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The Effect of Calcium Carbonate Nanoparticles and Compatibilizer on the Surface Roughness and the Surface Scratch Resistance of the Polyamide 6

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ABSTRACT: Due to the widespread use of polyamides in various industries and the need to achieve high resistance to surface scratches and optimum surface roughness, in this paper, surface roughness and surface scratch resistance of polyamide 6 reinforced with nanoparticles of calcium carbonate and maleated polyamide as compatibilizer based nanocomposites specimens have been investigated. For this purpose, components of nanocomposite specimens, with the different weight of nanoparticles of calcium carbonate, by twin coil extruder mixture and specimens by the method of injection molding were prepared. To perform the hardness scratch test, the nano-coupled hardness device was used in the atomic force microscope, which has a nanoscale test instrument equipped. In order to study the roughness and surface scratch resistance of the specimens, the effect of three variables, vertical force of the scratch, the weight of the reinforcing phase and the compatibilizer have been investigated. The results show that the addition of calcium nano carbonate particles from one to three parts per hundred resin, increases the roughness value by about two times, and also reduces the surface roughness by about a 40 percent reduction in the weight of a compatibilizer.

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1- Introduction

Scratches, regardless of their size and length, can greatly offset the appearance of polymeric parts. Therefore, the process of creating these scratches, how they are measured and methods of reducing them are investigated by researchers [1]. Since polymers are generally soft components, they are easily scratched, which tends to stress concentration and ultimately leads to failure [2]. Resistance against scratching of polymers depends on the nature of the polymer itself and parameters such as applied load, shape, size, scratch speed, and surface lubrication [3]. One of the polymers which have vast application in industries is polyamides. In order to improve the mechanical behavior of polyamides, extensive studies have been carried out. For example, Sirens et al. [4] showed that the addition of nanoparticles of clay improves the tensile and abrasive properties of polyamides. Muhd et al. [5] have investigated the impact of polyamide 6 in the presence of clay nanoparticles and showed that the presence of nanoparticles in the field leads to a drop in impact resistance.

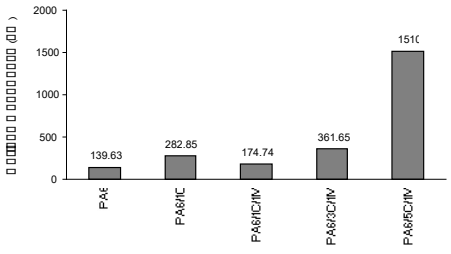

Fig. 1: Surface roughness of different samples

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Lewis et al. [6] have studied the wear behavior of polyamide 6 reinforced by carbon nanotubes. They have shown that the presence of reinforcement reduces the penetration depth of abrasion. Also, the presence of carbon nanotubes with increasing stiffness leads to a reduction in the penetration depth and scratched width and increases Young's modulus by up to twenty-seven percent [6]. Nouzad et al. [7] have studied the effect of calcium carbonate nanoparticles on polyamide 6, they have shown that the abrasion resistance in the presence of calcium carbonate nanoparticles increased and water absorption decreased. Sinha et al. [8] have studied the effect of nanoclay weights significantly on the properties of polyamide composites. They have shown that increasing the weight percentage of nanoclay can increase the hardness and reduce the scratch depth.

In the current study, the effect of adding calcium carbonate nanoparticles with different weighing percentages on the polyamide 6 scratch hardness has been studied in the presence of the compatibilizer and without it. The results show that the addition of calcium carbonate nanoparticles in the composite increases the surface roughness. On the other hand, adding compatibilizer to composite leads to uniform dispersion of particles and a significant reduction in surface roughness.

2- Materials and Methods

Materials used in the present study include polyamide 6 as a composite field, calcium carbonate nanoparticles with a density of 2.71 g/cm3 and a grain size of 40 to 130 nm with a melting point of 1339°C, with 4.5% Stearic coated, as a booster phase and the polyamide bonded with maleic anhydride (PA-g-MAH) with 0.8 to 1.3 percent maleic

anhydride as a compatibilizer. Samples and symbols, which have been used in this research, are shown in Table 1.

