International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-5, June 2019

Effect of Fillers on Erosion Wear Rate of Polymer Matrix Composites

Raffi Mohammed, B Ramgopal Reddy, Abdul Siddique Shaik, Aluri Manoj

Abstract*— *Over conventional materials as polymer matrix composites possess advanced properties; their usage has been increased from past few years in regard with the engineering applications over the enhanced performance and conventional materials. This influenced the researches to extend their work on composites of polymer. In this the researches are very keen to work on polymers composites erosion properties. The possible improvement of the composites which are filled in regard with the erosion resistance property has attracted the research scholars to know the practicability in usage of different materials of filler for particular applications of erosion resistance in polymer matrix. In concern with the filled composite tribological performance, available literatures are very few. The main agenda of the current study is to review the different literature of loaded composites erosion characteristics which were performed till date.

***Key words:** Erosion wear, impingement velocity, polymer matrix composites, impingement angle, standoff distance.*

1. INTRODUCTION

Researchers have been attracted to the composites which are based on polymers as they are suitable for engineering applications having required properties. Due to their durability and greater strength, cost effectiveness and easy process of fabrication, composites are well known [1], [2]. In order to achieve the various application requirements and he ratio of high strength to weight, polymer matrixes gets reinforced with the different fillers and fibers [3], [4]. Reinforcement of the filler particles to the composites of the advanced polymer have become an trend in different engineering applications of biomedical and aerospace [5],[6] satellite devices, structural applications, low thermal expansion, heat dissipation areas and low- weight are needed[7],[8]. Later the use of polymers in products of household, sports equipment and applications for commercial purpose which are strengthened with the fillers [9]. With the main motto to modify mechanical properties along with physical properties different kinds of reinforced fillers were used for polymers matrix by including the filling material, we can increase the mechanical properties as hardness, tensile and erosion resistance [10], [11].Even the traits of the composite which is resulted also effect the matrix material and filler properties down with fillers properties. Loss of material is promoted by the wear which is the mechanical damage and it additionally costs high. In order to escape from failure impact, wear should be referred well on material [12]. There are diverse wear utilized in influencing the materials. One such wear is the erosion wear which promotes the expulsion of material from the material surface, when the solid particles hit the surface of the material. The typical method of material damaging with polymer composites with erosion impacts the working conditions and Material properties highly [13]. The erosion attributes of the polymers are controlled by a few parameters for example, impinging velocity, angle of impingement, pressure, standoff distance, exposure time, erodent size, orientation of the fiber, length of the fiber, filler proportion and fiber content[14]. As of late, composites with reinforced fillers fabrication is high and research on erosion investigations of these kinds of composites were expanding. In this survey, wide reports of composites of polymers are made on erosion impact.

II. FILLERS AS MATRIX MODIFIER

For the most part, particles of solid which are reinforcing material for solid are fillers which were added to improve and change the properties of material, particularly for mechanical properties improvement. A metallic particulate, organic and inorganic material has been chosen as the materials of filler. Micro size and nano size fillers were used for the composite reinforcement [15]. Generally, fiber addition with the matrix upgrades the polymer composites mechanical properties while the particles of filler does the modulus increment [16]. Resin melting restriction, with the help of the filler by the absorption of heat in the composite whenever the conditions of working are high[17].Matrix uniformity and the distribution of the filler in composites gets affected by the reinforcing filler, which can cause the composite properties deterioration [18],[19]. The reinforcement potency of the material filled depends upon the many filler properties interface, contains shape of particle, size of particle, dispersion, surface reactivity, surface area, Matrix and filler bonding quantity and the fiber structure[20]. Discovering attributes of composites which are filled helps in composites preparation with properties required [21].

Manuscript published on 30 June 2019.
* Correspondence Author (s)
Raffi Mohammed, Research scholar, ANUCET Guntur& Associate Professor, MED, Ramachandra College of Engg., Eluru
Dr. B.Ramgopal Reddy, Associate Professor, Department of Mechanical Engineering of RVR & JC College of Engineering Chowdavaram, Andhra Pradesh.
Dr. Abdul Siddique Shaik, Faculty of Mechanical Engineering, King Khalid University, KSA
Aluri Manoj, Undergraduate student in the Department of Mechanical Engineering, RGUKT, Basar

Polymer composites mechanical and wear properties. Performance depends on the micro structural homogeneity and the scattering state of the filler material to a great extent.

As per Rothon [22], we have two categories in classification of fillers as synthetic and mineral fillers. Synthetic fillers have been setup by limited characterized readiness process: synthetic silica, carbon black, calcium carbonate which is precipitated, magnesium hydroxide, alumina trihydrate and so on are few synthetic fillers. Mineral fillers are available naturally. Dolomite, calcium carbonate, nano-clay, mica, talc, clay, calcium sulphate, crystalline silica, wollastonite and so on are some mineral fillers. Aside from these, in polymer composites different researchers had utilized various filler materials. Agricultural debris like mango's bare fronds and palm fronds were used as filler materials by Ibrahim [23] in polyester matrix. In order to study the developed composite's mechanical performance epoxy/glass fiber composite were added with the Silicon dioxide/Aluminum oxide/TiO2 particles [24]. Epoxy composite's wear and mechanical properties due to the graphite filler effect were studied by Shalwan and Yousif [25]. Mechanical characteristics of the reinforcement of the glass fiber and polyester composite having filler material of Al2O3 (Aluminum oxide), Sic (silicon carbide) and particles of fly ash, has explored by Patnaik et al. [26]. To explore of the reinforcement impact of industrial waste has been used in the polymer composites by Preby et al. [27]. In between coconut shell and wood apple a correlative study has done in a process to apprise the composite's tribological and mechanical properties which are bio-waste filled [28]. In matrix due to the inclusion of the particles of hard filler polymer composites tribological properties can be improved [29]. The existing document has well reported about the erosion and mechanical property of the composites of polymer on inclusion of filler. It was observed from the above that mechanical and wear resistance property can either demote or improve which is based on the filler along with matrix interaction within polymer composites [30].

