ISAR International Journal of Research in Engineering Technology, Volume 7 Issue 5, Sep-2022

EXAMINING FLY ASH-BLENDED POLYMER COMPOSITES

Sajeev P S,

Lecturer in Civil Engineering, Government Polytechnic College, Perintalmanna, Kerala.

Email: sajeevpoly@gmail.com

Abstract

The abrasion resistance and properties of polymer composites containing fly ash (FA) were investigated in this work. FA is used as a mineral addition together with resin to create epoxy-based polymer composites. Mixtures with varying ratios were added to the resin, ranging from 0% to 30% by weight, in place of the FA. After a day of curing in air conditioning, polymeric samples were removed from the molds. After seven days, polymeric samples reach their maximum strength. Thus, seven old specimens underwent abrasion testing. The pin-on-disc test was used to determine the abrasion properties of polymer composites over a 500-meter distance at room temperature and dry friction conditions. Three different loading conditions—5, 10, 15, and 30 N—were used. As the amount of fly ash grew, so did the hardness and wear resistance values. A load-dependent equation was presented to illustrate the correlation between hardness and wear rate. The friction coefficient increased as the values of surface roughness increased. Furthermore, dynamic friction was determined by the wear rate. The polymer composites' wear surfaces were examined with scanning electron microscopy. The polymer composites and pure epoxy samples were found to have wear rates ranging from 17.82 to 172.96 mm3/Nm.

Keywords: Fly ash; polymer composite; characterization; wear; friction

1. Introduction

One industrial byproduct thought to be an environmental hazard is fly ash, which is created when coal is burned to provide electricity [1]. Millions of tons are produced globally as a result of rapid industrial expansion, and relatively little of it is recycled for other uses. If not appropriately managed, this massive volume of industrial waste might result in serious ecological and environmental issues. Research on the possible reuse and efficient use of these wastes has been carried out globally due to their ecological and financial significance. [2]. As the need for energy increases, it is anticipated that the fly ash disposal issue would worsen. Fly ash is mostly used to make fly ash bricks, road embankments, and Portland cement. Fly ash hasn't been utilized in the automotive or product development industries, which might be crucial for its repurposing, aside from these extensive uses. A inexpensive, semi-viscous fluid, epoxy resin is strengthened into a strong matrix material by adding ceramic filler, such as fly ash. Various kinds of metal, ceramic, and biological materials are employed as reinforcement in the form of particles or fibers [3]. Filler material contributes to the component's cost reduction while improving the mechanical, thermal, and tribological qualities. Alumina and silica have been employed in polypropylene and polyethylene by several researchers. However, there haven't been many attempts to employ inexpensive materials like coir, rose husk, jute fiber, or even chicken feather [4, 5].

Tribology is a crucial factor to consider when describing any material since it has to do with material loss in the application region. These composites have good wear behavior qualities because of the hard reinforcing phases, particles, fibers, or whiskers that they include. When the temperature of the material reaches its melting point owing to frictional force, the wear rate accelerates quickly under loading conditions [6, 7]. Therefore, there should be as little wear as possible while using the material in order to prolong the part's life. Therefore, increased loading conditions result in a higher operating temperature with an increase in wear and hasten the replacement of parts [8]. Because of their great strength and slow rate of erosion, lightweight polymer matrix composites like glass fiber and carbon fiber are the best materials for applications including weight considerations in the automotive and aerospace sectors [9].

Accordingly, the current study has been centered on creating fly ash epoxy composite, and a sliding wear test has been conducted on it under various treatment settings to determine the least amount of wear the product is enduring. Three distinct treatment conditions—normal atmospheric, oven treatment, and micro oven treatment—have been used to conduct wear tests. The length of time needed to cure in an oven or micro oven has been established by experimenting with different temperatures and times, and the ideal condition is selected while taking mechanical strengths into account. The ideal oven treatment conditions are discovered to be 30 minutes at 1200c in the oven and 5 minutes in the micro oven at 60% power flow prior to the tribological experiment. The change in enthalpy brought on by the treatment is displayed on the DSC analysis curve. The goal of the current study project is to improve the polymeric sample's surface area and general characteristics in comparison to a standard curing-conditioned sample. The effects of applied load, sliding circumstances (duration, distance, speed, etc.), and fortification volume % on the dry sliding wear of composites have been discussed by a number of studies [10, 11].

2. Materials

2.1 Cement

Ordinary Portland cement, fine aggregate, coarse aggregate, fly ash, and red mud were the primary ingredients of the FGC. In the construction sector, cement, fine aggregate, and coarse aggregate are often utilized materials. According to IS 12269:1987, ordinary Portland cement of grade 53 is used, and it is classified as C150 (Type I) cement with a specific gravity of 3.15 by the American Society for Testing and Materials (ASTM). The coarse aggregate, which is hard blue granite stones from quarries and has a specific gravity of 2.78, is utilized in 20 mm size. The fine aggregate comes from a natural river and has a specific gravity of 2.67.

