

Hybrid Composite Material and Solid Particle Erosion Studies

D Chellaganesh, M Adam Khan, A Mohamed Ashif, T Ragul Selvan, S Nachiappan and J T Winowlin Jappes

School of Automotive and Mechanical Engineering (SAME), Kalasalingam University, Krishnankoil – 626126, Tamilnadu, India.

Email: mechchellam@gmail.com, adamkhanm@gmail.com

Abstract. Composite is one of the predominant material for most challenging engineering components. Most of the components are in the place of automobile structure, aircraft structures, and wind turbine blade and so on. At the same all the components are indulged to mechanical loading. Recent research on composite material are machinability, wear, tear and corrosion studies. One of the major issue on recent research was solid particle air jet erosion. In this paper hybrid composite material with and without filler. The fibre are in the combination of hemp – kevlar (60:40 wt.%) as reinforcement using epoxy as a matrix. The natural material palm and coconut shell are used as filler materials in the form of crushed powder. The process parameter involved are air jet velocity, volume of erodent and angle of impingement. Experiment performed are in eight different combinations followed from 2k (k = 3) factorial design. From the investigation surface morphology was studied using electron microscope. Mass change with respect to time are used to calculate wear rate and the influence of the process parameters. While solid particle erosion the hard particle impregnates in soft matrix material. Influence of filler material has reduced the wear and compared to plain natural composite material.

1. Introduction

The engineering materials are proving to aerospace, wind mill blades and automobile. The fibre composite materials are applied to reduce the wear rate. The natural fibres have received great interest as reinforcing material for polymer-based composite. In present scenario natural fibres such as sisal, kenaf, coconut and banana are studied [1-3]. The polymer composite are used in wide range of industrial application. The metal alloys products are replaced by polymer fibre composite materials. This is due to its good mechanical properties, low cost, easy to replace and eco-friendly [4-6]. The materials are subjected to surface wear due to solid particle erosion. It occurs naturally by hard abrasive particle such as sand, dust and it slurry hitting at various angles. The abrasive particles are impacting over the surface during relative velocity at the component. It is simulated using erosion test rig with standard procedures. Ku (2011) made a survey to report the properties of natural fibre based composite material [7]. It was a repeated rule of mixture and the depending parameter for properties. Uttam (2017) addressed erosion behaviour for the solid particle abrasion on carbon fibre reinforced composite materials [8]. The findings over the investigation shows the impact angle and the stand of distance for SPE are the predominant factor. It was also confirmed by the researches of different group for same material erosion studies [9].



Arjulasuresh (2008) made an attempt to study the solid particle abrasion on poly phenylene sulfide composites [10]. The finding over the research shows the impact angle are predominant factor in erosion. K.V.Pool (1986) research the studies on composite material erosion [11]. The research conclude that the erosion rate is high at inclined angle. A.P.Harsha (2007) investigated solid particle erosion behavior of polyetherimide based composite [12]. The investigation result shows the different impact angle and the impact velocity are main factor for erosion. Qchen (2003) investigated the solid particle erosion on composite material using computer simulation [13]. The finding matrix range, impact velocity, solid particle size are the important factor for wear.

The objective of the present investigation was to study the solid particle erosion wear on hybrid composite material. The samples after investigation were subjected to material characteristics with respect to the of basalt composites under various conditions like changing angle, change flow rate.

2. Experimental details

The natural fibre composite was developed as hybrid material with / without filler material. The composite was prepared using compression method for plate formation. The crushed dust particle is 100 +/- 15 microns. An orientation of the fibre kept at a perpendicular direction of 0°/90° and the thickness of the hybrid composite achieved is approximately 7mm. The mould cavities are brushed with wax to act as a releasing agent. The fibre and matrix proportions to develop the composites are as Kevlar – hemp – epoxy. The size of the sample used for erosion setup was 25 x 25 x 5mm. The samples are placed in fixture designed for various angle of jet / slurry impingement on erosion setup. In the proposed work, alumina of 50microns irregular in structure are used as abrasive erodent. The process parameters are defined to 2^k factorial design as given in Table 1.