III. SOLID PARTICLE EROSION ON POLYMER MATRIX COMPOSITES

In different applications polymer composites usage is very high, where there will be in effect by much failure and damage. In exceedingly erosive condition erosion is the essential tribological phenomena where the material structures get affected. Various methods can be utilized for erosion resistance improvement. With an aim to enhance the erosion resistance of the polymer; fiber reinforcement is one of the most renamed techniques. In later days, polymer matrix were joined with the filler particles and explored for thermal, chemical, physical, mechanical and other required qualities in view of the utilization need. From the past coming years, good interest has been shown on polymers which are filled with fillers for their tribological behavior and the property of wear resistance is tested for the filled composites [31]. In view of ASTM G76 standard the study was concluded on polymers regarding erosion wear. Reduced loss of erosion wear results has reported till date on performance of the reinforcement of the fiber-polymer composites. On the composite materials which are reinforced erosion characteristics comprehensive review was reported by Patnaik et al. [32]. The impact on erosion behavior of filler and fiber of the polymer composites has been detailed in their view. Evaluation of erosion wear by utilizing Taguchi analysis has also been done. Omrani et al. [13] investigated and discussed about, reinforcement of the polymer composites-natural fiber and their tribological characteristics detailed explanation has also been presented on characteristics of natural fibers. The reported works of composites on the erosion behavior which are filled has been documented concisely in this article. Survey observations made clear that only a limited count of review articles which discussed about the property of erosion of polymer composites has been published.

IV. RESULTS AND DISCUSSION

EROSION WEAR CHARACTERISTICS OF VARIOUS FILLER PARTICLES BASED POLYMER COMPOSITES

4.1 Fly ash

The residue which is unburned in power plants during the coal combustion is Fly ash. Relying on the presence of carbon content, the color of these wastes are gray (or) black generally [33], [34]. Different mechanical characteristics have been studied by the successful incorporation of the fly ash into the polymer matrix along with different metal [35]-[38]. Chand et. al. [39] has used the cenosphere fly ash which is treated with silane filled composite of polyethylene of higher density, to study its performance of wear. The erosion resistance has been improved due to the fly ash addition into fibers of jute and glass in hybrid composite. Conclusions from experimental analysis states that the erosion rate has a high effect in the composite by the reinforcement of the filler [40].Patnaik and Satapathy [41] has studied on polymer matrix which is embedded with the glass fiber using fly ash as filler. The fly ash which is selected contains aluminum oxide (20.2%), silicon oxide (48.3%), titanium oxide-1.9% and iron oxide (6.4%). Fly ash particle proportion has been varied for single composite for 50% of fiber 20, 10 and 0 weight percent of fly ash has been added. Erosion and mechanical tests on composites which are developed has been performed. From the observed results, fly ash addition shows some negative impact on mechanical property but it has enhanced the erosion property. Using Taguchi approach the impact of fly ash percentage, impact velocity, angle of impingement, size of erodent and standoff distance analysis is done. From the analysis of the Taguchi result, to minimize the rate of erosion the percentage of fly ash has a greater significance. At 600 angle of impingement erosion rate is observed maximum for filler composites. At the condition of higher erosion, a property of semi ductile has been exhibited by the filled composites by all the three proportions. Ismail et al.

[42] has revealed erosion and mechanical characteristics from his work done. Epoxy matrix has been reinforced using carbon fabrics. Matrix gets added with the fly ash at four different percentages of weight (0%, 2%, 4% and 6%) and impact erosion for solid particle has been tested.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

Flexural strength, tensile strength and such other mechanical properties are reduced by including filler. But a remarkable growth in erosion resistance by filled composites was shown. Reduction of erosion rate is influenced highly by the adding filler to the matrix is noticed in Taguchi analysis. When the angle of impingement is 30o shown behavior of erosion is ductile by both the composites. Even increment in the rate of erosion is spotted during the process of experimentation. Reinforcement of the E-glass fiber and the epoxy composite by adding fly ash, the test of solid particle erosion is performed by the Srivastava and Pawar [43]. Fly ash of 3.385 g/cm3 density is mesh size (105µm) sieved and incorporated with two various percentages of weight. Air jet erosion tester was used for erosion test at three various velocities of impact (24, 35 and 52m/s) and at different angles of erodent impact (30o-90o). Results of erosion test were compared between the unfilled and filled composites, where as improved Properties of erosion have been observed in the filled composite rather than in unfilled composites. This is due to having less strength of bonding between fiber and matrix. Minimum rate of erosion is noted at 24m/s composites velocity of impact which is having 4g of fly ash. It is proved from the analysis of SEM (Scanning Electron Microscopy) that, materials removal of fiber and matrix and even fibers breakage was the reasons for overall erosion and also spotted that addition of the filler helps in preventing cracks propagation. Raghavendra et al. [44] studied and compared the reinforcement of jute-(J) and glass-(G) Fiber which is filled with fly ash for their erosion and mechanical behavior. At variant percentages of weight 15,10,5&0 wt%) addition of micro-sized fly ash (10 and 40 µm) was done on varying the sequence of the fiber samples of composites were prepared such as JJJJ,GGGG,GJJG,JGGJ,GJGJ and a epoxy composite which is neat. The inclusion of fly ash material as filler has increased erosion and mechanical properties on all composites. Low erosion rate has been observed by reinforcing composites of jute and fly ash when compared with the composite of glass fiber and fly ash reinforcement. Strength increase of 10% has been observed in the filled composite, when compared between the GJJG sequence of unfilled and filled composite. Morphological studies have confirmed the better bonding across fiber and matrix reinforcement within the reinforcement of glass and jute fiber with polymer matrix.

