Effect of thickness and crack length on the impact behaviour of particle loaded GFRP composite

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Abstract - *The objective of this work is to obtain the dynamic fracture toughness of cross plied E-glass fibre reinforced epoxy resin composite (GFRP) with the addition of flyash particles and variation of fibre thickness and crack length. Izod and Charpy impact tests were performed to determine dynamic Impact toughness of the specimens. Results indicate that dynamic fracture toughness increases with addition of flyash filler and decreases with increase in thickness of the laminates and crack length.*

Key Words: Izod impact energy; Charpy impact energy; Dynamic fracture toughness; Scanning electron microscope.

1. INTRODUCTION

Fibre reinforced composites are attractive materials for the application of aerospace and automobile engineering due to its high specific strength and modulus. While studying the fracture toughness properties of glass fibre composite laminate, it was found that there are three main modes of failure in glass fibre composites i.e. fibre pull out, fibre fracture and delamination. One of the major drawback of laminated composite material is their tendency to delaminate. Interlaminar fracture toughness is one of the major factor controlling the growth of delamination cracks [1]. Interlaminar fracture toughness of reinforced composites increases with increase in toughness of the matrix, increase in matrix thickness in space between neighbouring fibres and with decrease in fibre content [2]. Delamination can be observed with increase in thickness of the un-notched specimen [3]. At the same time, increase in thickness of the laminate decreases the tensile strength of the specimen [4].

Impacts can be categorized as high velocity and low velocity impact. In low velocity impact, dynamic structural response of material is important because the time of contact between the impactor and the material is large so that the complete structure can respond to the impact. In case of high velocity impact, response of the material depends on the stress wave generation. Here the time of contact is very less so that the material does not have time to respond to it resulting in localized damage [5]. Damage strength in composites can be increased by introducing long fibres and good adhesion between fibre and matrix at low level of loading. However at high level of loading a weak interface results in high energy dissipation results increase in damage strength [6].

The basic objective of this work is to improve the fracture toughness of GFRP composite with the help of flyash particles and to investigate the effect of thickness.

2. EXPERIMENTATION

2.1 Material and Specimen Preparation

The glass fibre reinforced composites were made from cross-ply (90/0°) E-glass fibre and epoxy resin. Hand lay-up method was used for the fabrication of composite specimen. E-glass fibre sheets were used with epoxy resin to prepare composite plates with the variation of layers i.e. 6, 10, and 12. Epoxy resin (PL-411) and hardener (PH-861) were taken in the ratio 10:1 by weight. GFRP specimen were prepared with and without addition of flyash as filler. Flyash (5%) filled GFRP composite sample was also prepared by hand lay-up method. First 5% flyash powder was mixed properly with araldite and then hardener was mixed before reinforcement of E-glass fibre.

The flyash and epoxy resin mixture was laid down on the surface of cross plied glass fibre and gradually increased the layers followed by the mixture. Finally, a constant load of 13 kg was used to control the weight ratio of fibre and epoxy resin, which will squeeze out the extra epoxy resin from inside of the fibre layers. The specimen was left for curing at ambient condition for 24 hours. After 24 hours, the composite plate was kept in the furnace at 50° C for post curing 1 hr. After post curing of composite plates, specimens were prepared for izod and charpy impact tests. Notched specimens were prepared for izod impact test and ENF (end notch flexure) specimens were prepared for charpy impact test. A straight notch of 2 mm depth was cut in izod impact test specimens. The geometry of izod and charpy impact test specimens is listed in Table 1 and 2. Five specimens of each type were prepared for izod and charpy impact test.

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Table -1: Specimen dimension for Izod test

S.No.	Thickness (mm)	Width (cm)	Length (cm)	No of layers
1	1.4	0.9	5.25	6
2	2.4	0.9	5.25	10
3	3.4	0.9	5.3	12

Table -2: Specimen dimension for Charpy test

S.No.	Thickness (mm)	Width (cm)	Length (cm)	No of layers	Pre crack length
1	1.6	1	11.5	6	3
2	2.4	1	11.5	10	3
3	3.5	1	11.5	12	3
4	2.4	1	11.5	10	5.15
5	2.5	1	11.5	10	4.3
6	2.4	1	11.5	10	3.4
7	2.4	1	11.5	10	2.2

Burn off method was used to measure the weight fraction of glass fibre and epoxy resin in the composite. Composite specimen of 10mm X 10 mm dimension was cut and placed in a crucible. The crucible was kept in a furnace at 250°C for 5 hr. Epoxy resin was burned out and then weight of the fibre (left after burning of epoxy resin) was measured. Weight fraction of fibre was found to be 48.74%.

