# Erosive Behaviour of Carbon Fiber Reinforced Polymer Matrix Composites

S. Suresh Kumar[1#], M. Arul Jothi[2], S. Balajeganathasastha[2], S. Ragulmani[2]

[1]*Assistant Professor, Department of Mechanical Engineering, Kalasalingam Academy of Research and Education, Srivilliputtur, India*

[2]*UG Student, Department of Mechanical Engineering, Kalasalingam Academy of Research and Education, Srivilliputtur, India*

[#]*Corresponding Author: S. Suresh Kumar*

***Abstract*** **- Evaluation of erosive behaviour of material becomes important since, engineering materials used in aerospace applications are subjected to such kinds of load. In this research work, the erosive nature of light weight polymer composite that reinforced with carbon fiber is evaluated. The significant effect of process parameters on affecting the performance characteristics of the composite such as erosion rate is determined. The experimental results show that the parameters namely jet velocity, impact angle plays a major role on influencing the erosion rate of Carbon Fibre Reinforced plastics (CFRP).**

***Key words*****: erosion, carbon fibre, parameters, erosion rate, PMC**

## I. INTRODUCTION

The need for the newer materials in the modern industry scenario has been increased owing to their enhanced properties. Polymer Matrix Composites (PMCs) are the materials which growing fast owing to their light weight, good stiffness and higher strength characteristics. PMCs are used widely in the various engineering fields such as aerospace, automobile, structural applications. Among these areas, the importance of lightweight materials in the aerospace application is inevitable. The research works proven that role of PMCs can be extended to the aerospace field and hence many researchers are preparing and analysing the suitability of PMCs for such applications. The importance characteristics of PMCs required to be used in such applications are highly resistance to erosive behaviour. Many researchers have evaluated the erosive characteristics of composite materials and reported their findings. Suresh Arjula and Harsha [1] have done an experimental work with an objective to show the usefulness of the parameter to identify various mechanisms in solid particle erosion. The erosion efficiency map is plotted, which indicates the influence of hardness of various polymers and polymer composites on their erosion resistance. The erosion rate of the materials was reported at varying process conditions. Rekha Rattan, Bijwe [2] have evaluated the performance of woven carbon fabric reinforced (55 vol.%) polyetherimide (PEI) composites fabricated using three types of weaves viz. plain (P), twill (T),and satin-4 H (S) by impregnation technique. The experimental results revealed that plain weave composite proved slightly better erosion nature than satin weave composite. Composite with twill weave proved poorest performer. Harsha et al. [3] have analysed the solid particle erosion behaviour of various polyaryletherketones (PAEKs) and their short fibre reinforced composites. Neat polyetheretherketone (PEEK) and 20% glass fibre (GF) reinforced PEEK showed peak erosion at 30◦ impingement angle whereas other PAEK matrix and their composites showed peak erosion at 60◦ impingement angle. Nejat Sar et al. [4]. Analysed unidirectional carbon fibre reinforced PEI composites and they have observed that semi-ductile behaviour under low speed erosive studies. Highest wear rates were investigated at 45 degree for 1.96 m/s. The higher particle speed resulted in rougher surface as a result of severe fibre breakage and matrix erosion duringsolid particle erosion of carbon fibre– and glass fibre–epoxy composites Tewari et al. [5] have examinedthe erosive characteristics of the composites at different impact angles (15–90 degrees) and at three different fibre orientations (0, 45, and 90 degrees). The particles used for the erosion measurements were steel balls with diameter of 300–500 mm and impact velocity of 45 m/s. The unidirectional carbon and glass fibre reinforced epoxy composites showed semi ductile erosion behaviour, with maximum erosion rate at 60impactangles. The fibre orientations had a significant influence on erosion. Harsha et al.[6] Investigatederosion characteristics of polyetherimide and its compositesof randomly oriented short E-glass, carbon fibre and solid lubricants (PTFE, graphite, MoS2) filled polyetherimide (PEI) composites. The erosion rates (ERs) of these composites have been evaluated at different impact angles (15–90◦) and impact velocities (30–88 m/s). It is observed that 20% (w/w) glass fibre reinforcement helps in improving erosive wear resistance of neat PEI matrix. Erosion efficiency ($\eta$) values (0.23–8.2%) indicate micro-ploughing and micro-cutting dominant wear mechanisms. Patnaik et al. [7] evaluated erosion behaviour of fiber and particulate filled polymer composites. The new aspects in the experimental studies of erosion of fiber and particulate filled polymer composites were emphasised. The correlation was formed to solve the structure-erosion resistance relationships for polymers and polymer-based hybrid composites. Tibbets et al.

