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Kenaf natural fiber reinforced polypropylene composites: A discussion on manufacturing problems and solutions

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Abstract

As industry attempts to lessen the dependence on petroleum based fuels and products there is an increasing need to investigate more environmentally friendly, sustainable materials to replace existing materials. This study focused on the fabrication of kenaf fiber reinforced polypropylene sheets that could be thermoformed for a wide variety of applications with properties that are comparable to existing synthetic composites. The research done in this study has proven the ability to successfully fabricate kenaf–polypropylene natural fiber composites into sheet form. The optimal fabrication method for these materials was determined to be a compression molding process utilizing a layered sifting of a microfine polypropylene powder and chopped kenaf fibers. A fiber content of both 30% and 40% by weight has been proven to provide adequate reinforcement to increase the strength of the polypropylene powder. The use of a coupling agent, 3% Epolene enabled successful fiber–matrix adhesion. The kenaf–PP composites compression molded in this study proved to have superior tensile and flexural strength when compared to other compression molded natural fiber composites such as other kenaf, sisal, and coir reinforced thermoplastics. With the elastic modulus data from testing, it was also possible to compare the economic benefits of using this kenaf composite over other natural fibers and E-glass. The kenaf–maleated polypropylene composites manufactured in this study have a higher Modulus/Cost and a higher specific modulus than sisal, coir, and even E-glass thereby providing an opportunity for replacing existing materials with a higher strength, lower cost alternative that is environmentally friendly.

Keywords: E. Compression moulding; E. Thermoplastic resin; E. Forming

1. Introduction

One of the unique aspects of designing parts with fiber reinforced composite materials is that the mechanical properties of the material can be tailored to fit a certain application. By changing the orientation or placement of the fibers the material can be designed to exhibit properties that are isotropic or highly anisotropic depending on the desired end result. A major drawback of this customization is the economic costs that may be associated with this processing method. While customizing individual parts may be appropriate when working with low production level parts, when the idea is extrapolated to higher production parts, the customizing process becomes highly cost prohibitive. For higher production parts the use of thermoplastic sheets that have a pre-existing fiber orientation is a cost effective choice.

There has been extensive work throughout industry with forming and shaping oriented glass and carbon fiber reinforced thermoplastics. Common difficulties experienced

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show that the forming of straight, continuous fiber or woven fiber composite sheets typically results in wrinkling of the fibers and distortions. Randomly oriented fibers have provided good formability, but without the advantages of the highly directional properties often desired in composite parts. The more formable sheets that consist of aligned, discontinuous fibers appear to have been used with more success than continuous fibers [1].

As industry attempts to lessen the dependence on petroleum based fuels and products there is an increasing need to investigate more environmentally friendly, sustainable materials to replace the existing glass fiber and carbon fiber reinforced materials. Therefore, attention has recently shifted to the fabrication and properties of natural fiber reinforced materials. The automotive and aerospace industries have both demonstrated an interest in using more natural fiber reinforced composites, for example, in order to reduce vehicle weight, automotive companies have already shifted from steel to aluminum and now are shifting from aluminum to fiber reinforced composites for some applications. This has led to predictions that in the near future plastics and polymer composites will comprise approximately 15% of total automobile weight [2].

Natural fibers that have been evaluated as replacements for glass and other non-recyclable fibers include flax, hemp, kenaf, and sisal. These fibers are abundant, cheap, renewable, and easily recycled. Other advantages include low density, high toughness, comparable specific strength properties, reduction in tool wear, ease of separation, decreased energy of fabrication, and CO_2 neutrality [3]. These natural fibers can be split into two categories, bast and leaf. The bast fiber composites include kenaf, hemp and flax, while sisal may be considered a leaf fiber. The bast fibers exhibit a superior flexural strength and modulus of elasticity (MOE), but the leaf fibers show superior impact properties. Compared to glass fibers, the bast fibers tend to show approximately the same flexural strength and a higher MOE [3]. The main drawback in using these natural fibers is the hydrophilic nature of the natural fibers, which may lead to problems of adhesion with the hydrophobic polymer matrix. High temperatures must also be avoided due to the possibility of fiber degradation. In addition, since they are grown naturally, the properties of the fibers can vary immensely from plant to plant.

2. Manufacturing of natural fiber reinforced thermoplastic sheets

Mckenzi and Yuritta [4] compared different types of wood fiber–reinforced polymers to determine if wood fiber has advantages as a reinforcing material over other fibrous materials. Comparisons were made with nylon, rayon, glass, and Kevlar. The short length of the wood fiber led to the conclusion that the bonding of the matrix with the fiber was crucial since the full strength of the fiber would only be utilized if a strong bond were formed. It was also found that a wood fiber composite would have to be 67% thicker than a glass fiber composite in order to have the same strength. This increased polymer matrix requirement reduces the cost benefit of wood fiber over glass, but wood fiber provides advantages by consuming less energy during fiber manufacture and the potential for lower mass structures.

Michell [5] studied different types of composites containing wood pulp fibers. Michell has shown that wood pulp fibers are cheaper than other organic polymers and also lead to improvements of both the strength and tensile modulus of composites. The study concluded that although the wood pulp fibers were already being used in thermoset applications, there exists an opportunity for use as reinforcements in thermoplastic composites.

Wambua et al. [6] evaluated several different natural fiber–polypropylene composites to determine if they had the ability to replace glass fiber–reinforced materials. Polypropylene with a very high melt flow index was used to aid in fiber matrix adhesion and to ensure proper wetting of the fibers. Samples were made with 40% fiber content of kenaf, coir, sisal, hemp, and jute. After the samples were fabricated, tensile and impact tests were run to compare the properties of these composites to those made with glass fiber. The tensile strengths all compared well with glass, except for the coir, but the only sample with the same flexural strength was hemp. It was shown with kenaf fibers that increasing fiber weight fraction increased ultimate strength, tensile modulus, and impact strength. However, the composites tested showed low impact strengths compared to glass mat composites. This study demonstrated that natural fiber composites have a potential to replace glass in many applications that do not require very high load bearing capabilities.

Mohanty et al. [3] compiled an overview on the different biofibers, biopolymers, and biocomposites comparing advantages and disadvantages of these materials. Different fiber–polymer composites were fabricated and tested in this work. The specific properties of natural fibers such as hemp, kenaf, jute, flax, and sisal were compared with traditional composite reinforcements showing that the density of these natural fibers were much lower than the traditional materials thereby leading to strength/weight ratios comparable with those of such widely used materials as E-glass and Aramid. Testing of the biocomposites demonstrated an optimal fiber content of approximately 30%.

Mohanty et al. [7] evaluated biocomposites formed using chopped hemp fiber and cellulose ester biodegradable plastic. The effect of two different processing approaches was studied. For the first process, the chopped fiber (30% by weight) was mechanically mixed in a kitchen mixer for 30 min followed by compression molding using a picture-frame mold. The second process involved two steps, first an extrusion process yielded pellets of cellulose acetate plastic (CAP), secondly, the pellets were fed into a twin-screw extruder while chopped hemp fibers were fed into the last zone of the extruder. This process yielded thin strands of the composite, which were pelletized for