

Research Article

Production of Recycling Prototype of Machining Teflon Waste by Compression Molding and Sintering and Investigation of Mechanical Properties

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Abstract

In this study, for the first time within the Arnes Mechanical Machinery Design Center, the recycling of Teflon (PTFE-Polytetrafluoroethylene) wastes generated in the production of sealing elements by machining process was carried out, and know-how was obtained for the use of this recycling prototype as a secondary raw material. Within the scope of the study, the recycling prototype, which was separated as waste after the machining process, was characterized by DSC analysis and ground to 250-micron sizes. The resulting Teflon prototype was pressed by pressure molding and sintering processes. 370-390°C temperature and 2-4 hours time parameters were selected for sintering. To determine the mechanical properties of the secondary raw material prepared as a recycling prototype, a tensile test mold was designed, and tensile test samples were produced. As a result of the study, it was seen that the recycling Teflon prototype was successfully

produced. It was determined that the mechanical properties of the produced prototype improved with increasing sintering temperature and time. Environmental sustainability will be ensured by reusing the second-quality raw materials from the study in production.

Keywords: *Recycling, Teflon Waste, Compression Molding, Sintering, Mechanical Properties*

1. Introduction

In industrial settings, an apparatus designed to prevent the undesired escape of pressurized or lubricating fluids within a system is called "sealing equipment." PTFE (Polytetrafluoroethylene) stands out due to its exceptional physical and chemical characteristics, encompassing a broad temperature tolerance, high resistance to chemicals, hydrophobic attributes, and excellent abrasion resistance. These distinctive qualities of PTFE contribute to enhanced performance in sealing components, ultimately prolonging the equipment's and seals' lifespan while diminishing maintenance and repair expenditures. PTFE holds a preeminent status in the market, serving as the preferred material for piston seals, throat seals, dust seals, and bearing elements [1-3].

Teflon, the proprietary name for the PTFE polymer, belongs to the polytetrafluoroethylene class, a fluorinated ethylene polymer. Exhibiting resistance to heat, chemicals, moisture, and friction, Teflon maintains a continuous operating temperature of approximately 260°C, with a melting point at around 320°C. Above 260°C, the chemical structure of Teflon undergoes degradation, reaching complete deterioration around 350°C. As a result, Teflon is effectively utilized within the temperature range of up to 290°C. Its notable low coefficients of friction confer resistance to both abrasion and chemicals. Given these advantageous properties, Teflon finds widespread application in various industrial contexts where effective sealing is a prerequisite [4-6].

The machining technique frequently employs Teflon as a primary raw material for manufacturing sealing elements. In the machining process of Teflon, the generated waste typically ranges from 10% to 25%. This waste not only represents an economic loss but also poses environmental challenges. The disposal of Teflon shaving waste imposes an extra cost on companies. Exploring methods for recycling these raw materials becomes a practical solution for businesses to mitigate environmental impact and financial losses associated with waste generation [7-10].

In industries utilizing Teflon materials for production, economic advantages can be realized by recycling waste into manufacturing. Given the high value of Teflon, recycling waste becomes an economically beneficial procedure for businesses.

This research, conducted at the Arnes Mechanical Machinery Design Center, represents a pioneering effort in successfully recycling Teflon waste within the machining process for sealing equipment manufacturing. This initiative yielded valuable insights into recycling Teflon waste generated during production and contributed to its reintroduction into the production cycle, thereby promoting environmental sustainability. The study's

outcomes are geared towards minimizing Teflon waste, significantly mitigating environmental harm, and fostering the development of an eco-friendly production process.

2. Materials and Methods

This investigation involved recycling Teflon waste generated during the machining-based production of sealing equipments in the enterprise. The waste underwent grinding with an appropriate grinder, resulting in a powder with particle sizes below 250 μm . Subsequently, the powder was recycled as a secondary raw material using the pressure molding and sintering method, and the mechanical properties of the resulting prototype product were evaluated.

Initially, Differential Scanning Calorimetry (DSC) analysis was conducted on the Teflon waste, confirming that the waste exclusively comprised PTFE content. The grinding process employed the Retsch SM300 model blade grinder in the Textile Engineering Department of Dokuz Eylül University. The ground Teflon chips were reduced to powder with particle sizes conducive to pressure molding. Tensile test samples were molded following the TS EN ISO 527-1 standard [11]. Figure 1 provides the dimensions and solid model of the designed mold, along with the solid model of the tensile test sample. The dimensions of the tensile test sample are further detailed in Figure 2.

