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Preparation of apricot kernel shell powder added polyester/calcium carbonate composite discs and investigation of their abrasive properties

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ABSTRACT

Apricot kernel shell is suitable filler for abrasive materials with its strong, hard structure and dense cellulose content. Therefore, within the scope of this study, polyester composite (PE-CAC) discs containing apricot kernel shell powder were prepared in order to prepare abrasive polyester composite discs. In order to prevent these discs from damaging the surface on which they are applied during use, different amounts of calcium carbonate were added into the structure. The main purpose of this study is to prepare a new surface abrasion material. The chemical structure of the obtained composite discs was confirmed by Fourier transform infrared spectroscopy. Surface morphology and structure were confirmed by scanning electron microscopy technique. The distribution of additives within the composite structures was examined by EDX spectroscopy. The effect of heat generated during the etching process on the composite disc structure was investigated using thermal analysis techniques. The added composite structures were transformed into cylindrical discs with a diameter of 45 mm and a height of 30 mm and were used to remove paint on metallic surfaces. As the amount of apricot kernel shell powder in the composite structure increases, the abrasion efficiency increases. Additionally, as the PE/$CaCO_3$ composite disc application time increased, a significant decrease in surface roughness was observed. Ideal surface roughness was achieved, especially after 10 seconds of application time. As a result, PE/$CaCO_3$ composite discs with apricot kernel additives present an important alternative to existing methods, especially in the cleaning of dirt, rust and paint on metallic surfaces.

Keywords: Natural composites, Apricot kernel shell powder, Abrasive properties

1. Introduction

Nowadays, the need for multi-functional materials that can provide lots of functions at the same time is increasing [1-2]. For this reason, composite materials are very important as they carry the properties of both matrix and reinforcement materials together [3-5]. Composite materials can be defined as two or more phase system and when one of these phases is a polymer, polymeric composite material is obtained [5-8]. Matrix phase in polymeric composite materials can be linear, crosslinking and hyper-branched polymers [9-11]. The use of polymers as organic components in such materials provides lightness, flexibility and easy processing.

Today, abrasive or cleaning discs are frequently used in processes such as rust, contamination, cleaning or polishing of the paint on the surface that occurs during the use of metallic materials [12-15]. Additionally, these discs are used to smooth or shape the surface. They mostly function by attaching to a fixed or portable rotating device and applying friction [16]. Abrasive discs can be prepared from natural or synthetic materials, and they are usually prepared by attaching hard and abrasive materials to a binding matrix material. They are frequently produced from materials such as SiC, BC, BN, CeO, zirconia, aluminum oxide, iron oxide, silica and corundum [17-22]. However, today, studies on the preparation of abrasive discs from more sustainable,

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cheaper and environmentally friendly materials are increasing. Within the scope of these studies, materials such as clay, cellulose fibers, talc, phenol-formaldehyde resin and rubber were tried in the preparation of abrasive discs [19-23]. However, today, studies on the development of optimum abrasive disc materials are increasing, depending on the purpose and place of use. The main goal in this study is the synthesis and design of abrasive material that will clean the sensitive and precious metal and remove the paint on the metal surfaces. These processes are currently carried out with some abrasives, and these materials partially scratch and erode the metal surface. Thus, the surface quality also deteriorates. Another technique is the sandblasting technique and it threatens the health of the applicants depending on the materials used in sandblasting. In addition, there is too much sandblasting and it is not possible to apply it homogeneously to the surface. The cost of collecting and not reusing the sand applied after the process also increases. For the process of cleaning valuable metals, polyester composites containing apricot kernel shell were synthesized in order to eliminate these disadvantages and to clean without damaging the metal surface. In this study, composites were designed to contain different amount of apricot kernel shell powder, calcium carbonate and polyester resin. Calcium carbonate has been added to the composite structure to prevent scratching of the surface during the etching process. The synthesized composites were molded in cylindrical discs with a metallic shaft. The composites obtained were molded to the appropriate size and dried at room temperature for 24 hours. After structural properties were characterized by FTIR spectra, thermal properties and softening temperature were determined by Thermogravimetric Analysis (TGA) and Differential Scanning Calorimeter (DSC). Surface properties were determined by SEM technique at different magnifications. In addition, the cleaning property of the abrasive on the metal surface was determined by measuring the surface roughness and stripping amount. As a result, considering the current commercial abrasives, calcium carbonate-based PE composite material applicability is quite high and economical. In addition, its harmful effects for human health are very low. With this study, the gap in the literature was filled by creating a new type of composite that is rich in natural content and resistant to high temperatures, while being used differently from existing applications, is less harmful to human health.

