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Research Article

Effect of Nano Material Ratio on Some Surface Properties of Wood Polymer Nanocomposites

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Abstract: Organic materials such as agricultural wastes and forest industry wastes can be successfully used as organic fillers in polymer composite production. Wood polymer composites are generally defined as a group of materials formed by combining two or more materials in a polymer matrix. As a result of their studies to improve the performance level, researchers have determined that this situation can be eliminated by using nano materials as reinforcing reinforcement material in wood plastic composite structure. The aim of this study is to determine some surface properties of wood plastic nanocomposites reinforced with nano-sized SiO_2. Four wood polymer nanocomposites containing nano SiO_2 at four different ratios were produced for the purpose. Surface roughness and hardness values of the wood polymer composites were determined. It was determined that the surface roughness values of wood polymer nanocomposite groups decreased as the SiO_2 nano material ratio increased. On the other hand, when the data on pencil hardness values were analyzed, it was determined that the pencil hardness values of wood polymer nanocomposite groups increased as the SiO_2 nanomaterial ratio increased.

Keywords: wood; polymer; nanocomposite; surface roughness; hardness

Ahşap Polimer Nanokompozitlerin Bazı Yüzey Özellikleri Üzerine Nano Materyal Oranının Etkisi

Öz: Polimer kompozit üretiminde organik dolgu maddesi olarak tarımsal atıklar ve orman endüstri atıkları gibi organik maddeler başarılı bir şekilde kullanılabilmektedir. Ahşap polimer kompozitler genel olarak bir polimer matris içerisinden iki ya da daha fazla sayıda materyalin bir araya getirilmesiyle oluşturulan malzeme grubu olarak tanımlanmaktadır. Araştırmacılar performans düzeyinin geliştirilebilmesi için yaptıkları çalışmalar neticesinde bu durumun nano materyallerin ahşap plastik kompozit yapı içerisinde güçlendirici takviye malzemesi kullanılarak bertaraf edilebileceğini belirlemişlerdir. Bu çalışmanın amacı; nano boyutlarda SiO_2 ile desteklenmiş ahşap plastik nanokompozitlerin bazı yüzey özelliklerinin belirlenmesidir. Amaca yönelik dört farklı oranda nano SiO_2 içeren ahşap polimer nanokompozit üretilmiştir. Üretilen ahşap polimer kompozitlerin yüzey pürüzlüğü ve sertlik değerleri belirlenmiştir. SiO_2 oranı arttıkça ahşap polimer nanokompozit gruplarının yüzey pürüzlülük değerlerinin azaldığı belirlenmiştir. Diğer yandan sertlik değerlerine ilişkin veriler incelendiğinde, SiO_2 oranı arttıkça ahşap polimer nano-kompozit gruplarının sertlik değerlerinin de arttığı görülmüştür.

Anahtar Kelimeler: ahşap; polimer; nanokompozit; yüzey pürüzlülüğü; sertlik

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1. Introduction

As a composite term, it is a new material group formed by the combination of two or more materials. Composite materials can be divided into different subgroups according to their composition. In general, it is possible to classify composites as ceramic matrix, metal matrix and polymer matrix composites. Petroleum-based plastics are largely used in the production of polymer composites. In addition to plastics, inorganic fillers such as talc, dolomite and calcium carbonate are mostly used as filling materials in the production of polymer composites. In the polymer composite industry, alternative raw materials have been sought for reasons such as the wear that inorganic fillers cause on machine parts during production and their high costs. The fact that organic fillers can be used in high amounts, require low energy, are biodegradable and can be found all over the world has accelerated the studies in this field. Organic materials such as agricultural wastes and forest industry wastes can be used successfully as organic fillers in polymer composite production. As a result of developing technology and changing human needs, polymer-based composites have brought about some changes, as in other material groups. The change and development of technology has provided the opportunity to apply different methods and use different tools to use material groups for different purposes (Karian, 2003; Kaymakci, 2019).

