International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Mechanical Properties of Polyester Composites Filled with Micro-sized Ceramic Particulates

Mohit Kumar Anuragi*, Alok Agrawal, Feeroz Mansoor

Department of Mechanical Engineering, Sagar Institute of Research and Technology, Bhopal-462041, India

A B S T R A C T

The present work consists of an experimental investigation of polyester-based composites filled with a varied content of aluminium oxide micro-particulates. Here, a set of composites is developed with a filler loading ranging from 0 wt. % to 50 wt. % using a simple hand lay-up method and their mechanical properties are evaluated as a function of filler loading. The properties investigated are tensile strength, flexural strength, compressive strength and hardness of the developed material. From the experimental results, it is found that the inclusion of aluminium oxide particulates in the polyester resin improves the different mechanical properties of the composites. Properties like flexural strength, compressive strength and hardness increase as the content of filler in the polyester matrix increases for the complete range of filler loading. Against that, the tensile strength of the composites increases with filler loading when the content of filler is low i.e. 30 wt. % and later, with further increase in filler loading, the tensile strength starts decreasing. From the investigation, it is noticed that the inclusion of aluminium oxide in the polyester resin improves the overall properties of the composites when the filler loading is judicially chosen.

Keywords: Polymer matrix composites, polyester, aluminium oxide, mechanical properties.

1. Introduction

The inclusion of rigid particles into the polymers can produce several desirable effects on their properties. The various properties of such particulate-filled resin result from a complex interplay between the properties of the individual constituent phases; the resin, the filler and the interfacial region. Each filler type has different properties and these in turn influence the properties of polymers accordingly. The principal relevant parameters that affect the innumerable behaviour of filled polymers are the weight fraction of filler, the particle size, the filler aspect ratio, the strength of the filler and the adhesion at the resin-filler interface. The amount of filler that is incorporated inside the matrix is considered to be the most significant factor which can alter the performance of the composite system. It has been shown by many researchers that dramatic improvement in mechanical properties can be achieved by the incorporation of either micro or nano-particles since rigid inorganic particles generally have a much higher stiffness than polymer matrices [1]. Aluminium oxide is a well-known aluminium-based ceramic which is being used widely as a filler material in polymer composites owing to its excellent tribo-mechanical and admirable thermo-electrical properties. Tilbrook et al. [2] studied the mechanical properties of Al2O3-filled epoxy composite for a very wide range of filler content and found that Young's modulus and shear modulus of epoxy resin increase with the filler loading. Goyal et al. [3] reported a similar trend in the variation of Young's modulus of poly-ether-ether-ketone with Al2O3 content. However, they observed that the modulus decreased appreciably with an increase in temperature. A similar relation between Young's modulus and temperature was observed by Jiang et al. [4]. Lim et al. [5] also studied the influence of particle shape and size on the mechanical properties and fracture behaviour of epoxy/Al2O3 nanocomposites and reported that composites prepared with smaller size particles deliver better properties.

Agarwal and Satapathy [6] used micro-size aluminium oxide as fillers with two different matrices, one with thermoset polymer epoxy and the other with thermoplastic polymer polypropylene. They reported enhanced mechanical properties in their investigation. Rawat et al. [7] investigate the impact of incorporating micro-sized aluminium oxide particles on the mechanical properties of polymer-based composites. The inclusion of micro-sized aluminium oxide particles led to notable results, with a substantial increase in tensile strength, reaching 62.4 MPa. Moreover, the composite exhibited enhanced hardness, reaching 82.5 Shore D. Girimurugan et al. [8] studied the mechanical behaviour of aluminium oxide (Al2O3) particles which are reinforced with polylactide (PLA) in different concentration ratios. In their analysis, it is observed that the inclusion of the micro-particulates enhances the mechanical properties of the composites as a linear function of the filler material.

Kanna et al. [9] investigated the mechanical properties of the composites with polypropylene as a base matrix. From the investigation, they reported that the inclusion of the micro-particulates' flexural strength and elongation at the break of the composite decreases, whereas, the flexural and tensile modulus of the composite increases. They further found that the inclusion of filler increases the hardness of the material. Kumar and Anbuchezhiyan [10] investigated the impact of Al2O3 filler in GFRP/banana fibre composite for CNC vertical milling. The study provides insightful findings, revealing a significant enhancement in the composite's performance during CNC vertical milling. The incorporation of Al2O3 filler notably improves the machinability of the composite, as evidenced by a reduced cutting force of 220 N. This reduction in cutting force indicates an enhanced milling efficiency and demonstrates the positive influence of Al2O3 filler in optimizing the machining characteristics of GFRP/banana fibre composite. From the previous investigation, it is observed that aluminium oxide has the potential to improve the mechanical properties of the polymer. However, it is also observed that the mentioned filler material has not fully explored its potential. Also, the combination of polyester resin with aluminium oxide particulates is missing. Given that, the present work consists of developing polyester composites with micro-sized aluminium oxide particulates are evaluating the mechanical properties like tensile strength, flexural strength, compressive strength and hardness of the same as a function of filler loading.

