Influence of the addition of nano-Silica particles as reinforcement on the tensile yield properties of Polyamide 6 polymeric matrix used in medical applications

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Abstract: It is well known that the polymer matrix nanocomposites are one of the most important polymeric materials that are used in medical applications due to the exhibition of very good mechanical and thermal properties. In this study the authors have used Polyamide 6 (Nylon) polymer for preparing polymeric nanocomposite samples. Silica nano-particles have been used as reinforcement for reinforcing the polyamide 6 polymer matrix. After the sample preparation, influence of nano-particles on the tensile ultimate strength and tensile Young modulus of the Polyamide 6 has been investigated experimentally. It is found that using nano-silica can significantly improve the tensile properties of Polyamide 6 polymer. Test results shows that addition of nano-scale silica particles can modify the tensile characterstics of the polymer i.e. improve the tensile elastic Young's modulus of the polymer. Similar trend is observed for the tensile ultimate strength of polyamide 6 nanocomposites, where the presence of nano-silica modify the ultimate strength of the material.

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1. Introduction

With recent growth of health science and medical engineering, the new materials have become crucial for developing the health care goods. It is well established that polymer materials are used as common constructive materials in many health applications i.e. manufacturing medical equipment etc.. Specially, polymers are used as the composite matrix in composite materials. Composite materials are one of the main branches of science that nearly started at about half century ago. In these high performance materials, a combination of some reinforcement parts and matrix part forms a new composite material [1-6].

In the composite materials, combination of the properties of each ingredient caused the good performance of the final composed material. Moreover, for enhancing composite properties, reinforcing fillers can be added to composites. Among the reinforcing fillers, nano materials have been attended in recent years [7-9].

Nano materials are special effects on the composite materials due to their nano size. Nano size of these reinforcing fillers cause more surface area. Effective surface area of filler leads to good interactions with matrix. Therefore nanomaterials are used as the reinforcement in many researches by the previous investigators [10, 11].

With recent development of nanotechnology, nano-materials have been increasingly applied to prepare nano-structures. Nanocomposite materials become one of the constructing materials for manufacturing engineering products [12-14]. Incorporation of nano-sized particles into polymeric matrices produces higher values of stiffness or strength in structural materials. These nanostructure materials often show a combination of physical and mechanical properties that are not achievable with conventional materials [15-18].

In industries, polyamide 6 is used for manufacturing nanocomposites. According to the superior mechanical properties and low weight, polyamide 6 is widely used in producing consuming products. For improving and optimizing the mechanical properties of this polymer, nano-sized fillers are incorporated with this high performance polymer. Adding nano-silica to polyamide 6 for improving the mechanical properties of this polymer has been investigated by previous researchers [19-21]. Garcia et al. [19] preformed the compounding of colloidal silica nanoparticles filled polyamide 6 using a twin-screw extruder, which has a very high significant market share due to its low cost and easy maintenance.

The influence of silane treatment on polyamide 6 filled by nano-silica prepared via in situ

polymerization is investigated in ref. [20]. A study on silica reinforced polyamide 6 Nanofillers in polymeric matrix can be found in ref. [21]

In order to measuring the yield behavior of nano-silica modified polyamide 6 nanocomposite, appropriate tensile samples prepared via injection molding processing method. Please note that in this study, the authors have focused on investigating the yield characteristics i.e. yield strength and elastic Young's modulus of the neat and nano-silica modified polyamide 6 nanocomposite samples. The values of the yield strength and the Young modulus as a function of nano-silica concentration have been measured. The results has been investigated and discussed in order to provide a wide knowledge about the tensile behavior of sample

2. Experiments

Materials

In order to prepare appropriate test samples, the polymer is extruded.The polyamide 6 polymer which have used in this study was obtained from Polymer Chemical Industries Co., Iran.

In addition nano-silica filler which have used as reinforcement was with an average particle size of 20 nm were supplied by Walker Co.

The fumed silica nanoparticles had been chemically well-treated by the manufacturer to disperse well in polymers such as epoxy and other thermoplasts.

Table 1: Formulation used

	Polyamide 6 (%)	Nano-silica (%)
PA	100	0
PA-1	100	1
PA-2	100	2
PA-3	100	3
PA-4	100	4
PA-5	100	5

Sample preparation

For silica-modified formulations, first appropriate amount of nano-particle reinforcement was weighted and then this weighted amount was applied for mixing with the polymer matrix.

