Journal of Nano- and Electronic Physics
Vol. **13** No 6, 06018(4pp) (2021)

Журнал нано- та електронної фізики
Том **13** № 6, 06018(4cc) (2021)

Effect of Reinforcing Particle Shape on the Behavior of Composites Materials

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(Received 01 November 2021; revised manuscript received 02 December 2021; published online 20 December 2021)

In this paper, the effect of particle shape on the mechanic behavior of glass particle reinforced composites is evaluated. Small particles adhere strongly to the polymer, which leads to a strong reinforcing effect. When the total contact surface increases, more loads are transferred to the reinforcing particles. In our previous studies, it has been shown that addition of circular particles with decreasing diameter does not affect the composite. The objective of this research is to investigate the mechanical behavior of thermoplastic matrix composite nylon 66, reinforced with glass particles, under unidirectional tensile loading using finite element analysis. Numerical results are presented for a variety of particle shapes, including circular, triangular, square, rhombic, pentagonal and hexagonal. The results show that Von Mises stresses consistently increased as the shape of the reinforcing particles changed from triangular to square, rhombic, pentagonal, hexagonal and circular in this order.

Keywords: Particles, Nylon 66, Composite, Shape effect, Tensile loading, Finite element.

DOI: 10.21272/jnep.13(6).06018 PACS numbers: 81.05.Qk, 81.07.Lk, 1.07.De

1. INTRODUCTION

The addition of rigid reinforcing materials to polymer materials is an established practice in the polymer industry. By introducing a rigid second phase, substantial improvements in stiffness, strength, creep performance, and fracture toughness can be obtained. Reinforcing materials are usually spherical, plate-like or fiber-like. Fiber is often used as a reinforcing material, although this usually leads to anisotropy. This may cause problems and change the size of the components. Therefore, when tight tolerances or isotropic properties are required, spherical or plate-like particle fillers are sometimes a better choice [1]. In fact, thermoplastics can be repeatedly softened by increasing temperature and hardened by cooling. This is the opposite of thermosetting plastics. Once cured, they cannot be altered or reshaped at elevated temperatures [2]. Compared to metal parts, thermoplastics have many advantages, including weight, ease of manufacture, and cost effectiveness. Although these advantages enable them to proliferate in various industries, the lack of structural load-bearing capacity hinders their use in the automotive and aerospace industries [3]. The overall material cannot meet certain material requirements in advanced industries. Therefore, composite materials have been developed. The combination of the required properties of thermoplastics and glass particles (high strength and high modulus) is the goal of composite production [4]. The high cost and technical difficulties encountered in the production of fiber-reinforced composite materials sometimes limit their use in many applications [5]. Particle-reinforced materials are more attractive because they are cost-effective, isotropic, and can be processed using similar techniques for monolithic materials [6]. The effective behavior of macroscopically isotropic particle-reinforced two-phase composites is primarily determined by the fabric behavior and volume fractions of the matrix and inhomogeneities. The details of the geometric arrangement of the constituents and, therefore, the shapes of the particles play solely secondary roles [7]; a decrease in the particle diameter (circular) does not have an effect on the composite [8]. The particles are used to increase the modulus of the matrix, reduce permeability, and reduce ductility. Young's modulus is the stiffness (ratio between stress and strain) of a material in the elastic phase of a tensile test. Since the rigidity value of solid particles is much higher than that of the matrix, it can be significantly improved by adding micro- and nanoparticles to the polymer matrix [9].

A particle can have one dimension or not have a long dimension. Composite materials consist of particles of one material dispersed in a matrix of another material. Generally, the particles are spherical, elliptical, polyhedral, or irregular in shape. The particles are added to the liquid matrix and then solidified in some process. The particles can be treated or untreated during the enhancement process. They are used to increase the strength or other properties of cheap materials during reinforcement with other base materials [10]. Kamalbabu concluded that reinforced composites with smaller particle sizes show better tensile properties than other composites. Morphological analysis shows that smaller particles are evenly distributed in the matrix, and the fracture surface is smooth [11]. The objective of this research is to investigate the mechanical behavior of thermoplastic matrix composite nylon 66, reinforced with glass particles, under unidirectional tensile loading by finite element analysis, in which different shapes are used (circular, triangular, square, rhombic, pentagonal and hexagonal).

2. THEORETICAL ANALYSIS

The improvement in mechanical properties has led to great interest in nanocomposites. The mechanical properties of particle-reinforced materials depend on the bond between the particles and the matrix and the quality of the particles. Since particles and a matrix

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