2. Materials and Method

Unsaturated isophthalic polyester supplied by Carbon black composites, Mumbai India, is the matrix material in the present investigation. Polyester resin is used with its corresponding accelerator i.e. cobalt accelerator and catalyst i.e. MEKP catalyst. The advantage of polyester resin composites is that they can be cured in a variety of ways without altering the physical properties of the finished part. Their advantages include low viscosity, low cost, and fast cure time. Aluminium oxide (Al2O3) is an aluminium-based ceramic material that has been used as a filler in the present work. It is an inorganic material. It also possesses high strength and stiffness. It is therefore chosen as the primary filler material with an average size of 20 microns which is procured from Rankem Corporation Limited located in New Delhi, India. The preparation of the different categories of composite with the simple hand lay-up method. Multiple sets of samples are prepared by varying the content of the aluminium oxide filler in the polyester resin. The different sets of composites prepared are shown in Table 1.

Table 1 - List of polyester-based composites filled with aluminium oxide

S. No.	Composition
1	Neat Polyester
2	Polyester + 10 wt. % Al2O3
3	Polyester + 20 wt. % Al2O3
4	Polyester + 30 wt. % Al2O3
5	Polyester + 40 wt. % Al2O3

The tensile strength of the composites is measured with a computerized Tinius Olsen universal testing machine by ASTM D638 procedure by applying uni-axial load through both ends at a crosshead speed of 0.5 mm/min. Static uniaxial compression tests and flexural tests on specimens are carried out using the same computerized Tinius Olsen universal testing machine. The method by which the compression test is conducted is ASTM D695. The flexural strength is measured by a point bend test carried out by ASTM D2344-84. In the present investigation, the Affri LD250 hardness measuring instrument is used to determine the micro-hardness of the fabricated composite. The tests are performed as per ASTM E384.

3. Results and Discussion

The tensile strength of all the fabricated samples is shown in Figure 1. From the figure it is observed that the tensile strength of the composite increases with filler loading up to a certain filler loading of 30 wt. % and decreases thereafter. The tensile strength of neat epoxy is 33.5 MPa which increases to 41.1 MPa when 30 wt. % of the aluminium oxide filler is added. When the filler loading increases beyond 30 wt. %, the tensile strength starts decreasing and for a maximum filler loading of 50 wt. %, the tensile strength of the material reaches 34.5 MPa. The mentioned trend is mainly because when filler loading is high, problems like an agglomeration of filler, formation of stress concentration points, presence of interface defects and improper wetting of fillers originate and this drastically reduces the tensile strength.

The flexural strength of all the fabricated composite samples is shown in Figure 2. From the figure, it is clear that the flexural strength of the composite increases as the content of the filler in the polyester matrix increases. The flexural strength of the unfilled polyester is 40.6 MPa which increases with the loading of the filler. The maximum flexural strength obtained is 49.6 MPa for a filler loading of 50 wt. %. It is further observed that when the filler loading is up to 30 wt. %, the increment in the flexural strength is high. With 30 wt. % filler loading, the measured flexural strength of the composite is 48.8 MPa showing an increment of 20.19 % over neat epoxy. Against that, for a filler loading of 50 wt. %, the increment in the flexural strength is 22.16 % showing a marginal increment over composites prepared with 30 wt. % of the filler loading.