2. Material and Method

2.1. Materials

High molecular mass unsaturated ortho-phthalic anhydride based unsaturated polyester (PE) resin was used as matrix material in the production of composite discs. $CaCO_3$ and other chemicals used in the study were provided by Sigma-Aldrich chemical company. Apricot seed shell powders were obtained by grinding apricot kernels in a ball mill and sieving them with a particle size of 200 µm.

2.2. Instrumentation

In the study, composite abrasive discs were prepared using unsaturated polyester resin, apricot kernel shell powder and $CaCO_3$. The chemical structure of these discs was confirmed using Fourier Transform Infrared Spectrometry (FTIR). FTIR analyzes were performed using a Perkin Elmer spectrum two FTIR spectrophotometer in the range of 4000–400 cm^{-1}. These analyzes were performed in ATF measurement mode with a measurement sensitivity of 4 cm^{-1}. The surface and morphological properties of the obtained composite discs were determined by SEM analysis. SEM measurements were determined with a LEO EVO-40xVP model electron microscope. Before analysis, the samples were coated with 20 nm Au/Pd with Balteck sputter. The chemical structure of the prepared PE-CAC composites was analyzed by EDX analysis. EDX analyzes were performed with a Rönteck Xflash detector analyzer attached to a LEO EVO-40xVP scanning electron microscope. Thermal properties and thermal stability of PE-CAC composites were determined by thermogravimetric analysis and differential scanning calorimeter. Shimadzu TGA-50 was used in TGA analyses. TGA analyzes were carried out in a static air atmosphere using a heating rate of 10°C/min between 20°C and 900°C. Softening temperatures of polyester resin and PE-CAC composites were determined by DSC analyses. Shimadzu DSC-60 was used in these analyses. In DSC analyses, 5 mg of sample was analyzed in aluminum sample cuvettes with a heating rate of 10 °C/min. DSC analyzes were performed under nitrogen flow (25 mL/min) between 20°C and 500°C.

2.3. Preparation of Abrasive PE-CAC Composite Discs

Within the scope of the study, polyester resin/apricot kernel shell powder/CaCO3 (PE-CAC) composites were prepared for cleaning and stripping the paint layer on metallic surfaces. While polyester resin was preferred to obtain a solid and hard surface in this composite structure, apricot seed shell powder was used to clean and polish metallic surfaces. CaCO3 was added to prevent scratching the surface during the cleaning process. Its effectiveness was examined in detail by adding CaCO3 at different rates (1%, 3%, 5% and 10%). By mixing at appropriate mixing ratios, a viscous liquid was obtained. This viscous liquid was added to 45 x 30 mm cylindrical molds and a 0.75 mm steel metal rod was deposited in the center of the cylinder. The molded resin was dried at room temperature for 1 week. Then, the obtained discs were removed from the molds and dried in an oven at 100°C for 1 day, and the composite disc structures seen in Figure 1 were obtained.