The development of nanoscience and nanotechnology has enabled the use of a wider range of material groups in this regard and has led to the industry gaining a different perspective by allowing the production of high value-added products. The superior properties of nanomaterials have enabled the use of polymer composites in many applications such as food, biomedical, electroanalysis, energy storage, wastewater treatment, automotive, etc. (Autthawong et al., 2021; Taghiyari et al., 2022)

Wood polymer composites are generally referred to as a group of materials formed by combining two or more materials in a polymer matrix. Wood-based fillers used in the production of wood polymer composites not only improve performance but also reduce the price of the final product. However, the performance of polymer composites reinforced with lignocellulosic fibers within certain ratios, depending on the place of use, does not meet user demands sufficiently (Łukawski et al., 2022). As a result of their studies to improve the performance level, the researchers determined that this situation can be eliminated by using nano-materials as a reinforcing reinforcement material in the wood plastic composite structure (Rangappa et al., 2021). For this purpose, different types of natural and synthetic clays, carbon materials (nano-sized carbon black, single or multi-walled carbon nanotubes, exfoliated graphite layers, etc.), various nano-sized metals, metal salts and metal oxides, amorphous silica, polyhedral silicon compounds (silsesquioxane, etc.) and cellulose fibers can be used. Studies have focused on improving the physical, mechanical and thermal properties of nanomaterials, but studies on the change of surface properties of wood plastic nanocomposites have been limited (Ayrilmis et al., 2013; Deka & Maji, 2013; Ghasemi et al., 2012; Hemmasi et al., 2013; Kaymakcı, 2016; Madhoushi et al., 2021). Therefore, the aim of this study is to determine some surface properties of wood plastic nanocomposites supported with nano-sized SiO_2.

2. Experimental

2.1. Material

Industrial pine wood flour was used as lignocellulosic filler. Pine wood flour used as filler was obtained from the sawmill factory operating in Kastamonu region. In this study, industrial 40 mesh pine wood flour was used. Polypropylene (PP) (Borealis) homopolymer was used as the polymer matrix. Details of the polymer used are given in Table 1. Maleic Anhydride Polypropylene (MAPP) (Optim-425/ Pluss Polymers Pvt. Ltd) was used to eliminate the incompatibility between the plastic and the lignocellulosic filler and to increase the binding. The properties of MAPP are shown in Table 2. Silicon dioxide (SiO_2) (Graphene Company) was used as reinforcing filler material in the study. Technical information about the reinforcing filler material is shown in Table 3.

Table 1. Some physical and process properties of the polymer used.

Properties	Value
Appearance	White pellet
Density	910 kg/m³
Melting flow rate (230°C/2.16 kg)	25 kg / 10 min
Tensile modulus	1750 MPa
Thermal melting temperature (0.45 N/mm²)	115°C
Impact resistance (Notched)	3.5 kJ/m²
Hardness, Rockwell (R-scale)	98
Melting temperature	220-206°C

Table 2. MAPP properties.

Properties	Value
Appearance	White transparent pellet
Melting flow rate (190°C/2.16 kg)	120 g / 10 min
Density	0.91 g/cm³

Table 3. Some physical and technical properties of silicon dioxide.

Properties	Value
Appearance	White powder
Average particle size	800 nm
Density	2.29 g/cm³
Purity	99.8%

2.2. Methods

Since the raw materials used within the scope of the research, plastic, pine wood flour, reinforcing filler materials, incompatibility agent and lubricants are used as purchased from the manufacturer, the production of wood plastic nano composites is described below.

2.2.1. Production of wood plastic nanocomposites

The production of wood plastic nanocomposites was carried out in a single screw extruder. For this purpose, plastic, wood flour and SiO_2 nano materials were processed in a 30 mm single screw extruder with a length-to-diameter (L/D) ratio of 30:1. The eight-barrel temperature zones of the extruder were controlled at 175 and 190 °C. This mixture was melted in the extruder and pushed towards the outlet with the screw in the extruder. After the material coming out of the mold at the end of the extruder was cooled, it was divided into small pieces with the help of a crusher. The granules were then dried in a drying oven to a certain moisture content. The pellets obtained from here were turned into plates with the help of a press. Samples were then cut and prepared according to the relevant standards from the plates obtained in this way. The planned study in the production of wood plastic nanocomposites was carried out according to the experimental design given in Table 4.