2.2 Flyash

The chemical analysis of fly ash reveals a diverse composition, contributing to its versatile properties. The predominant oxides include 47.4% SiO2, indicative of a substantial silica content that enhances the material's pozzolanic activity. The presence of 6.66% CaO suggests potential reactivity with water, contributing to cementitious characteristics. Aluminum oxide (Al2O3) at 19.8% and iron oxide (Fe2O3) at 11.8% confer strength and durability to the fly ash. The significant content of Fe2O3 also imparts a reddish color to the fly ash. The oxides Na2O (0.57%) and MgO (4.76%) play a minor yet influential role, contributing to the overall chemical balance.

The loss on ignition (LOI) value of 6.39% indicates the combustible components present in the fly ash, which may affect its thermal behavior during applications. Understanding these chemical constituents is crucial for optimizing the utilization of fly ash in various industries, such as construction and manufacturing. The high SiO2 and Al2O3 content align with the potential for fly ash to act as a supplementary cementitious material, enhancing the performance of concrete. Additionally, the diverse chemical makeup underscores the importance of tailoring processing techniques to leverage the specific attributes of fly ash in different applications, ultimately contributing to sustainable and efficient material utilization.

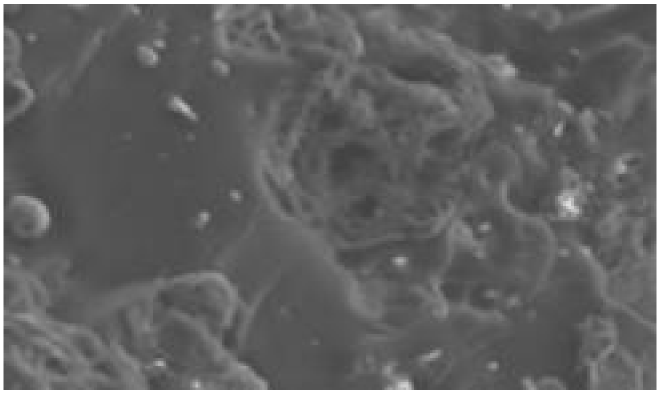
2.3 Polymer composite wear tests

Using a ball-on-disc test device, scratches were made on epoxy-based samples in order to conduct friction and wear testing. WC-Co balls with an average hardness of 1895 HV and an 8 mm diameter were utilized in the abrasion testing. Faults arising from possible corrosion on the abrasive element's surface have been eliminated by employing a different abrasive element in every experiment. The ball-disk system underwent abrasion tests with dry friction, room temperature, weights of 5, 10, 15, and 30 N, a shear rate of 0.3 m/s, and a distance of 500 m. The rugosimeter, which is derived by multiplying the wear cross-sectional areas by the circumference of the created wear trace, provided data assistance for the calculation of the specimens' abrasion volumes at the conclusion of the wear test. By dividing the slip distance on the polymer composite sample by the quantity of weared volume of the applied load, the rate of wear was determined. A friction coefficient software was used to determine the friction coefficients of weared samples based on sliding distance.

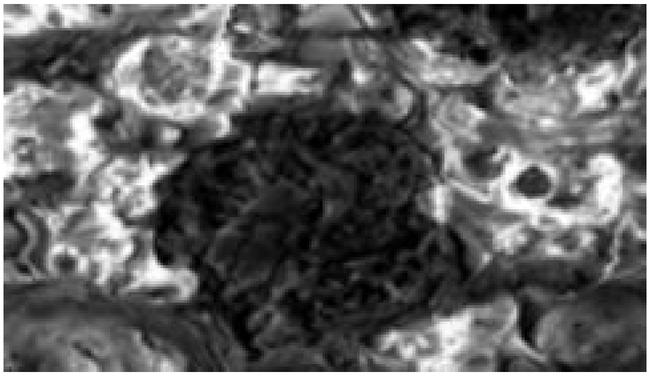
3. Results and Discussion

3.1 SEM Analysis

Figure 1 displays the SEM microstructures of the epoxy composite samples that were utilized in this investigation and included different amounts of FA. Figure 1 illustrates how the tightly solidified polymer matrix has covered the area surrounding the fly ash granules. This instance demonstrated the strong connection between the fly ash granules and the polymer matrix. As the quantity of FA rose, the hardness values of the composites increased correspondingly. The pure epoxy resin has a hardness of 84 Shore D (HD). The blended polymer composite samples containing 10%, 20%, and 30% FA yielded hardness values of 86 HD, 88 HD, and 91 HD, respectively. Compared to the control sample (0% FA), the blended composite sample with 30% FA had a hardness value that was 8.33% greater.



