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ORIGINAL ARTICLE

# Erosion behaviour of epoxy based unidirectionl (GFRP) composite materials

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**Abstract** In the present work, the solid particle erosion behaviour and wear mechanism of commercial epoxy based unidirectional glass fibre reinforced plastics (GFRP) composites were investigated. The erosion experiments have been carried out using irregular silica sand (SiC) particles (150 ± 15 μm) as an erodent. The erosion losses of these composites were evaluated at various impingement angles (30°, 60° and 90°) with the change of both of erosion time and pressure. The erosion behaviour of (GFRP) has changed from ductile to brittle at 60° impingement angle and the erosion loss was the highest. The morphology of eroded surfaces was observed under scanning electron microscope and damage mechanisms were discussed.


## 1. Introduction

Polymer composites are extensively used as structural materials in various components and engineering parts in automobile, aerospace, marine and energetic applications due to their excellent specific properties. Polymer composites in pipe line carrying sand slurries in petroleum refining, helicopter rotor blades [1], pump impeller blades, high speed vehicles and aircraft operating in desert environments [2] are often exposed to conditions in which they may be subjected to solid particle erosion. The mechanical properties such as flexural strength can be degraded by the presence of localized impact damage after particle erosion [3]. It is also widely recognized that polymers and their composites have a poor erosion resistance against the operational requirements in dusty environment that might be overcome by understanding the characteristics of the polymeric composites. Consequently many researchers

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[4–6] have investigated the erosion behaviour of polymers and the composites worn by solid particles. There are some reports that discuss the particle erosion behaviour of continuous fiber laminated composites. However, these mainly discussed the erosion behaviour and the performances, although, various types of laminates were used for reinforcing plastics [7,8]. After developing primitive fiber reinforced plastics (FRP) in 1940's they have been widely used because of their superior specific strength and also high corrosion resistance. Initially FRP was composite reinforced with glass fibers (GFRP), however, reinforcement by new fibers such as carbon/graphite and aramid have increased their importance recently. Following the development of these high-performance fibers, use of FRP into industrial applications such as load bearing parts of buildings, bridges, tank/vessels and transportation can be recognized .To ensure the durability of FRPs for industrial applications, it is necessary to discuss the degradation behaviour and mechanism under various conditions such as stress, corrosion and erosion, etc. Several parts and equipments are exposed to erosive conditions, for example, pipes for hydraulic or pneumatic transportation, nozzle and impeller for sand-blasting facility, internal surface of vessels used for fluidized bed or with catalysis, nose of high-velocity vehicle, blades/propellers of planes and helicopters, etc. Some of them are made from fibrous composites [9]. In this study, we focus on the sand erosion damage of fibrous composites. There are several reports in the literature which discuss the erosion behaviour of fibrous composites. These papers mainly showed, however, only the erosion behaviour and the performances to erosive damage [10–13]. Although various types of fiber are used for reinforcing plastics, no paper in which the effect of types of fiber, e.g., strand mat, woven cloth, unidirectional UD fiber, etc. on sand ero-

**Table 1** Composite material testing standards.

| Test type | Standard |
|---|---|
| Tension | EN ISO 527-5 1997 |
| | ANSI/ASTM D3039/D3039M-00 |
| | ASTM D638-01 2001 |
| Compression | BS EN ISO 14126:1999 |
| | ASTM D3410/D3410M-95 1995 |
| Shear | ASTM D5379/D5378M-98 1998 |

**Table 2** Mechanical properties of GFRP samples used in the erosion tests.

| Property | GFRP | GFRP Ref. [20] | GFRP design manual [21] |
|---|---|---|---|
| $E_{11}$ (GPa) | 22.8 | 20.7 | 17.2 |
| Tension (compression) | (22.5) | (20.2) | (17.2) |
| $E_{22}$ (GPa) | 8.9 | – | 5.516 |
| Tension (compression) | (–) | (–) | (6.90) |
| Poisson's ratio $v_{12}$ | 0.3 | 0.32 | – |
| Tension (compression) | (–) | (0.33) | |
| Ultimate strength (MPa) | 255 | 265 | 207 |
| Tension (compression) | (265) | (267) | (104) |
| $G_{12}$ (GPa) | 3.41 | 3.75 | – |
| Ultimate shear strength (MPa) | 78 | 85.9 | – |

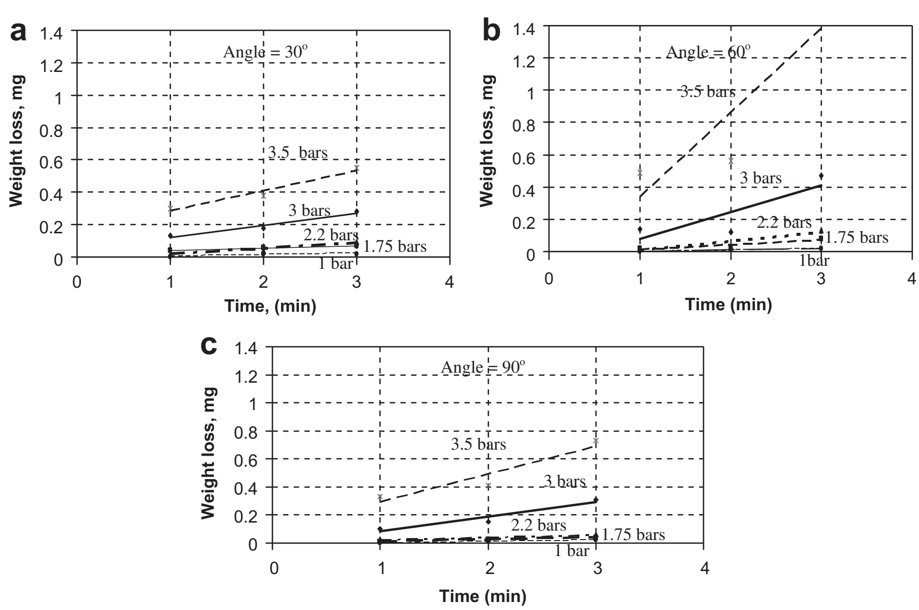


**Figure 1** Weight loss of GFRP composite as a function of erosion time at different pressures (a) 30° (b) 60° and (c) 90°.