Evaluation of New Filaments from Used Disposable Face Masks in the 3D Printing Industry: Part II

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Introduction

According to United Nations News (2022), issues related to plastic waste (approximately 8 million tons of plastic waste) and an additional 87,000 tons of medical clothing waste (such as surgical masks, shoe covers, gowns, etc.) have prompted a worldwide environmental crisis. In 2019, for example, people began to wear face masks to help control the spread of COVID-19. Despite the challenges of face mask-wearing, the use of disposable masks has dramatically increased, resulting in huge amounts of waste. The disposable masks are made from polymers (plastic-based materials), and the increased waste threatens human health, marine environments, and the ecosystem (Edmond, 2020; Potluri & Needham, 2005). Furthermore, single-use masks (e.g., taking 450 years to biodegrade) are often disposed of in landfills, affecting air pollution (e.g., burning the mask waste), and degrading water and land quality (Lu, 2021; Trafton, 2021). Several academic studies have been conducted regarding plastic grocery bags to develop a new biodegradable and compostable material as a plastic alternative that does not contribute to landfills (Ahamed et al., 2021; Li et al., 2022). With this in mind, using single-use face masks, Nam et al. (2022) found the optimal melted of disposable face masks to be in the temperature range of 156°C to 184°C and at an average temperature of 169 degrees (169°C ± 3°C). This implies that it is feasible to assume that disposable face masks (including inner, middle, and outer layers) could be melted down to make an effective alternative plastic. Therefore, in this study, we aimed to develop 3D printing filaments and evaluate their tensile properties compared to recycled filaments from 3D printing waste materials and commercially available filaments. We hypothesized that these three materials would have similar tensile properties.

Method

Material Selection and Process. Three types of filaments were selected for this experiment: (1) developed filament (from used disposable face masks; DF), (2) recycled filament (from 3D printing waste; RF), and (3) commercial filament (CF). To produce the recycled filaments, a heat gun tool, a filament extruder, and a chemical exhaust fume hood with a flow rate of 25 cubic feet per minute per square foot were used. The first material (DF) was developed from used disposable face masks, while the second material (RF) was produced from 3D printing waste using a filament extruder (ProtoCycler Plus™) and plastic pellets made from renewable sources (known as PLA). These pellets are essential materials used in the process of making recycled plastic products. The melted materials were ground down and mixed with the plastic pellets using the filament extruder, resulting in new and recycled filaments. The last material (CF) was obtained from an innovation hub at an R1 university in the Southeastern United States.

Tensile testing was conducted on the Shimadzu AGS-X (Shimadzu Scientific, Inc., Japan) in accordance with ASTM D-638 (Standard Test Method for Tensile Properties of Plastics). To examine the tensile strength (the maximum force required to break the materials), stress-strain, average strength, and modulus values were determined through three trials for each filament type. A one-way analysis of variance (ANOVA) using Tukey's HSD (Honest Significant Difference) was employed to determine whether there were statistically significant differences among the three types of filaments: DF, RF, and CF, using SPSS 21 (with a significance level of $p < 0.05$).

Results and Discussion

The one-way ANOVA results showed statistically significant differences in modulus (± 0.91, $p < 0.05$) between commercial filaments (CF) and recycled filaments (RF). No significant differences were identified within the developed filament (DF), recycled filament (RF), and commercial filament (CF) types. Additionally, no statistically significant differences in strength and stress-strain within the filaments were found (See Figures 1 and 2). Therefore, we concluded that the DF not only has very similar mechanical properties to the RF but also could perform comparably to the RF and the CF in terms of flexibility and usability. This experimental study demonstrates the potential effectiveness of using disposable face masks as an alternative material to develop PLA filament, as DF has properties that preserve tensile strength compared to RF and CF. This practical understanding of recycled material development, processes, and sustainability initiatives could influence students' projects in the classroom and laboratory, enhancing their sustainability initiatives and teaching them how to incorporate recycled materials into their creative products using 3D printing technology.

In terms of the industry, plastic waste poses a threat to human and environmental health and highlights the need to improve waste management practices. Diverting landfill waste through the development of sustainable products created from recyclable materials, such as the 3D printing filament produced in this study, can protect human health and the environment while fostering long-term ecological balance in the industry. Therefore, academia and industry should collaborate to generate sustainable products and improve understanding of product development and design processes with these materials. Also, the study will allow students the opportunity to rethink open-loop recycling practices in their classrooms and future businesses. It is becoming increasingly important to incorporate the United Nations Sustainable Development Goals (United Nations, n/a) in support of a more sustainable future that includes entrepreneurship education and practices.

Consequently, future research would focus on creating a variety of accessories (e.g., eyeglasses frame, phone case, golf tee, etc.) using the developed filaments, with the involvement of researchers, designers, and students in hands-on practices. This will help address the lack of repurposed/recycled products and engage students in understanding the material development process, leading to the creation of more sustainable products.

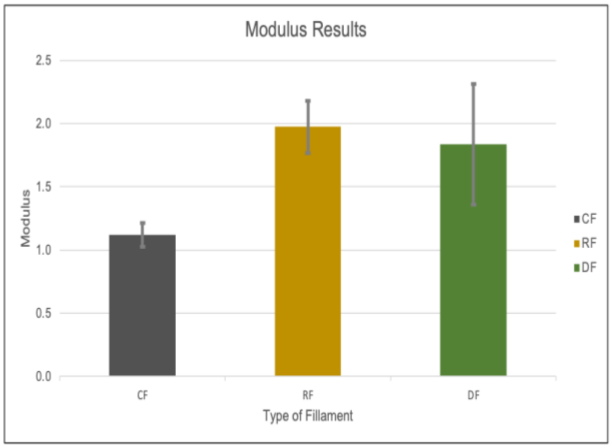

Figure 1. Modulus Results among Three Types of Filaments

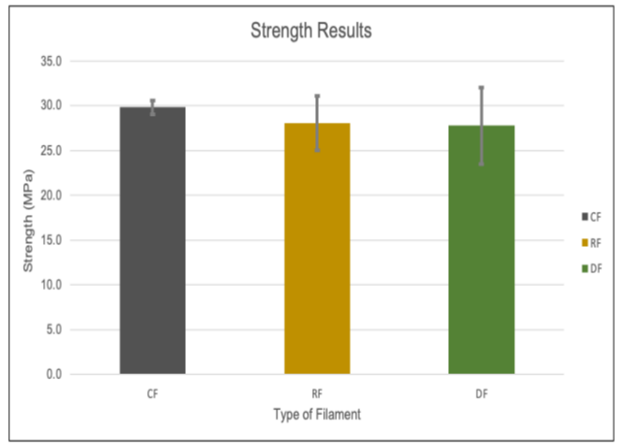

Figure 2. Strength Results among Three Types of Filaments

Notes. CF = commercial filament; RF = recycled filament; DF = developed filament.

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