Board 124: MAKER - Recycling HDPE in an Academic Makerspace

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Abstract

Academic makerspaces are becoming increasingly common on university campuses. Their growing numbers raise the question of, "how can university makerspaces engage a diverse set of users in their spaces, in order to fully represent their university's student body?" To this end, a project in the Ingram Hall Makerspace was implemented to attempt to engage diverse students by doing post-consumer recycling of HDPE (#2) plastic. This paper will describe the process used to clean, cut and/or shred the plastic, and then mold the prepared plastic into new products. At present, students can make a screwdriver, coaster, or a key chain out of the post-consumer plastics. The molds for the project were CNC-milled in the Ingram Hall Makerspace by manufacturing engineering students out of aluminum blocks. This paper will go through some lessons learned about the mold making process. As a part of the presentation, the evolution of the molds and sample products will be displayed. The paper also discusses some future projects that have been started to move the overall project forward with the goal to make student-led post-consumer recycling an active part of the Ingram Hall Makerspace experience.

Background

This project is part of an ongoing effort to bring local on-campus recycling of post-consumer HDPE #2 plastics to the Ingram Hall Makerspace on the Texas State University campus. A manufacturing engineering senior design team was tasked with creating a simplified process to transform post-consumer High Density Polyethylene (HDPE) into a casted functional product. Post-consumer plastic poses a significant threat to the environment due to the long time it takes for it to decompose [1], and that 36 million tons of plastic waste is generated in the United States each year [2]. As HDPE plastics can be recycled at least ten times without significant degradation of its mechanical properties [3], they are an ideal target for recycling programs to reduce landfill waste and maximize the useful life of these plastics. Challenges in recycling post-consumer plastics center around the purity of the plastic product, as different types of plastics are often mixed in manufacturing for specific properties and/or colors, and cleanliness of the plastic at collection [4]. Collecting, sorting, and cleaning the post-consumer plastic waste all pose additional challenges to the recycling of post-consumer plastics and so recycling rates of these plastics are much lower than of industrial plastic wastes, which are recycled a much higher rate [4]. HDPE was selected for this project because it can be melted and remolded whilst retaining most of its initial mechanical properties [5]. Many makerspace recycling efforts focus on recycling 3D printing filament waste generated in the makerspace [6,7,8]. The Ingram Hall Makerspace's recycling program began in 2019 by senior design students interested in ways to harness their manufacturing engineering skills to help the environment. The design goal for this mold making project was to develop a way for a student makerspace user to bring in a #2 plastic, such as an empty shampoo bottle or milk jug, and leave an hour later with a coaster made from the same plastic. The three products processes that were developed by the manufacturing engineering senior design team are a coaster (Figure 1), screwdriver (Figure 2), and cell phone holder (Figure 3).

Figure 1: Coaster with TXST Mascot Logo

Figure 2: Screw Driver

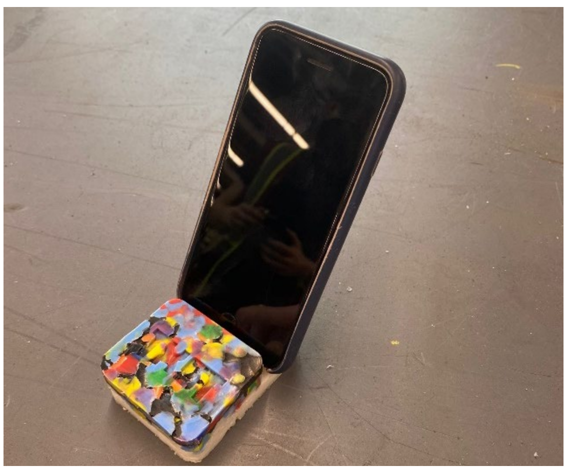

Figure 3: Cell Phone Holder

Process

The HDPE plastic is cleaned, shredded, and stored by color in advance, so that it is ready to be remanufactured into a new product. This remanufacturing process is also called mechanical recycling [4,5]. The main process that was developed in the senior design project consists of student-designed molds that they machined in the makerspace from aluminum blocks. Each mold took several iterations to overcome design challenges. Regardless of the product being created, the students followed the engineering design process in developing their molds, with the prototyping, testing, and redesign cycle providing them hands-on learning about mold design for manufacturing processes. Specifically, the students discovered that just because they could model something in SolidWorks did not mean that they were able to physically machine it. Designing an effective alignment mechanism for their two-part molds also became quickly apparent as, due to the heat of the process, they were handling the mold parts with thick gloves that decreased their dexterity. They also found sharp corners in designs to increase the cooled plastic sticking in the molds. Therefore, their redesign cycles focused upon the importance of the part release from the mold, ease of mold alignment, and the physical machining of the mold. Figures 4-6 show the current molds.

Figure 4: Coaster Mold

Figure 5: Screwdriver Mold

Figure 6: Cell Phone Holder

The manufacturing process consists of the following steps:

1. Preheat the molds in a hot oven for 5 minutes, as shown in Figure 7.

Figure 7: Pre-heating molds (450 °F)

2. Spray molds with release agent (CRC Silicone Mold Release), add the previously shredded HDPE, and place the molds inside the oven.
3. Allow HDPE to melt for 5 minutes, shown in Figure 8.

