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Investigation on dry abrasion wear of natural and synthetic fiber reinforced polymer composites filled with stone waste

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Abstract

The fiber reinforced polymer composites filled with industrial stone waste was fabricated using vacuum assisted resin transfer molding (VARTM). The fabricated samples of composite plates were subjected to parametric studies of dry abrasion wear test. The control factors considered for parametric studies of were load, abrading velocity, percentage of stone waste and size of abrasive particles.

The mean S/N ratios for dry abrasion wear were to be 4.71db, 6.48db and 7.98db for granite added jute, glass and carbon fiber reinforced polymer composites. ANOVA analysis helps to identified the order of most influencing input operating parameters on output response dry abrasion wear and order of most significance input operating parameters in decreasing order abrasion load>Wheel

rotation>Filler content>Abrasive size for granite added jute, glass and carbon fiber reinforced polymer composites.

Introduction

Polymer composite materials are the most prominent materials in various industrial applications due to their ease of synthesis, attractive properties, and economical cost. The application found the use of synthetic as well as natural fiber reinforcement in fabrication [1], [2], [3], [4]. The different applications necessarily require abrasion-resistant properties for such things as brake shoes, seals, rollers, clutches, washers, tires, and impellers. The abrasion resistance properties of fiber-reinforced polymer composites can be improved by the incorporation of shard filler particles.

Past studies illustrated the two- and three-body abrasive wear behavior of polymer composites. Harsh et al. [5] conducted three body abrasive experiments on the polyaryl ether ether ketone (PEEK) composites and examined the influence of fibers, solid lubricants, mass of abrasives, and load. The research finding indicates that fiber increment enhanced wear resistance, whereas the inclusion of solid lubricant graphite showed detrimental wear performance. Carbon fiber-reinforced polymer composites show the worst abrasive wear resistance as compared to glass-reinforced polymer composites. The effect of surface modification of jute fiber on abrasive wear of composites was examined by Swain et al. [6]. The composites fabricated with alkaline and benzoyl chloride-treated jute fiber showed better wear performance as compared to composites with untreated jute fiber. Sandeep and Justin [7] analyzed the effect of graphite filler on the abrasive wear performance of glass fiber-reinforced polymer composites. The experimental result depicted that the addition of 3 wt% graphite shows better wear resistance as compared to 6 wt% and 9 wt% reinforced composites. A three-body abrasion wear test was conducted on glass/carbon fiber-reinforced polymer hybrid composites by Mandel et al. [8] They found that hybrid fiber composites show better wear resistance than glass and carbon fiber-reinforced composites. Erturk and Fahri investigated the effect of pure water, mineral oil, HNO3, and NH3 treatment on the abrasive wear performance of hybrid reinforced polyester composite [9]. They observed that the sample treated with HNO3 and NH3 showed the worst wear performance as compared to the sample treated with pure water and mineral oil. The impact of alkaline treatment on the abrasion wear performance of Urena Lobata natural fiber-added polymer composites was evaluated by Niokuet et al. [10]. They found that alkaline-treated composites show improvements in wear resistance as compared to untreated composites. Chand and Neogi examined the abrasion wear mechanism of FRP composites. After performing the experiment, they concluded that wear rates increase with an increment in sliding distance [11]. Wear micrographs clearly indicate that macro- and micro-pits, along with micro-cracks, were formed during experiments. The same authors performed an abrasion wear test on laser-irradiated GFRP composites, and experimental results depicted that laser irradiation improved the abrasive wear performance of GFRP composites [12]. Abrasive wear characteristics A lantana camara fiber-reinforced polymer composite was investigated by Deo and Achary [13]. They observed that abrasive wear increases with an increment in sliding velocity; the reverse trend was obtained for sliding distance. Vishwas et al. [14] performed abrasive wear on a novel Jute/Natural rubber flexible green composite and concluded that the specific wear rate is dependent on the sliding distance and component that is exposed to the abrasive medium, and the specific wear rate of a flexible composite can be reduced by the addition of rubber. Vivek Mishra and Sandhyarani Biswas explored the abrasive wear phenomenon for Bidirectional Jute fiber-reinforced epoxy composites and found that 36 wt% fiber loading exhibits minimum wear among all fiber loadings [15]. The impact of short glass fiber on the abrasive wear of polyurethane composites was studied by Suresh et al. [16] observed that the addition of short glass fiber content enhances wear resistance. In an article investigating the effect of BC filler on abrasive wear, the filler additions showed significant influence on three body abrasive wear behaviors at different loads [17]. In another work, they examined the impact of graphite filler on the abrasive wear performance of carbon-epoxy composites, and experimental results exhibit that the addition of silane-treated graphite filler to C-E samples enhances wear performance [18].

