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Interfacial shear strength of glass fiber reinforced polymer composites by the modified rule of mixture and Kelly-Tyson model

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Abstract

Four types of commercial grade glass fiber reinforced thermoplastics (GFRP) were used in this study. Polymer matrices included polycarbonate (PC), polyoxymethylene (POM), polypropylene (PP) and polyamide 6 (PA6). The contents of GF were 10%, 20% and 40%. The GFRP were fabricated to dumbbell specimens by injection molding machine. Tensile strength of the GFRP composites was carried out by tensile testing. Theoritical caluculation of interfacial shear strenght was analyzed using a modified rule of hybrid maixture (MRoHM) strength equation according to the orientation and direction of glass fiber reinforcing. The fiber orientation was characterized from the fractured surface observation by scanning electron microscope and optical microscope. The tensile strength of GFRP composites increased with incresing glass fiber contents. However, the declination of tensile strength from the prediction was attributed to the reduction of glass fibers length and fiber orientation in GFRP composites. It is interesting to report that the interfacial shear strength of GFRP composites was calulated according to the MroHM and the Kelly-Tyson model, which the interfacial shear strength of the composites increased with incresing glass fiber contents.

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1. Introduction

The most important property of short fiber reinforced polymer composites is tensile strength. Several parameters, which control the strength of composite, can be affected by the type and conditions of the fabrication processes. For short fiber reinforced thermoplastic injection molding is the most popular fabrication process because of the high production efficiency [1-4].

The injection-molded process for short fiber reinforced composites has quite complex fiber orientation distributions that vary both through the thickness and at different positions along the composite molding. Fiber orientation can be strongly influenced by processing condition, mold geometry and specimen geometry. Preferentially oriented fiber does not mean the perfect alignment and there should be a fiber orientation distribution with a small average angle of the fibers with the flow direction [1, 5].

It is very important to be able to predict the mechanical properties of a short fiber reinforced composite given the component properties, their geometric size and arrangement. The suitable analytical modeling will not only help in interpreting the experimental results but also optimizing specific applications in many sectors. Moreover, the composite mechanical properties can be inferred with no need of conducting long experiments. Over the last decade, several theoretical models have been proposed in order to predict the strength of short fiber reinforced composites (SFRP). One of the major approaches is the modified rule of mixtures (MRoM), which has been mostly used by taking into consideration the effects of fiber length and orientation distribution. The properties of a hybrid composite depend on the fiber content, fibers length, orientation of fibers, extent of intermingling of fibers, fiber to matrix interface, layering pattern of both fibers and also dependent on the failure strain of individual fibers [5-11].

In this study, aims to develop and validate a predictive capability for tensile strength of short fiber reinforced polymer composites to enable strength predictions in injection molded components. The short glass fiber reinforced polymer composites were made four type have polycarbonate, polyoxymethylene, polypropylene and polyamide were prepared by injection molding of long fiber pellet. The analytical model used for predicting the tensile strength of hybrid injection molded composite will be introduced. The predictive method is based on a modified rule of hybrid mixture (MRoHM) as function of fiber orientation direction, fiber length distribution and tensile strength of the composites are discussed.

2. Theoretical prediction

Tensile strength is one of the most important properties of engineering materials. The important motivation for using composite materials as a class of engineering materials is their high tensile strength that can be achieved by incorporating high strength fibers into polymer matrix. A composite works by taking an applied stress and distributing it on the matrix and predominately, on its reinforcing fibers. It is important to be able to predict the tensile strength of short fiber reinforced polymer composites by using the given component properties, their geometric size and fiber arrangement. The rules of mixture for predicting tensile strength of composite (σ_c^u) can be defined as following equation.

$$\sigma_c^u = V_f\sigma_f + V_m\sigma_m \tag{1}$$

The modified rule of mixtures (MRoM) is also often used to predict the tensile strength of short fiber reinforced composites by assuming a perfect bonding between fibers and matrix. Then equation (1) will be modified as

$$\sigma_c^u = f_o f_l V_f \sigma_f + V_m\sigma_m \tag{2}$$

The well-known Kelly-Tyson model considering the effect of fibers with shorter (sub-critical) and longer (super-critical) than the critical fiber length is given as

$$\sigma_c^u = \sum_{l_i=l_{min}}^{l_c} \frac{l_i}{2l_c}\sigma_f V_{f,i} + \sum_{l_j=l_c}^{l_{max}} \left[1 - \frac{l_c}{2l_j}\right]\sigma_f V_{f,j} + \sigma_m V_m \tag{3}$$