[8] have investigated the vapor-grown carbon nanofiber with diameters under 200 nm and conically shaped graphene planes canted with respect to the longitudinal fiber axis. Because of the strong inter-fiber bonding, compounding these fibers with polymeric resins demands some care. The erosion characteristics of PMCs were determined.

Few literatures were reported on the experimental studies on evaluating the erosive nature of CFRP. However, there is a scope to determine the erosion rate of carbon fibre reinforced polymer matrix composite with varying process conditions. In this research work, experimental investigations have been conducted to examine the influence of impact angle and air jet velocity on the erosion rate.

## II. MATERIALS AND METHODS

### *2.1 Fabrication of PMC*

A hand layup technique was applied to fabricate the carbon fibre reinforced polymer matrix composite. The polyester and carbon fibre was considered as matrix and reinforcement material respectively. The final composite with 5 fibre layers areobtained which is having the dimension of 200x200x3 mm. The physical and mechanical properties of the fabricated composite material was determined and the same is presented in TableI.

Table I Properties of PMC

| | |
|---|---|
| Tensile strength (N/mm$^2$) | 441.94 |
| Impact energy (J/ mm$^2$) | 34 |
| Flexural strength (N/mm$^2$) | 724.46 |
| Hardness (HRR) | 112 |
| Density (g/mm$^3$) | 1.515 |

### *2.2 Experimental work*

The fabricated composite is investigated using air jet erosion testing machine which is shown in Figure 1. The process parameters considered for the experimental work and their levels were presented in Table II. The sample size considered for the investigation is 25x25x3 mm. By varying the process parameters, the experimental work was carried out and the erosion rate was measured. The equation 1 is used for calculating erosion rate of the sample at varying process conditions.

$$Erosion\ rate = \frac{weight\ loss\ of\ the\ sample\ during\ erosion}{Discharge\ rate\ x\ time} \text{--(1)}$$


Fig.1 Experimental facility

Table II Process parameters and their levels

| Parameters/levels | Level 1 | Level 2 | Level 3 |
|---|---|---|---|
| Jet Velocity (m/s) | 72 | 100 | 129 |
| Impact angle (Degree) | 30 | 60 | 90 |

## III. RESULTS AND DISCUSSION

The experimental conditions and the calculated erosion rate for the fabricated samples are shown in Table III.

Table III Experimental results

| S. No | Angle (degree) | Velocity (m/s) | Initial weight (g) | Final weight (g) | weight loss (g) | Erosion rate*10$^{-5}$ (g/min) |
|---|---|---|---|---|---|---|
| 1 | 30 | 72 | 0.9025 | 0.8998 | 0.0027 | 8.18182 |
| 2 | | 100 | 0.945 | 0.9423 | 0.0027 | 8.18182 |
| 3 | | 129 | 0.9095 | 0.903 | 0.0065 | 19.697 |
| 4 | 60 | 72 | 1.1122 | 1.1092 | 0.003 | 9.09091 |
| 5 | | 100 | 1.1156 | 1.11 | 0.0056 | 16.9697 |
| 6 | | 129 | 1.11 | 1.1019 | 0.0081 | 24.5455 |
| 7 | 90 | 72 | 1.1451 | 1.1415 | 0.0036 | 10.9091 |
| 8 | | 100 | 1.1415 | 1.1383 | 0.0032 | 9.69697 |
| 9 | | 129 | 1.115 | 1.1122 | 0.0028 | 8.48485 |

The influence of erosion process parameters on the erosion rate is shown in Figure 2. The changes in the impact angle and jet velocity on the erosion rate are explained in the Figure 2. It is understood that the increased erosion rate was observed with an increased impact angle. This is owing to the increased shear efficiency with an increased impact angle.

