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Original Article / Araştırma Makalesi

PRODUCTION AND CHARACTERIZATION OF WASTE MASK REINFORCED POLYESTER COMPOSITE

Atık Maske Takviyeli Polyester Kompozit Üretimi ve Karakterizasyonu

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ABSTRACT

In this research, waste masks (WM) that pollute the environment have been evaluated in the polyester composite. Some physical and chemical properties of the obtained composite have been characterized. In particular, its density, Shore D hardness, thermal conductivity, thermal stability, and porosity have been determined. Waste masks were collected, disinfect, ground, dried and added into unsaturated polyester (UP) at the rates of 0 %, 2 %, 5 %, 7 %, and 10 % by mass as a filler. Mask wastes were reinforced to the unsaturated polyester in certain proportions and were homogenized thoroughly for 10 minutes at a mixing speed of 1000 rpm. Then, the chemical reaction has been carried out with the help of methyl ethyl ketone peroxide (MEKP) and cobalt octoate (Co Oc) catalysts. The chemical bond structure of the produced polyester composites was determined by Fourier transform infrared spectrophotometer (FTIR). According to the results, both density and Shore D hardness of the composites decreased as the WM ratios in the composites increased. It has been evaluated that the mechanical strength of the polyester composite and porosity raises with increasing WM ratio. The increase in WM by mass in the polyester composite raises thermal conductivity and activation energy.

Keywords: Activation energy, Polyester composite, Porosity, Thermal conductivity, Waste mask.

ÖZ

Bu araştırmada çevreyi kirleten atık maskeler (WM) polyester kompozit içerisinde değerlendirilmiştir. Elde edilen kompozitin bazı fiziksel ve kimyasal özellikleri karakterize edilmiştir. Özellikle yoğunluğu, Shore D sertliği, ısıl iletkenlik katsayısı, ısıl kararlılığı ve gözenekliliği karşılaştırılarak belirlenmiştir. Atık maskeleri toplanır, dezenfekte edilir, öğütülür, kurutulur ve dolgu maddesi olarak ağırlıkça % 0, % 2, % 5, % 7 ve % 10 oranlarında doymamış polyestere (UP) eklenir. Maske atıkları doymamış polyestere belirli oranlarda ilave edilerek 1000 rpm karıştırma hızında 10 dakika boyunca iyice homojenize edilir. Daha sonra metil etil keton peroksit (MEKP) ve kobalt oktoat (Co. Oc.) katalizörleri yardımıyla kimyasal reaksiyon gerçekleştirilmiştir. Üretilen polyester kompozitlerin kimyasal bağ yapısı Fourier dönüşümlü kızılötesi spektroskopisi (FTIR) ile belirlenir. Elde edilen sonuçlara göre kompozitlerdeki WM oranları arttıkça kompozitlerin hem yoğunluğu hem de Shore D sertliği azalmıştır. Artan WM oranı ile polyester kompozitin mekanik mukavemetinin ve gözenekliliğinin arttığı tespit edilmiştir. Polyester kompozitte kütlece WM'deki artış, termal iletkenlik katsayısını ve aktivasyon enerjisini arttırır.

Anahtar kelimeler: Aktivasyon enerjisi, Atık maske, Gözeneklilik, Polyester kompozit, Termal iletkenlik.

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INTRODUCTION

In recent years, the use of wastes that cause environmental problems in the production of polymer composites has become increasingly common. Especially during the Covid 19 pandemic period, many studies have been carried out in the literature for the disposal of waste masks.

In many studies in the literature, polymer composites have been obtained from waste masks by various methods (Mellin vd., 2016; Mohan, Jayanarayanan, & Mini, 2021; Xiang vd., 2021) Recycling masks, which are the most common medical wastes, are important in terms of environmental pollution. There are many polymeric components such as polypropylene in their structure (Joseph, James, Kalarikkal, & Thomas, 2021). Preferring biomaterials instead of polymeric masks also offers an alternative solution (P. Morganti, Yudin, G. Morganti, & Coltelli, 2020).

In research, masks are recycled by using an extruder at a temperature of approximately 200 °C. The surface morphology, chemical bond structure, and thermal analysis of the obtained product have been characterized (Battegazzore, Cravero, & Frache, 2020).

