CHAPTER - 5

EXPERIMENTAL DETAILS

5.1 Introduction

The present study is to investigate the influence of nanoclay on the mechanical and low velocity impact properties of the E-glass fibre/epoxy composites. Universal testing machine has been used to study the mechanical properties like tensile, flexural and interlaminar shear strength. Drop weight impact testing machine has been used for impact properties in terms of maximum load carrying capacity, energy absorption, deflection at peak load and damage tolerance.

5.2 Mechanical properties

5.2.1 Tensile test

Tensile testing, also known as ‘tension testing’ is a fundamental materials science test in which a sample is subjected to uniaxial tension until failure. The tensile tests were carried out according to ASTM D3039 [ASTM standard 2001] using a minimum of 5 specimens for each glass fibre/epoxy nanocomposites for tensile test (Figure 5.1). Length of the samples was 250mm and the nominal thickness was 4mm, while the width was maintained at 25mm. The tests were performed in a universal testing machine (AG-IS Shimadzu) with a constant cross-speed of 5mm/min, at room temperature as shown in Figure 5.2. The tensile strength was calculated by using the following equation.

\[ \sigma = \frac{P_{\text{max}}}{A} \]  

Where, \( \sigma \) - Tensile strength, MPa  
\( P_{\text{max}} \) - Maximum load, N  
\( A \) - Average cross-sectional area, \( \text{mm}^2 \)
Figure 5.1 Universal testing machine

Figure 5.2 Sample position
5.2.2 Flexural test

The flexure test method measures behavior of materials subjected to simple beam loading. It is also called a transverse beam test with some materials. Flexure testing is often done on relatively flexible materials such as polymers, wood and composites. There are two test types; 3-point flex and 4-point flex. In a 3-point test the area of uniform stress is quite small and concentrated under the center loading point. In a 4-point test, the area of uniform stress exists between the inner span loading points. The 3-point flexure test is the most common for polymers. Specimen deflection is usually measured by the crosshead position. Test results include flexural strength and flexural modulus.

![Three point flexural](image)

**Figure 5.3 Three point flexural**

The flexural properties of the glass fibre/epoxy nanocomposites were measured using a three-point bending test according to the ASTM D790 [ASTM standard 2002] procedure A standard. The flexural test samples were machined as a dimension of 80mm long x 10 mm wide x 4mm thick. The testing samples were shown in Figure 5.4 (a). The flexural test were performed in a Lloyd LR 100K testing machine with a constant cross speed of 3 mm/min as shown in Figure 5.4 (b). The flexural strength was measured using the following equation.

\[
\xi = \frac{3PL}{2be^2} \quad (5.2)
\]

Where,
- \(\xi\) - Flexural strength, MPa
- \(P\) - Rupture load, N
- \(L\) - Support span, mm
- \(b\) - Width of specimen, mm
- \(e\) - Thickness of specimen, mm
5.2.3 Interlaminar shear test

Short Beam Shear is used to determine interlaminar shear strength of parallel fibers. It is applicable to all types of parallel fiber reinforced plastics and composites. The data can be used for research and development purposes concerned with interply strength, or prove useful in comparing composite materials. The thickness and width of the test specimen are measured before conditioning. The specimen is placed on a horizontal shear test fixture so that the fibers are parallel to the loading nose. The loading nose is then used to flex the specimen at a speed of 3 mm/min until breakage. The force is then recorded.
The interlaminar shear strength (ILSS) of glass fibre/epoxy nanocomposites was determined according to ASTM D2344 [ASTM standard 2006] procedure. The test samples were 24mm long x 6.35 mm wide x 4mm thick (Figure 5.5).

The test was performed in a Lloyd LR 100K testing machine with a constant cross speed of 3 mm/min. In each case, five specimens were tested and the average value is taken into consideration. The interlaminar shear strength was calculated using the following equation.

\[
\tau = \frac{0.75P_R}{b.e}
\]  

Where,  
\( \tau \) - Interlaminar shear strength, MPa  
\( P_R \) - Rupture load, N  
\( b \) - Width of specimen, mm  
\( e \) - Thickness of specimen, mm

5.3 Impact test

The impact tests on composite laminates could be performed by the following three methods.

(i) Drop weight test method  
(ii) Pendulum type test method  
(iii) Gas-gun

The drop weight machines can handle impact masses not exceeding 15 kg with a velocity less than 7 m/s. The pendulum impactor is used for the same impact masses, but the velocity is limited to about 2 m/s. The gas gun impactor is suitable for very small impact masses less than 250 g with high velocities more than 100 m/s [Mili, F. et al, 2001].
Drop weight impact testing was performed on the glass fibre/epoxy nanocomposites specimens as per the ASTM D3029 [ASTM standard 1982]. The testing specimen with 150 mm x 150 mm x 4 mm was prepared. To perform an impact test, the impactor was raised to a height of 1 m and dropped freely along two guiding rail, which result in an impact energy up to 24.89 J.

![Drop weight machine](image)

**Figure 5.6** Drop weight machine (a) Test equipment and (b) Specimen fixture set-up

Prior to impact loading, a nanocomposite specimen was clamped in a fixture with a rectangular slot (sq. 100 mm) as shown in Figure 5.6 (b). The hardened steel impactor with hemispherical tup of 12.5 mm diameter was dropped through 1 m to hit the laminate at the center of the span. The impactor mass of 2.5 kg was kept constant throughout this experimental work. It was found that, the weight and drop height changes were directly proportional to the impact energy.

The energy was calculated based on potential energy stored by the mass before releasing, using the equation \( E = mgh \), where \( E \) is the impact energy, \( m \) is
the mass of the impactor, \( g \) is the acceleration due to gravity and \( h \) is the drop height.

In the study falling height was chosen as 0.5, 0.75 and 1 m [Giovanni Belingardi. et al, 2008]. A load cell positioned in the proximity of the head of the dart collected and stored the impact information. For each type of glass fibre/epoxy nanocomposites laminates were subjected to impact at 12.45, 18.67 and 24.89 J. Impact response of the nanocomposites samples which included velocity, deflection, load and energy as a function of time was recorded. From the data, load–time and load–deflection curves was plotted at three different impact energy levels.

5.4 Scanning Electron Microscopy (SEM)

The fracture surfaces of the flexural and impacted samples were examined using scanning electron microscopy (SEM) to understand the deformation and failure behaviors at various magnifications. SEM was carried out using Hitachi S-3400N which operated at an acceleration voltage of 120 kV.

For conventional imaging in the SEM, specimens must be electrically conductive, at least at the surface, and electrically grounded to prevent the accumulation of electrostatic charge at the surface. They are usually coated with gold or palladium alloy coating of electrically conducting material, deposited on the sample either by low-vacuum sputter coating or by high-vacuum evaporation. In the study sample surfaces were coated with a thin gold film to increase their conductance for SEM observation.

5.5 Summary

The glass fibre/epoxy nanocomposites were prepared by hand lay-up techniques. The prepared nanocomposite was machined as per the ASTM standard for tensile, flexural, interlaminar shear and impact tests.