2.2 Izod and charpy impact test

The izod and charpy impact test was performed with the instrumented Izod and Charpy equipment (Model; Resil Impactor-50, CEAST, S.p.A., Italy) as shown in Fig.1. The impact length and velocity used were 0.327m and 3.46m/s. The test was performed on notched specimens. During test a mass of 0.932 kg was dropped on the specimen from a specific height. The mild steel impactor designed with a spherical end of 31 mm diameter. The charpy test was also performed on the same machine but the specimen geometry and loading condition (specimen orientation on vice and application of load) was different from izod impact test.

Fig. 1 shows the Resil impact testing machine with vice for izod impact test. It can be seen from Fig. 1 that there is a display fitted in the machine which displays the impact energy absorbed by the specimen.

Fig-1: Photograph of Resil impact testing machine.

From impact energy, dynamic fracture toughness was calculated.

Dynamic fracture toughness was calculated using the following relation [1]

$$K_{dc} = \frac{E}{h \; x \; w} \quad (1)$$

Where

E = Impact energy absorbed by the specimen, h = Thickness of the specimen, w =Width of the specimen

In izod impact test all the specimens were fractured. But in case of charpy impact test some specimen fractured and in some specimen only crack growth occurred.

3. RESULTS AND DISCUSSION

3.1 Effect of layers with Impact energy

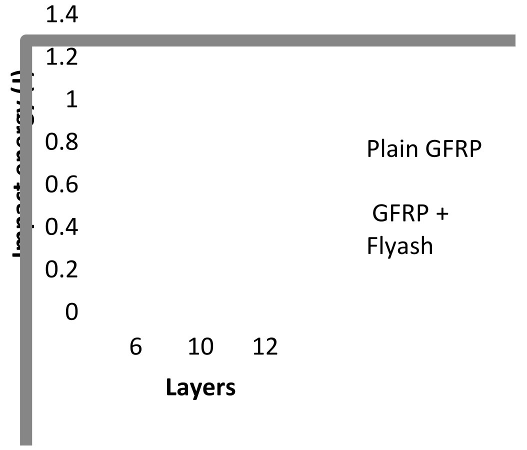


Chart -1: Variation of impact energy with layers in

izod test

Chart. 1 shows the variation of impact energy with layers in case of izod impact test. The results clearly indicate that impact energy increases with increase of layers. However the impact energy of plain GFRP specimen is less than the specimens containing fly ash as filler. Fibre fracture occurred in case of izod impact loading which has been explained with help of SEM images. Therefore the specimen with maximum number of layers absorbed more energy, which is shown in Chart 1 i.e. specimen with 12 layers absorbed more energy than specimen with 6 and 10 layers.

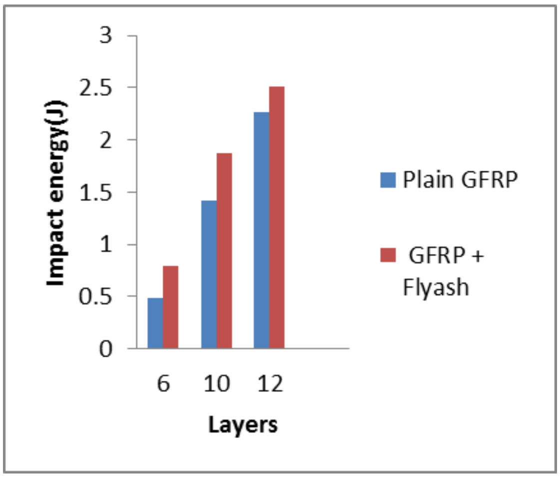


Chart -2: Variation of impact energy with layers in charpy test

Chart 2 shows the variation of impact energy with layers in charpy impact test. Chart. 2 depicts that the impact energy of the specimen increases with increase in layers. Increase in layers leads to increase in the stiffness of the specimen. As the impactor strikes the specimen more stiff specimen didn't bend easily and got fractured while less stiff specimen bent easily and crack propagated to some extent. Therefore more stiff specimen absorbed more energy and less stiff specimen absorbed less energy. It can be seen from the Chart 2 that the impact energy of plain GFRP specimen is less than that of flyash filled GFRP specimen.

