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Fractography of Chopped Fiber Glass Reinforced Epoxy Composite at +50^{O}C and -50^{O}C under Dynamic Impact Loading

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ABSTRACT

Hand lay up process was used to fabricate the chopped fiber composite containing 52 vol% fiber fraction. The impact testing for fracturing the samples was conducted using Charpy impact test at +50°C and -50°C. The energy to fracture the specimens was found to decrease with reduced temperature. The sample broke at +50°C gave plastic deformation with mixed fracture mode of cracked fiber bundles, buckling and fiber splitting. While at -50°C the fractured specimens gave the same plastic deformations but with more fibers splitting than that tested at +50°C. The failures were concentrated at pendulum striking areas and V notch areas. These failures caused by compressive stress at striking areas and tensile stress at notch areas. Fiber protrusion was seen in samples tested at both temperatures and it happened because of short fiber filaments. The short fiber filaments gave easier matrix cracking at short distances and this may be one of the reasons of having lower energy absorption compared to the continuous woven fiber.

Keywords: *Chopped Fiber Glass Composite, Charpy Impact Test, Fiber Splitting, Fracture*

Introduction

The prediction of fiber glass composite impact damage is a difficult task for which complete success may not be possible to be achieved. The damage usually consists of combination of failures such as fiber splitting, delamination, matrix cracking, fiber pull out and buckling. Extensive experimental investigations have revealed definite patterns for the shape of the damage and growth under many tests. Recent study by Kalthoff (2004) explained that the weak interface of matrix between the plies gives failure at one side of the specimen using notch fiber glass samples under Charpy impact test. Khalid (2004) found that the Charpy impact energy of aramid and glass epoxy composites increased with the increase of test temperatures. Thomason et al. (1997) explained that the impact strength increased with increasing chopped fiber (non-mat) concentration. Yoshiyuki et al. (1998) found that the tensile stress caused delamination at the V-notch area with Charpy impact test. Gilchrist et al. (1996) concluded that fiber delamination is caused by compressive stress in association with matrix cracking, fiber fracture and splitting using carbon fiber composite under bending test. The fractography of chopped fiber mat reinforced composite at subzero and elevated temperatures has not been investigated thoroughly yet.

In this present research an investigation was conducted to understand and to correlate the chopped fiber composite behaviours in fracturing by impact. The paper describes the fracture modes and energy absorption of this materials fractured by impact loading at +50°C and -50°C.

Experiment

Chopped strand mat glass fiber type TGFM-450 P, supplied by Hightech Polymer Sdn Bhd was used for fabrication of composite samples in this investigation. WM-215 TA thermosetting epoxy resin and WM-215 TB hardener supplied by Wah Ma chemical were mixed at a ratio of 4:1 respectively. Hand lay up process was used to consolidate the mixed liquid compound to the chopped fiber. During curing the sample was pressed under a 981 N load to obtain 52 vol% of fiber and cured for 14 hours at room temperature. Standard Charpy samples were cut using abrasive waterjet machine. The V-notch of 45° with a depth of 2 mm was prepared by milling process. To attain the test temperatures, samples were placed in temperature environments for 1 hour before fracturing the specimens as shown in Table 1.

Table 1: Environment at which the samples are placed to get the desired temperature

Temperature,°C	Condition	Measurement gauge
+50	Oven	Temperature indicator
-50	Liquid nitrogen + alcohol	Thermocouple

Tinius & Olsen Model 84 Charpy impact tester with 700 kg hammer was used to perform the Charpy impact test. The fractography of the fractured sample was examined using JEOL-5400 scanning electron microscope.

