Dokuz Eylül Üniversitesi Mühendislik Fakültesi Fen ve Mühendislik Dergisi
Dokuz Eylul University Faculty of Engineering Journal of Science and Engineering

Basılı/Printed ISSN: 1302-9304. Elektronik/Online ISSN: 2547-958X

The Change of Mechanical Properties of Acorn Powder Reinforced Polystrene and Polyoxymethylene due to Gamma Radiation

Meşe Palamudu Tozu Takviyeli Polistiren ve Polioksimetilenin Gama Işıması ile Mekanik Özelliklerindeki Değişim

Yılmaz Kısmet [1], Akar Doğan [1*]

[1] Munzur University, Faculty of Engineering, Department of Mechanical Engineering Tunceli, TURKEY
Sorumlu Yazar / Corresponding Author *: akardogan@munzur.edu.tr

Geliş Tarihi / Received: 09.12.2019 *Araştırma Makalesi/Research Article*
Kabul Tarihi / Accepted: 15.01.2020 *DOI: 10.21205/deufmd.2020226527*
Atıf şekli/ How to cite: KISMET, Y., DOGAN, A.(2020). The Change of Mechanical Properties of Acorn Powder Renforced Polystrene and Polyoxymethylene due to Gamma Radiation. DEUFMD 22(65), 619-624.

Abstract
In the present study, the effects of gamma radiation on the mechanical properties of acorn powder reinforced polystyrene (PS) and polyoxymethylene (POM) were investigated. Different amounts of acorn powder reinforced PS and POM samples were produced by using a plastic injection machine and these samples were exposed to 45 kGry gamma irradiation. Subsequently, the test samples were examined for the changes in their tensile, three-point bending and Izod impact strengths and the effect of gamma irradiation on the samples was established through comparing the findings with the pre-radiation state. With the increasing amount of acorn powder, the tensile strength of acorn powder reinforced PS and POM materials decreased. In contrast to the tensile strength, the bending strength of the samples increased with the increasing amount of filler material. In addition, an increase in the mechanical properties such as tensile and bending strength of materials exposed to gamma radiation has occurred.
***Keywords**: Polystyrene, Polyoxymethylene, Acorn Powder, Gama Radiation, Mechanical Properties*

Öz

Bu çalışmada, gama ışımasının palamut tozu (vaks) takviyeli polistren (PS) ve polioksimetilenin (POM) mekanik özellikleri üzerinedeki etkisi incelenmiştir. Plastik enjeksiyon makinası ile üretilmiş farklı oranlarda dolgu takviyeli PS ve POM numuneleri 45 kGry'lık gama ışımasına maruz bırakılmıştır. Daha sonra bu numunelerin çekme gerilmesi, üç nokta eğilme mukavemeti ve izod darbe dayanımlarında ki değişimler incelenmiş ve ışıma öncesi durum ile mukayese edilerek gama ışımasının etkisi ortaya konulmuştur. Meşe palamudu tozu miktarının artması ile, meşe palamudu tozu takviyeli PS ve POM malzemelerinin çekme mukavemeti azalmıştır. Çekme mukavemetinin aksine, numunelerin eğilme mukavemeti dolgu maddesi miktarının artışı ile yükselmiştir. Ek olarak, gama radyasyonuna maruz kalan malzemelerin çekme ve eğilme mukavemeti gibi mekanik özelliklerde bir artış meydana gelmiştir.
***Anahtar Kelimeler:** Polistren, Polioksimetilen, Palamut Tozu (Vaks), Gama Işıması, Mekanik Özellikler*

1. Introduction

Currently, polymer and polymer matrix materials are frequently preferred due to characteristics such as being readily available, low cost and malleable [1-3]. These materials are widely used in the industry, such as the automotive, food, medical and aerospace industries.

Thermoplastic polymers are particularly preferred for the production of various materials used in daily life. Polystyrene (PS), which is an amorphous thermoplastic with two different chain structures, amorphous and crystal/quasicrystal, has an interwoven chain structure. Polystyrene has a brittle and fragile structure due to such characteristics [4-6]. Polyoxymethylene (POM), on the other hand, is an engineered thermoplastic with a quasicrystal structure, high stiffness and low friction and is produced as a co-polymer and homo-polymer. Polyoxymethylene is preferred for the production of gears, bearings, camshafts, gaskets, seat belts and furniture components due to their high strength and solvent and flame resistance [4-7].