In other study, the draw attention to waste management and micro-plastic pollution, alternative solutions have been improved for mask recycling. Waste masks have been evaluated with economical and safe methods by using physical and chemical processes and different techniques. It has been discussed that countries should dispose of or recycle waste masks according to their geographical conditions, lifestyles, and technological possibilities (Aragaw, 2020; Asim, Badiei, & Sopian, 2021).

Physical separation, heat treatment, homogenization, reinforcement, composition, and curing time are important parameters in recycling waste masks. By characterizing the physical and chemical properties of the product obtained, efficient production can be achieved under optimum conditions (Crespo, Ibarz, Sáenz, Gonzalez, & Roche, 2021).

Researchers on the evaluation of waste and recycling products have highlighted the production of composites. Especially, the addition of additives and fillers in unsaturated polyester has led to the development of new composites. Many studies with unsaturated polyester have shown that it can yield polymer-compatible composites such as polyethylene, polypropylene, polyethylene terephthalate (Ahmad vd., 2017; Meira Castro vd., 2013; Mosadeghzada, Ahmada, Daika, Ramli, & Jalaludin, 2009; Nuzaimah, Sapuan, Nadlene, & Jawaid, 2019; Reygrobellet, Cuesta, & Crespy, 1999).

Also, there are studies in the literature on the use of polyesters as sensors due to their electrochemical properties. Polymers modified with bio or inorganic reinforcements are also used as biosensors. It can show high performance in biomedical applications due to its selective film feature (Aksoy, Paşahan, Güngör, Köytepe, & Seçkin, 2017; Güngör, Paşahan, Aksoy, Köytepe, & Seçkin, 2020; Paşahan, 2012; Paşahan, Köytepe, & Ekinci, 2011; Savan vd., 2016; Titretir vd., 2017).

Many organic or inorganic reinforcement materials are used in composite materials made with unsaturated polyesters. For example, with the reinforcement of pumice stone, both the density of the polyester composite has decreased and a porous structure has been obtained (Erzen & Aydoğmuş, 2021). With the reinforcement of recycled polyethylene terephthalate, polymeric wastes, which are an environmental problem, have been evaluated and a polyester composite with high thermal stability is produced (Aydoğmuş & Arslanoğlu, 2021). Improvements have been observed in both mechanical and thermal properties of the composite obtained by adding waste crumb rubber to unsaturated polyester (Aydoğmuş & Demirel, 2021). In another study, waste biomass supplementation reduced the density and Shore D hardness of the polyester composite (Aydoğmuş & Dağ, 2021).

In this research, low density, and economical composites have been obtained by evaluating waste masks in unsaturated polyester. A new polyester composite has been improved to cause environmental pollution of waste masks and to recycle them. Producing polyester composites with strong mechanical strength by using environmentally hazardous wastes will set an example for many sectors.

MATERIAL AND METHOD

Materials and methods of the experimental study

Mask wastes have been safely collected, disinfected, cut under laboratory conditions, and ground to a particle size of -50/100 mesh. Waste mask particles were prepared for composite production after drying in an oven at 105 °C for 2 hours. MEKP, Co. Oc. catalysts, and unsaturated polyester raw material were supplied from Turkuaz company. Waste masks were homogenized in UP for 10 minutes and at a mixing speed of 1000 rpm. Then, a certain amount of MEKP and Co. Oc. were added to the mixture and mixed at 1500 rpm for 120 seconds. The mixture obtained has been poured into standard molds and waited for 24 hours for curing and prepared for the necessary analyses.

Also, the thermal decomposition behavior of the synthesized composites has been carried out in an inert environment at a heating rate of 10 K/min in the PID-controlled system.

For the composites obtained, the approximate activation energies were calculated with the help of Coats-Redfern method by working in the temperature range of 25 °C to 600 °C.

The experimental work plan for the production of polyester composite from waste masks is given in Table 1.