3.2 Effect of layers on dynamic fracture toughness

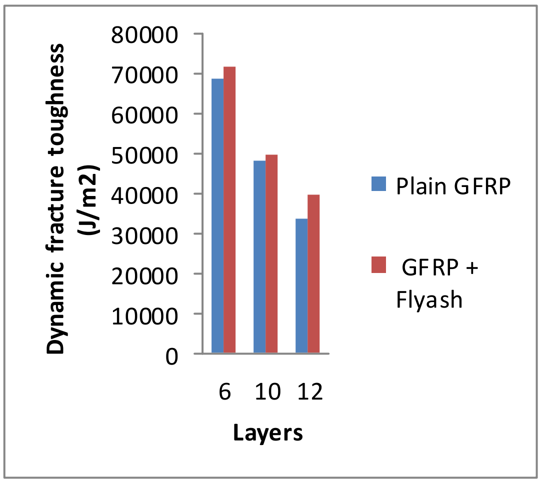


Chart -3: Variation of dynamic fracture toughness with layers in izod test

Chart 3 shows the variation of dynamic fracture toughness with layers ranging from 6, 10 and 12 respectively. It can be observed from Chart 3 that the dynamic fracture toughness of GFRP composite is lower than that of the Flyash/GFRP specimens. However the difference is very less in case of 6 and 10 layers. Flyash particles deviate the cracks that are developed during fracture. Hence more energy is required for the propagation of crack. Thus dynamic fracture toughness of the flyash filled GFRP composites is more than plain GFRP composite.

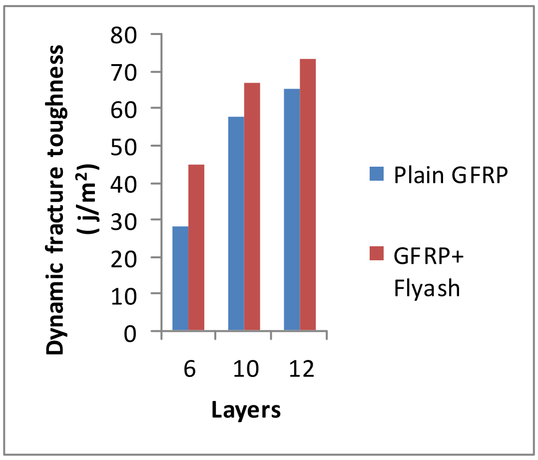


Chart -4: Variation of dynamic fracture toughness with layers in charpy test

Chart. 4 shows the variation of dynamic fracture with layers in charpy impact test. Dynamic fracture toughness increases with increase of layers. Dynamic fracture toughness depends upon impact energy, thickness and interface bond strength. In charpy impact test the effect of increase in impact energy is higher than that of thickness. It can be seen from the Chart 4 that the dynamic fracture toughness of plain GFRP specimen is less than that of flyash filled GFRP specimen.

3.3 Effect of crack length on Impact energy

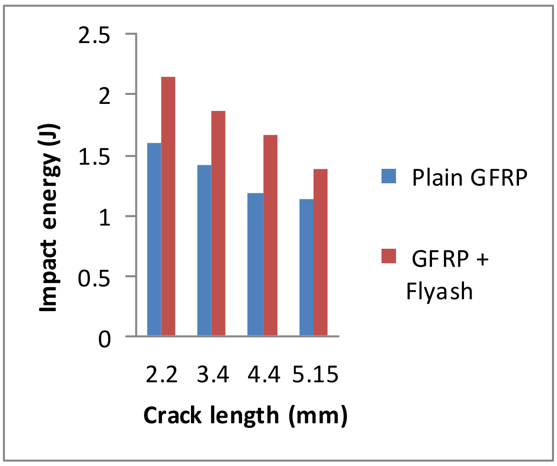


Chart -5: Variation of Impact energy with Crack length in charpy test

Chart 5 shows the variation of impact energy absorbed with the variation of initial crack length in charpy impact test. It can be observed from the Chart 5 that impact energy decreases with increase in crack length. The specimen with lowest initial crack length has absorbed more energy due to fracture of specimen and the specimen with the highest initial crack has absorbed lowest impact energy due to delamination. It can be seen from Chart 5 that impact energy of plain GFRP specimen is less than that of flyash filled GFRP specimen. While testing it was observed that crack propagation occurred for the specimen with the crack length of 3.4 mm and above. For the specimen with the initial crack length of 2.2mm crack propagation didn't take place [1].