4.2 Red Mud

Red mud is the leftover which is comes into existence at the time of Bayer process where aluminum extraction is done. Iron oxides of 60%(approximately) is present in the red mud and Al_2O_3, Fe_3O_3, TiO_2, CaO, Na_2O, SiO_2 etc at different proportions as remaining constitutes[45].Study on polymers which are formed by the red mud are investigated actively by many researchers [46]-[50]. Satapathy and Patnaik[51] has explored erosion wear resistance of polymer composites which is loaded with Red mud and stated that red mud is a good build up material for wear application in polymer composites. Reinforcement of epoxy and glass fiber with red mud as filler material has studied by Biswas and Satapathy [52]. The motto of this study is to find the red mud composites tribo performance. Having 50% fiber weight and 0%, 10%and 20% composition of red mud, the composites are made. Following the ASTM G76 the erosion test has performed which developed composites rate of erosion were observed by taking different factors into account like temperature of erodent, red mud content, standoff distance, angle of impingement and velocity of impact. Especially, addition of red mud has lowered the flexural and tensile strength of polymers but marginal increase in impact strength is observed. Parameter influence in Taguchi analysis has shown that, prominent decrease in erosion is observed in addition of red mud then different parameters. At the 60o angle of impact maximum erosion is seen for all the filled composites. The composites property of semi ductile is influenced at different applications of high- erosion, the work offered the viable use of composite filled with red mud which is developed such as industrial fans, fiber boats and water sports kits. Erosion effect has been examined on fabricated composites of glass-polyester using particulates of red mud as filler by Jena et al.[53].Preparation of composite material was with the added filler (red mud particulate) to the reinforced glass fiber with polyester matrix. By changing weight percentage of fiber and proportion of red mud, total fabricated composite samples were eight varying the circumstances of the experiment, composites were tested erosion rate of the solid particle by utilizing erosion test rig which is of jet type. Erosion mechanism of composite of glass-polyester with red mud filler's ductile property has been changed by introducing filler. Erosion behaviors of composites of glass-epoxy and bamboo-epoxy which are filled with red mud was studied and explored. Later, the two composites wear and mechanical characteristics have been compared. Air jet type test rig has been utilized top test erosion, next to the experiment's design of Taguchi method. Settings of optical parameters were used to determine with the help of Taguchi approach. Better performance has been seen with the bamboo-based composites when correlated with the glass fiber composites. In both glass and bamboo fiber composites erosion wear resistance has been improved by the filler inclusion [54].

4.3 Alumina

Alumina filled epoxy /glass composites were investigated to know the reaction of erosion on unlike parameters by performing slurry erosion test by Josh et al. [55]. 5%, 10%, 15% are the different proportions of Alumina added to matrix. Composites hardness increases by adding the filler Alumina.

Penetration of abrasive slurry is restricted by the hardness increment on the surface of composite. Good results on erosion with the help of filler and also prohibited the abrasion penetration. By adding alumina as a filler material with polyester matrix Patnaik et al. [56], performed the erosion test with three various alumina proportions (0%, 10% and 20%) fabrication of composite is done. Fiber matrix debonding has worked appreciably, where as the composite improves the erosion resistance. Even the flexural properties like tensile gets reduced by the filler particulates addition. Wear rate to reduce optimum filler percentage is 11.82 which is found through analysis of genetic algorithm.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

Alumina filled hybrid composite containing reinforcement of glass fiber which explains erosion effect is a further work of Patnaik et al.[57].Test results of erosion were compared with polyester composites with glass fiber unfilled. Filled composites undergo minimum erosion loss compared with the unfilled composites. Filler addition takes the credits for this where the erodent particles which are impacting hard and impacting force, part gets absorbed and fiber damage action gets delayed. Epoxy composites which are filled with Alumina have reinforced coir fibers have been explored by property of erosion resistance by Das and Biswas [58]. Erosion resistance results show that the better results are found with filled composite when compared with the unfilled. Bagci [59] fabricated a composite material by using 15% of SiO2 and 15% of Al2O3. Low erosion was noted by the filler addition greatly improved the composites bond strength. From the surface of the composite the reinforcement delimitation shown eroded surface by SEM analysis due to solid particles repeated attack.

4.4 Tungsten carbide

To examine the behavior of the erosive wear, the impact of inclusion of Tungsten Carbide powder in composite of reinforced fiber-epoxy is explored by Mohan et al. [60]. Fabricated compositions were 34% of matrix, 64% of fibers and 4% of tungsten carbide (WC). Erosion rate is influenced by the different angles of impinging (30o-90o) and velocities of impinging (40 and 80m/s). Less erosion rate is categorized with the composite filled with WC while compared with the composites which are unfilled. Matrix and fiber material damage has been observed intensely by the SEM analysis of the unfilled composite on the surface which is eroded. On three samples of epoxy (epoxy composite of WC filled and silica filled and composite of plain epoxy) by performing pin on disk experiment by Crivelli Visconti et al. [61]. While compared with the plain matrix better wear resistance has been shown by filled matrix. At different experimental conditions, good wear resistance is exhibited by the WC. Abrasive wear for two-body test on WC unfilled-filled epoxy composites which is conducted by Mohan et al. [61]. 60% of fiber is added to the matrix with the 4wt% of WC. Filler materials impact on wear rate concludes the erosion test result. Better wear performance has been shown by the filled composites when compared with the unfilled.