Different types of organic and inorganic fillers of the natural and synthetic structures are used in the production of polystyrene and polyoxymethylene, similar to various thermoplastics [8-10]. Such reinforcement elements were usually intended to eliminate the disadvantages that could occur during the use of any product made of thermoplastics [10-12]. Therefore, natural fillers with organic properties, such as hemp, seaweed, straw, rapeseed and various plant products are used as reinforcement materials, after the process of drying. Talc, calcium, mica and calcite, materials with inorganic structure, are also preferred as filler in materials. Such filler materials facilitate several improvements in the mechanical, thermal and flow properties of various thermoplastics [12-16].

Oaktree is a highly durable tree and its seeds are called acorns. Acorns are covered with a capsule that contains a pericarp wall and under the pericarp wall, there are seed shells that form the hard, outer structure of the acorn. Inside the acorn, there exists the acorn tissue called the Cotyledons and a plumule bud in the center of this tissue, and a root (radicle) at the end of the plumule. Acorn is widely used in the dyeing, leather and medical industries and also is a protein-rich food source for various mammals.

Gamma radiation is an application used in the polymer industry and is preferred mostly for the sterilization of plastic medical products. Outside this application, gamma radiation is used for bonding mechanisms in polymer composites between matrix and filler [15-17]. For the reinforcement of polymer composites performed an average of 30 to 150 kGy gamma radiation is applied [17-18]. The intermolecular bonds in the matrix material that form the composite strengthen prior to degradation with higher doses. For polyethylene and polypropylene have a radical network structure and there is a need for gamma radiation of about 50 to 100 kGy to reinforce their network structures by stimulating these mechanisms [17-18]

The present study focused on forming composites by mixing different proportions of acorn powder into polystyrene and polyoxymethylene, exposing these composite samples to gamma irradiation and examining the changes in the mechanical properties.

2. Materials and Method

The matrix materials used in the present study are polystyrene and polyoxymethylene, produced by "Dongguan Liangsu Masterbatch" with product code "LSM R6109" and by "Albis Plastic" with product code "ALCOM POM 770/1 WT1153-07LB", respectively. The filler used in the present study is dried and powdered acorns.

Different mixtures were formed by using the filler material with 5%, 10% and 20% of weight contents in the matrix. These mixtures were first mechanically prepared in a mixer, then poured into a single screw extruder to obtain a homogeneous mixture. Matrix and filler mixtures were homogenized at 150 to 170 °C in an extruder with three-zone and die heating. The molten mixture flowing out of the 4 mm diameter cylindrical cross-section at the extruder outlet was extruded into wires, dipped in the cooling pool and sent to the crusher via a conveyor belt. Granules, in sizes of 3 to 5 mm, were obtained as the material was passed through the crusher. The obtained granules were poured into a plastic injection machine (EKİN 100 Ton) and standard test samples were produced (Figure 1).

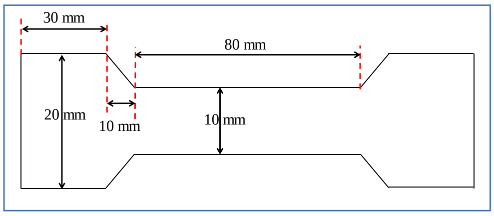

Figure 1. Type 1A Standart Test Samples

Produced test samples were exposed to 45 kGry gamma irradiation for 24 hours at the Turkish Atomic Energy Authority (TAEA).

The samples were tested for tensile, bending and impact strength after the radiation exposure. Tensile and three-point bending tests were carried out using the "Shimadzu ag-x 10" tensile test device at the Mechanical Engineering Department of Munzur University. The tensile test was carried out by DIN EN ISO 527 standard and the samples were forced to tensile stress through pre-loading with 2N and 50mm/min. Three-point bending test was carried out in accordance with the DIN EN ISO 178 standard and the samples were subjected to vertical loading with 10 mm/min. speed and maximum 6mm deflection. Izod impact test was carried out using the "CEAST-Fractovis Plus" device following the DIN ISO 180 standard. Obtained results were graphically plotted and compared with the results before the radiation exposure.

3. Results and Discussion

The findings based on the mechanical analysis of acorn powder reinforced polystyrene (PS) materials exposed to gamma irradiation were presented below.

