Chapter 2

Research Objectives and Methodology

2.0 Research Objectives

A uniform dispersion of intercalated or exfoliated nanoclay layers into polymer matrix improves the mechanical properties, thermal stability, and barrier properties. Although different methods have been investigated, screw extrusion technique for the dispersion of nanoclay in thermoset polymers has not been reported. Based on the gap in literature, this research employs a co-rotating twin screw extrusion technique for dispersing nanoclay in vinylester. The dispersion technique, improvement in properties and morphology studies were undertaken.

The main aim of this research was to examine the influence of twin screw extrusion on the dispersion of nanoclay in vinylester and evaluate the mechanical properties, diffusivity and erosion resistance of the nanocomposites. The objectives of the research were:

- Parametric optimization of co-rotating twin screw extruder for the dispersion of MMT in vinylester by adopting Taguchi’s Orthogonal Array technique
- Determining the effect of mechanical properties of MMT/vinylester/ glass nanocomposites with varying amounts of nanoclay
- Reducing the diffusivity through vinylester gelcoat by dispersing organomodified nanoclay in artificial sea water medium as per ASTM D1141
- Determining the effect of nanoclay on the diffusivity of nanoclay/vinylester gelcoat using Fick’s law and Langmuir adsorption model processed using twin screw extruder in artificial seawater medium at room temperature
Optimization of erosion parameters of nanoclay/vinylester/glass composites using Taguchi’s Orthogonal Array technique for erosion rate and erosion efficiency

Characterization of nanocomposites for dispersion and morphological studies using TEM, XRD and SEM

2.1 Research Methodology

The nanoclay/vinylester/glass and nanoclay/vinylester specimens were characterized for mechanical and diffusion properties respectively. Overall methodology of the research is presented in Figure 2.1.

---

**Dispersion of nanoclay in vinylester employing twin screw extrusion technique**

- Preparation of
  - Nanoclay/vinylester/glass composites
  - Nanoclay/vinylester gelcoats

- Parametric studies of twin screw extruder
- Moisture diffusion studies of nanoclay/vinylester gelcoats
- Erosion studies of nanoclay/vinylester/glass composites

*Fig. 2.1 Methodology for the studies of nanoclay/vinylester/glass composites*
2.2 Dispersion studies of MMT in vinylester using Twin Screw Extruder

Influence of co-rotating twin screw extrusion for dispersing MMT in vinylester, on the properties of the nanocomposites was investigated. Four main factors namely, MMT (3, 4 and 5 wt %) loading in vinylester, speed (100, 200 and 300 rpm), temperature (5, 15 and 30 °C) and number of passes (5, 10 and 15) were considered for the design of $L_{27}$ OA lay-out. Four response factors such as glass transition temperature of the MMT/vinylester gelcoat and UTS, interlaminar shear strength, and flexural strength of the MMT/vinylester/glass nanocomposites were studied. The morphological studies of MMT/vinylester gelcoat are carried out using SEM, XRD and TEM. Figure 2.2 represents the methodology used for the parametric studies.

![Flowchart for dispersion studies of MMT in vinylester](diagram.png)

**Fig. 2.2** Methodology for the dispersion studies of MMT in vinylester
2.3 Moisture diffusion through nanoclay / vinylester gelcoat composites

Moisture absorption through nanoclay/vinylester composites in artificial seawater medium and their resulting property degradation was studied. Cloisite-15A, an Organomodified nanoclay and Cloisite-Na, naturally occurring nanoclay were studied to examine the influence of organomodification on the moisture ingress behaviour of the nanocomposites processed using ultrasonication and twin screw extrusion. Mass up-take and micro-hardness were recorded periodically. XRD graphs and TEM micrographs were used for exfoliation studies of nanoclay. Fick’s law of Diffusion and Langmuir model were adopted for determining diffusion co-efficient. Figure 2.3 shows the methodology adopted for the studies.

Fig. 2.3 Methodology for moisture diffusion studies of nanoclay in vinylester
2.4 Development of erosion resistant polymer nanocomposite based on nanoclay

Solid particle impact response of nanoclay dispersed glass fibre reinforced vinylester composites was investigated based on Design of Experiments. The experiments were designed considering five main factors such as nanoclay loading (2, 3, and 4 wt %), velocity of impact (33, 45 and 66 m/sec), angle of impact (30 °, 60 ° and 90 °), size of impacting particles (177, 420, 595 microns), and stand-off-distance (120, 180 240 mm). The influence of these factors and interactions on erosion rate was studied using L\textsubscript{27} experimental lay-out. Mechanism of erosion was examined using SEM micrographs. The methodology adopted for the studies is shown in Figure 2.4.

Fig 2.4 Methodology for erosion studies