Table 1. Process parameter for 2³ factorial design

Process Factors	Units	Lower End (-1)	Upper End (+1)
Angle	Degree	45	90
Erodent flow rate	m/s	2.5	4
Filler wt. %	%	0	5

The response over the process parameter is made with respect to the change in mass. Empirical equations are used to identify the erosive wear rate with reference to time. After experimental investigation the surface morphology of the sample were studied using SEM microscope.

3. Results and Discussion

At consecutive cycle, the mass change for defined process parameters were measured to calculate the wear rate. The theoretical erosive wear rate influenced from the change in mass of the sample to the flow of erosion rate. From the mass change the wear rate at individual process are calculated and plotted in Figure 1.

The experiments result illustrates the influence of the impact angle and mass of erodent addition of filler material with respect to change in erosion time. Along with the process parameter the influence of filler material were also studied in detail. At the initial stage, the wear rate found to be aggressive in both the conditions. The mechanism involved at this stage indicates that at lower impact angle the wear rate has increased. When the impact angle is 45 Degree, the flow of erodent tends to slide over maximum surface area. On other hand the velocity of the erodent influence to influence on wear rate. The wear rate on the consecutive time will lead to vary on the progress.

For the proposed condition, the samples with the filler material has resulted with common wear mechanism and without filler material founds to invariant. This confirms the bonding quality of the composite material with filler to enhance the mechanical and erosive property of the material.

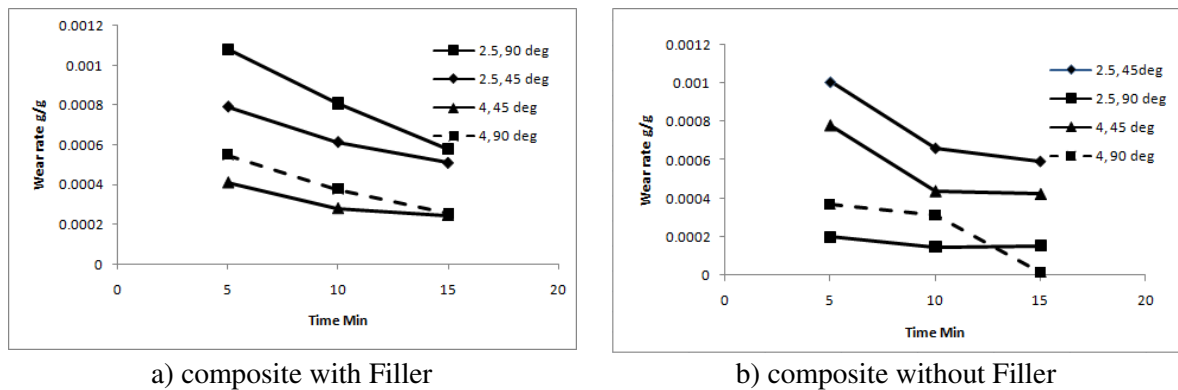


Figure 1: Erosive wear rate of the hybrid natural fibre composite material differentiating with and without filler combination