Table 1. Experimental Working Plan for the Polyester Composite

Experiment No	WM (wt.%)	UP (wt.%)	Co. Oc. (wt.%)	MEKP (wt.%)
1	0	98	0.4	1.6
2	2	96	0.4	1.6
3	5	93	0.4	1.6
4	7	91	0.4	1.6
5	10	88	0.4	1.6

The porosity of the polyester composites

The porosity (ε) of polyester composites can be expressed depending on the particle and bulk density. In this study, the particle density ($\rho_{particle}$) was measured by grinding and compacting the polyester composite obtained in very small particle sizes. It was compressed into pellets with a certain particle diameter, and its mass was measured. Bulk density (ρ_{bulk}) was calculated after the polyester composites were produced, poured into standard molds, and waited one day for it to cure (Orhan, Aydoğmuş, Topuz, & Arslanoğlu, 2021).

$$\varepsilon = 1 - \frac{\rho_{bulk}}{\rho_{particle}} \quad (1)$$

RESULTS AND DISCUSSIONS

Properties of the Polyester Composites

Some physical and chemical properties of the obtained polyester composite have been compared with other studies. The characterization results of the polyester composite have been found to be compatible with the literature (Aydoğmuş & Arslanoğlu, 2021; Aydoğmuş, Arslanoğlu, & Dağ, 2021; Yanen, & Aydoğmuş, 2021; Yıldız, Karaağaç, & Güzeliş, 2021).

The physical and chemical properties of the polyester composite have been characterized depending on the use of WM in different proportions by mass. In this research, properties of polyester composite such as density, Shore D hardness, thermal conductivity coefficient, and thermal stability have been determined. As seen in Figure 1, the density of the composite decreases as the waste rate raises.

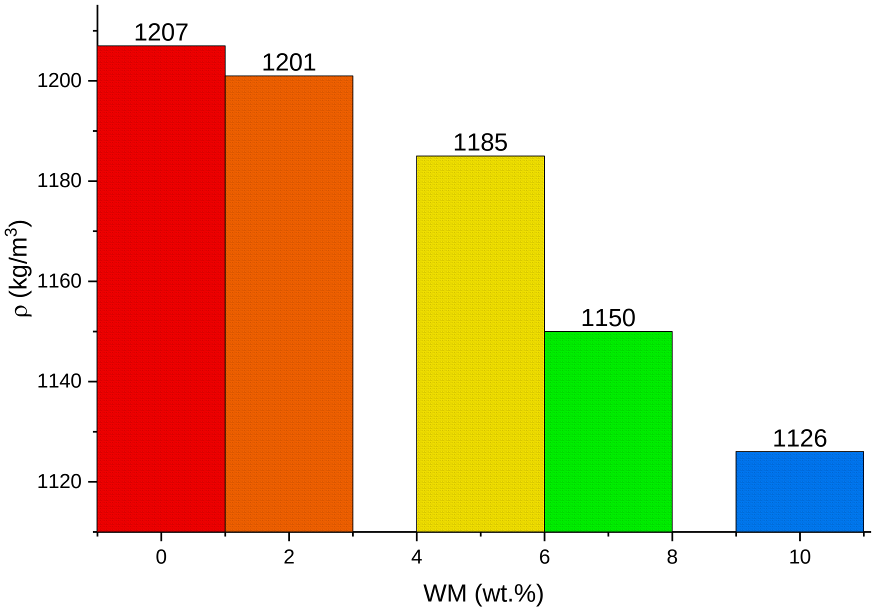

Figure 1. The Variation of Bulk Density of the Polyester Composite with WM Ratio

In Figure 2, it is stated that Shore D hardness of the polyester composite decreases as WM ratio raises.