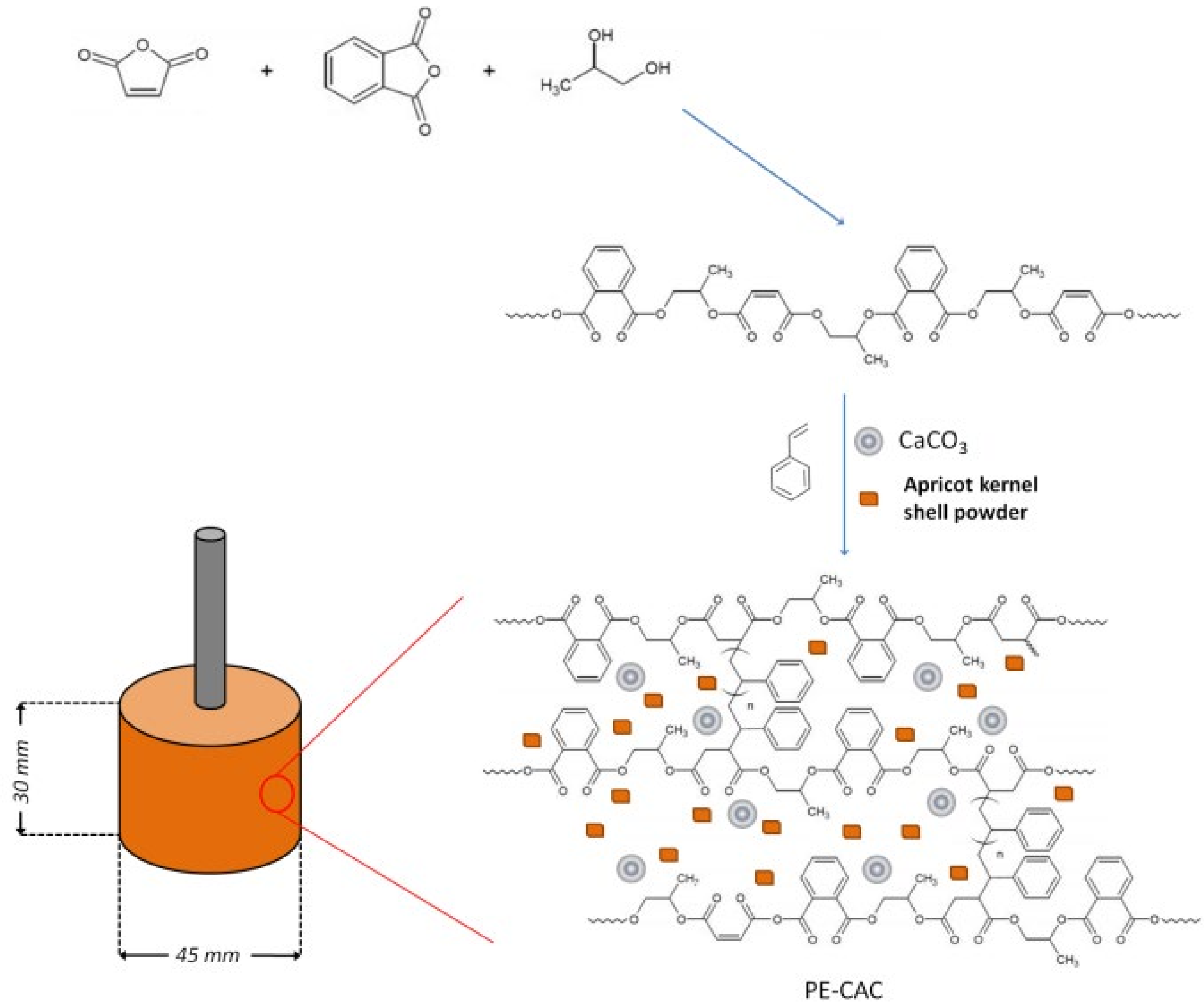

Figure 1. Chemical structure of PE-CAC composite discs and their dimensions

3. Results and Discussions

3.1. Characterization of PE-CAC composite disc structures

Within the scope of the study, unsaturated phthalic anhydride-based polyester resin with high viscosity and high molecular weight was used as matrix material. A fixed amount of 5% apricot kernel shell powder and different amounts of calcium carbonate (1%, 3%, 5% and 10%) were added into this structure. Using the obtained viscose resin, cylindrical discs with a diameter of 45 mm were obtained. The chemical structure of these cylindrical disks was confirmed by FTIR analyses. The spectra obtained from FTIR analyzes are given in Figure 2. When the FTIR spectrum in Figure 2 was examined, H-bond stretching vibration of OH groups was seen in the spectrum of pure polyester resin in the range of 3000-3650 cm-1. Additionally, aliphatic C-H stretching vibrations were seen in the range of 2800 -2950 cm-1. Carbonic group stretching vibrations were detected at approximately 1601 cm-1 and C-O-C etheric stretching vibrations were detected at approximately 1000 cm-1. At 1402 cm-1, stretching vibrations belonging to C=C groups in the structure are seen. After $CaCO_3$ groups and apricot seed shell powder additives are added to this structure, C=O peaks are observed at 3600-3700 cm-1 and approximately 1720 cm-1 due to CO_3 groups. In addition, C-O-C stretching vibrations were observed at 1075 cm-1 due to the cellulose groups in the apricot seed shell powder. The inclusion of these peaks in the spectrum confirms the desired composite disc structure.