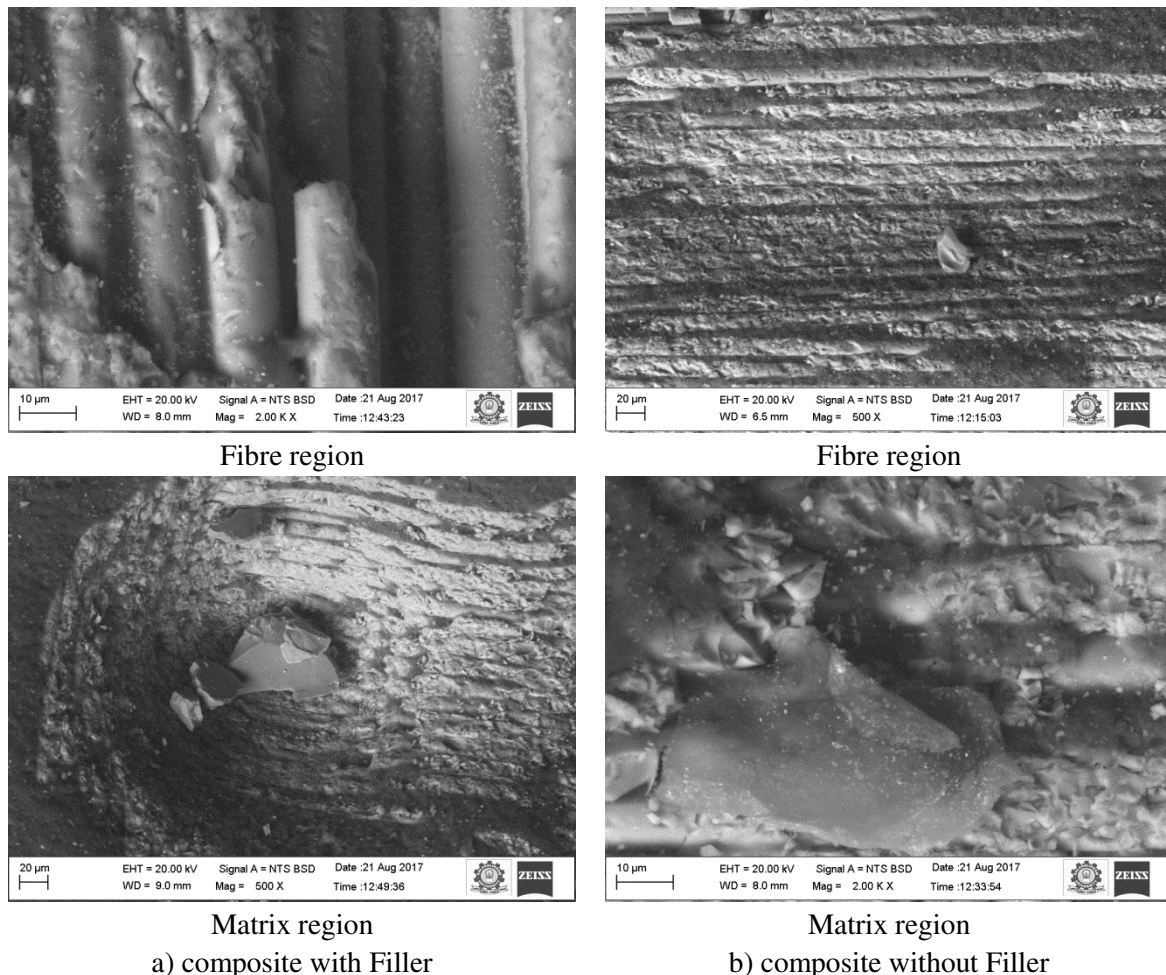


Figure 2: Electron microscopic image of the hybrid composite with and without filler material after erosion studies

Figure 2 illustrates the surface studies of the erosive samples using scanning electron microscopic techniques. While machining the composite material, it was reported that the fibres are pulled out due to impact load and ploughing were also influenced due to the same. The same mechanism observed over the surface of the erosive wear of the proposed hybrid composite.

Figure 2a indicates the surface morphology of the hybrid composite material sample with filler material. The bonding of the fibre and matrix material was confirmed to superior than the composite without filler material. Figure 2b shows the surface studies of the hybrid composite material without filler materials. It is clear to infer that the composite without filler material has completely washed out with the flow of hard erosive particle. However, the fibre with filler material has superior strength. It has sliced the fibres with sharp erodent particle at 45 degree impact angle. Figure 3 represents the shape and structure of the hard abrasive erodent used for investigations. One hard particle has placed in matrix impinged at 90 Degree of sample placed. Therefore the influence of hard particle erosion found significantly less with filler based composite material and aggressive on composite without filler material.