Results and Discussion

Figures 3.1 and 3.2 give the micrographs at two different locations of the pendulum striking areas of the specimen fractured by impact at +50°C. Fig. 3.1 shows failure consisting of protruded fiber bundles, fiber splitting and deformation which acted from the pendulum striking location on the left side of the sample. At the right side of the striking area on Fig 3.2 gives filament splitting, buckling and matrix cracking. The compressive strength during impact gave fiber protrusion towards surface since the short fiber filament in the chopped glass mat was highly pressed. It is to be noted that fiber buckling propagated from the pendulum striking area down to the interior with an inclination of 45° (Figs. 3.1 and 3.2). These are due to the compressive strength acted from the Charpy pendulum which gave plastic deformation at the contact areas. Similar failure features were observed at the same areas in the woven sample tested at +50°C where deformation was dominant (Nazrin et al. 2005).

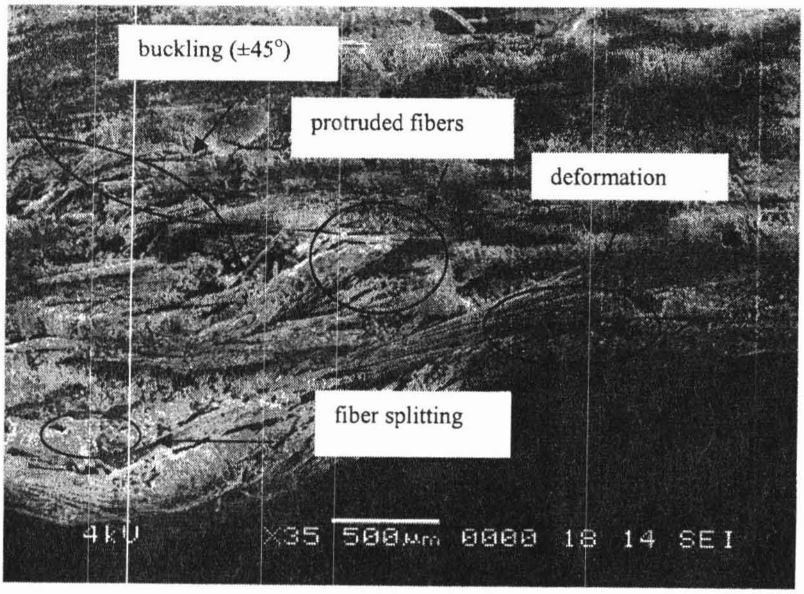

Fig. 3.1: Failure on the left side of pendulum striking area.

The tensile fracture gave matrix cracking comprising deformed fiber yarns at the V-notch in figure 3.3. Since in the chopped fiber short filaments are randomly arranged, the peeling force has pressed the yarns to move upwards at the bottom of the V-notch. The yarns are thought to failed in flexure mode at +50°C. It is to be noted that the angle of yarn deformation is 45°, measured from the base. Similar observation of tensile failure was also made on the woven sample tested at +50°C where the peeling force was dominant to the composite failure at V-notch (Nazrin *et al.* 2005). It is believed that shorter fiber length made easier for cracking to initiate and propagate in smaller distance which may be one of the reasons for having lower energy absorption of 270 KJm^{-2} in chopped fiber composite compared to 400 KJm^{-2} of woven fiber when fractured under similar conditions (Nazrin et al. 2005).