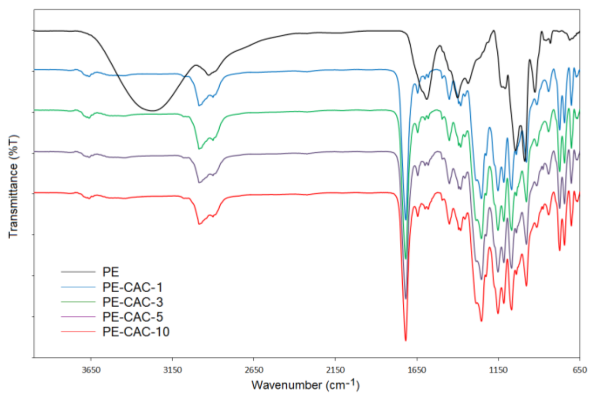

Figure 2. FTIR spectrums of polyester resin and PE-CAC composites

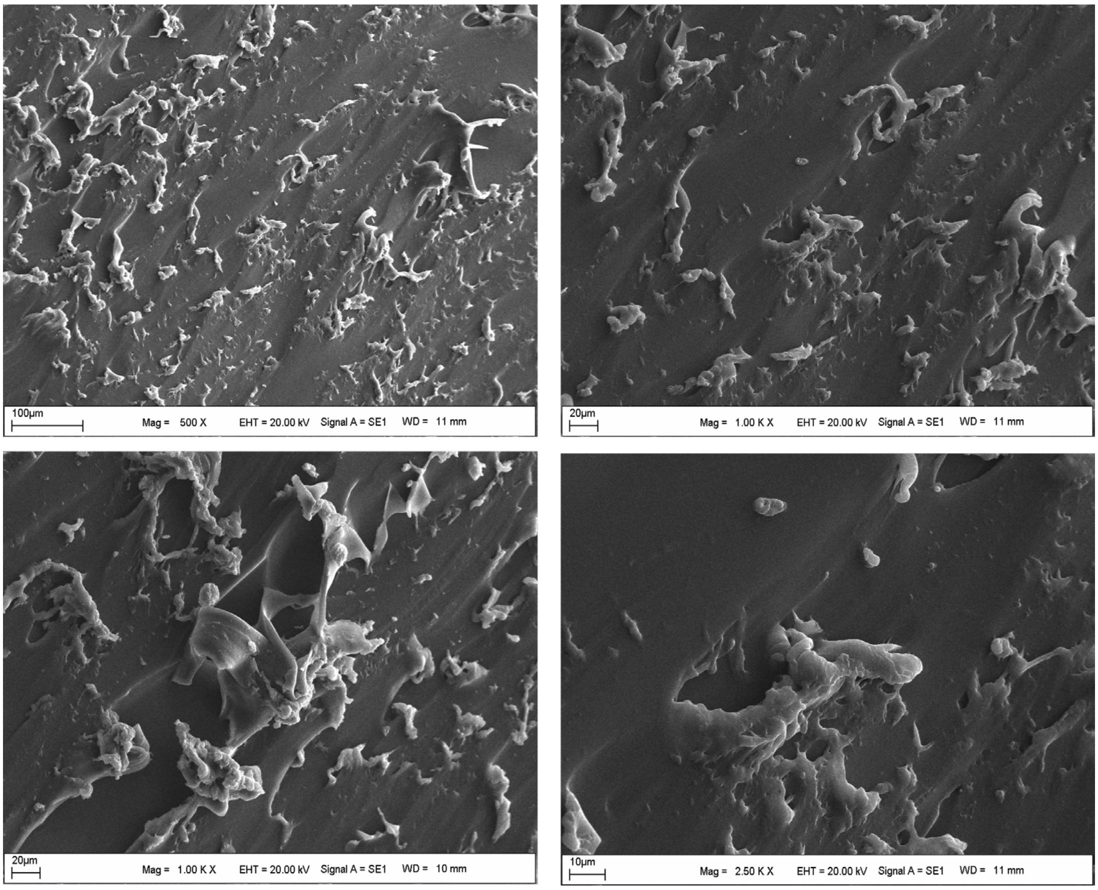

Figure 3. SEM images of polyester resin

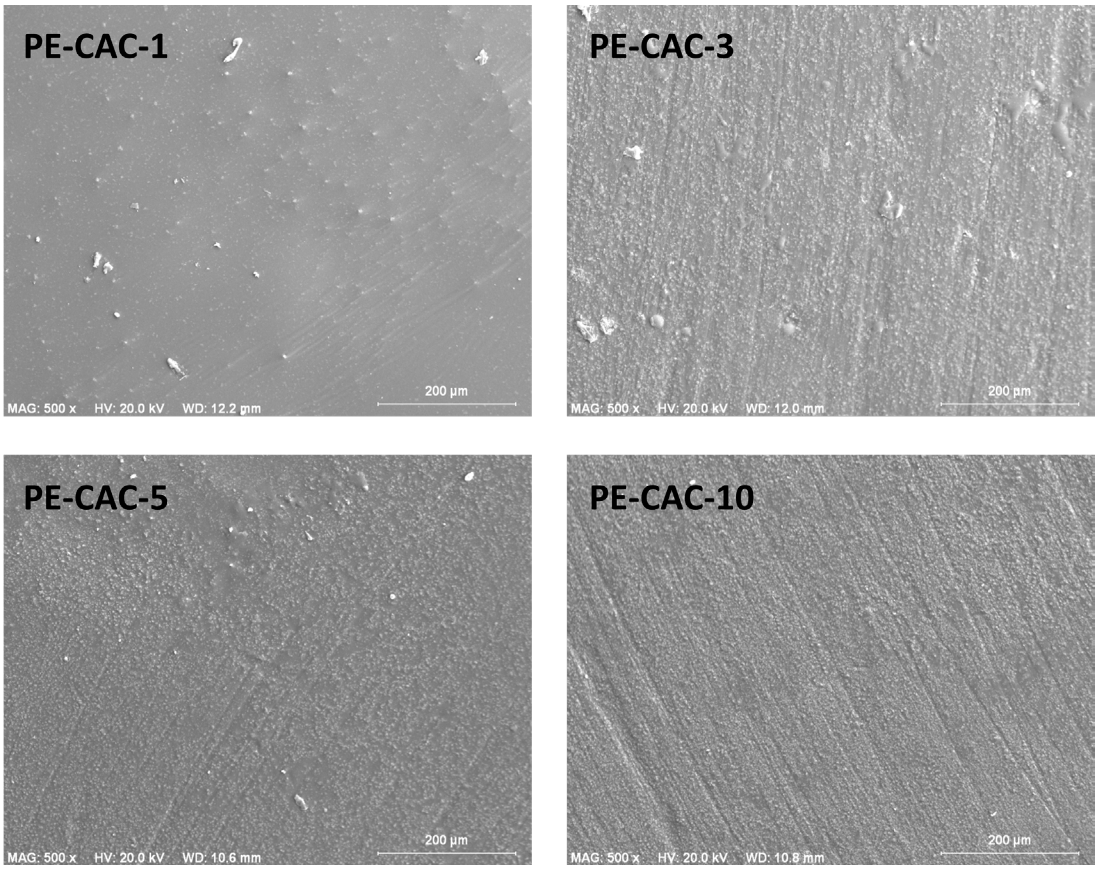

Figure 4. SEM images of PE-CAC composite discs

SEM images of the pure polyester resin used in the study are given in different magnifications in Figure 3. When this figure is examined, the structure appears to be homogeneous and stretched in a certain direction. There is no foreign phase or pollution in the structure. Rough surface and partially fibrillated structures are observed. However, with the addition of apricot seed shell and CaCO3 additives to this structure, a smoother surface structure is formed in which no fibrillation on the surface is observed (Figure 4). In addition, particulate structures and different phase regions are observed in the structure due to additives. As the amount of additive increases, particulate formations and surface roughness on the surface increase

EDX spectra were taken to analyse the structure of the discs prepared for abrasive use. Figure 5 shows the EDX spectrum of the pure disc structure prepared using pure polyester resin. Only C and O peaks are seen in this spectrum. The Kα peak for element C is observed at 0.278 keV and the Kα peak for element O is observed at 0.528 keV. The peaks between 2 and 3 keV are due to the Au/Pd coating applied to the surface before EDX analysis. EDX spectra of composite discs prepared using unsaturated polyester resin are given comparatively in Figure 6. In these spectra, For Ca element, Lα peak at 0.345 and Kα peak at 3.689 keV is observed due to the CaCO3 structure included in the structure. This peak intensity increases as the amount of additive in the structure increases. This change confirms that shifting has been achieved at the desired rates.