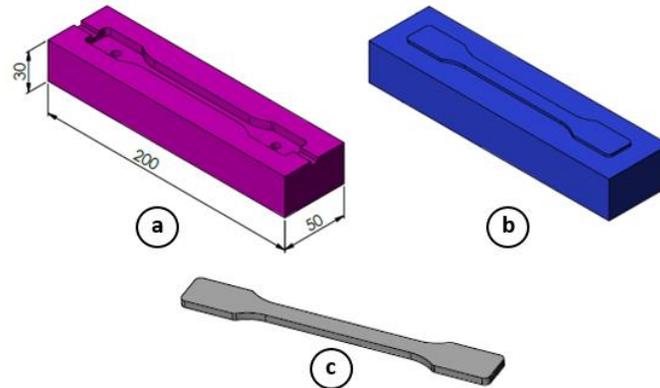


Figure 1: For Tensile Test Sample a. Female Mold, b. Male Mold, c. Sample Solid Model

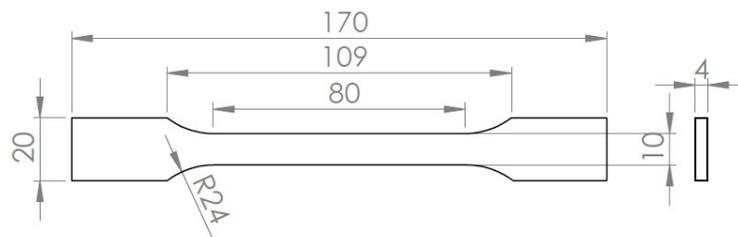


Figure 2: The Dimensions of the Tensile Test Sample

In the mold design, screws were incorporated to facilitate the detachment of the sample from the model. Following the design phase, the ground raw material powder was introduced into the mold and subjected to pressing for 5 minutes under 2 MPa pressure. The test mold and test sample images produced are shown in Figure 3.

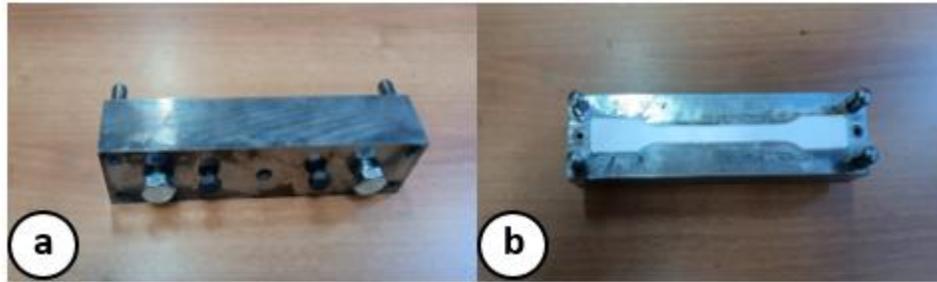


Figure 3: Produced a. Test Mold, b. Tensile Test Specimen

Following the pressing phase, the prepared tensile test samples underwent sintering processes. This involved sintering at two distinct temperatures (370 and 390°C) and for varying durations (2-4 hours) [12]. After the sintering process, the samples were cooled in ambient air. Detailed sintering parameters are provided in Table 1.

Table 1: Sintering Parameters

	Parameter 1	Parameter 2	Parameter 3	Parameter 4
Temperature (C°)	370	370	390	390
Heating Rate (C°/h)	90	90	90	90
Cooling Rate (C°/h)	30	30	30	30
Waiting Time (hours)	2	4	2	4
Environment	Air	Air	Air	Air

Tensile tests were carried out using three samples for each parameter.

3. Results

The results of the DSC analysis applied to Teflon waste are given in Figure 4. According to the results, the sample's melting point was determined to be 327°C, which is the characteristic value of the PTFE material [13]. Thus, it has been confirmed that shaving waste consists only of Teflon content.

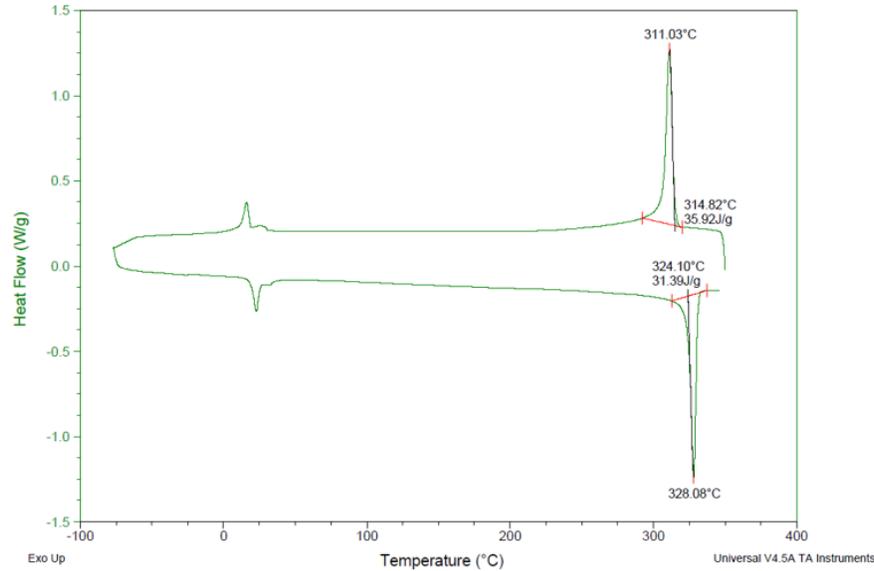


Figure 4: DSC Analysis Result of Teflon Shavings Waste

Tensile test results of samples sintered for 2 and 4 hours for the sintering temperature parameter of 370°C are given in Figure 5.

