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Physical properties of cellulose sound absorbers produced using recycled paper

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HIGHLIGHTS

- We developed a cellulose absorber, which are produced by recycling waste paper.
- This study analyzed the physical properties of a cellulose absorber.
- The NRC was measured to be 0.75 for a product with a cellulose sound absorber.

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ABSTRACT

Cellulose products made from recycled paper can be utilized as sound absorbing and insulation materials. Cellulose is a sound absorbing material composed of paper, and is thus environmentally friendly and recyclable. In this study, the physical properties of a sound absorber produced using cellulose were investigated. The investigated properties were proof against climate, color change, thermal conductivity, and NRC (noise reduction coefficient). To obtain adequate NRC for the cellulose sound absorber, porous cellulose materials were foamed. Cell size distribution results showed that the most common size range for the cells was 10–25 µm, followed by 25–50 µm. Thermal conductivity of the cellulose sound absorber with a density of 55 kg/m^3 was measured to be 0.039 W/m K. Further, NRC of the absorber with a density of 36 kg/m^3 and a thickness of 60 mm was measured to be 0.75.

1. Introduction

Cellulose is the most representative biopolymer and is widely used as a raw material for producing paper or cotton. Numerous studies have been conducted to investigate the physical properties of cellulose with various additives [1,2]. Further, research has been conducted on SiO_2-coated materials to enhance the fire resistance properties of cellulose fibers [3].

Cellulose is the main raw material used in paper production; thus, paper is eco-friendly and recyclable. Recently, recycling has gained significant attention as a solution for global environmental conservation and CO_2 reduction. In addition to paper, research has been conducted to develop and analyze the physical properties of wood plastics composites (WPCs) made from recycled wood [4]. Furthermore, a study was conducted to develop insulation materials by utilizing eco-friendly materials such as flax and hemp fibers [5]. Enhancing recyclability and developing eco-friendly materials are being considered as effective approaches toward resource conservation and utilization. Because of the sustainability of cellulose, insulation materials produced using cellulose as the main raw material are being developed [6] and are being utilized as interior finishing materials in buildings. Gutiérrez et al. [7] used large-scale samples of cellulose reinforced with curauá fibers to investigate the degree of change in Young's modulus of the samples according to the weight of the added curauá fibers and the variations in the thermal conductivity of the samples under different temperature conditions.

A variety of materials are used for construction purposes, and these materials must provide thermal insulation to maintain the interior thermal conditions different from ambient air, and acoustic insulation to minimize ambient noise nuisance. To achieve thermal insulation, materials such as glass wool, rock wool, and polyester are applied to both the interior and exterior of the building. Materials such as wool are safe and natural and are widely used to improve the acoustic performance of buildings. Ballagh

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[8] investigated the correlation between NRC and physical properties (density, fiber diameter, and flow resistivity) of wool, as this correlation affects the acoustic performance of wool. In addition, Papadopoulos [9] has emphasized the need for further research to investigate the environmental and health aspects of insulation materials as well as their moisture resistance, which is one of their physical properties. Some sound absorbers are also produced from recycled waste materials in consideration of environmental aspects. Hong et al. [10] investigated the changes in the sound absorbing performance of materials produced using recycled rubber particles pulverized in various sizes. Maderuelo-Sanz et al. [11] developed sound absorbers using recycled fibers obtained from end-of-life tires. Because sound absorbing materials composed of synthetic materials emit greenhouse gases and are not eco-friendly, Putra et al. [12] developed and evaluated the sound absorbing performance of sustainable acoustic absorbers produced using sugarcane fibers. Al-Homoud [13] developed programs for energy cost reduction as well as product manuals for buildings by using eco-friendly insulation materials. Asdrubali [14] investigated and evaluated CO_2 emission from currently used general insulation materials and eco-friendly insulation materials.

In this study, we developed an eco-friendly insulation material by using recyclable waste such as newspapers and magazines in order to promote conservation and sustainable use of natural resources. By re-processing cellulose fibers extracted from waste materials, we developed a cellulose sound absorber with heat insulation and sound absorbing properties; this absorber can be used in buildings. Further, the physical properties of the developed sound absorber were analyzed.

2. Experimental

2.1. Materials

The manufacturing process of the cellulose sound absorber consists of six stages, as shown in Fig. 1. First, waste paper is collected and sheared, and is then mixed with starch to obtain a fixed shape. This is followed by the process of pellet formation, in which the two materials are combined into small pellets. After formation, the pellets are mixed with polypropylene and other materials to produce foam that is used to obtain the product. The final product is produced via extrusion in which environmentally friendly vapors are used to maintain a constant density of the finished product. Nicolajsen [15] investigated the thermal performance of a cellulose loose-fill insulation material, which is obtained by spraying an insulation material by using pressure, and compared it with the performance of normalized sound absorbing materials having a specified size.