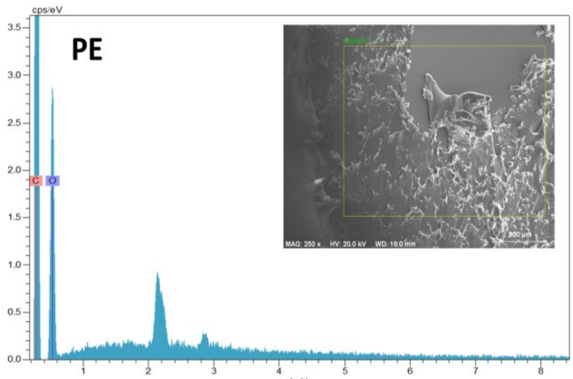

Figure 5. EDX spectrum of polyester resin

The element maps of the resulting composite discs are given in Figure 7. According to this figure, C and O elements are distributed homogeneously in the pure polyester structure. After adding CaCO3 to this structure, the Ca element is also clearly visible. The Ca ratio increases regularly with the amount of CaCO3 in the structure. In addition, C and O saturation increases with the addition of apricot seed shell powder to the structure of composite discs. The fact that the Ca distribution in the composite disc structure is homogeneous and increases regularly proves that the desired composite structures are produced.

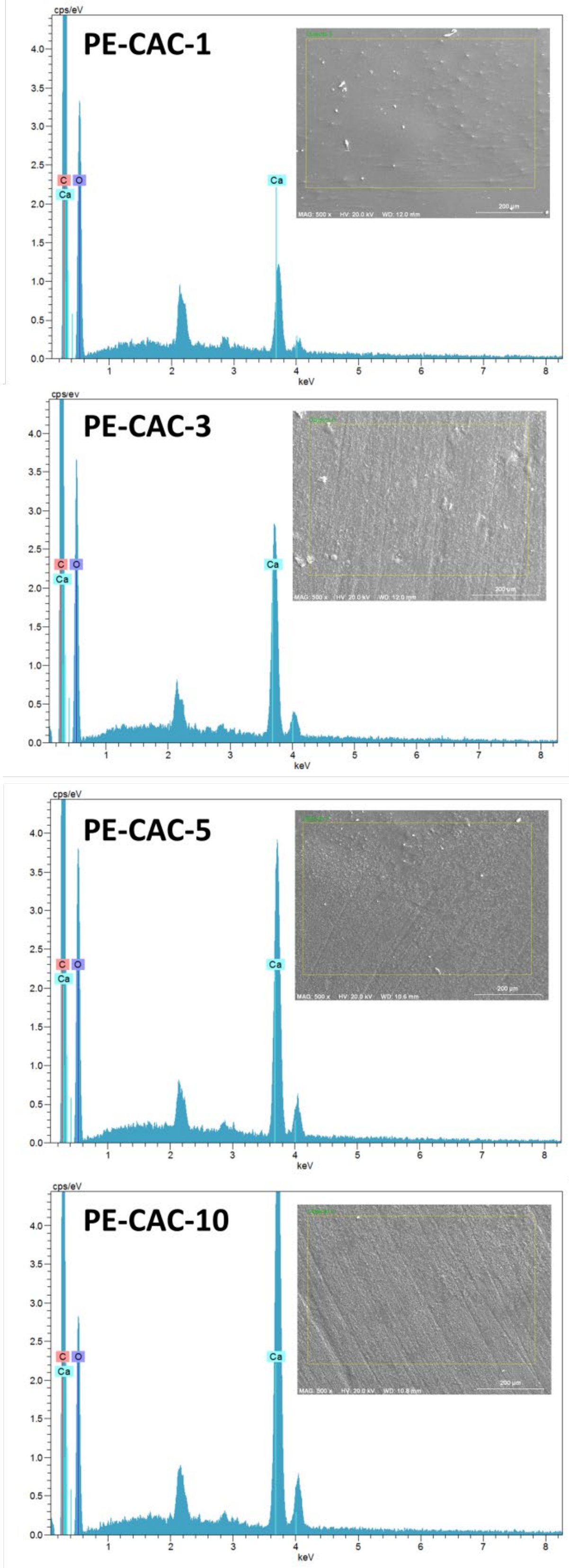

Figure 6. EDX spectrum of PE-CAC composites

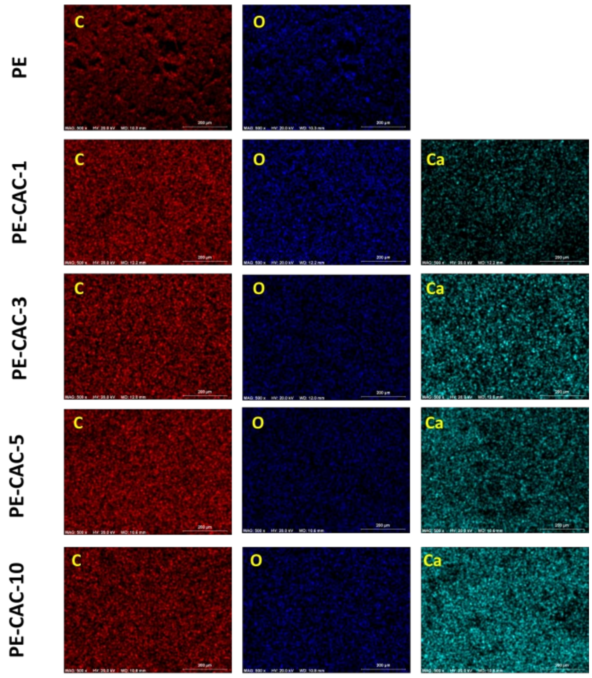

Figure 7. Elemental mapping images of PE-CAC composites

3.2. Thermal properties of PE-CAC composite disc structures

One of the basic properties sought in abrasive materials is thermal stability. It must be able to withstand temperature increases caused by friction, especially during application. For this reason, the thermal properties of the prepared composite discs were determined by TGA and DSC analyses. TGA thermograms of the prepared composite discs and unsaturated polyester structure are given in Figure 8. There are 4 basic mass losses in the thermogram of the pure polyester structure. The first mass loss resulting from the removal of structural moisture in the polyester structure was observed