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A Targeted Functional Value Based Nanoclay/PA12 Composite Material Development for Selective Laser Sintering Process

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Abstract

The work presents an evaluation of possibilities of mixing Nanoclay with polyamide (nylon 12 or PA 12) powder in order to enhance fire retarding properties. Further the work deals to estimate making of part which are useful in daily use with Selective Laser Sintering process using the Nanoclay and PA12 mixture. To achieve the identical process condition in order to qualitatively compare the results with that of SLS fabricated parts, a pressure-less casting process is employed to prepare specimen of PA12 based composite powder (containing 0-15 wt % Nanoclay). Surface modified montmorillonite Nanoclay is used for reinforcing the cast parts of PA12. The composite powders are examined by material characterization techniques (SEM, DSC and XRD). The effects of Nanoclay on the thermal (viscosity, melt flow index, molecular weight etc.), and mechanical properties of the casted parts are investigated. The results show that the uniform dispersion of Nanoclay is achieved in the prepared specimen. The composite powder has much high thermal stability than pure PA12 material. On addition of such a small quantity of Nanoclay most of the mechanical properties and flammability properties are improved while elongation at break (%) decreased significantly. The study will be useful in making the value added parts using an alternate material.

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Keywords: Value Creation by Sustainable Manufacturing , Nanoclay, PA2200 (PA 12), Selective Laser Sintering, Value Engineering.

1. Introduction

Selective laser sintering (SLS) is a group of automated, highly productive, energy saving and powder based sustainable manufacturing process [1-2]. The acceptance of SLS process (an AM process) in future predicted for value chains are having shorter, smaller, more localized, more concerted, and offer considerable sustainability

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benefits. It is intrinsically less wasteful and it has potentials to overcome social and economic barriers from the environmental impact of business activities. The possible sustainability benefits of this technology are being improved resource efficiency, extended product life etc. These can be achieved through technical approaches such as repair, remanufacture and refurbishment. However, despite these benefits, it could be an enabler and a driving force for enhanced industrial sustainability. The consequences of its execution on the industrial system could bring about another scenario wherein less eco-efficient localized production may be necessary. [2].

SLS process directly forms 3D solid parts of any complexity through selective sintering of successive layers of powdered raw materials using 3D CAD model [2]. Range of materials, such as wax, cermets, ceramic, polymers, metals, metals system, alloys, biomaterial, and etc., can be used as a SLS process material [1-13]. Among these available SLS materials, polymers mainly thermoplastic are preferred over other SLS materials due to their lower cost, low processing temperatures and sintering laser power, etc. [4, 10]. However mechanical properties and fire retardant property of polymers are poor than those of composite materials [2]. Presently, micron size inorganic fillers, such as cement, glass beads, silicon carbide, and aluminum powder have been widely used to reinforce for SLS process [3], [14-17]. Usually these fillers can improve the mechanical properties, such as the modulus, and hardness etc. Improvement is a function of concentration of fillers. Polymer/layered silicate (PLS) nano-composites have excellent combination of mechanical propertiesrelative to virgin polymers for sustainable manufacturing [18-20]. In literature, it has been outlined that addition of clay nanoparticles increases the viscosity of PA6. It has been observed that bed temperature during SLS process and laser power that is required to fabricate the part significantly increases [21].Wang et al. [22] have fabricated functional parts from the blends of PA12 material, and organically modified rectorite clay(OREC) using SLS process. Significant improvement in mechanical properties has been observed for these materials [22]. It has been established that the ultimate tensile strength, elongation at break, and other properties of the PA/clay composite SLS specimens degrade relative to pure PA12. It has also been suggested that the suitable part bed temperature for the part fabrication needs to be optimized for the blended powder to avoid part curling [23]. Nowadays, several methods are available to prepare PLS composite powders, mechanical mixing, grinding, and dissolution-precipitation process [22-25].

2. Experimental

The PA12 powder has been used with 56 microns particle size, and surface modified Nanoclay of 6-13 microns particle size. The composite materials are formed by loading the different concentration varying between 5wt% and 15wt% of SMMT Nanoclay filler in PA12. The powders are mechanically mixed using ball milling processes. Pressure less casting is employed to make specimen for i.e. tensile strength, flexural strength and modulus, compressive strength, impact strength, density, and fire retardant properties. The specimen are fabricated in a rich nitrogen environment in case of EOSINTP385 machine, thus, the identical environment has been employed. The SLS system has CO_2 laser (λ=10.6μm) [26].Various tests that have been carried out are given in table 1.

Table 1. Standard testing procedures followed

Test name	Standard	Machine	Description
Tensile test	ISO 527.2	H25KS	Cross head speed 5 mm/min
Three point flexural test	ISO 178	Instron 3345	Speed of 2 mm/min
Compression test	ISO604	Instron 3345	Speed 5 mm/min
Izod impact test	ISO 180	Model IT 504	Unnotched specimen
Flammability test	UL94-V	Flammability tester	Vertical and inclined at 45° test
Microscopic morphology	-	Hitachi-3400N	Resolution 10nm at 30 kV and 300,000X magnification
X-ray diffraction	-	X'Pert PRO diffractometer	λ=0.1540nm,scan0.1°/10 sec
Melting and crystallization	ISO 11357	SDT Q 600	Heating 10℃/min; to 250℃.
Melt flow index	ISO-1133	Melt flow index tester (International Engg.)	Melt temperature of 235℃
Density	ISO 1183-3	Density tester	Electronic measurement