4.5 Silica

Abenojar et al. [62] studied on epoxy composite which is silica filled for cavitation erosion. The filled composites improved erosion resistance has been observed in the results.

Three various ceramic fillers were utilized (silicon carbide (Sic), alumina (Al2O3) and cement by pass dust (CBPD) fabricated hybrid composites were explored for performance of solid state erosion. Enhancement in erosion resistance has seen in Al2O3 compared to SiC and CBPD. Filler materials importance to affect erosion rate is proved by the ANOVA analysis [63]. Composite fabrication of silicon oxide (SiO2) particle fillers for reinforced glass fiber- epoxy is done by Bagci et al. [64]. When compared between composites of 30% SiO2 and 15% SiO2, high erosion rate is observed with the 15% SiO2. As weak bonding property has been seen in case of 15% SiO2 when compared with particle reinforcement of 30%. Patnaik et al. [65] examined the composites of glass fiber polyester which is filled with Silicon Carbide is compared with unfilled glass fiber. Results of the test are clear that the enhancement in property of erosion resistance of composite which is filled is compared with unfilled composite. High impact velocities ductile characteristics have been seen and at minimum impact velocities, semi- ductile erosion traits have been seen for SiC filled composites. Increase in micro hardness has been observed while flexural and tensile strengths decreased with composite of glass polyester which are filled with SiC in the work done by Patnaik et al. [66]. Significant increase in erosion resistance when the filler weight content increases. Ductile property of the polymer composite has been changed with the addition of the filler as it is proved when unfilled composites erosion rate has increased. Glass epoxy composite were reinforced with the SiC which was extracted from the bamboo for exploring the developed erosion characteristics. SiC filler content increase results in decrease in rate of erosion wear. The investigation results concluded that the filler weight percentage results in the composites property enhancement of erosion resistance in composites which are filled [67].

4.6 Borax

Some researchers used borax/boric acid in polymer composites which are product of highly refined in industries [68], [69]. With matrix weak bonding is developed by the borax and the impact of abrasive particle results higher erosion wear [70]. Reinforcement of the glass-fiber epoxy composite with boric acid filled with 15% and erosion resistance loss have been reported by the investigation of Bagchi and Imrek[71]. This results mainly due to weak interaction between the boric acid and epoxy matrix. SEM analysis reported the heavy erosion damage between particles and matrix is poor. Composite which is the reinforcement of the glass fiber and epoxy with Bagci and Imrek [72] Tensile and hardness property were increased with the addition of filler which results the reduction of rate of erosion rate.

4.7 Basalt Powder

A Kinci et al. [73] examined the polyethylene composites which are filled with Basalt particle for their erosion behaviors. 70%, 50%, 30% and 10% were the four different weight percentages of Basalt. For their tensile properties, erosion rate, fracture toughness and hardness testing has been done for fabricated composites which are filled. Decrease in toughness and tensile strength and increase in hardness is observed on basalt addition. At various experimental conditions erosion test rig was utilized for erosion wear test. Experimental observations state that no effect has been observed till when the basalt composite is 30%, later the erosion rate increased with the increment in filler weight.

Matrix has more effect on the abrasive attack than filler is proved by the erodent surface examination.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-5, June 2019

4.8 Granite Particles

Fabrication of composites has been done by varying four different weight proportions of filler (15%, 10%, 5% and 0%). By changing fillers content, velocity, impact angle, standoff distance and abrasive size the experiment was conducted on erosion. Although inclusion of filler has reduced flexural and tensile strength badly but the wear response has improved. Ductile composite has changed to semi-ductile material by filler addition. Impact energy which is caused by the erodent will be absorbed by the added filler material. Here composites erosion has been reduced in return [75].

4.9 Tantalum Niobium Carbide

Tantalum niobium carbide filled composite of glass epoxy's wear behavior has been studied by Mohan et al [76] by changing input parameters test was done with pin on disc machine. Filled composites wear rate has been seen low. Hard particles addition proceeds as wear resistance and matrix reinforcement has been protected from wear damage.

4.10 Egg Shell Powder

Epoxy composites were added to the powder of eggshell at different percentages (12, 8 and 4 wt %) and erosion loss was tested. Compared to unfilled, filled composites show better performance in erosion results. As filled composites of boiled shell has moisture content to show poor erosion resistance when compared to the filled composites of unboiled shell [77].

4.11 Wheat Flour

Srivastava [78] on composite of glass fiber with wheat flour filled has done the solid particle erosion test. As the fiber and matrix reinforcement has the poor bonding property, poor erosion has been exhibited by the unfilled composites has been reported from the result of investigation. Superior erosion resistance was observed with the filled composite, good bonding strength is observed by the composite of glass fiber with wheat filler.

4.12 Rice Husk

Rout and Sat apathy [79] has examined the epoxy composites which is filled with rice husk and stated that reinforcement of the filler has resulted the good erosion and mechanical properties. At three different weight percentages (15%, 10% and 5%) Fabrication of composites is done, in that higher erosion rate is observed by the composite of 15% rice husk. Erosion wear loss is prohibited by the incorporated rice husk in the incorporated rice husk in the matrix. Impacting erodent kinetic energy has been reduced by part of energy absorption and also delays the exposure of the fiber, which became the erosion loss reduction's main reason.

