Doctor Thesis

Structure and properties of short fiber reinforced polymer composite and hybrid composite fabricated by injection molding process

UAWONGSUWAN PUTINUN

Abstract

Short fiber reinforced polymer composites have found extensive applications in many fields due to their low cost, easy processing and superior mechanical properties over the neat thermoplastics. For interpreting the mechanical properties of composite by several variable parameters, additional measurements are required when changes occur in the composite system variables. Thus, experiments may be time consuming and cost prohibitive. Therefore, theoretical models of determining composite properties should use to predict the effects of a large number of parameters on the properties of composites. Prediction of the performance of injection molded short fiber reinforced polymer composites is desirable from the design standpoint. The using of appropriated models and suitable variables can predict the mechanical properties of short fiber composites and hybrid composites with good agreement with the experimental results.

The rising concern towards environmental issues has led to increasing interest in fully green composites. Polylactic acid (PLA) based biocomposite reinforced with different natural reinforcement were prepared. The addition of natural reinforcements improved the stiffness of PLA as the result of addition of high stiffness material. However, the tensile, flexural and Izod impact strength of PLA biocomposites decreased when the reinforcement content increases. The application of flexible epoxy surface treatment improved mechanical properties of PLA biocomposites by improving the bonding between natural fiber and PLA matrix. However, it can be seen that the effectiveness of flexible epoxy treatment depended on the types of reinforcements. As the major drawback of using bio-based polymer matrices is their high cost, which makes them unaffordable even for large-scale productions. Some other drawbacks of bio-based composites include brittleness and

low heat distortion temperature, which restrict their use in a wide-range of applications. The concept of hybrid systems for improved material performance is well known in engineering design. Hybrid green composites can be designed by the combination of synthetic fiber and natural fiber in a matrix. The development of the fabrication of long natural fiber reinforced thermoplastic through long fiber thermoplastic (LFT) technology provided natural fiber reinforced thermoplastic pellets with very high fiber concentration. The effects of twisted and un-twisted jute yarn during LFT pellet preparation and re-compounding on mechanical properties of jute fiber/polypropylene (JF/PP) and glass fiber/jute fiber/polypropylene (GF/JF/PP) hybrid composites were evaluated. Mechanical properties of JF/PP composites are mainly depended on the fiber aspect ratio, fiber orientation and the distribution of jute fibers. The incorporation of glass fibers is found to improve mechanical properties of jute fiber reinforced polypropylene composites. The increasing of mechanical properties of hybrid composites was depended on type of JF/PP pellets. In order to maximize the effectiveness of glass fiber hybridization, the fiber distribution and fiber orientation of jute fiber might be seriously considered.

Sandwich injection molding is an extension of the conventional injection molding technology which two different materials are either simultaneously or in rapid sequence injected through the same gate. The fabrication of GF/JF/PP hybrid sandwich composites through the combination of two different materials several benefits can be obtained. Regards the effect of glass fiber hybridization on the jute/PP sandwich structure composite, the addition of glass fiber in the core layer or skin layer can significantly improve both tensile and flexural modulus of sandwich composite. By using the concept of hybridization and sandwich structure, several combinations of sandwich hybrid composites can be designed. This design`s flexibility is very useful in engineering design to achieve the optimum properties for appropriate application.

The extrusion compounding for preparing fiber filled polymer pellets, has a practical processing limit on the fiber attrition problem, which decreases the reinforcement efficiency of the fibers. In this study, the novel processing technique for the fabrication of short fiber reinforced composite is introduced as the direct fiber feeding injection molding (DFFIM) process. This process reduces the fiber breakage during conventional screw

compounding and results in longer length of retained fiber. The fiber in composites fabricated with DFFIM process show poor quality of fiber distribution when compared with the compounded composite. The new parameter called fiber distribution index is introduced and this parameter can be used as the indicator for the quality control of fiber distribution in short fiber reinforced composites. The modification of interfacial property of composites fabricated by DFFIM process was evaluated through the hybrid glass fiber/carbon fiber and glass fiber/jute fiber reinforced polypropylene composites. The effects of addition of coupling agent and carbon fiber surface treatment on interfacial bonding between carbon fiber, glass fiber, jute fiber and polypropylene were discussed. The using of polyamide 6 (PA6) and maleic anhydride grafted polypropylene (MAPP) as co-coupling agent significantly improved the interfacial bonding between carbon fiber and polypropylene. In addition, the amino silane sized carbon fibers further improved the bonding between carbon fiber and the co-coupling agent as compared to the as-received carbon fiber. The using of MAPP as coupling agent improves the interfacial bonding between both glass fiber and jute fiber with PP matrix. The new injection molding technology is a simple process without the requirement of extrusion compounding step and it can be easily adapted to existing injection molding equipment. This technology provides a unique route and high processing flexibility to market for injection molders to incorporate cost reduction into their business strategy.