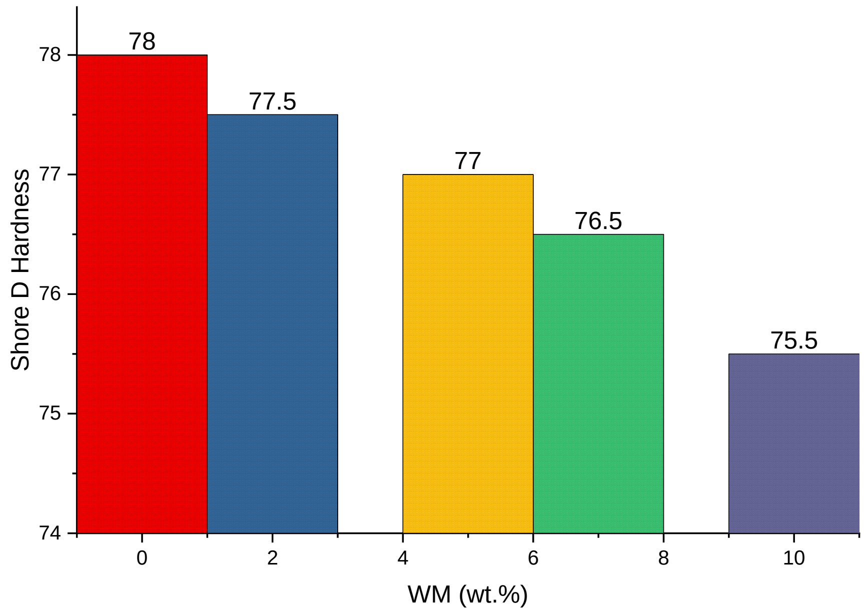

Figure 2. The Change of Shore D Hardness of the Polyester Composite with WM Ratio

It is seen in Figure 3 that WM changes the property of the polyester composite, in other words, it increases the thermal conductivity coefficient.

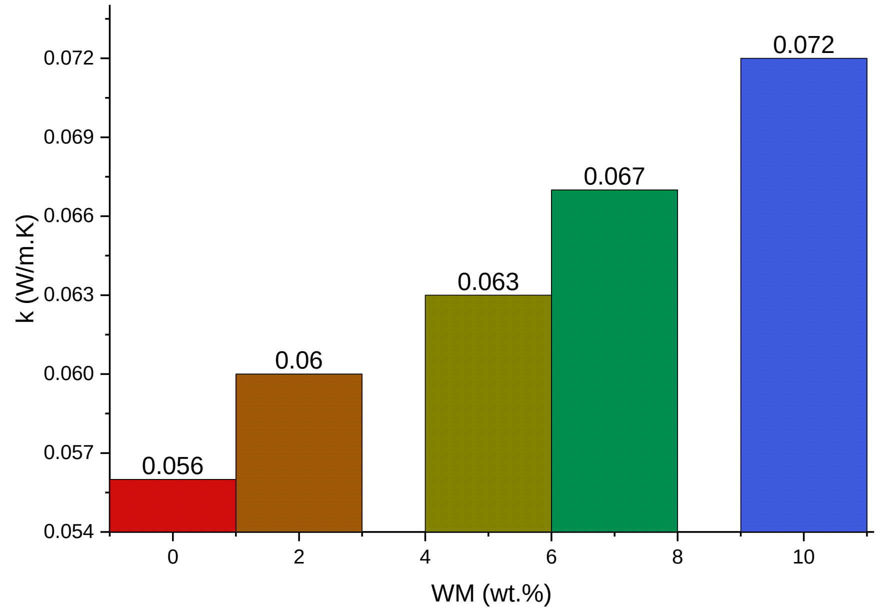

Figure 3. The Change of Thermal Conductivity of the Polyester Composite with WM Ratio

In Figure 4, it has been seen that porosity raised as WM ratio (wt.%) increased in the produced polyester composite.

