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Rupinder Singh, Ranvijay Kumar, Ida Mascolo, Mariano Modano

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On the applicability of composite PA6-TiO_2 filaments for the rapid prototyping of innovative materials and structures

Rupinder Singh[a], Ranvijay Kumar[a], Ida Mascolo[b], Mariano Modano[c]

[a] Department of Production Engineering, Guru Nanak Dev Engineering College, Ludhiana, India
rupindersingh78@yahoo.com (Rupinder Singh), ranijayk12@gmail.com (Ranvijay Kumar)
[b] Department of Civil Engineering, University of Salerno, Italy
imascolo@unisa.it (Ida Mascolo)
[c] Department of Structures for Engineering and Architecture, University of Naples Federico II, Italy
modano@unina.it (Mariano Modano)

Abstract

In the present paper a meticulous study for controlling the process parameters of twin screw extruder has been highlighted for in-house preparation of reinforced PA6-TiO_2 hybrid feed stock filament (HFSF) of fused deposition modelling (FDM) for applications in several engineering fields. The experimental study has been reported for field engineers, to understand the influence of twin screw extrusion (TSE) process parameters on mechanical and metallurgical properties of Nylon-TiO_2 HFSF for printing of functional prototypes by FDM, with special focus on the additive manufacturing of innovative composite materials and structures with arbitrary geometry at different scales. These properties were statistically compared to verify the suitability of the screw extrusion process. The study suggested the long-term performance level of the TSE process after it has been brought under statistical control. The provided data from the experimentation highlights the ability of the TSE process to produce a product that will consistently meet the design requirements and the customer expectation.

Keywords: Hybrid feed stock filament, Fused deposition modelling, Nylon-$TiO_{2,}$ rapid prototyping, mechanical metamaterials

1 Introduction

The polyamide6 (PA6)/ Nylon6 fibers are tough, possessing high tensile strength, as well as elasticity and luster. They are wrinkle proof and highly resistant to abrasion and chemicals such as acids and alkalis. The fibers can absorb up to 2.4% of water, although this lowers tensile strength. The glass transition temperature of PA6 is 47°C [1]. The most common feedstock which is mechanically recycled is PA6 fibers known for melt processing capabilities [2]. PA6 can be considered as human-made long chain polymeric material. It is widely used, economical materials characterized by excellent all-round properties, easy moulding and manufacturing. Traditionally PA6 is a very stable polymer and not readily degraded in the ambient environment. As a result, environmental pollution from synthetic plastics has been recognized as a large problem [3]. Government, researchers, and social organization worked on this issue to resolve it by improving reusability with objective of wire extrusion, additive manufacturing techniques or by making liquid fuel using thermal cracking process, [4-5]. Compared to the recycling process of metals, glass and alloys, PA6 polymers recycling is often more challenging because of low density. Various studies have been reported for significant improved properties of polymers with aid of micro or nano-compoties. Silica nanopowder (<30nm) at certain level incorporated to PA6 matrix confirmed better mechanical properties to the base polymer [6], Zinc oxide (ZnO) incorporated to the PA6/PBT (butylene terephthalate) blend matrix was resulted into finer morphology but caused deterioration in melt rheological properties [7]. Polyhedral oligomeric silsesquioxane (POSS) at 1-5wt% mixed with PA6/PP (polypropylene) blend ensures the valuable changes in the mechanical, morphological and thermal properties. Presence of POSS decreased the melt flow index, increased the yield and impact strength and improves the degree of crystallinity [8]. One of the studies reveals that the incorporation of CaO