Effects of extrusion temperature on the rheological, dynamic mechanical and tensile properties of kenaf fiber/HDPE composites

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The effects of extrusion processing temperature on the rheological, dynamic mechanical analysis and tensile properties of kenaf fiber/high-density polyethylene (HDPE) composites were investigated for low and high processing temperatures. The rheological data showed that the complex viscosity, storage and loss modulus were higher with high processing temperature. Complex viscosities of pure HDPE and 3.4 wt% composite with zero shear viscosity of \( \frac{2340 \text{ Pa s}}{2340 \text{ Pa s}} \) were shown to exhibit Newtonian behavior while composites of 8.5 and 17.5 wt% with zero shear viscosity \( > \frac{30,870 \text{ Pa s}}{30,870 \text{ Pa s}} \) displayed non-Newtonian behavior. The Han plots revealed the sensitivity of rheological properties with changes in processing temperature. An increase in storage and loss modulus and a decrease in mechanical loss factor were observed for 17.5 wt% composites at high processing temperature and not observed at low processing temperature. Processing at high temperature was found to improve the tensile modulus of composites but displayed diminished properties when processed at low processing temperature especially at high fiber content. At both low and high processing temperatures, the tensile strength and strain of the composite decreased with increased content of the fiber.

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1. Introduction

The interest in using natural fibers in polymer matrix composite (PMC) has increased in recent years. This is due to the lightweight, non-toxic, low cost and biodegradable properties of natural fibers. The use of natural fibers, derived from renewable resources, as reinforcing agent in both thermoplastic matrix composites provides positive environmental benefits with respect to disposability and raw material utilization [1].

Kenaf fiber has potential as reinforcement filler in PMC. The purpose of producing PMC is to create a new material that has better properties compared to their individual material. Kenaf fiber can generally be classified into two types. The first type is the outermost layer known as bast while the second type is the inner part, known as core. The core is very soft, hollow and suitable for application as organic filler in plastic, while bast fiber has hard properties and is suitable for blending with plastic, textile industry and also fiberglass technology applications. Kenaf fiber is also used as reinforcement for plastic and synthetic product, cosmetic product, organic filler and medicine. Besides that kenaf fiber is also environmentally friendly.

The performance of a composite material varies with the fiber–matrix bond strength and to some extent, depends on the choice of suitable processing techniques. There are various methods of processing natural fiber–polymer matrix composites. Methods such as extrusion, compression and injection molding are used to introduce fibers into the thermoplastic matrix. Twin-screw extruder system, with a feeding and a mixing zone, consists of screws with a multiplex shape. In this system, the fillers are very well blended with the matrix polymer because the mixtures pass through a number of mixing blocks [2]. Potente et al. [3] studied the impact of speed, melt throughput, continuous-phase viscosity, screw configuration, and disperse-phase content on the melting behavior and morphology development in the melting zone of a twin-screw extruder of polypropylene/polyamide-6 composite. Their result showed a finely dispersed morphology at the start of the melting section and the screw can feed and mix the melted mixture simultaneously. The use of unmodified and modified sugarcane bagasse cellulose/HDPE composite with zirconium oxychloride formed by compounding 10% by weight of fiber using extrusion and compression molding showed that the modified composites present better tensile strength compared to unmodified composites. The cellulose agglomerations were responsible for poor adhesion between the fiber and matrix in unmodified composites [4].

Rheological measurement conducted in various steady state and dynamic environments is a widely used technique for determining the sensitivity of a material during processing [5]. From the findings conducted on multi-wall carbon nanotube (MWcnt)/poly(ether ether ketone) (PEEK) composites containing

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