 2021, 114698.

[2] V M Medunetsky, V A Zenkov, M V Abramchuk and S Yu Perepelkina "The use of polymer composite materials in cylindrical gears", IOP Conf. Series: Materials Science and Engineering 1100 012030.

[3] Shao-Yun Fu, Xi-Qiao Feng, Bernd Lauke and Yiu-Wing Mai, "Effects of particle size, particle/matrix interface adhesion and particle loading on mechanical Properties of particulate polymer composites", Elsevier, Composites Part B: Engineering, volume 39, Issue 6, September 2008.

[4] H. M. Ragab, N. S. Dia et al, **"**Tuning the electrical and optical performance of PVA/PANI films via Fe2O3 nanorods for advanced energy storage and optoelectronic devices", RSC advances, 2026

[5] A. K. *Mohsin et al.*, "Structural Property Correlation in PVA/Al_2O_3 Nanocomposites," Journal of Nanostructures, Volume *16*, Issue 3, 2026.

[6] Satish J, Dr. K.G. Satish, "Preparation of magnesium metal matrix composites by powder metallurgy process", IOP Conf. Series: Materials Science and Engineering 310(2018) 012130.

[7] Satish J et al, "Preparation of polyster resin polymer matrix composites reinforced with aluminium oxide", JETIR, Volume 12 Issue 1, January 2025.

[8] Fahamsyah H. Latief, Achmad Chafidz, Harri Junaedi, Adel Alfozan and Rawaiz Khan, "Effect of Alumina Contents on the Physicomechanical Propertiesof Alumina (Al_2O_3) Reinforced Polyester Composites", Hindawi, Advances in Polymer technology, Volume 2019, Article ID 5173537.