(a)



(b)

Figure 1. SEM micrograph of FA polymer composites: (a) 10% FA, (b) 30% FA matrix / fly ash

3.2 Surface Roughness

In assessing the surface roughness of polymer composites with varying fly ash (FA) content, notable trends emerge. The samples without added waste material and those with low FA content exhibit comparable roughness values, suggesting minimal impact on surface texture. However, a distinct trend surfaces in samples with a high volume of FA, where the surface roughness is notably lower than the FA-free specimen. The surface roughness values for fly ash-added polymer composites are as follows: pure epoxy - 0.38 µm, 10% FA - 0.419 µm, 20% FA - 0.474 µm, and 30% FA - 0.521 µm. This decline in roughness with increased FA content indicates a potential enhancement in the material's surface quality and smoothness, showcasing the influence of fly ash on the composite's final surface characteristics. Understanding these variations is crucial for tailoring composite formulations to achieve desired surface properties for specific applications, ranging from manufacturing to construction.

3.3 Friction Coefficient and Wear Rate

Friction coefficients for samples containing FA and control at various loads. Although the friction coefficient in FA0 samples is the lowest at 0.39, in 30% of FA-containing series, it climbed to 0.53. When compared to control series, the use of FA in polymer composites results in a greater friction coefficient. An increase in load causes all of the series' friction coefficients to rise. By eliminating particles and additives from the sample during wear and in the wear zone (between the sample and the pin) during wear, the friction coefficient rose in the samples with high additive content. Generally speaking, one of the best markers of wear resistance is a low friction coefficient. It was discovered that when the material's additive ratio increased, the friction coefficient also increased. Both the friction coefficient and the amount of nanoclay added to the matrix increased. This is thought to be caused by weakening polymer chains that result from adding more additional ingredients.

Depending on the FA concentration, the wear rates of polymer composites for 5, 10, 15, and 30N. The wears of composites reduced as the FA content increased. Pure epoxy series yielded the greatest wear rates under all loading scenarios. The range of wear varied depending on fly ash content: at 5N, it was 59.64x10-4 to 17.82x10-4 mm3/Nm; at 10N, it was 80.13x10-4 to 36.75x10-4 mm3/Nm; at 15N, it was 119.14x10-4 to 42.87x10-4 mm3/Nm; and at 30N, it was 172.96x10-4 to 60.12x10-4 mm3/Nm. Put otherwise, an increase in waste content resulted in a 2.87-fold improvement in fly ash composites' wear resistance at 30 N. Wear rate decreased as the FA addition ratio increased. This indicates that the addition of FA causes the polymer material to become harder and changes the surface character of polymer composites. Because there was greater homogeneity in the distribution of grains with good abrasion resistance, wear strength was higher in high FA ratios than in low FA ratios. However, independent of the FA ratio, the wear rate increased with load for all samples when the wear loading value was taken into account. Because of increasing friction and abrasion on the fly ash sample surface, the wear rate increased as the load rose from 5N to 30N.

A fascinating discovery from this investigation is the correlation between wear rate and hardness for polymer composites including FA. The FA concentration rises, the samples' hardness values also rise. As may be observed, wear resistance rises as hardness does. The relevant equations. For every loading test, the coefficient of correlation is extremely near to 1.0, with a maximum value of 30 N. To help with the examination of the surface quality on the tribological characteristics of the investigated epoxy-based polymer composites, the derived regression functions. The friction coefficient as a function of surface roughness is displayed in this graphic. Surface roughness and friction coefficient have a weaker association at 5N (R=0.948) loading conditions than at 30N (R=0.994). These findings demonstrate that under high loadings, the relationship between friction and surface roughness is improved.

4. Conclusion

Using fly ash improved the hardness values of the composites containing FA in comparison to the control sample. Surface roughness ratings rose with the fly ash ratio. Compared to the control sample (0% FA), the blended composite sample with 30% FA had a hardness value that was 8.33% greater. The surface roughness values in specimens with and without low FA concentration were obtained in close proximity to one another. When compared to control series, the use of FA in polymer composites results in a greater friction coefficient. An increase in load causes all of the series' friction coefficients to rise. The pure epoxy sample's surface roughness rose by 37% after 30% fly ash was added. The range of wear varied depending on fly ash content: at 5N, it was 59.64x10-4 to 17.82x10-4 mm3/Nm; at 10N, it was 80.13x10-4 to 36.75x10-4 mm3/Nm; at 15N, it was 119.14x10-4 to 42.87x10-4 mm3/Nm; and at 30N, it was 172.96x10-4 to 60.12x10-4 mm3/Nm. Because there is a more uniform distribution of particles with a strong resistance to abrasion, wear strength is better in high FA ratios than in low FA ratios. By increasing the fly ash concentration, samples with more fly ash at 30 N show an approximately 2.87-fold improvement in wear resistance. Surface hardness and wear rate have been found to be well correlated; for epoxy-based and FA mixed polymer composites, the friction coefficient and friction coefficient are derived, respectively. Surface roughness and friction coefficient have a weaker association at 5N (R=0.948) loading conditions than at 30N (R=0.994). The "border effect" is produced on the surface by an increase in load. At greater loading circumstances, the border effect causes the friction coefficient to rise. FA particles were discovered to be uniformly dispersed inside the epoxy matrix during microstructure investigations. In the additional fly ash specimen wear tests, surface wear events included scratches, delamination wear, abrasive wear, and sticky wear. The wear depth reduces as the fly ash additive ratio rises.

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