Figure 8: Shredded HDPE melting in mold

4. Open the oven door and use a spatula to press down on the melted material in the mold, adding more shredded HDPE as needed (Figure 9).

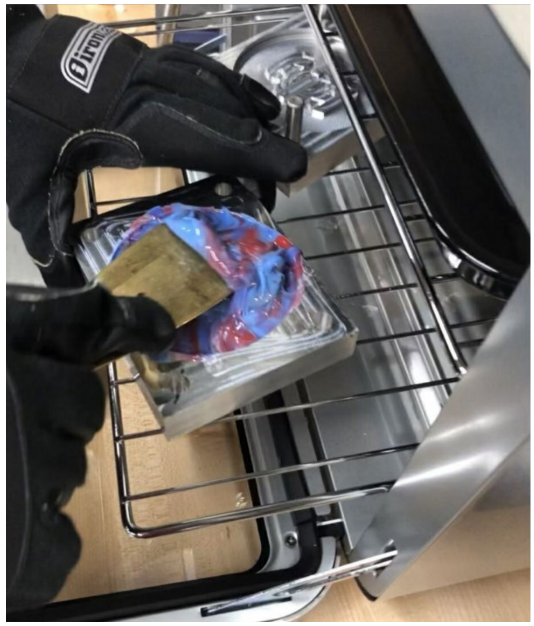

Figure 9: Working melted HDPE into the mold

5. Repeat Steps 3 & 4 until the mold is full and all the HDPE is melted, as shown in Figure 10.

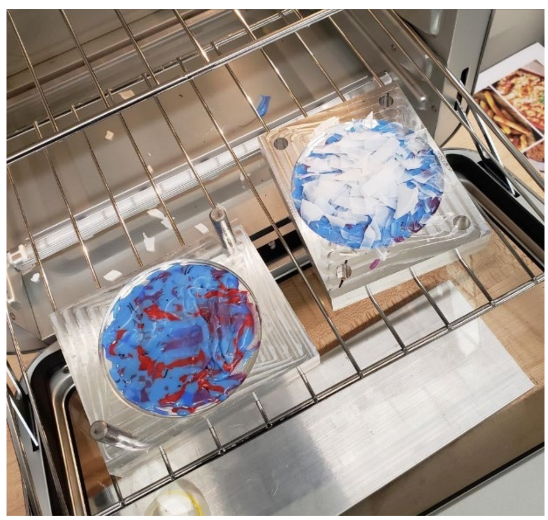

Figure 10: Molds full of melted HDPE

6. Remove the mold from the oven, align it using the mold's alignment mechanism, and press it using the vertical press as shown in Figure 11.

Figure 11: Press pushing mold pieces together to fuse melted HDPE into new product

7. Allow the mold to cool down for 5-10 minutes while pressed.
8. While still wearing the heat-resistant gloves, remove the product from the mold. An example of the demoded product is shown in Figure 12.

Figure 12: Product after removal from mold

9. Remove any excess material and perform any postprocessing if necessary. Examples of final products are presented in Figure 13

Figure 13: Final Product After Removing Excess Material

Lessons Learned and Conclusions

Currently the product manufacturing process takes about 50 minutes, the team is committed to maintain this time and perform this process in Ingram Hall Makerspace the under one hour timeframe. The shredding process is also being developed in the next stage of this project. For the projects reported here, all plastics were initially being cut into small pieces by hand. Obviously, hand cutting pushes the total project time to be in excess of one hour. Therefore, a concurrent student project is to develop a safe, reliable shredder to substantially reduce the overall time from old product to new. A four-person team developed the pictured molds. A different five-person team is currently working on additional mold designs that build upon the lessons learned from this cycle of mold development. The shredding project has additionally involved four students. Currently, the regular users of the Ingram Hall Makerspace can come in and make recycled plastic projects using the existing molds. The users of the molds are trained by student staff in the makerspace, which is the training protocol for the other makerspace equipment.

This mold making project currently has cost approximately $3,000. The main costs have been the purchase of an oven, the aluminum stock for manufacturing the molds, and high-temperature gloves. The press, which is pictured in Figure 11, was already in the Ingram Hall Makerspace. The in-progress shredder project is expected to cost approximately $4,000. These costs have been covered through donations to the senior design fund at Texas State University.

At each step in the design process the students have expressed interest in the process and excitement about telling others about their project. These students especially liked having tangible things they can show others that they have made that support sustainability. The students who have taken part in these projects have presented at multiple innovation showcases, environmental days, and conferences, winning awards for sustainability and innovation.

The students working on this project learned the importance of designing for manufacturability. After having some products get stuck in molds, they had to develop new versions that had better release either through changes in slopes or how the mold was constructed. As well, they learned about the limits of machineability while making their molds. This hands-on senior design project allowed the students to achieve the course learning objectives, including designing for manufacturing, learning modern manufacturing tools, and conducting ethical design/designing for the environment.

Acknowledgements
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