Abrasive wear is a complex phenomenon due to the involvement of various input parameters, and these parameters play a vital role in influencing the output parameters response (wear). Material researchers need to optimize these parameters; various optimization techniques, such as Taguchi surface response methods and various multi-objective techniques, were implemented by researchers [21], [22], [23], [24], [25], [26], [27], [28]. Swain et al. [6] implemented the Taguchi technique to optimize the abrasion wear performance of jute fiber-reinforced composites. The Taguchi optimization technique was utilized by Sahin [19] to optimize the control parameters of abrasive wear for PTFE composite. They found that the optimal testing parameters and the result—predicted volume loss and specific wear rate values—lie close to the experimental values of the S/N ratio with an error of 1.604 and 2.81%, respectively. Mukesh et al. [20] optimized the abrasion wear parameters of hybrid epoxy polymer composites through the Taguchi technique; they further used the multi-objective hybrid AHPVIKOR technique for ranking purposes. The Taguchi technique shows the order of influencing factors of specific wear rate as abrading distance > normal load > reinforcement composites > abrasive size. The ranking of optimization analyses is done using the hybrid AHPVIKOR technique. It shows the order as MBE-5 > MBE-7.5 > MBE-2.5 > MBE-10 > MBE-0. The Taguchi experimental design was implemented by Vivek Mishra and Sandhyarani Biswas for evaluating the abrasive wear of Bidirectional Jute fiber-reinforced epoxy composites [15]. Factors like abrasive size, sliding velocity, and normal load affect the coefficient of friction of composites. Subhakanta Nayak and Jyoti R-Mohanty implemented a grey-based Taguchi approach for optimization of abrasion wear of areca sheath-reinforced polymer composites [21]. In dry abrasion, a percentage contribution of filler weight (56.90%), load (38.22%), and sliding velocity (3.67%) was achieved from ANOVA results. Taguchi design integrated with a neural network approach was used by Subhrajit Ray for optimization of the abrasive wear of marble-particle-filled Glass-epoxy composites [22]. They found that the optimal setting for minimum abrasive wear was sliding velocity (210 cm/s), normal load (10 N), filter content (15%), and abrading distance (80 m).

Section snippets

Materials and methods

In this article the composite panels were fabricated using epoxy as matrix material. The reinforcement is used in the form of glass, carbon and jute fibers. Waste granite powder was used as filler material for development of sustainable composite panels. Table 1 present the micro constituents of granite powder and mechanical strength respectively. …

Fabrication process

Vacuum Assisted Resin Transfer Molding (VARTM) technique was used for fabrication of a series of hybrid polymer composites. In this process fiber content is kept 40wt% (10 layers) constant and filler content is varying in four different weight fraction from 2wt% to 8wt%. A mixture of different wt. % granite filler with ethanol is prepared for spray on fiber sheet. The mixture is sprayed it on fiber sheet thoroughly with the help of mist spry gun. After some time, ethanol is evaporated in …

Dry abrasion wear test

The three-body abrasive wear tests were performed as per ASTM-G6541 standards using a dry sand and rubber wheel abrasion tester. The dry sand particles of AFS 60 grade were used as abrasives and they are irregular in shape with sharp edges. The abrasives were introduced between the test sample and rotating hard rubber wheel. The rubber wheel was composed of organic chlorobutyl material (hardness: 60±5 shore). The tests were conducted at rotational speed of 200rpm to 800rpm for 20min. The …

Taguchi DOE procedure

Taguchi is a one of the best statistical analysis tool of design of experiments. In dry abrasion wear various parameters are involved, some are controllable such as: abrading distance, normal load, abrasive size, abrading wheel speed, reinforcement composition, etc. The uncontrollable parameters such as: environmental temperature, humidity, etc. are not considered in this study. These operating parameters influence the output response (specific wear) of dry abrasion wear directly or indirectly. …

Results and discussion

The dry abrasion wear experiments were conducted as per Taguchi orthogonal array L_{16} and output response was measured for each experiments presented in Table 5. Minitab 17 software was used for analysis. The output response is converted into S/N ratio for dry abrasion wear test. The main factor plots for S/N ratio were presented in Fig. 1, Fig. 2 and Fig. 3 for granite added jute, glass and carbon fiber reinforced polymer composites respectively. The mean S/N ratios for dry abrasion wear were …

Conclusions

Some findings were drawn through the research work conduct mention below:

1. The stone industrial waste (Granite powder) added (Natural/Synthetic) fiber reinforced Polymer Composites fabricated through vacuum resin transfer molding technique, then dry abrasion wear parametric optimization carried out through Taguchi optimization technique. …

2. The following operating parameters (abrasion load, wheel speed, filler percentage and abrasive particle size) of dry abrasion test were optimized …

3. The mean S/N …

…

CRediT authorship contribution statement

Vikash Gautam: . **Deepak Kumar:** Methodology. **Ashiwani Kumar:** Writing – original draft. **M.J. Pawar:** Writing – review & editing. …

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. …

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