4.13 Blast Furnace Slag

Slag of Blast Furnace (BFS) - as good erosion and mechanical characteristics were possessed by these composites where these composites which are filled can be utilized in the environments of high erosive [80]. Erosion resistance has been improved significantly on the composites of epoxy filled with BFS by erosion test. This shows BSF filler's potential in epoxy composites [81]. Padhi and Satapathy [82] have studied the erosion rate of reinforced glass fiber with BFS filler. Matrix got added with the BSF at three various weight percentages (10%, 20% and 30%). Semi- brittle nature is indicated at 75o impingement angle and higher erosion is shown irrespective of addition of filler. Reinforcement of the polymer matrix with the hard crystalline BFS filler particles may be reason for this. Filler content is next to impact velocity on a way to impact erosion rate reduction. Padhi [83] reported the impact on composites of glass fiber and epoxy by BES. Filler content has important part in enhancement of composites erosion resistance from the results observed from experimental analysis.

4.14 Borosilicate glass

Borosilicate consists of silica, boric oxide and few amount of alkali such as potassium oxide and sodium oxide. Gaurav Gupta et. al. (2014) found a good result using borosilicate glass microspheres as a filler material to the polymer matrix composite. Borosilicate glass microsphere possesses versatile properties such as higher thermal stability, high specific compressive strength and low moisture absorption. It is also having good corrosion resistance, thermal resistance and wear resistance [84].

4.15 Linz-Donawitz

Linz-Donawitz slag is a major solid waste generated in huge quantities during steel making. It is generated from slag formers such as dolomite/burned lime and from oxidizing of iron, silica etc. during refining of iron into steel in the Linz – Donawitz furnace. The major constituents of the Linz-Donawitz slag are iron oxide, silicon oxide and calcium oxide [85]. Pravat and Satapathy (2013) performed the experiment by taking Linz-Donawitz as a filler material in the epoxy composite [86].

4.16 Cement by pass Dust (CBPD)

Cement By-Pass Dust (CBPD) is a byproduct generated during cement manufacturing. It is a fine powder and similar to Portland cement in appearance. It is generated during the calcining process in the kiln. The major constituents of CBPD are CaO, SiO_2, Al_2O_3, Fe_2O_3, K_2O, Na_2O etc. Gupta et. al. (2011) studied the erosion wear behavior of Cement By-Pass Dust (CBPD) filled bamboo fiber composites. The key results were obtained by varying the weight percentage of the Cement By-Pass Dust (CBPD) in the bamboo fiber reinforced epoxy composite. The erosion rate of unfilled epoxy composite is greater than the CBPD filled epoxy composite irrespective of impingement angles [87].

4.17 Copper Slag

Copper slag is an industrial waste and it is generated as a byproduct during the smelting and refining of copper. During the production of one ton copper, approximately 2.2-3 tons of copper slag generates.

Copper slag is rich in various metal oxides, and it has very good properties to be used as a filler material in polymeric matrices. Sandhyarani (2014) studied the erosion wear behavior of Copper Slag Filled Short Bamboo Fiber Reinforced Epoxy Composites. The maximum erosion takes place at an impingement angle of60° for all the samples [88].

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

V. CONCLUSION

Due to the improved strength characteristics and also the good replacement material which suits the tough environmental material applications, polymer composites which are filled were attractive. As these materials utilization has been increasing researchers had focused on it to the potential utilization where important factor is erosion. The following conclusions were drawn.

1) Filler composites erosion behavior has been reviewed in this paper and filler reinforcement with the polymer matrix has an important job in effecting the properties of erosion can be noticed from results. Hence, whenever the erosion property is an important criterion, various applications can use filled composites.

2) As mentioned in literature, filler and matrix reinforcement bonding is very important for erosion resistance. Good matrix and filler bonding raise the polymers hardness. It very well may be reasoned that interface does a prevailing job by influencing the erosion qualities.

3) Filled polymer composite properties are decided by the particle size which plays a dominant role, even it is critical to examine the impact of size of filler in influencing erosion characteristics. Erosion performance can be varied by the impact of filler amount and filler particle type.