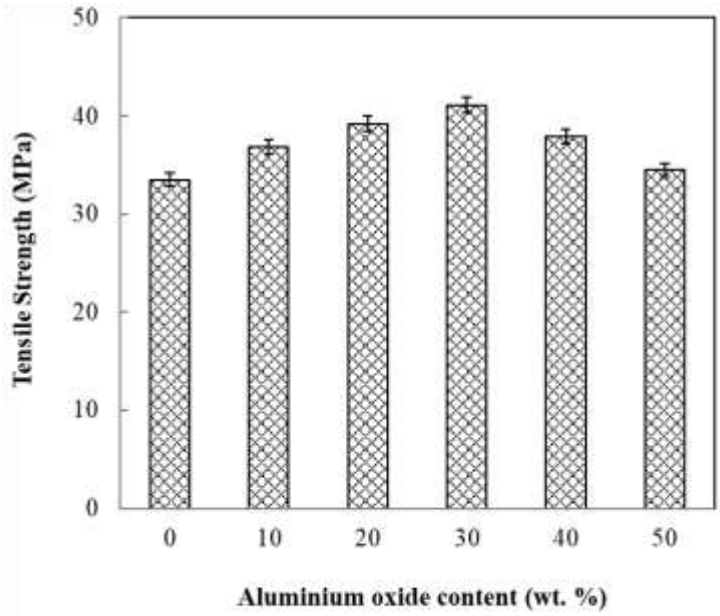

Fig. 1 - Tensile strength of polyester/ aluminium oxide composites

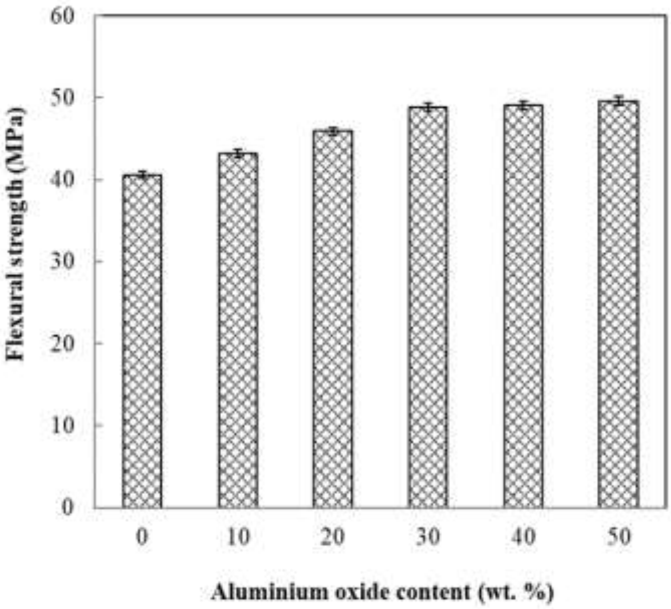

Fig. 2 - Flexural strength of polyester/ aluminium oxide composites

The compressive strength of all the fabricated samples is shown in Figure 3. From the figure, it can be seen that with the addition of micro-size aluminium oxide, the compressive strength of polyester increases and this improvement is found to be more for increased filler content. The compressive strength of the neat polyester is 72.8 MPa. The maximum value obtained is 93.1 MPa which is an increment of 27.88 %. This improvement is mainly because of the high compressive strength of filler material. The results obtained during the experimentation hardness are shown in Figure 4. From the figure, it is clear that with the increase in the content of micro-size aluminium oxide in the polyester matrix, the hardness of the composites increases and reaches its maximum value of 0.387 GPa for 50 wt. % of filler loading. It is evident that with the addition of aluminium oxide particles, the micro-hardness of the composites is improved and this improvement is a function of the filler content. This improvement is primarily because of the high hardness value of aluminium oxide particulates. This increment is attributed to around 409 % which is an appreciable improvement.

.