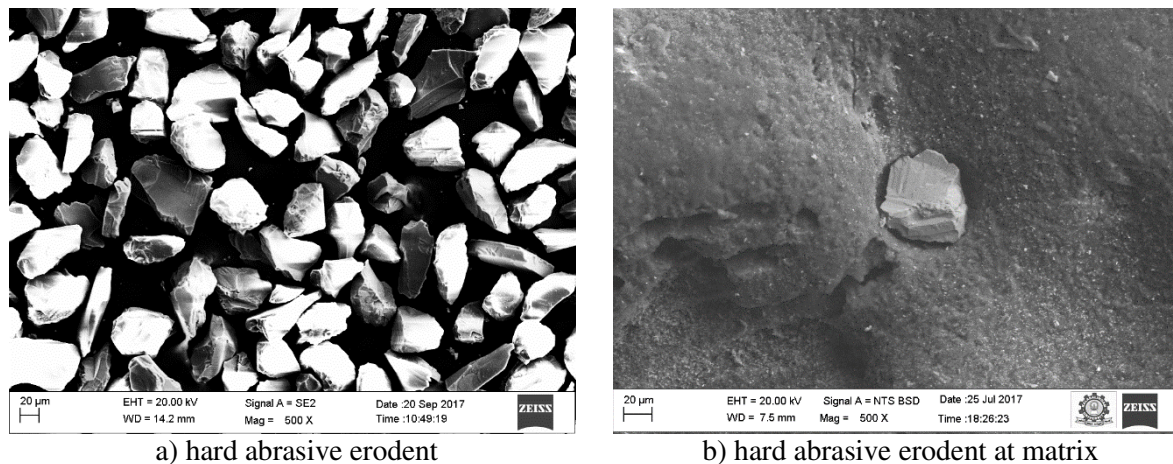


Figure 3. Microscopic image of the hard abrasive / erosive particle and rested over the matrix due to high impact velocity and soft matrix material.

From the experimental analysis, the influence of the process parameters are analysed using 2^K factorial design concept. Where; K is three factor from the process parameters namely – process time, impact angle and mass of erodent flow. Figure 4 represents the contribution of process parameter calculated manually using analysis of variance (ANOVA) concept.

The maximum contribution of erosion time is dominating in the range of 35 – 37% for both the combination of materials. In continuation the mass of erodent flow during the experimental design has shown maximum of 19 – 20% contribution. It is identical to represent that in proposed composite material impact angle has less and negligible contribution of 0.3 – 0.9% towards the proposed work. All the above the error for the proposed problem is maximum and this cannot be manipulated because the hybrid composite material do have produce same result. This is due to regime of the composite varies fibre – filler – matrix in different region.

From the research, it important to convey that the metals and alloys do produce same result. The error rate may be less for metals and alloys compared to the composite material.