REFERENCES

1. Doreswamy D, Shivamurthy B, Anjaiah D. "An investigation of abrasive water jet machining on graphite/glass/epoxy composite." Int J Manuf Eng, (2015):1–11.
2. Feng J, Venna SR and Hopkinson DP. "Interactions at the interface of polymer matrix- filler particle composites." Polymer, 103(2016):189–195.
3. Ragab KA, Abdel-Karim R, Farag S. "Influence of SiC, SiO2 and graphite on corrosive wear of bronze composites subjected to acid rain" Tribol Int, 43,(2010):594–601.
4. Sudeepan J, Kumar K, Barman TK. "Study of friction and wear of ABS/Zno polymer composite using Taguchi technique." Procedia Mater Sci, 6(2014):391–400.
5. Conti G and Orlando. "Quality management and safety of bioresorbable polymers for biomedical applications." Bioresorbable Polymers for Biomedical Applications, (2017):101– 132.
6. Zare Y and Shabani I. "Polymer/metal nanocomposites for biomedical applications." Mater Sci Eng C. 60(2016): 195–203.
7. Hussain ARJ, Alahyari AA, Eastman SA. "Review of polymers for heat exchanger applications: factors con- cerning thermal conductivity." Appl Therm Eng 2017, 113(2017):1118–1127.
8. Ngo IL, Jeon S and Byon C. "Thermal conductivity of transparent and flexible polymers containing fillers: a lit- erature review." Int J Heat Mass Transf, 98(2016):219–226.
9. Boumbimba RM, Froustey C, Viot P. "Preparation and mechanical characterisation of laminate composites made of glass fibre/epoxy resin filled with tri bloc copolymers" Compos Struct., 114(2014):414–422.
10. Zhou R, Lu DH, Jiang YH. "Mechanical properties and erosion wearResistance of polyurethane matrix composites"Wear, 259(2005):676–683.
11. Ahmed S and Jones FR. "A review of particulate reinforcement theories for polymer composites." J Mater Sci, 25 (1990)4933–4942.
12. Sharma SC, Satish BM, Girish BM. "Wear characteristics of phosphor – bronze/silicon carbide particulate composites: J Mater Process Technol, 118 (2001):65–68.
13. Omrani E, Menezes PL and Rohatgi PK. "State of the art on tribological behavior of polymer matrix composites reinforced with natural fibers in the green materials world." Eng Sci Technol Int J, 19 (2016):717–736.
14. Deepak R, Arumugaprabhu V and Uthayakumar M. "Erosion performance studies on Sansevieria cylindrica reinforced vinylester composite" Mater Res Express, Epub ahead of print 16 March (2018).
15. Katchy EM. "Introduction to polymer technology." 1st edn. Enugu. ElDemark (2000).
16. Kumar A and Gupta RK. "Fundamentals of polymers." International edn. Singapore: McGraw Hill (1998).
17. Strzemiecka B, Voelkel A, Chmielewska D. "Influence of different fillers on phenolic resin abrasive composites. Comparison of inverse gas chromatographic and dynamic mechanical- thermal analysis characteristics." Int J Adhes, 51(2014):81–86.
18. Semakina OKD, Phomenko ANE, Leonteva AAD. "Research of surface properties of fillers for polymers." Procedia Chem,15(2015):79–83.
19. Hashmi SAR, Dwivedi UK and Chand N. "Graphite modified cotton fibre reinforced polyester composites under sliding wear conditions." Wear, 262(2007):1426–1432.
20. Ishak ZM and Bakar AA. "An investigation on the potential of rice husk ash as fillers for epoxidized natural rubber (ENR)." Eur Polym J, 31 (1995):259–269.
21. Vigneshwaran S, Uthayakumar M and Arumugaprabu V. "A review on erosion studies of fiber- reinforced polymer composites." J Reinf Plast Compos. 36(2017): 1019–1027.
22. Rothon.RN. "Particulate fillers for polymers." United States: iSmithers Rapra Publishing., 12(2002).
23. Ibrahim RA. "Tribological performance of polyester composites reinforced by agricultural wastes: Tribol Int., 90(2015):463–466.
24. Nayak RK, Dash A and Ray BC. "Effect of epoxy modifiers (Al2O3/SiO2/TiO2) on mechanical performance of epoxy/glass fiber hybrid composites." Procedia Mater Sci. 6(2014):1359–1364.
25. Shalwan A and Yousif BF. "Influence of date palm fibre and graphite filler on mechanical and wear characteristics of epoxy composites" Mater Des., 59(2014):264–273.
26. Patnaik A, Satapathy A, Mahapatra SS. "A comparative study on different ceramic fillers affecting mechanical properties of glass polyester composites" J Reinf Plast Compos., 28(2009):1305–1318.
27. Prabu VA, Johnson RDJ, Amuthakkannan P. "Usage of industrial wastes as particulate composite for environment management: hardness, tensile and impact studies." J Environ Chem Eng., 5 (2017):1289– 1301.
28. Ojha S, Raghavendra G and Acharya SK. "A comparative investigation of bio waste filler (wood apple- coconut) reinforced polymer composites" Polym Compos., 35(2014):180–185.
29. Lingaraju D, Ramji K, Mohan Rao NBR. "Characterization and prediction of some engineering properties of polymer – clay/silica Hybrid nanocomposites through ANN and regression models." Procedia Eng., 10(2011):9–18.
30. Li J, Sheng XH. "Tribological properties of PTFE composites with addition of PA6." Mater Technol., 25(2010):30–34.
31. Sudeepan J, Kumar K, Barman TK. "Study of tribological behavior of ABS/CaCO3 composite using grey relational analysis." Procedia Mat Sci., 6(2014):682–691.
32. Patnaik A, Satapathy A, Chand N. "Solid particle erosion wear characteristics of fiber and particulate filled polymer composites: a review." Wear, 268(2010):249–263.
33. Basu M, Pande M, Bhadoria PBS. "Potential fly-ash utilization in agriculture: a global review" Prog Nat Sci., 19(2009):1173–1186.
34. Ahmaruzzaman M. "A review on the utilization of fly ash." Prog Energy Combust Sci., 36 (2010):327– 363.
35. Chaowasakoo T and Sombatsompop N. "Mechanical and morphological properties of fly ash/epoxy composites using conventional thermal and microwave curing methods" Compos Sci Technol., 67 (2007):2282–2291.
36. Kulkarni SG, Meghnani JV and Lal A. "Effect of fly ash hybrid reinforcement on mechanical property and density of aluminium 356 alloy" Procedia Mater Sci., 5(2014):746–754.
37. Kulkarni SM. Effects of surface treatments and size of fly ash particles on the compressive properties of epoxy based particulate composites."Journal of material science, 34(2002):321–4326.
38. Uthayakumar M, Kumaran ST and Aravindan S. "Dry sliding friction and wear studies of fly ash reinforced AA- 6351 metal matrix composites." Advances in tribolog (2013).
39. Chand N, Sharma P and Fahim M. "Correlation of mechanical and tribological properties of organosilane modified cenosphere filled high density polyethylene." Mater Sci Eng A., 527 (2010):5873–5878.
40. Soma Dalbehera SKA. "Effect of cenosphere addition on erosive wear behaviour of jute glass reinforced composite using Taguchi experimental design" Mater Today Proc., 2(2015):2389–2398.
41. Patnaik A and Satapathy A. "Erosion wear response of flyash-glass fiber-polyester composites: a study Using Taguch experimental design." Malaysian Polymer Journal, 4(2009):13–28.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)