The increased jet velocity increases the erosion rate which is due to the increased cutting force being developed. As an outcome, the quantum of material eroded from the fabricated composite is increased. However, the decreased trend was noted at higher air jet velocity.

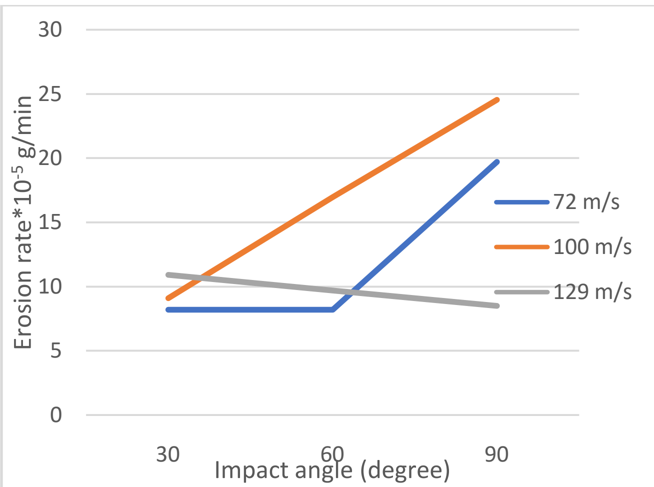


Fig.2 Effect of parameters on erosion rate

## IV. CONCLUSIONS

The polyester based carbon fibre of 5-layer reinforced polymer matrix composite was successfully fabricated and the following observations were made.

- The mechanical (tensile, flexural, impact, hardness) and physical (density) properties of the fabricated composite was evaluated.
- The investigation through erosion testing machine was done at varying process conditions.
- The increased trend of erosion rate with impact angle and jet velocity was observed.
- An increased jet velocity increases the cutting force and hence it increases the erosion rate.

## REFERENCES

[1]. Suresh Arjula, HarshaA.P ., (2006). Study of erosion efficiency of polymers and polymer composites. Polymer Testing 25 188–196.

[2]. Rekha Rattan,Bijwe .J., (2006). Carbon fabric reinforced polyetherimide composites: Influence of weave of fabric and processing parameters on performance properties and erosive wear. Materials Science and Engineering A 420 342–350

[3]. HarshaA.P,Tewari U.S, Venkatraman .B., (2003). Solid particle erosion behaviour of various polyaryletherketone composites.Wear 254 693–712

[4]. Nejat Sar, Tamer Sınmazc¸Elik ., (2007). Erosive wear behaviour of carbon fibre/ polyetherimide composites under low particle speed.Materials and Design 28 351–355

[5]. Tewari U.S, Harsha A.P, Hager A.M, Friedrich.K .,(2003). Solid particle erosion of carbon fibre– and glass fibre–epoxy composites.Composites Science and Technology 63 549–557

[6]. HarshaA.P, Avinash, Thakre A (2007). Investigation on solid particle erosion behaviour of polyetherimide and its composites. Wear 262 807–818

[7]. Amar Patnaik, Alok Satapathy, Navin Chand, Barkoula N.M, SandhyaraniBiswas ., (2010). Solid particle erosion wear characteristics of fiber and particulate filled polymer composites. Wear 268 249–263

[8]. Gary Tibbetts .G, Max Lake .L, Karla Strong. L, Brian Rice .P., (2007) A review of the fabrication and properties of vapor-grown carbon nanofiber/polymer composites.Composites Science and Technology 67 1709–1718