Figure 2 presents the change in the tensile strength of acorn powder reinforced PS samples before and after gamma irradiation. Figure 2 indicates that the tensile strength of the samples decreased due to the increased amount of filler material in polystyrene, both before and after gamma irradiation. However, it was observed that the tensile strength of the samples slightly increased due to the irradiation effect compared to the pre-radiation state. While the tensile stress of pure PS was measured as 40 MPa before irradiation, this value increased to 40.8 MPa due to irradiation. The tensile strength of the PS samples with 20% filler reinforcement increased from 34.1 MPa to 36.4 MPa due to irradiation.

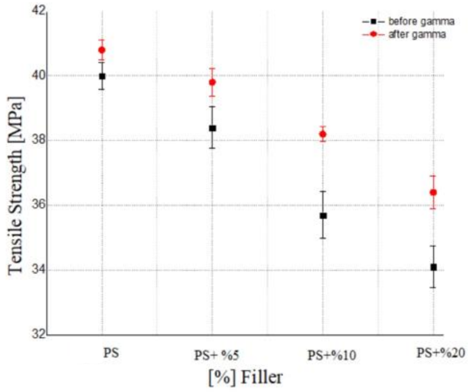

Figure 2. Change in the tensile strength of acorn powder reinforced PS samples before and after gamma irradiation.

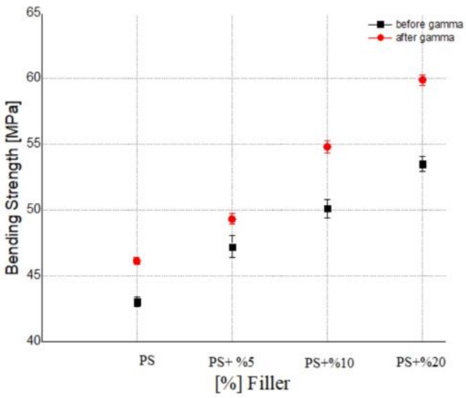

Figure 3. Change in the three-point bending strength of PS samples with filler reinforcement before and after gamma irradiation.

Figure 3 presents the change in the three-point bending strength of PS samples which filler reinforcement before and after gamma irradiation. According to Figure 3, filler-reinforced polystyrene samples with became relatively ductile compared to the pure samples and their resistance to vertical loading has increased. This increase was more apparent, especially in filler-reinforced samples exposed to gamma irradiation. While the three-point bending strength of pure polystyrene, which was not exposed to gamma irradiation, was 43 MPa, this value increased by 40% and reached approximately 60 MPa in PS samples that had 20% filler reinforcement and were exposed to gamma irradiation.

The change in the Izod impact strength of PS samples, which were filler-reinforced and exposed to gamma irradiation, was presented in Figure 4. As seen in Figure 4, the impact strength of the samples increased due to both the increase in filler amount and gamma irradiation. Once the pure PS samples that were not exposed to irradiation and those that had 20% filler reinforcement and were exposed to gamma irradiation were compared, such increase was determined to be approximately between 10% to 15%. The most significant consideration is that the standard deviation ranges of the tested samples were particularly high. Such a high standard deviation range was because brittle PS samples were either crushed during the impact or that the test strip did not remain constant during the impact.

Figure 5 shows the change in the tensile strength of the filler-reinforced POM due to gamma irradiation. Once Figure 5 was scrutinized, it was possible to state that the tensile strength of POM decreases due to increased filler, both before and after irradiation. However, it was also determined that the tensile strengths of the samples with 10% and 20% filler reinforcement improved significantly due to gamma irradiation when compared to the pre-irradiation state. While the tensile strength of the POM sample with 10% filler reinforcement before the exposure to irradiation was measured around 50 MPa, this value increased approximately to 55 MPa due to irradiation. Similarly, the pre-irradiation tensile strength of the POM sample with 20% filler reinforcement increased approximately by 5 MPa due to irradiation and was determined as 53.5 MPa.

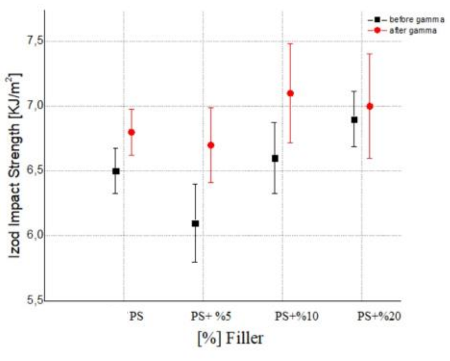

Figure 4. Change in the Izod impact strength of PS samples with filler reinforcement before and after gamma irradiation.

