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Effect of oil palm nano filler on mechanical and morphological properties of kenaf reinforced epoxy composites

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HIGHLIGHTS

- Nano OPEFB kenaf hybrid epoxy nanocomposites were fabricated by hand lay-up.
- Effects of nano OPEFB incorporation on mechanical properties were investigated.
- Effects of nano OPEFB incorporation on morphological properties were determined.
- Comparative study were made with MMT and OMMT kenaf hybrid epoxy nanocomposites.

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ABSTRACT

Epoxy based hybrid nanocomposites was prepared by dispersing the nano filler (nano OPEFB filler, MMT, OMMT) at 3% loading through high speed mechanical stirrer followed by wet hand lay-up technique. Mechanical and morphology properties of hybrid nanocomposites were carried out. Obtained results indicated that the addition of 3% nano OPEFB filler into the kenaf epoxy composites considerably improves the mechanical and morphological properties. Nano OPEFB/kenaf hybrid epoxy nanocomposites displayed comparable properties to MMT/kenaf but less than OMMT/kenaf hybrid epoxy nanocomposites. We concluded that nano OPEFB hybrid composites will provide alternative constructional materials respect to steel, bricks and cement for Malaysia.

1. Introduction

Composite materials are the most attractive materials having properties that are not found in nature, consisting of two or more chemically different constituents namely the polymeric matrix and reinforcement. The reinforcement normally is more stiffer and stronger with relative to the matrix, while the matrix hold the reinforcement in its set place [1,2]. Considerable growing awareness and issues of greener and sustainable environment in the society generated profound interest in the usage of natural fiber as reinforcements in polymer composites [3,4]. Numerous recycling and renewable waste materials resources involving leaves, wood chips, waste newspaper, waste concrete, reservoir silt, etc., are being successively utilized in gypsum or polymer matrix due to growing environmental issues from past recent years in the constructional and building applications in ordered to replace traditional expensive building materials like bricks and concrete [5]. This thereby reduces the need for raw materials, waste management/production and a wide range of environmental impacts [6]. Natural fiber reinforced composites exhibit many advantages and disadvantages compared with conventional synthetic composites. The disadvantages such as poor wetting and weak interfacial bonding reduced the mechanical as well as thermal properties of the composites, however it can be overcome by modification of the fibers through physical/chemical treatment or by incorporating interfacial additives/compatibilizers [7–9]. The interfacial additives may be nano sized filler (nano silica, nanotubes, nanoclay) or synthetic fiber (glass fibers, aramid fibers) to produce hybrid composites through proper material design [10]. The properties of these hybrid

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composites solely governed by many factors including; matrix, fibers dimension, type of nano filler, fiber–matrix interface bonding, nano filler–matrix interface bonding [11,9].

Currently, hybrid composites are receiving considerable attention as the advanced constructional and structural materials with true balance between cost effectiveness and better performances. The hybrid materials are made by combining two or more different types of fibers in a common matrix or reinforcement in polymer blends [12–14], and offered interesting potential application for both structural, semi and non-structural industrial areas.

Nanocomposites is a multiphase dense complex material in which at least one of its phase has either one, two or three dimensions lower than 100 nm [11]. Nanocomposites represents the most promising, attractive, indispensable and encouraging approaches in the field of future advanced engineering applications tailored by adding nano scale fillers in the polymer matrix to meet the growing demands of the specific properties in the versatile industrial and practical applications [15,16]. Nanocomposites offered unique mechanical, thermal, optical, electrical, magnetic and barrier properties relative to pure polymer [17] and even to traditional/conventional composites such as glass fiber reinforced composites [11].

The hybrid nanocomposites bring the revolution in the field of material science displaying the most hi-tech advanced composite materials. The addition of nano particles shows remarkable improvement in the thermal, physical, mechanical and thermomechanical properties due to perfect dispersion, a high aspect ratio and effective polymer filler interaction [18,9].

Kenaf fiber is comparatively commercially available and economically cheaper among other natural fiber found in Malaysia and it is regarded as an industrial and most beneficial crop (Fig. 1), generating huge biomass content for both research and innovation. Kenaf fiber are extensively been used in fiber reinforced polymer composite sector as it displayed remarkable properties for reinforcement in composites consisting of different polymeric matrix under stress and varied flexural loading condition [19,15,20].

Epoxy is the most widely used thermosetting matrix materials, showing extensive applications. However cured epoxies represent low fracture toughness, inherently low impact resistance, reduced resistance to crack initiation and propagation [21,16]. It has been established that the addition of additives and nano fillers (<10 wt.%), such as reactive oligomeric compounds, low molecular weight polymers, plasticizers, nano-particles and nano-fillers certainly modify the epoxies, with enhanced mechanical, morphological, thermal and electrical properties [22,23].

The lignocellulosic and agriculture-plant based biomass materials are presently the most appropriate and inexpensive precursors for the production of nanomaterials or fillers. Saw dust, bagasse, rice husk, cellulosic nano fibers from rubber wood, coconut shells, nano fly ash and coir pith are being successively reported by several researchers [24–29].

Moreover, palm oil fuel ash to prepare cellulose acetate butyrate (CAB) composite, oil palm shell and oil palm ash as nano filler, carbon blacks (CB) and activated carbons (AC) derived from bamboo stem, coconut shell and oil palm empty fruit bunch fibers (OPEFB) fibers are also been explored and reported as filler in epoxy and polyester matrix to improve their properties [30–33].

Currently nanoparticle fillers and layered silicate minerals such as montmorillonite (MMT) and organically modified montmorillonite (OMMT) nanoclay received higher attention as they possess the potential tendency to modify significantly the mechanical, thermal and functional properties of both thermoset and thermoplastic polymers due to its high modulus, high strength and high aspect ratio [34,35]. Nanoclay are the general term for naturally occurring layered mineral silicates nanoparticles, having phyllosilicate or sheet structure with a thickness of about 1 nm and surfaces about 50–150 nm in one dimension [36,37]. MMT are the most commonly used layered silicate in polymer nanocomposites, among hectorite, pyrophyllite, nontronite and saponite nanoclay [37]. MMT belong to 2:1 phyllosilicates nanoclay family, having 2 tetrahedral sheets sandwiching a central octahedral sheet [38]. Naturally occurring MMT is highly hydrophilic, hence are typically modified by clay surface modification usually with ammonium salts or phosphonium salts through compatibilization or "intercalation" methods, in order to make them compatible with hydrophobic polymers [39]. The surface energy of MMT decreases and the interlayer spacing expands in the resulting organically modified nanoclays (OMMT) material, thus it can compatibilized with a wide variety of matrix polymers [40]. Currently, OMMT or 'organoclays' are one of the attractive and most promising hybrid organic inorganic nanomaterials generally used for improving the

Fig. 1. The dense kenaf plantation in Malaysia [20].