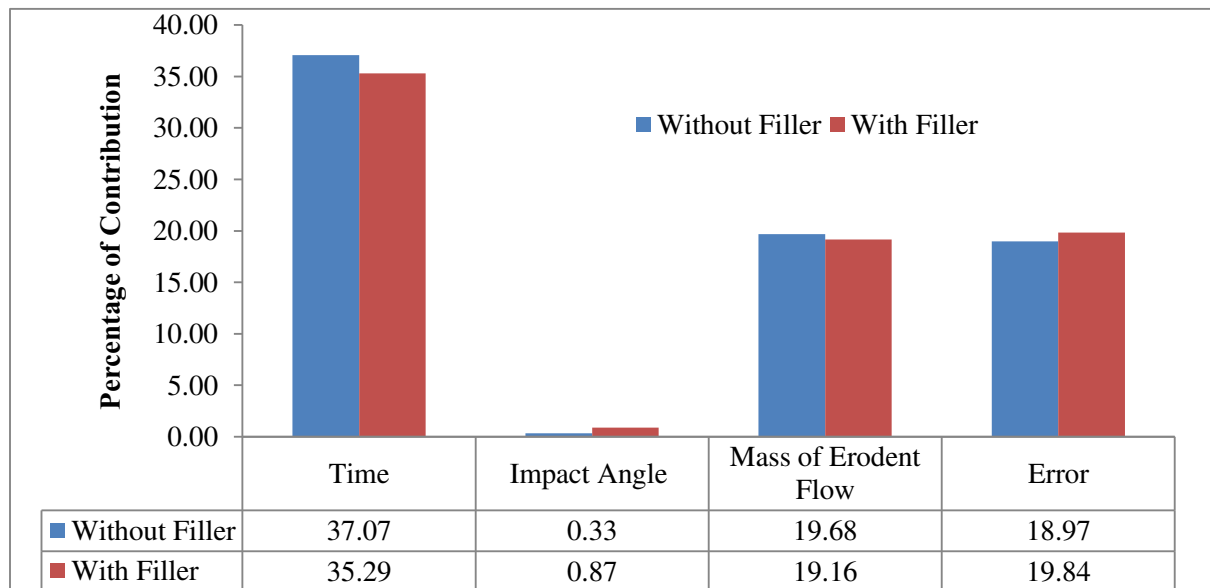


Figure 4: Influence of process parameters in terms of percentage of contributions for the hybrid composite with and without filler materials.

4. Conclusions:

From the solid particle erosive wear analysis on hybrid composite material, following conclusions are drawn from the experimental investigations, characterisation studies and mathematical results:

- Experimental results with erosive wear rate is initially drastic and converged on prolonged exposure. This is due to fine hard abrasive particle impregnated over the soft matrix has given less wear. This convergence has not fit in composite without filler. This is due to erosion on matrix and fibre content.
- Surface result infers on impact angle of the erodent and sample. At perpendicular angle erosion found less and at inclined range it varied due to slicing of fibre material.
- All the above, mathematical model using factorial design has indicated that the erosion time and erodent mass flow has maximum contribution towards the solid particle erosive wear.

References

- [1] Hager A, Friedrich K, Dzenis Y and Paipetis S A. 1995 Study of erosion wear of advanced polymer composites. In: Street, K. (ed.), Whistler, B.C., Canada, *Proceedings ICCM-10*. Cambridge, England: Woodhead Publishing Ltd., 155–162.
- [2] Tilly G P. 1969 Sand erosion of metals and plastics: a brief review. *Wear* **14** 241–248.
- [3] Tilly G P. 1969 Erosion caused by airborne particles. *Wear* **14** 63–79.
- [4] Geethamma V G, Mathew K T, Lakshminarayanan R, Thomas S 1998 Composite of short coir fibers and natural rubber: effect of chemical modification, loading and orientation of fiber, *Polymer* **39** 1483 - 1491.
- [5] Brahmakumar M, Pavithran C, Pillai R M. 2005 Coconut fibre reinforced polyethylene composites: effect of naturalwaxy surface layer of the fibre on fibre/matrix interfacial bonding and strength of composites, *Composites Science and Technology* **65** 563 – 569.

- [6] Hand N, Dwivedi U K. 2006 Effect of coupling agent on abrasive wear behaviour of chopped jute fibre-reinforced polypropylene composites, *Wear* **261** 1057 – 1063.
- [7] Ku H, Wang H, Pattarachaiyakoo N, Trada M 2011 A review on the tensile properties of natural fiber reinforced polymer composites, *Composite Part B: Engineering* **42** 856 – 873.
- [8] Chowdhury M A, Debnath U K, Nuruzzaman D M, MonirulIslam M, 2017 Study of Erosive Surface characterization of copper alloys under different test conditions, surface and interfaces **9** 245 – 259.
- [9] Pei X, Friedrich K 2012 Erosive wear properties of unidirectional carbon fiber reinforced PEEK composites, *Tribology International* **55** 135 – 140.
- [10] Suresh A, Harsha A P, Ghosh M K 2009 Solid particle erosion studies on polyphenylene sulfide composites and prediction on erosion data using artificial neural networks *Wear* 184 – 193.
- [11] Pool K V, Dharan C K H and Finnie I 1986 Erosive wear of composite materials, *Wear* **107** 1 – 12.
- [12] Tewari U S, Harsha A P, Häger A M, Friedrich K 2003 Solid particle erosion of carbon fibre– and glass fibre–epoxy composites, **63** 549 – 557.
- [13] Chen Q, Li D Y 2003 Computer simulation of solid-particle erosion of composite materials, *Wear* **255** 78 – 84.