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Predicting the Tensile Modulus of Randomly Oriented Nonwoven Kenaf/Epoxy Composites

N. G. Andre[a], Z. A. Mohd. Ishak[a,b,*]

[a]*School of Materials and Mineral Resources Engineering, Engineering Campus, Universiti Sains Malaysia, 14300 Nibong Tebal, Pulau Pinang, Malaysia*

[b]*Cluster of Polymer Composites, Science and Engineering Research Centre, Engineering Campus, Universiti Sains Malaysia, 14300 Nibong Tebal, Pulau Pinang, Malaysia*

Abstract

As there has been an increasing trend in using nonwovensnatural fiber in composites, there is a need to find good micromechanical models to represent their behavior. In this study,randomly oriented nonwoven kenaf/epoxy composites at various fiber loading has been fabricated by using resin transfer moulding (RTM) method. Experimental results show that increasing the fiber loading has led to the increment of tensile modulus. The validity of rule of mixtures (ROM) and modified rule of mixtures (MROM) which includes model by Krenchel and Nairn has also been analyzed. ROM has failed to predict the tensile modulus of the composites. Meanwhile, MROM managed to produce an accurate tensile modulus prediction due the inclusion of fiber length factor by Nairn model and fiber orientation factor by Krenchel model.

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*Keywords:*Resin transfer moulding; Natural fiber-reinforced polymer composites; Micromechanical model; Elastic modulus

1. Introduction

A great deal of attention has been directed to the development of green materials nowadays due to environmental

* Corresponding author. Tel.: +604-599-5999; fax:+604-594-1011.
E-mail address: zarifin.ishak@gmail.com

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concerns. Polymer reinforced with natural fibers is one of those that has been progressing well[1]. The upsurge in the usage of natural fibers in many applications has led to the utilization of nonwovens natural fiber. Due to its advantages such as lightweight, excellent strength, sound efficiency, flexibility and the attractive cost/performance ratio, there has been an increasing trend in using nonwovens to make composites for automotive interior components[2]. It is also important to note that nonwovens also possess vital intrinsic quality that reduces delamination issue as it provides excellent z-directional properties[3].

One of the major reason for using fibrous reinforcement is to provide stiffness where it is a crucial properties especially in structural or semi-structural applications[4]. Stiffness, which was defined by the modulus of elasticity is basically a numerical evaluation of the ratio of the increment of stress to the increment of strain. Before it is measured or characterized, prediction can be made by utilizing various micromechanical models that has been developed and established in different studies before. However, there have been little studies in the implementation of micromechanical models on randomly oriented natural fiber nonwoven composites[5]. Hence, there is a need to find good micromechanical models to represent the tensile modulus of this type of composites. This is possible by comparing the experimental data with the predicted results. It is also important to note that the intrinsic properties of fibers are key factor to produce an accurate prediction of Young's modulus.

The aim of the current study is to analyze the validity of two micromechanical models in predicting the tensile modulus of randomly oriented nonwoven kenaf/epoxy composites. First, resin transfer moulding was utilized to produce the composite. Second, the intrinsic properties of fibers such as aspect ratio and longitudinal Young's modulus were characterized. The measured intrinsic properties were then applied onto the rule of mixtures (ROM) and modified rule of mixtures (MROM) to predict the tensile modulus of composites over a range of fiber volume fraction, V_f (0.15-0.42). Finally, the predictions were compared to the experimental results and analysis of the comparison were carried out.

2. Theoretical background

2.1. Rule of mixtures (ROM)

The rule of mixtures is the simplest model that is used to predict the elastic modulus of composites. This model allows elastic modulus calculation for composites by assuming equal amount of strain experienced on both matrix and fiber. The strain originates from the application of uniform stress over a uniform cross-sectional area. The equation of the model is expressed as below:

$$E_C = E_f V_f + E_m V_m \tag{1}$$

Where, E_m, E_f, $V_m$and V_f represent the moduli and volume fractions of the matrix and fiber respectively and E_C represents the modulus of composite. The ROM model is suitable to estimate the tensile modulus of composites with aligned continuous fiber. This simple model assumes that there are equal strain experienced in both matrix and fiber.

2.2. Modified rule of mixtures

The rule of mixtures can be extended to include the effect of fiber length and orientation. It is expressed as below:

$$E_C = \eta_l \eta_o E_f V_f + E_m V_m \tag{2}$$

Where, η_l is the fiber length distribution factor and η_o is the fiber orientation distribution factor while the effect of voids has been neglected[6]. In this particular study, the fiber orientation factor was based on Krenchel's[7]:

$$\eta_o = \cos^4(\alpha_o) \tag{3}$$