between 80-120°C. Degradation of the free monomer in the structure took place between 120-200°C. Between 200-375°C, a basic mass loss of approximately 60% occurred. Mass loss due to thermal degradation was seen between 575°C and 600°C. The final mass loss is the mass loss resulting from carbonization, which occurs between approximately 700°C and 820°C. Three main mass losses were observed during composite production. Between 80-180°C, a mass loss of approximately 9% was observed due to moisture in the composite structure. The second and major mass loss occurred between approximately 300°C and 425°C. The third and final mass loss occurred between approximately 425°C and 600°C. It is seen that the thermal stability of the composite structure increases significantly compared to the pure polyester structure.

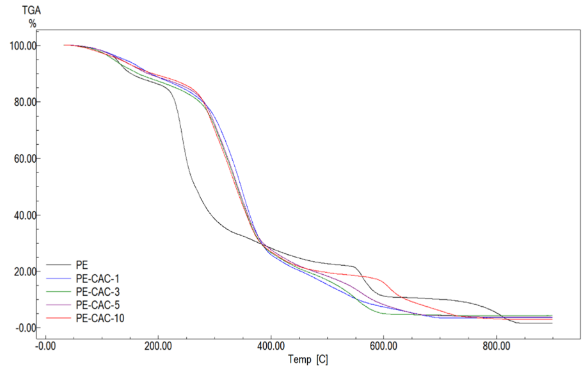

Figure 8. TGA thermogram of polyester resin and PE-CAC composite discs

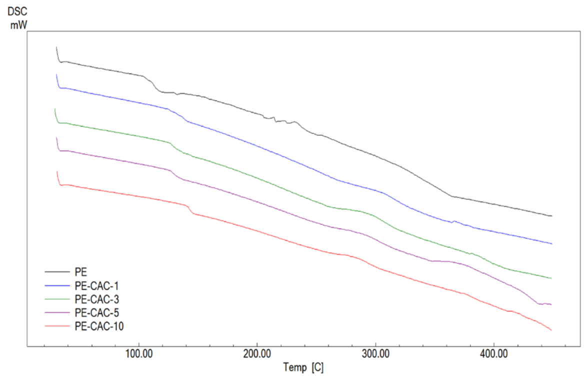

Figure 9. DSC curves of polyester resin and composite PE-CAC discs

Figure 9 shows the DSC curves of the pure polyester structure and the prepared PE-CAC composite structures. According to these DSC curves, while the TG value of the pure polyester structure was approximately 108°C, it was observed that the structural rigidity increased and the TG value increased with the addition of apricot kernel shell powder and CaCO3 to the structure. Tg values of PE-CAC-1, PE-CAC-3, PE-CAC-5 and PE-CAC-10 structures were determined as 128.5°C, 132.1°C, 138.7°C and 149.6°C, respectively.