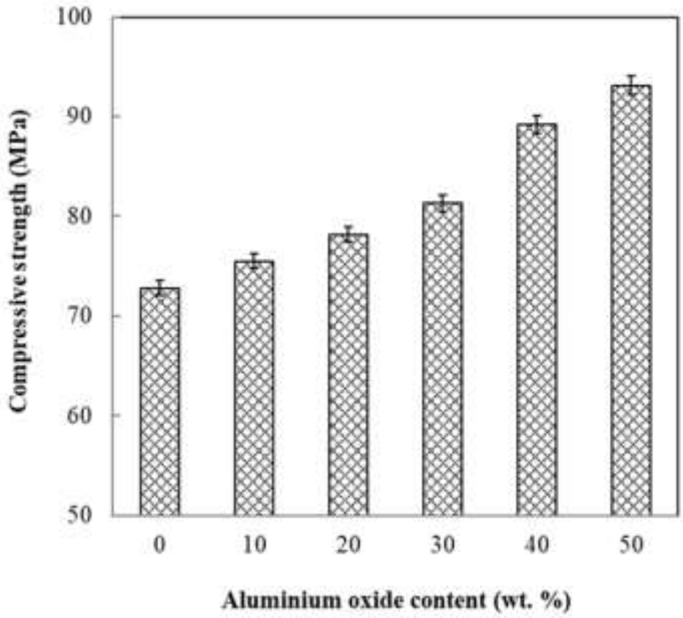

Fig. 3 - Compressive strength of polyester/ aluminium oxide composites

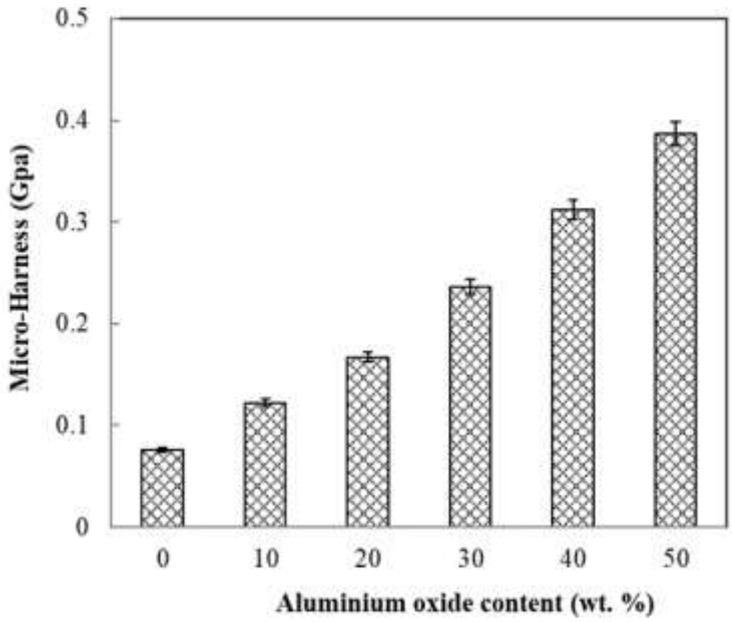

Fig. 4 - Hardness of polyester/ aluminium oxide composites

4. Conclusion

This present investigation on particulate Aluminium oxide/polyester composites has led to the following conclusions:

1. The tensile strength of the composite increases with an increase in filler content for a certain filler loading of 30 wt. % and decreases thereafter. The maximum tensile strength among the various fabricated samples was of the sample with 30 wt. % of Al2O3. Its values were reported to be 41.1 MPa.

2. The flexural strength of polyester increases with an increase in aluminium oxide content. The maximum value obtained is 49.6 MPa with 50 wt. % of filler content and this is an increment of 22.16 %.

3. The compressive strength of polyester increases and this improvement is found to be more for increased filler content. The maximum value obtained is 93.1 MPa which is an increment of 27.88 %.

4. With the increase in the content of aluminium oxide in the polyester matrix, the hardness of the composites increases and reaches its maximum value of 0.387 GPa for 50 wt. % of filler loading. This increment is around 409 %.

References

1. Fu SY, Feng XQ, Lauke B, Mai YW (2008). Effects of particle size, particle/matrix interface adhesion and particle loading on mechanical properties of particulate–polymer composites. *Composites: Part B: Engineering*, 39: 933–961.
2. Tilbrook MT, Moon RJ, Hoffman M (2005). On the mechanical properties of alumina–epoxy composites with an interpenetrating network structure. *Materials Science and Engineering A*, 393: 170–178.
3. Goyal RK, Tiwari AN, Mulik UP, Negi YS (2007). Dynamic mechanical properties of Al_2O_3/Poly(ether ether ketone) composites. *Journal of Applied Polymer Science*, 104: 568–575.
4. Jiang W, Jin FL, Park SJ (2012). Thermo-mechanical behaviors of epoxy resins reinforced with nano-Al_2O_3 particles. *Journal of Industrial and Engineering Chemistry*, 18: 594–596.
5. Lim SH, Zeng KY, He CB (2010). Morphology, tensile and fracture characteristics of epoxy-alumina nanocomposites. *Materials Science and Engineering A*, 527: 5670–5676.
6. Agrawal, A., & Satapathy, A. (2015). Effect of Al2O3 addition on thermo-electrical properties of polymer composites: An experimental investigation. Polymer Composites, 36(1), 102-112.
7. Rawat, M. K., Kukreja, N., & Gupta, S. K. (2020). Effect of reinforcing micro sized aluminium oxide particles on mechanical properties of polymer based composite. Materials Today: Proceedings, 26, 1306-1309.
8. Girimurugan, R., Vairavel, M., Moorthy, A. A., Prakash, E., & Madheswaran, S. (2021). Experimental Studies on Mechanical Behaviour of Polylactide (PLA) Matrix—Aluminium Oxide (Al 2 O 3) Particles Reinforced Composites. In *Advances in Materials Research: Select Proceedings of ICAMR 2019* (pp. 589-597). Springer Singapore.
9. Kanna, M. R., Jerusha, E., Bhattacharya, S., Pore, S. B., Ahamed, S. I., & Rajkumar, S. (2022). Mechanical properties of micro and Nano-Filler content on polypropylene composites. *Materials Today: Proceedings*, *59*, 1261-1265.
10. Kumar, K. S., & Anbuchezhiyan, G. (2023, May). Effect of Al2O3 filler in GFRP/banana fiber composite for CNC vertical milling. In Journal of Physics: Conference Series (Vol. 2484, No. 1, p. 012025). IOP Publishing.