42. Ismail M, Suresh B, Rajendran N. "Investigations on mechanical and erosive wear behaviour of cenosphere filled carbon-epoxy composites." International conference on mechanical, automotive and materials engineering (ICMAME'2012), Dubai, 7–8 January, (2012).
43. Srivastava VK and Pawar AG. "Solid particle erosion of glass fibre reinforced flyash filled epoxy resin composites." Compos Sci Technol., 66(2006):3021–3028.
44. Raghavendra G, Ojha S, Acharya SK. "A comparative analysis of woven jute/glass hybrid polymer composite with and without reinforcing of fly ash particles" Polym Compos., 37(2014):658–665.
45. Liu Z and Li H. "Metallurgical process for valuable elements recovery from red mud – a review." Hydrometallurgy, 155(2015):29–43.
46. Prabu VA, Manikandan V, Venkatesh R. "Influence of red mud filler on Palmyra fruit and Palmyra fiber waste reinforced polyester composite: hardness, tensile and impact studies." Mater Phys Mech.,24 (2015):41–49.
47. Prabu VA, Kumaran ST and Uthayakumar M. "Influence of red mud particle hybridization in banana/sisal and sisal/glass composites."Part Sci Technol, (2017).
48. Liu X and Zhang N. "Utilization of red mud in cement production: a review." Waste Manag Res., 29 (2011):1053–1063.
49. Prabu VA, Manikandan V and Uthayakumar M. "Effect of red mud on the mechanical properties of banana/polyester composites using design of experiments." Proc Inst Mech Eng L J Mater Design Appl., 227(2013):143–155.
50. GA, Omastova ́Mand Proke˘s J. "Synthesis and characterization of red mud/polyaniline composites: electrical properties and thermal stability." Eur Polym J., 43(2007):2471–2480.
51. Satapathy A and Patnaik A. "Analysis of dry sliding wear behavior of red mud filled polyester composites using the Taguchi method." J Reinf Plast Compos., 29 (2010):2883– 2897.
52. Biswas S and Satapathy A. "Tribo-performance analysis of red mud filled glass-epoxy composites using Taguchi experimental design." Mater Des. 30(2009):2841–2853.
53. Jena H and Satapathy AK. "Fabrication, mechanical characterization and wear response of hybrid composites filled with red mud: an alumina plant waste."Int J Manuf MaterSci., 2.27(2012).
54. Biswas S and Satapathy AA. "Comparative study on erosion characteristics of red mud filled bamboo– epoxy and glass– epoxy composites." Mater Design. 31(2010):1752–1767.
55. Joshi AG, Kumar MP and Basavarajappa S. "Influence of Al2O3 filler on slurry erosion behavior of glass/epoxy composites." Int Conf Adv Manuf Mater Eng., 5 (2014):863–872.
56. Patnaik A, Satapathy A, Mahapatra SS. "Parametric optimization erosion wear of polyester- GF- alumina hybrid composites using the Taguchi method" J Reinf Plast Compos., 27(2008):1039–1058.
57. Patnaik A, Satapathy A, Mahapatra SS. Tribo- performance of polyester hybrid composites: damage assessment and parameter optimization using Taguchi design." Mater Des. 30 (2009):57–67.
58. Das G and Biswas S. "Erosion wear behavior of coir fiber-reinforced epoxy composites filled with Al2O3 filler" J Ind Text., 47(2017):472–488.
59. Bagci M. "Determination of solid particle erosion with Taguchi optimization approach of hybrid composite systems" Tribol Int.,94(2016):336–345.
60. Mohan N, Mahesha CR and Rajaprakash BM. "Erosive wear behaviour of WC filled glass epoxy composites." Procedia Eng., 68(2013):694–702.
61. Crivelli Visconti I, Langella A and Durante M. "The wear behaviour of composite materials with epoxy matrix filled with hard powder." Appl Compos Mater, 8(2001):179–189.
62. Abenojar J, Tutor J, Ballesteros Y. "Erosion-wear, mechanical and thermal properties of silica filled epoxy nanocomposites." Compos Part B Eng., 120(2017):42–53.
63. Mahapatra SS and Patnaik A. "Study on mechanical and erosion wear behavior of hybrid composites using Taguchi experimental design" Mater Des., 30(2009):2791–2801.
64. Bagci M, Imrek H and Mashi Khalfan O. "Optimization of test parameters that influence erosive wear behaviors of glass fiber-reinforced epoxy composites by using the Taguchi method" J Tribol., 137 (2014):11602.
65. Patnaik A, Satapathy A, Mahapatra SS. "Implementation of Taguchi design for erosion of fiber- reinforced polyester composite systems with SiC filler." J Reinf Plast Compos., 27(2008):1093–1111.
66. Patnaik A, Satapathy A, Mahapatra SS. "Modified erosion wear characteristics of glass- polyester composites by silicon carbide filling: a parametric study using Taguchi technique." Int J Mater Product Technol., 38(2010):131.
67. Mantry S, Mohapatra S, Mohapatra S. "Erosion behavior of glass-epoxy composites filled with SiC from bamboo leaf." Int Polym Process., 26(2011):164–172.
68. Baysal E, Yalinkilic MK, Altinok M. "Some physical, biological, mechanical, and fire properties of wood polymer composite (WPC) pretreated with boric acid and borax mixture." Constr Build Mater.21(2007):1879–1885.