The nano-silica particles was then mixed and diluted with neat polyamide 6 polymer matrix. This is conducted to prepare appropriate composites with filler contents ranging 0 to 5 wt. % .

As the processing method, a twin-screw extruder has been used. The extruder with operation temperature of 220 C has been used for extruding the nanocomposite polymeric samples. The process is conducted by the extruder which is shown in the Figure 1. Since the nanomaterials have a tendency to agglomeration, a well-performed extruding process is necessary and was conducted to achieve a well-dispersed compound.

Fig.1: Extruder machine used in this study. As the processing method, a twin-screw extruder has been used. The extruder with operation temperature of 220 C has been used for extruding the nanocomposite polymeric samples.

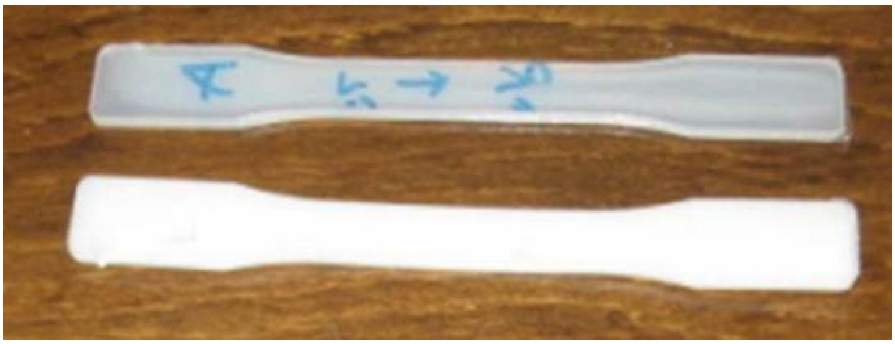

Fig. 2: Tensile Samples: For preparing tensile test samples, specimens with dumbbell shape with a gauge length of 50 mm were prepared.

Tensile Test

For preparing tensile test samples, specimens with dumbbell shape with a gauge length of 50 mm were prepared.

Tensile test was performed at a crosshead speed of 5 mm/min. Samples for tensile tests conformed to ASTM D638 standard.

Then, both sides of the test samples were polished by sand paper until all visible defects on the surface of samples disappeared. Tensile tests were performed using an Instron tensile machine.

3. Results and discussion

It should be noted that increasing in elastic rigidity (Young modulus) of materials is very useful for engineers for engineering and civil applications. As we know, most of polymers have a low value of modulus and therefore they might be not useful for producing engineering products.

Similarly, tensile strength is another crucial mechanical factor for evaluating the performance of the polymer materials. Low strength polymers cannot be used for casting and production of high-performance goods.

In Table 2, Young modulus of neat polyamide 6 polymer test sample i.e. PA sample and the nano-silica filled nanocomposite polymeric test samples i.e. PA-1, PA-2, PA-3, PA-4 and PA-5 samples is presented. As seen, the modulus of polyamide 6 increases significantly with the addition of nano-silica content.This is the result of reinforcing effect of the rigid nanoparticles on the soft matrix. The tensile strength of neat polyamide 6 polymer and the nano-silica filled polyamide 6 is listed in Table 3. As seen, for lower concentrations of nano-silica, the strength of polymer increases significantly with the addition of nano-silica content. However, by further addition beyond 4%, a reduction is observed. This reveals that the higher strength of nano-silica filled polymer might be diminished at higher filler concentrations.

Table 2: Young modulus of formulations

Composition	Young's Modulus (GPa)
PA	2.9
PA-1	3
PA-2	3.1
PA-3	3.2
PA-4	3.2
PA-5	3.4

Table 3: Strength of formulations

Composition	σ_u (MPa)
PA	70
PA-1	72
PA-2	75
PA-3	76
PA-4	79
PA-5	72

4. Conclusions

In this paper, addition of nano-silica to a thermoplastic polyamide 6 has been investigated. The nano-silica/polyamide 6 has been extruded via a twin-screw extruder. Test specimens have been prepared. It has been found that an increase in elastic Young modulus of polyamide 6 can be obtained via adding nano-silica. The ultimate strength of polyamide 6 shows an increasing-decreasing trend by addition of nano-silica.

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