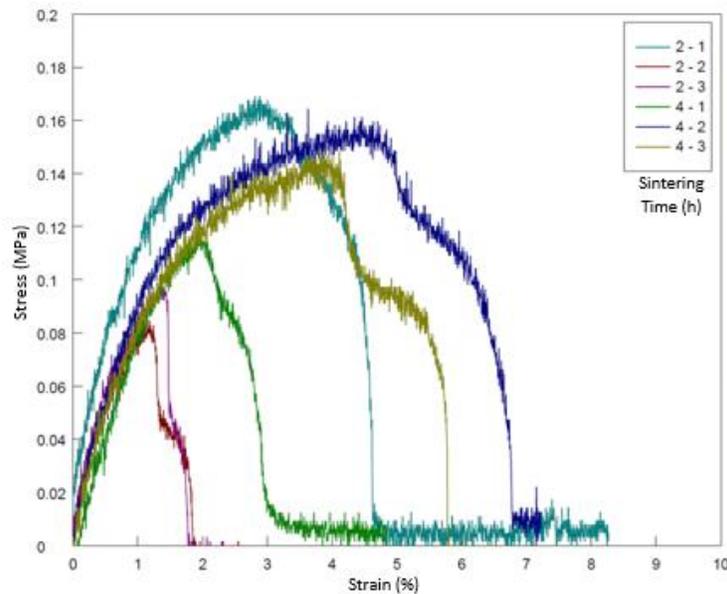


Figure 5: Tensile Test Results for 370°C Sintering Temperature

According to Figure 5, it was determined that tensile strength values varied between 0.09-0.17 MPa, and elongation at break values ranged between 1.1-3.9%. The maximum tensile

strength was observed at 0.17 MPa in the sample sintered for 2 hours, and the maximum elongation at break was 3.9% in the sample sintered for 4 hours.

Figure 6 presents the tensile test results for samples sintered at temperatures of 390°C for 2 and 4 hours.

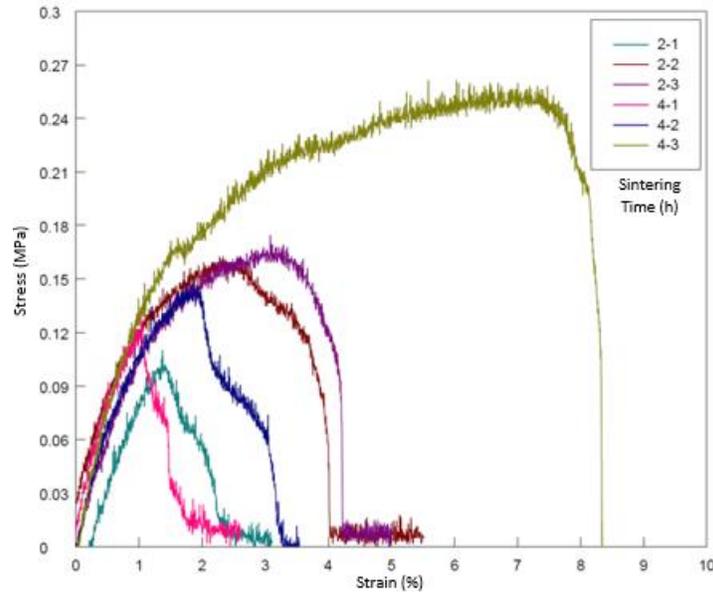


Figure 6: Tensile Test Results for 390°C Sintering Temperature

According to Figure 6, it was determined that tensile strength values varied between 0.11-0.26 MPa and elongation at break values ranged between 1.0-5.8%. The maximum tensile strength was seen in the sample sintered for 4 hours with 0.26 MPa, and the maximum elongation at break was seen in the same sample with 5.8%. Thus, it was determined that the increase in temperature and time increased the strength and elongation values of the samples obtained. Although the results were low and close to each other, it was seen that temperature and time optimization were crucial in obtaining the desired mechanical values [14-17]. Examples of samples broken after the tensile test are given in Figure 7.



Figure 7: Samples Broken After Tensile Test

4. Discussion and Conclusion

This study determined the recycling of Teflon waste from producing sealing equipment through machining and their mechanical properties. The general results of the study are given below:

- Recycling Teflon waste by physical methods offers a more sustainable recycling opportunity by minimizing the potential environmental effects of chemical processes.
By recycling Teflon waste, additional costs for the disposal of shaving waste can be prevented.
- By optimizing the sintering temperatures and times used in recycling, advantages such as lower energy consumption and less waste production can be achieved, and efficiency in production processes can be increased.
- The study results promise that mechanical properties can be improved by applying different recycling process parameters.
- Recycling Teflon waste as secondary raw material will make shaving recycling processes in line with industry requirements in the machining sector. This will increase the industrial applicability of recycling.
- The recycling of Teflon waste, which is the study's outcome, is a first for Turkey and the enterprise. In this respect, the unique aspect of the study is that Teflon waste will be used in the industry as a secondary raw material.

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