69. Alsaadi Mand Erkli˘g A. "A comparative study on model and mode II interlaminar behavior of borax and SiC particles toughened S -glass fabric/epoxy composite." Arab J Sci Eng., 42 (2017):4759 –4760.
70. Bagci M and Imrek H. "Erosion wear performance of borax filled novel hybrid composites by using the Taguchi experimental design" Ind Lubr Tribol., 68 (2016):134–140.
71. Bagci M and Imrek H. "Solid particle erosion behaviour of glass fibre reinforced boric acid filled epoxy resin composites." Tribol Int., 44(2011):1704–1710.
72. Bagci M and Imrek H. "Application of Taguchi method on optimization of testing parameters for erosion of glass fiber reinforced epoxy composite materials." Mater Des. 46(2013):706– 712.
73. Akinci A, Ercenk E, Yilmaz S. "Slurry erosion behaviors of basalt filled low density polyethylene Composites." Mater Des. 32 (2011):3106–3111.
74. Ray S, Rout AK and KuSahoo A. "A study on tribological behavior of glass-epoxy composite filled with granite dust." IOP Conf Ser Mater Sci Eng., 225(2017):12097.
75. Rout A, Satapathy A, Mantry S. "Erosion wear performance analysis of polyester-GF-granite hybrid composites using the Taguchi method."Procedia Eng., 38(2012):1863–1882.
76. Mohan N, Mahesha CR, Shivarudraiah. "Dry sliding wear behaviour of Ta/NbC filled glass- epoxy compo- sites at elevated temperatures" Procedia Eng., 64(2013):1166–1172.
77. Panchal M, Raghavendra G, Prakash MO. "Effects of environmental conditions on erosion wear of eggshell particulate epoxy composites"Silicon, 10.2(2018):627–634.
78. Srivastava VK. "Effects of wheat starch on erosive wear of E-glass fibre reinforced epoxy resin composite materials." Mater Sci EngA., (2006):282–287.
79. Rout AK and Satapathy A. "Study on mechanical and tribo-performance of rice-husk filled glass- epoxy hybrid composites." Mater Des. 41(2012):131–141.
80. Padhi PK and Satapathy A. "Prediction and simulation of erosion wear behavior of glass- epoxy composites filled with blast furnace slag." Adv Mater Res., 585(2012):549–553.
81. Padhi PK, Satapathy A, Mishra SK "Erosive wear behavior of glass-epoxy hybrid composites reinforced with blast furnace slag." International conference on Advancements in Polymeric Materials, APM Ahmedabad: CIPET, 10–12 February (2012).
82. Kumar Padhi P and Satapathy A. "Solid particle erosion behavior of BFS-filled epoxy-SGF composites using Taguchi's experimental design and ANN." Tribol Trans., 57(2014):396– 407.
83. Padhi PK. "Parametric evaluation of erosion response of epoxy resin filled with blast furnace slag using Taguchi technique." International Conference on Advancements in polymeric materials Ahmedabad: CIPET, 10–12 February (2012).
84. G. Gupta and A. Satapathy, "Processing, Characterization, and Erosion Wear Characteristics of Borosilicate Glass Microspheres Filled Epoxy Composites", Polym. Composite, DOI 10.1002/pc.23079, pp. 1-8, 2014.
85. P.R. Pati and A. Satapathy, "A Study on Processing, Characterization and Erosion Wear Response of Linz– Donawitz Slag Filled Epoxy Composites", Adv. Polym. Technol., DOI 10.1002/adv.21509, pp. 21509(1-8), 2015.
86. P.R.Pati and A. Satapathy, "Prediction and simulation of erosion wear response of Linz-Donawitz slag filled epoxy composites using ANN", Int. J. Mech. Eng. Robot., vol. 1, pp. 39-45, 2013.
87. A. Gupta, A. Kumar, A. Patnaik and S. Biswas, "Effect of Filler Content and Alkalization on Mechanical and Erosion Wear Behavior of CBPD Filled Bamboo Fiber Composites", J. Surf. Eng. Maters. Adv. Technol., doi:10.4236/jsemat.2012.23024, pp. 149-157, 2011.
88. S. Biswas, "Erosion Wear Behavior of Copper Slag Filled Short Bamboo Fiber Reinforced Epoxy Composites", Int. J. Eng. Technol., Vol. 6, pp. 91-94, 2014.

Published By:
Blue Eyes Intelligence Engineering & Sciences Publication (BEIESP)

AUTHORS PROFILE

Raffi Mohammed is a Research scholar At ANUCET Guntur and he is currently Working as Associate Professor in the Department of Mechanical Engineering of Ramachandra College of Engineering, Eluru. He is having a total experience of 10 Years to teach UG/PG courses in Mechanical Engineering. He has published Many papers in national and international Journals and member of various professional Bodies.

Dr. B.Ramgopal Reddy is currently Working as Associate Professor in the Department of Mechanical Engineering of RVR & JC College of Engineering Chowdavaram, Guntur. He is having a total Experience of 20 years to teach UG/PG Courses in Mechanical Engineering. He has Published many papers in national and International journals and member of Various professional bodies.

Dr. Abdul Siddique Shaik is currently Working as a faculty of Mechanical Engineering in King Khalid University, KSA. He is having a total experience of 18 Years to teach UG/PG courses in Mechanical Engineering.

Aluri Manoj an undergraduate student in the Department of Mechanical Engineering, RGUKT, Basar.

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication (BEIESP)