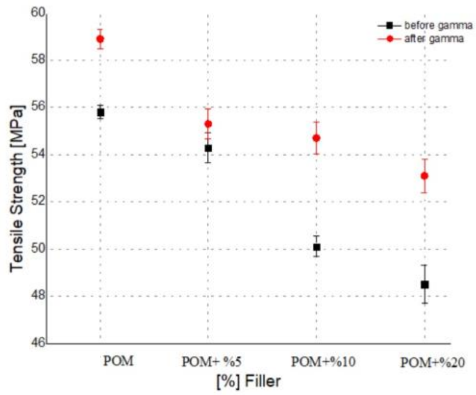

Figure 5. Change in the tensile strength of filler-reinforced POM samples before and after gamma irradiation.

The strength of filler-reinforced POM against vertical loading based on gamma irradiation was presented in Figure 6. Principally, it was observed that the bending stress of POM improved due to the increased amount of filler material. While the three-point bending strength of pure POM was approximately 48.5 MPa, this value increased to 51 MPa in samples with 10% filler reinforcement. The vertical impact strength of the filler-reinforced POM increased due to gamma irradiation, and in samples, with 20% filler reinforcement this value reached up to 55 MPa.

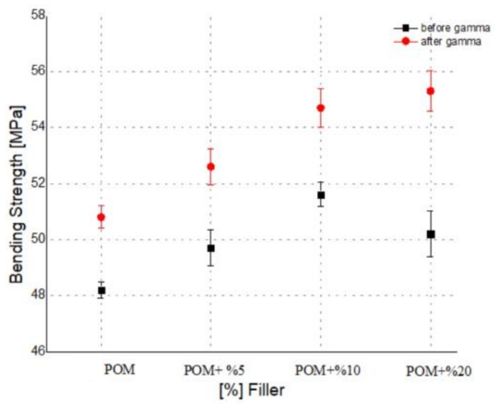

Figure 6. Change in the three-point bending strength of filler-reinforced POM samples before and after gamma irradiation.

Figure 7 presents the change in Izod impact strength of filler-reinforced POM before and after gamma irradiation. According to Figure 7, the Izod impact strength of the samples decreased due to an increased amount of filler material; yet, it could be improved due to gamma irradiation. While the Izod impact strength of pure POM was approximately 15.5 Kj/m², this value increased to 19 Kj/m² once the samples were exposed to gamma irradiation. Similarly, the impact strengths of the filler-reinforced samples presented an average improvement of 2-3 Kj/m² due to gamma irradiation.

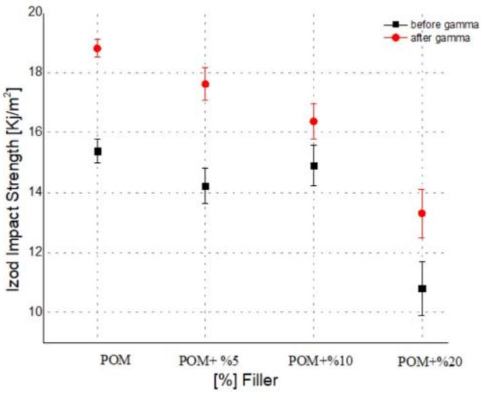

Figure 7. Change in the Izod impact strength of filler-reinforced POM before and after gamma irradiation.

4. Conclusion

The present study investigated the mechanical properties of the polystyrene and polyoxymethylene matrix material samples reinforced with the dried and powdered acorn. Tensile, three points bending and Izod impact strengths of the samples were determined both for increased amounts of filler material in the matrix and the effect of exposure to gamma irradiation.

Increased amounts of filler material in the polystyrene and polyoxymethylene matrix resulted in a decreased tensile strength of samples. However, such a decrease was relatively improved due to exposure to gamma irradiation and the resultant increase was approximately 5%.

Contrary to the observed changes in tensile strength behavior, flexural strength of samples increased with increasing amount of filler material. Such an increase was since polystyrene and polyoxymethylene, which had brittle nature, became partially ductile due to the reinforcement provided by the filler material. Therefore, the energy generated by the force applied via vertical loading did not directly break the material but ran through the sample around the filler particles, parallel to the sample axis. Hence, the samples became more durable. Furthermore, the samples became much more durable to vertical loading and their strength improved by 40%, due to the effects of gamma irradiation.

The Izod impact strength of polystyrene samples partially increased due to increased amounts of filler material, while the impact strength of polyoxymethylene matrix samples decreased significantly due to 10% filler reinforcement. Since the samples with brittle polystyrene matrix were broken due to impact, it was not possible to obtain sound results and the standard deviation values turned out to be extremely high.

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