Table 4. Wood plastic nano composite production design.

ID	Plastic Rate (%)	Wood Flour Rate (%)	MAPP (%)	Nano Material Rate (%)
A	50	50	3	0
B	50	50	3	2
C	50	50	3	4
D	50	50	3	6

2.2.2. Determination of properties of wood plastic nanocomposites

Ten samples from each wood polymer nanocomposite group reinforced with SiO_2 were used for surface roughness measurements. Mitutoyo SJ-301 surface roughness tester, stylus type profilometer was used for surface roughness tests. The three roughness parameters characterized by ISO 4287 (1997), namely average roughness (Ra), average hill-to-valley height (Rz) and maximum hill-to-valley height (Ry) were considered. Roughness values were measured with a precision of 0.5 μm. The measurement speed, pin diameter and pin top angle were set to 10 mm/min, 4 μm and 90° respectively. Measurements were performed at room temperature and the pin was calibrated before the tests.

Ten specimens from each group of wood polymer nanocomposites reinforced with SiO_2 were used for hardness measurements. A total of 40 hardness measurements were performed, four of each of the ten samples for each composite formulation type in accordance with ISO 4586-2 (2018). An Elcometer 3092 Sclerometer hardness tester was used for the pencil hardness tests. A spring (gray spring (0-3 N), red spring (1-10 N), blue spring (0-20 N) and green spring (0-30 N) were used for hardness determination. The force at which the tip leaves a mark or destroys the surface was observed by making short and straight movements while gradually increasing the load.

3. Results and Discussion

Data on Ra, Ry and Rz values of SiO_2 reinforced wood polymer nanocomposites are presented in Table 5.

Table 5. Surface roughness values of wood polymer nanocomposites.

ID	Ra (µm)	Ry (µm)	Rz (µm)
A	1.82	12.63	8.65
B	1.75	12.32	8.37
C	1.62	11.83	7.83
D	1.55	11.34	7.23

When the values shown in Table 5 are analyzed, it was determined that the surface roughness values of the wood polymer nanocomposite groups decreased as the SiO_2 nanomaterial ratio increased. While the lowest surface roughness values were determined in the nanocomposite groups containing 6% nanomaterial, the highest surface roughness value was determined in the composite groups, which we express as the control group without nanomaterial. The lower surface roughness values of the wood polymer nanocomposite groups reinforced with SiO_2 are attributed to the nanomaterial filling the voids on the surface and filling the microcracks on the surface by acting as a filler between wood flour and polymer.

Data on the pencil hardness values of SiO_2 reinforced wood polymer nanocomposites are presented in Table 6.

Table 6. Hardness values of wood polymer nanocomposites.

ID	Hardness (N)
A	5.12
B	5.98
C	6.57
D	7.32

When the data on pencil hardness values shown in Table 6 were analyzed, it was determined that the pencil hardness values of the wood polymer nanocomposite groups increased as the SiO_2 nanomaterial ratio increased. The highest pencil hardness values were determined in nanocomposite groups containing 6% nanomaterial, while the lowest pencil hardness values were determined in composite groups without nanomaterial. The pencil hardness value of wood polymer nanocomposites reinforced with SiO_2 increased by 42.97% as the SiO_2 value increased from 0% to 6%. This is thought to be due to the interaction of nano-sized materials with the polymer matrix, the strengthening of nanometer-scale physical and chemical connections and the increase in the hardness and strength of the nanocomposite.

4. Conclusions

The aim of this study is to determine some surface properties of wood plastic nanocomposites supported with nano-sized SiO_2. In this context, surface roughness and pencil hardness tests were performed on wood polymer nanocomposite groups. According to the results obtained; it was determined that the surface roughness values of wood polymer nanocomposite groups decreased as the SiO_2 nano material ratio increased. On the other hand, when the data on pencil hardness values were analyzed, it was determined that the pencil hardness values of wood polymer nanocomposite groups increased as the SiO_2 nanomaterial ratio increased. In the light of the data obtained within the scope of this study, it was determined that the use of SiO_2 nano material improves the surface properties of wood polymer nanocomposites.

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