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Effect of Broken Fiber on Stress Transfer of Short Fiber Reinforced Thermoplastic Matrix Composite

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Short fibers are becoming increasingly popular reinforcing elements in products made by injection molding. Short-fiber reinforcement allows the polymer to be processed employing the same methods as those used for unreinforced polymers. The best mechanical performances are achieved in composites when fibers are aligned in the loading direction. There are different methods developed by researchers in order to manufacture aligned short fiber reinforced polymer composites. Unidirectional composites tend to be very stiff and strong in fiber direction but very weak in the transverse direction. Their weakness in transverse direction is attributable to presence of significant stress concentration at the interface of matrix and fiber. In short fiber composites, loads are not directly applied on the fibers but are applied to the matrix and transferred to the fibers through the fiber ends. The process of transfer of load between fibers and matrix in the neighborhood of a fiber break or a matrix crack depends on the strength of the interface. The objective of this study is to analyze the fiber breaking effect in composite made of nylon 66 (PA) matrix reinforced with short glass fiber, in which the fiber diameters of 4.76, 6.35, and 9.5 μm were used. A fiber volume fraction of 20 % was assumed in each model.

Keywords: Broken fiber, Thermoplastic matrix, Composite, Short fiber, Stress transfer, Finite element.

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1. INTRODUCTION

Short fiber reinforced polymers can also be classified into two groups depending on the type of polymer e.g., thermoplastic and thermoset. Thermoplastic materials offer clear advantages over thermosets. In fact, thermoplastics can be repeatedly softened by increasing temperatures and hardened by cooling, contrary to a thermosets, which, once cured, cannot be reshaped or remold at elevated temperatures [1].

Thermoplastics have many advantages over metal parts including weight, ease of fabrication and economy. Although the advantages have allowed them to proliferate in various industries, the lack of structural load carrying capacity has hindered their use in automotive and aerospace industries. To mitigate the disadvantage, short fibers such as glass or carbon fibers, etc. are added to these polymers to improve the elastic modulus, strength to weight ratio, creep resistance, and dimensional stability. This increase in the load carrying capacity is what allows these composites to be widely explored in the Automobile & Aerospace component industry. However, the application of fiber-filled thermoplastic materials has been limited in many cases due to the inability to accurately predict performance and durability as the behavior of the polymer composites depends primarily on the fiber length and the fiber orientation distribution [2]. Quantitative prediction of the strength of the short fiber reinforced thermoplastics is a complex problem. A reason for this is non-uniformity of stress distribution along the short fiber length and radial interface in these composites; this implies that the average stress carried by fibers at the point of failure will be less than their ultimate tensile strength. Fiber reinforced composite is subjected to longitudinal tensile loading, the main part of the load is born by the fibers. The short fibers are considered to be uniaxially aligned with the stress applied in the axial direction of the fibers. It is considered a composite containing fibers, which all have the same length and diameter, and are all parallel [3]. The technique provides a method for achieving a uniform, homogeneous dispersion of reinforcing fibers and thermoplastic resin. Watching the structure of composites, we can notice its heterogeneous nature. The composite material consists of fibers and matrix. The fibers are embedded into the matrix. During the manufacturing process, the matrix is warmed up to high temperature, and then the fibers are added. Due to the high temperature and the mismatch between the thermal properties of the components, there is interaction between the fibers and the matrix [4]. This study is a continuation of a work done about the influence of fibers arrangement on the mechanical properties of short fiber reinforced thermoplastic matrix composite [5]. The distance between fibers decreases when the volume fraction increases. At higher fiber volume fraction, the spacing becomes very small.

The purpose of this work is to analyze the fiber break effect of short glass fiber reinforced nylon 66 (PA) matrix composites considering the interaction between matrix and fibers interface. Fiber reinforced composite is subjected to longitudinal tensile loading. Controlling the fiber orientation distribution in short fiber reinforced composites made with a thermoplastic polymer matrix affects the mechanical performance of the material in the fiber direction [6]. The mechanical performance of discontinuous fiber reinforced thermoplastics is affected by the followings:

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