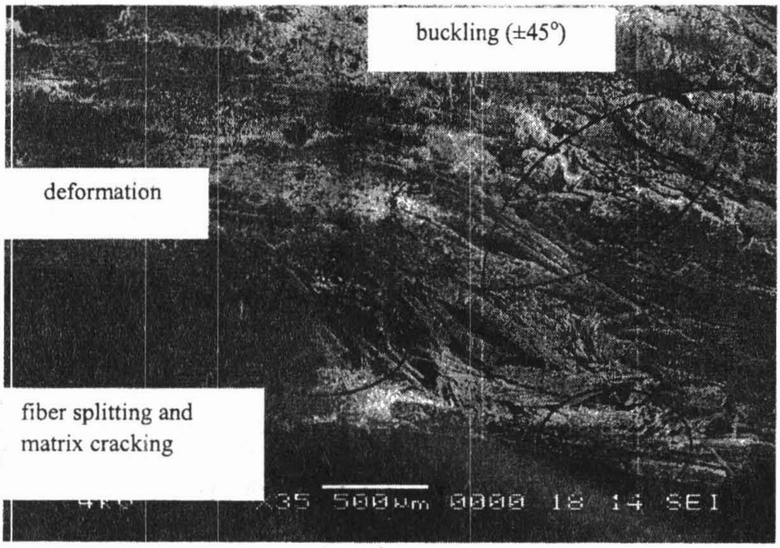

Fig.3.2: Failure on the right side of pendulum striking area at +50°C.

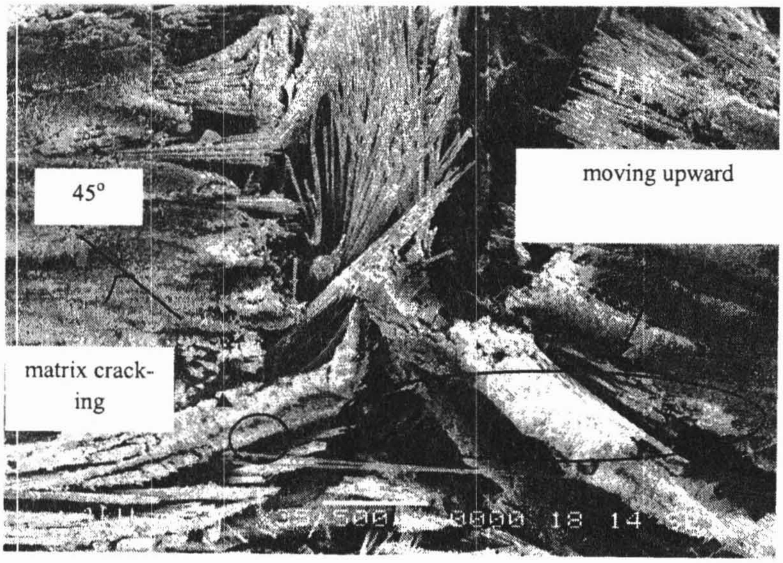

Fig. 3.3: Chopped fiber composite failure on the V notch area at +50°C.

Fig. 3.4 gives the fractography at the pendulum striking area of the specimen tested at -50°C which consists of protruded fiber and deformation at the left side of pendulum striking area. Similar failure mode was also observed on the right side of the sample. Fiber buckling with an inclination of 45° propagating from the pendulum striking area down to the interior was also observed in this figure. The deformation at the pendulum striking area is seen lesser with -50°C sample compared to the one tested at +50°C (Fig. 3.1). The contour of deformation at +50°C is according to the shape of pendulum which again suggests a plastic deformation mode. Clumps of bundle splitting were also seen on the buckling area in this figure. Since the sample hardness is increased at -50°C (Noraini 2005), matrix brittle fracture has splitted the fiber bundle to larger extent which was not found in the sample tested at +50°C. It is presumed that the splitted fiber bundle is due to brittle matrix cracking, the energy absorption is lower when tested at -50°C compared to the sample tested at +50°C. However, shorter and randomly oriented chopped fiber filaments also played an impo