Such products synthesized by environmentally friendly manufacturing processes can be utilized to reduce airborne sound and impact sound [16] in addition to being used as sound absorbing materials.

2.2. Fabrication of foam extruder

For obtaining an improved resin with sound absorbing properties, the polymer processing technology must be used. The finished product obtained using waste polymer foam is produced through extrusion. In order to produce a molded product through extrusion, a foam extrusion molder was developed, as shown in Fig. 2. The extruder contained a single screw. The screw had a diameter of 19 mm ∅, and a length/diameter (L/D) ratio of 28. Further, four heating sectors existed within the extruder, and the temperature of each sector could be controlled using a computer. The temperatures of transfer, melting, and gauge sectors were 150 °C, 160 °C, and 195 °C, respectively. Further, the die temperature was reduced from 200 °C to 150 °C in order to facilitate sample production using foam.

2.3. Tests

To identify the physical properties of the developed cellulose sound absorber, we analyzed various property-related parameters of the absorber. First, we examined its foaming characteristics, which were essential for producing the cellulose sound absorber. We evaluated the foaming characteristics according to temperature changes during the manufacturing process. Further, we also analyzed the structural characteristics of the foamed cell.

The cellulose sound absorber was produced though the fusion of foaming strands emanating from 30 to 50 pores. Therefore, the density and expansion rate of the strand blowing agent used in this study ADCA (Azodicarbonamide) were examined according to temperature, and experiments were conducted to investigate the behavior of the agent by examining the cross-section of cells. Experiments were conducted by varying the concentration level of the blowing agent. The temperatures of the resin were set to 150 °C, 160 °C, and 195 °C in the order of its temperature in the flow from the gear pump, melting point (MP) 1, and MP 2. The temperature of the die, the last flow area, was set to increase by 10 °C from

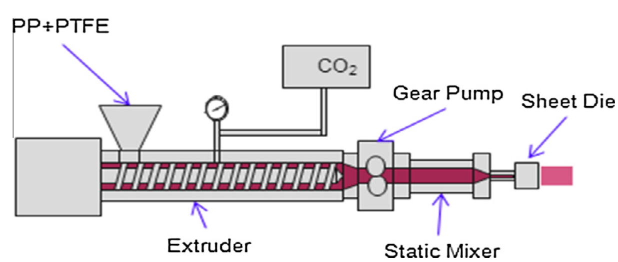

Fig. 2. Schematic representation of the extruder.

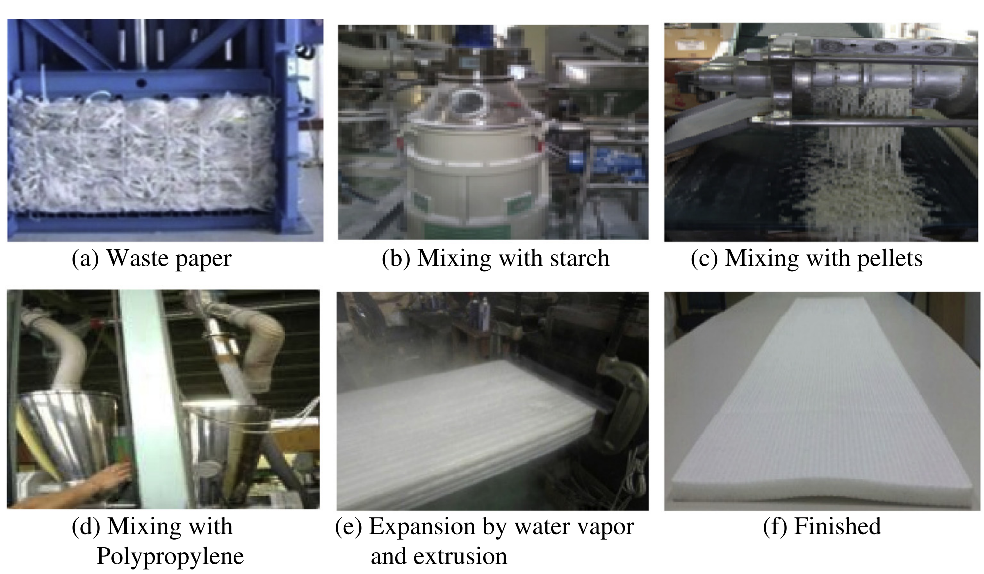

Fig. 1. Process of transforming waste paper into the final product.