3.3. Abrasive properties of PE-CAC composite disc structures

The composite discs prepared within the scope of the study were connected to a mechanism rotating at 1500 rpm and were used as abrasive material in cleaning the automobile body paint. Figure 10 and Figure 11 show these abrasion test results. In the images given in Figure 10, the surface photograph of the sample that was eroded at the 5th and 20th seconds can be seen. Although a partial opening is seen on the surface in the 5th second, it is seen that the surface is completely cleaned in the 20th second. The change in surface roughness during this cleaning process is given in Figure 11. According to this figure, it was observed that the surface roughness decreased over time in all composite structures during the process. A significant change was noted especially between the 6th and 14th seconds. The desired optimal cleaning time was determined to be approximately 16 seconds.

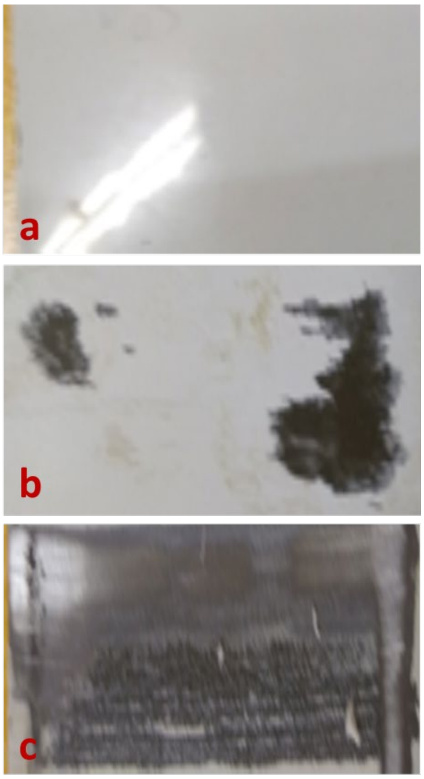

Figure 10. Images of car metal surface after abrasion and polishing with composite discs for different times (0, 5 and 20 second).

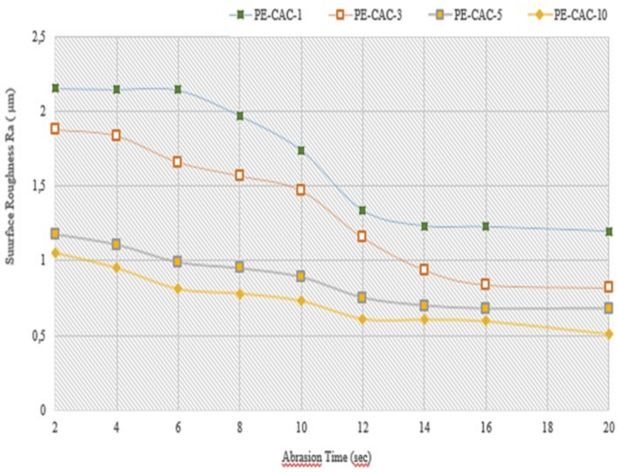

Figure 11. Surface roughness of car metal surface after abrasion and polishing with composite discs for different times.

4. Conclusions

Abrasive and polishing discs are used to remove paint layers from painted metallic surfaces, to remove rust from rusty surfaces, and to clean and polish metallic surfaces. For this purpose, multifunctional composite disc structures that can simultaneously clean and polish painted metallic surfaces were prepared in the study. In the preparation of these discs, ortho-phthalic anhydride based unsaturated polyester resin, apricot kernel shell powder and $CaCO_3$ at 1%, 3%, 5% and 10% weight ratios were used. The resulting composite structures were characterized by FTIR, SEM, EDX and thermal analysis techniques. In these tests, it was seen that composite structures based on pure polyester structure gave a rougher and more rigid surface. It was also determined that the composite structure was more thermally stable than pure polyester. As the amount of additive in the structure increased, the Tg value of the composite increased. The abrasion properties of composite discs were tested on automobile body paint at 1500 rpm. As a result, the composite discs obtained were found to be very fast and effective in removing paint from metallic surfaces. When all analysis results were examined, it was seen that the composite structure was formed as desired and that the composites gave better results by abrading and stripping paint-like materials on the surfaces to which they were applied, compared to sanding systems, without causing much damage to the surface.

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