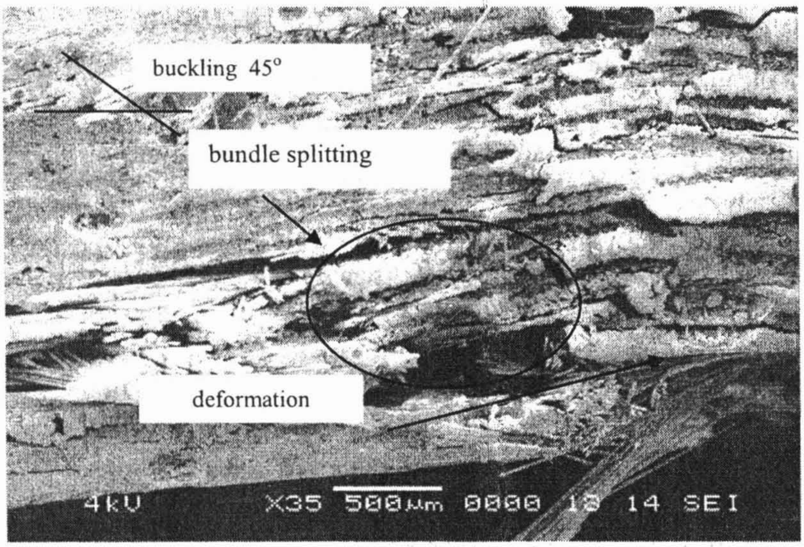

Fig. 3.4: Failure on the left side of the pendulum striking area.

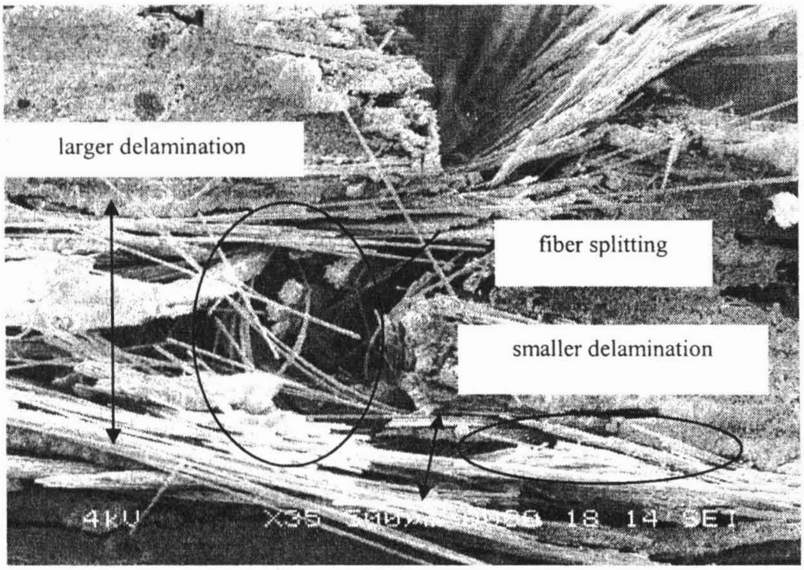

Fig. 3.5: Failure on the V notch area at -50°C.

At the V-notch area larger delamination occurred on the left side while smaller delaminations on the right side (Fig. 3.5). However, the sample tested at +50°C, gave the same size of delaminations on both sides (Fig. 3.3). It is believed that impact testing at +50°C, the tensile stress has easily peeled the V-notch area giving equal delamination characteristic on both sides. The splitted fiber yarn was not found to move upwards in sample tested -50°C compared to the +50°C sample. Instead of deforming, the yarns are seen to be splitted to individual filaments perpendicularly to the direction of impact blow (Fig. 3.5). Such difference of fiber failure may be due to the increased brittleness of the matrix at –50°C thus restricting fiber yarns to be deformed rather than fracturing the epoxy in the presence of tensile stress.

Conclusion

1. The tensile stress and compressive stress are dominant forces of giving tensile fracture and compressive fracture at the V notch and pendulum striking area tested at +50°C and -50°C temperatures.
2. Shorter fiber length had caused the matrix cracking easier to initiate and propagated in shorter distances which may be the cause for having lower energy absorption in the chopped fiber composite compared to the woven fiber reinforced epoxy composite in literature.
3. The increased matrix brittleness at -50°C had restricted the fiber yarn to highly deformed resulting many individual fibers and large bundle splitting with extensive matrix cracking.
4. Chopped composite reinforced epoxy composite sample gave fiber protrusion during impact at both temperatures. It is absent with woven fiber reinforced composite in literatures.

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