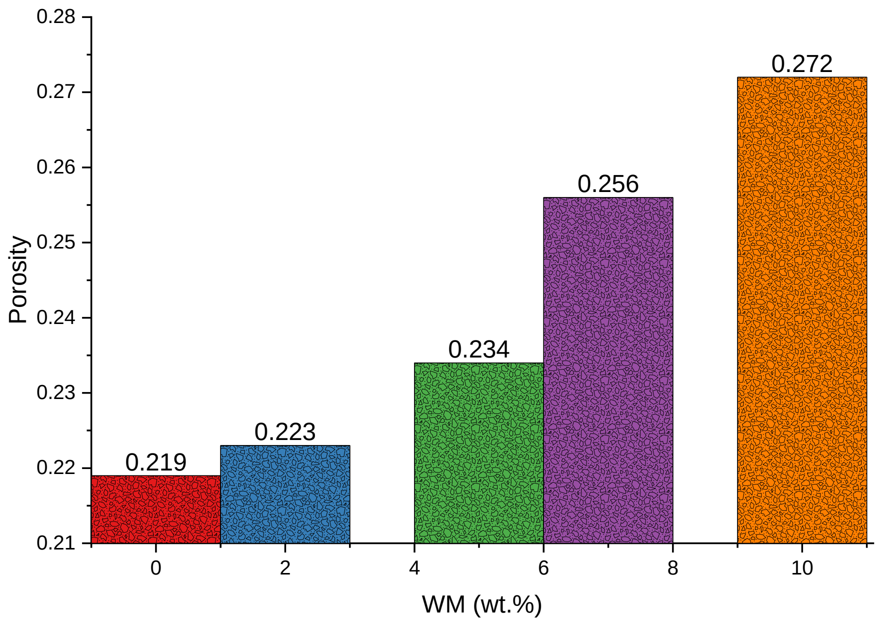

Figure 4. The Variation of the Porosity of Polyester Composite with WM Ratio

FTIR Spectra of the Polyester Composite

The chemical bond structure of the composite obtained from the unsaturated polyester and polypropylene-based mask (WM) is expressed in the FTIR spectrums seen in Figure 5. When FTIR spectra for unsaturated polyester are examined, hydroxyl bonds are seen at a wavelength of about 3500 cm^{-1}. Especially in propylene, which is in the composition of the mask, C-H bond vibrations come to the fore at wavelengths of 2850 - 3000 cm^{-1}. The carbonyl bond vibrations in the structure of unsaturated polyester also peak at 1715 cm^{-1} wavelengths (Abdullah & Ahmad, 2013).

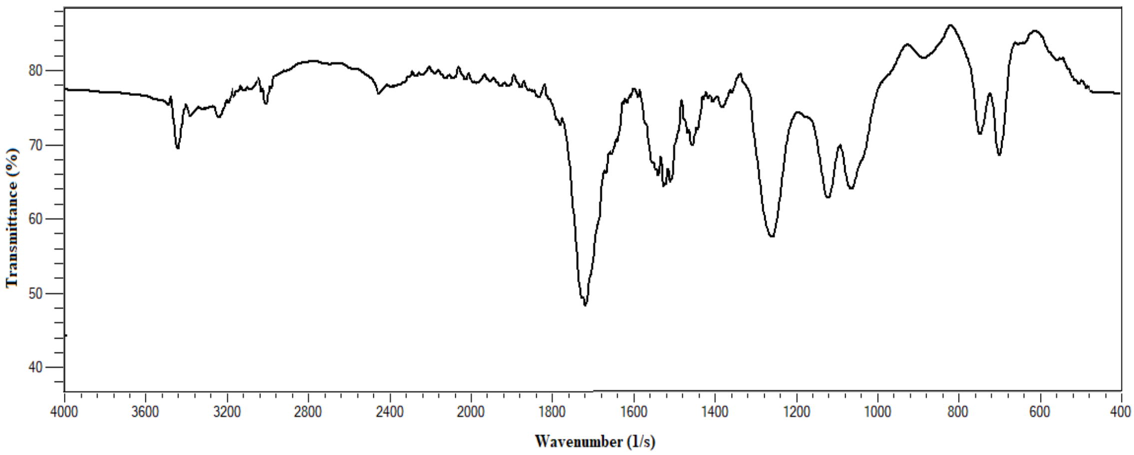

Figure 5. FTIR Spectra of WM Reinforced Polyester Composite for Experiment 3

CONCLUSIONS

In this research, an economical polyester composite was produced by evaluating waste masks. According to the findings, it has been seen that a polyester composite with low density and high thermal stability can be produced. As WM ratio increases in the mixture, the thermal conductivity coefficient, porosity, activation energy of the polyester composite also raise but density is decreased. It has been determined that Shore D hardness of the polyester composite is inversely proportional to the increasing WM ratio.

The use of high WM in unsaturated polyester negatively affects both the porosity and surface morphology of the synthesized composite. Hence, it has been found that it is appropriate to use WM up to 5 wt.% in the polyester composite.

The calculated activation energies are 136.45 kJ/mol for experiment 1, 138.27 kJ/mol for experiment 3, and 141.85 for experiment 5. As WM ratio increased, the activation energy of the polyester composite increased, indicating that the thermal stability improved.

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