3.4 Effect of crack length on dynamic fracture toughness

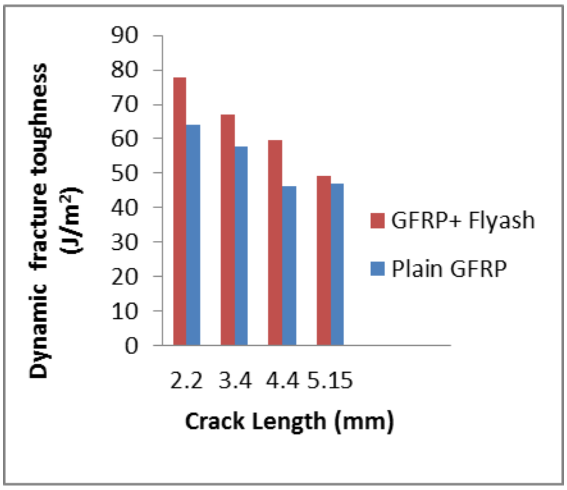
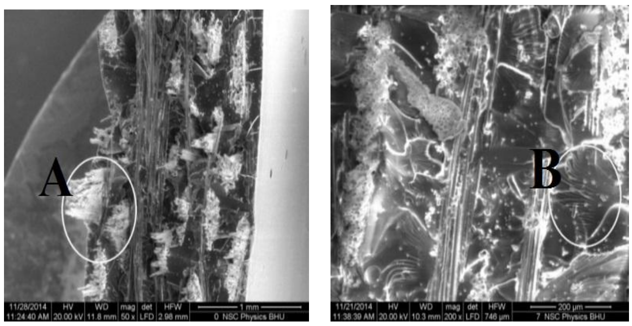


Chart -6: Variation of dynamic fracture toughness with crack length in charpy test.

Chart 6 shows the variation of dynamic fracture toughness with the increase in crack length. Dynamic fracture toughness decreases with the increase in crack length because as the crack length increases, energy required for the propagation of crack decreases. Since the dynamic fracture toughness is inversely proportional to the crack length, increase in crack length decreases the dynamic fracture toughness of the specimen. It can be seen from the Chart. 6 that the dynamic fracture toughness of the plain GFRP specimen is less than that of flyash filled GFRP specimen.

3.7 Microscopic analysis

After izod and charpy impact testing, specimens were investigated under scanning electron microscope for microscopic analysis. SEM images of some specimen are shown below.



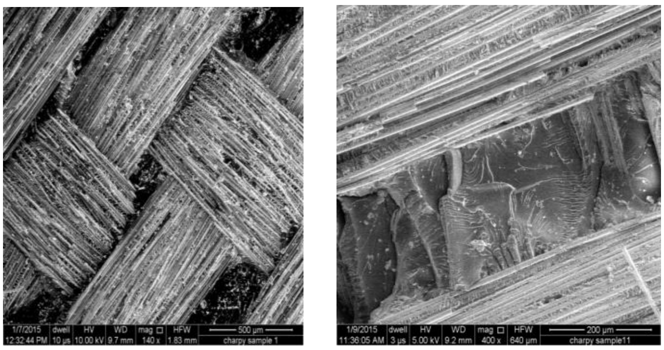
(a) (b)

Fig -2: SEM images of the fractured surface of plain GFRP.

Fig. 2(a) shows fibre fracture of the plain GFRP specimen in case of izod impact test. There is no fibre pullout. Fractured fibres can be seen in the micrograph by region A in case of izod impact test. In Fig. 2(b) minute crack flow lines can be seen in the region B, which shows that there is brittle fracture of the matrix. Brittle fracture caused the matrix to absorb less energy before fracture. However most of the energy was absorbed by the fibres before fracture. It can be seen from Fig. 2(a) that crack didn't deviate around fibres. This indicates that the fibre/matrix interface was strong enough so that crack deviation didn't take place. The percentage of flyash added as filler was only 5% by weight. Flyash particles pinned the crack & inhibits its propagation [7].Therefore impact energy absorbed and dynamic fracture toughness of flyash filled GFRP composite was more than that of plain GFRP composite.

(a) (b)

Fig -3: SEM images of the fractured surface (a) GFRP +5% of Flyash (b) Plain GFRP.



(a) (b)

Fig -4: SEM images of flyash filled GFRP composite for charpy impact test.

It can be seen from the Fig. 3 and 4 that debonding occurred in case of charpy impact test. Crack didn't penetrate the fibre lamina. This shows that plain GFRP and flyash filled GFRP composite possess weak interfacial strength. The matrix left after debonding is shown in the Fig. 3(a) which show the area surrounding the irregular surface. Energy is transmitted from matrix to the fibre resulting in debonding. Debonding depicts that the interfacial strength of fibre-matrix is weak.

4. CONCLUSIONS

The experimental results confirmed that the addition of 5% flyash as filler increases the toughness of the GFRP composite under impact loading. In izod impact test, impact energy increases with increase in thickness of the GFRP composite while dynamic fracture toughness decreases.

In Charpy impact test dynamic fracture toughness and impact energy increases with increase in thickness and decreases with the increase in crack length.

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