Table 1: Samples and symbols used in this research

Samples Number	Samples Symbol	PA–g–MAH (phr*)	CaCo3 (phr*)	PA6 (%wt)
1	PA6	0	0	100
2	PA6/1C	0	1	100
3	PA6/1C/1M	1	1	100
4	PA6/3C/1M	1	3	100
5	PA6/5C/1M	1	5	100

* phr: part per hundred resin

3- Results

3- 1- Surface roughness

In this research, nano-scoping software was used to extract roughness of surfaces. For all samples, this is done. The results of surface roughness from different samples with different weights of calcium nano carbonate have been shown in Fig. 1. This figure shows that PA6/1C/1M has a better surface roughness than the rest of the specimens. Also, by increasing the weight fraction of calcium carbonate nanoparticles, surface roughness increases. The reason for this increased roughness can be stated to be that mineral additives, due to several factors such as dimensions, mobility, characteristics of the end groups, relative composition, and molecular structure can migrate to the surface of the polymers and lead to increased surface roughness.

3- 2- Scratch

In general, the hardness of material scratching increases with the presence of a reinforcing phase, which reduces the penetration of the scratcher to the surface of the material. In this study, the scratch test was carried out in all samples with vertical forces of 100 µN and 150 µN in 30 seconds over 4 µm with Berkovich's head from the diamond. In order to reduce the error, at least 3 scratches were created in different parts of the sample. Also, in this study, friction coefficient, scratch depth, and relative height were used to compare the resistance to scratch damage between polyamide 6 and calcium carbonate-enhanced nanocomposites. The coefficient of friction in different samples has different values, which are extracted in two vertical forces of 100 µN and 150 µN, and are presented in Table 2.

Table 2: The coefficient of friction in different samples with two vertical forces of 100 µN and 150 µN.

Samples Number	Samples Symbol	Friction coefficient 100 µN	Friction coefficient 150 µN
1	PA6	0.70	0.75
2	PA6/1C	0.80	0.85
3	PA6/1C/1M	0.85	0.92
4	PA6/3C/1M	0.90	-
5	PA6/5C/1M	-	-

The relative height or the height of the stairs is from low to high peaks on the surface. In this study, in order to obtain it in different samples, atomic force microscopy images and nano-scopes software are used. The values of the maximum relative height of the various samples are presented in Fig. 2.

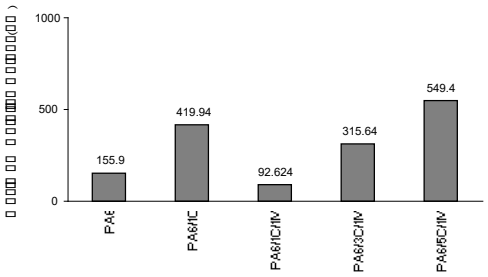

Fig. 2: The maximum relative height of the various samples

The scratch depth is also extracted from the relative height of atomic force microscopy images and nano scopes software. The maximum scratch depth values for two different strengths of 100 µN and 150 µN for various samples are presented in Table 3.

Table 3: Maximum scratch depth values for two different strengths of 100 µN and 150 µN samples.

Samples Number	Samples Symbol	Scratch depth 100 µN	Scratch depth 150 µN
1	PA6	176.04	340.51
2	PA6/1C	299.29	683.53
3	PA6/1C/1M	168.37	366.03
4	PA6/3C/1M	344.82	691.90
5	PA6/5C/1M	1131	2974

4- Conclusion

• The addition of calcium carbonate nanoparticles in the composite due to the accumulation of particles on the surface increased the surface roughness and increased the amount of roughness by increasing the calcium carbonate content. But adding a compatibilizer causes a uniform dispersion of particles and a significant reduction in surface roughness.

• The addition of nanoparticles with homogenous dispersion in the field increases the scratch resistance, but in samples with three and five parts by weight due to the accumulation of particles and the phenomenon of the agglomerate, the scratch resistance has dropped.

• Increasing vertical force in all specimens reduces scratch resistance, increases relative height and scratch depth.

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